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The Evolution of Real Options and its Applications in Management: A Review of Literature

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Abstract:
Real options evolve from options pricing theory (OPT), a very unique and widely applicable theory that traces its origin to the study of derivatives. Options, unlike the other financial derivatives, have unique risk management features that allow investors in financial assets to minimize their downside losses while they benefit maximally from upside potentials. An option gives the holder the right to a flexible investment decision in a later period. With the landmark derivation of option pricing formula in 1973, OPT has not only been successfully applied in other areas of finance but has also been extended to other disciplines in management. Real options, arguably the leading extension of OPT; apply the options theory to the appraisals of capital investment projects. This paper traces the evolution of real options to financial options and the study of derivatives. It reviews the study of derivatives and the evolution of options as derivatives with unique risk management characteristics. The review further covers the literature on applications of OPT in finance and the eventual evolution of real options. The paper then reviews real options and its applications in diverse disciplines of business and management. From the wide applications of real options' thinking and tools as revealed in the literature, the paper shows that real options have a great potential in offering plausible explanations to existing relationships in management including strategic management and in discovering new theories that will transform the field of management.

Keywords: *Real options, literature review, strategic investments, flexibility*

1. Introduction

Following the breakthrough in option pricing theory (OPT) with the derivation of option pricing formula by Black and Scholes (Black & Scholes, 1973), the theory has been widely applied in other areas of finance. These include, among others, in the pricing of convertible securities, warrants and in the valuation of the values of debt and equity of a firm. However, a very interesting extension of OPT is in the valuation of investment projects or "real" assets of organizations. This has been termed real options and was coined by Stewart Myers of Massachusetts Institute of Technology (MIT) in 1977 (Myers, 1977). Ever since, and just like for OPT; finance theorists have attempted to derive an equally well acceptable real options valuation formula for investment projects. Extant literature on real options have continued to show that real options technique is more robust than the traditional capital budgeting techniques and thereby pushing for the adoption of real options by practitioners. In addition to using real option technique for valuation of firms' investment projects, real option framework or thinking is now being applied in many other management disciplines including strategy, human resources management, organization theory & behaviour, management information science, operations and marketing.

The risk management framework of real options approach is now being applied to topics in other areas of management. The OPT from which real options is derived is based on maximization of returns on financial assets in the presence of uncertainties. Real options theory uses the same principle to maximize investments in 'real' assets or investment projects in the presence of uncertainties. The uncertainties can be in form of market demand for the firm's products/services or technical and cost uncertainties in the development of the assets. In OPT, an amount is paid upfront to shield the investors from losses should the price of the asset fall below an agreed amount on an appointed date while the investor receives as returns the difference between the prevailing price of the asset on the appointed date and the earlier agreed price of the asset. In the presence of uncertainty, the use of OPT therefore maximizes returns on investment as it protects the investor from downside risk while the investor benefits maximally from upside potential. This novel risk management features have encouraged the extension of option thinking to investment projects and to other practices in management. In this case, the firm can incur some upfront cost in order to enjoy the right of flexibilities of decisions in the nearest future subject to how events unfold.

Real options framework has therefore been closely linked with strategic decisions by firm managers. The decisions are usually irreversible investment decisions under uncertainty. In the same way the use of financial options has been shown to maximize investors' returns on financial assets, it has been argued and shown empirically that the use of real options theory maximizes the value of firms' investment projects. From human resource management to management information system and marketing, real option thinking has been shown to enhance firm value. Incorporating real options in human resource (HR) investments, in form of upfront investments in human resources of the firm, can enhance firm value under uncertainty (Sanyal & Sett, 2011). Employment costs can be increased to embed managerial flexibilities, in form of real options, for future HR decisions. Real options logic has also been shown to be valuable in technology investments by firms (McGrath R. G., 1997). A firm can incur upfront technology investments in order to maximize the value of the firm should future events become favourable to the firm. In another study, real options theory is shown to marry the theory of financial options to foundation ideas in strategy, organizational theory and complex systems (Kogut & Kulatilaka, 2001). The application of real options theory in marketing and strategy covers such area as valuing the uncertainty associated with prospective purchasing and selling decisions (Adams, 2004). In operations strategy and management, construction of plants and purchase of machineries have been handled in such a way as to incorporate flexibilities into the investment decisions. All these efforts and many others have been geared towards maximizing the value of the firm.

While researchers in other areas of management have attempted to apply real options framework to topics of interests in their fields, real options' researchers in finance have been preoccupied with developing intuitive, robust and generally acceptable real option valuation formula for investment projects. The objective is to come up with a capital budgeting tool that will replace the traditional discounted cash flow technique. The award-winning option pricing formula of Black and Scholes cannot be correctly applied for investment projects because of difference in assumptions underlying financial and real assets. Studies on real options in finance therefore centre on deriving the real options pricing formula from first principle on a case by case basis. Attempts are however being made in the literature to simplify the assumptions and therefore develop more intuitive real options formula that can be applied in practice while still incorporating and valuing the managerial flexibilities in the investment projects. The ultimate is to develop simplified real options capital technique that will enjoy the level of acceptability enjoyed by Black and Scholes' option formula by practitioners. However, real options' researchers continue to show that the use of real options, whether as strategic framework or as a capital budgeting tool, adds values to firm.

Extant literatures have shown that the use of real options as a capital budgeting tool can amplify the values of projects to which it is applied and hence the value of the firm. Researchers have identified various forms of managerial / strategic flexibilities, in form of real options, which can be incorporated into firms' investment decisions. The identification and incorporation of these real options follow the thinking of financial options in which a price is played upfront to enjoy a right that can maximize asset's value in the future. These real options include option to wait, option to switch between inputs and/or output, time-to-build option, growth option, option to alter operating scale, option to abandon, learning option, growth option and various interactions of these real options. The logic in these real options is the same: if the firm can incur some costs or pay a price before investing under uncertainty to incorporate a real option into a project, then it will be able to maximize the value of such investment by exercising the right built into that project in the future. Real options' researchers have been able to show, albeit mostly on project by project basis,that formal adoption of real options can greatly improve firm value and hence firm performance. Although the formal adoption of real options as a capital budgeting tool by managers is still relatively low, the intuitive and formal application of real options' logic are however prevalent in practice.

2. From the Beginning

2.1. The Theory of Derivatives

Over the years finance theorists have explored various ways of developing financial instruments to manage risks inherent in investments in financial assets. Since risks and returns are positively related in finance, finance theorists have attempted to introduce into the market exotic financial instruments that can minimize risks while at the same time maximize returns from those investments. Key innovations along this line are financial instruments termed derivatives. Derivatives are financial instruments that have values that depend on the values of other financial assets (Bodie, Kane, & Marcus, 2009). They are otherwise regarded as contingent claims because their values are contingent on the values of some other instruments. They are referred to as derivatives because their values are derived from the values of other financial instruments. The financial assets on which the values of derivatives are derived are termed underlying assets. Underlying assets include common stocks, stock indices, foreign exchange, commodities and interest rates. Derivatives are usually introduced into portfolio of assets by portfolio managers to manage the risk and achieve the desired returns on investment portfolio. They are also used by financial managers of firms to manage risks inherent in their operations. Derivatives have evolved over the years from over-the-counter trading of derivatives to the establishment of exchanges that are now used for trading of standardized derivatives. The key derivatives include forward contracts, futures, swaps and options. These are discussed below.

2.1.1. Forward Contracts

The search for financial instruments that can be used to manage uncertainties in the prices of financial assets such as foreign exchange, commodities and interest rates produced forward contracts. Forward contracts are contracts written on an underlying asset that allow one party to buy the underlying asset from another party on a given future day at a price agreed on the day of the contract. The prices of financial assets such as foreign exchanges, commodities and interest rates have been known to fluctuate and thus usually subject returns on portfolio investments and firm operations to great uncertainties. Forward contracts have thus allowed producers and buyers of such commodities as crude oil, metals and agricultural commodities to manage uncertainties in their incomes and expenditures using forward contracts. Financial managers in firms, especially multinational firms, have also used forward contracts to minimize disruptions in their forecasts and operations using forward contracts usually written on foreign exchanges. Prices of commodities such as crude oil are usually subject to fluctuations due to uncertainties in supply and demand. Parties across different continents of the world continue to engage in forward contracts due to the pressing need to minimize uncertainties in revenues of producing countries and on operations of the buyer countries.

In the same way, the need to manage uncertainties in foreign exchange rates also makes managers of multinational companies to lock in exchange rates for their future operations. For example a United States-based firm wishing to establish a commitment to investment in the United Kingdom, in say three months' time, may need a forward contract with a bank to lock in the exchange rate between the Pound Sterling and the US Dollar. The amount that is needed and the future exchange rate are agreed on the date of the contract. The bank is obligated to sell the Pounds to the firm on the specified future date at the agreed exchange rate while the firm is also obligated to buy the Pounds in exchange for the US Dollar amount. In the same way for commodities, the buying party, for example a firm that needs the commodity as a raw material for its operations, will write a contract with the commodity producing firm/country agreeing on the future prices, quantities, date and delivery methods. Forward contracts have traditionally been used by agricultural commodities' producers to manage uncertainties in their revenues. Over the years, finance theorists have developed valuation methods for forward contracts and have also explored the effects of forwards contracts on firm values (Bessembinder, 1991; Black F. , 1976; Holden, Løland, & Lindqvist, 2011; Livingston, 1987; Parsons, 1989; Power & Turvey, 2009; Yang H. C., 1984). The prices of forward contracts are now readily obtained using pricing formula that takes into consideration the current price of the underlying asset, the duration of the contract and the volatility in the prices of the underlying assets. Although forward contracts dealers, usually banks, have evolved to act as intermediaries between the two parties involved in forward contracts, there is still the challenge of standardization and liquidities of the contracts as they are not traded on exchanges.

2.1.2. Futures Contracts

Forward contracts are usually traded over-the-counter with no standardized forward contract exchanges. Futures contracts are just like forward contracts in that one party agrees to sell or buy an underlying financial asset from another party on a future specified date at a price agreed on the day of the contract. Future contracts are also derivatives as their prices are derived from such underlying assets as commodities, foreign exchange, stock indices, common stock and interest rates. Unlike forward contracts, futures contracts are standardized and traded on futures exchanges. There are future exchanges in major financial cities of the world including New York, London, and Tokyo among others. The quantities, maturity periods and delivery options of underlying assets in futures contracts are standardized to suit the demand of writers of futures contracts. Futures contracts are thus easier to write and are more liquid than forward contracts since they are daily traded on the floors of futures exchanges. The risks of defaults are also greatly minimized as the operational guidelines of the exchanges ensure that both buyers and sellers provide up-to-date resources that are commensurate with the prevailing prices of the underlying assets. Studies on the pricing of futures contracts and other related topics have been quite successful and have greatly contributed to the use of the contracts in practice (Ciobanu & Sechel, 2012; Cotter J. , 2005; Eytan & Harpaz, 1986; Hegde, 1987; Hemler, 1990; Hranaiova, Jarrow, & Tomek, 2005; Kritzman, 1993; Niederhoffer & Zeckhauser, 1980; Thomas, 2002). Futures contracts, just like other derivatives, are used by individual investors, portfolio managers and financial managers in firms to hedge against risks inherent in the underlying financial assets.

2.1.3. Swap

Forward and futures contracts usually involve single definition of the underlying asset and single maturity period. Swap, on the other hand, is a financial derivative that has an underlying asset with different properties and multiple maturity periods. In a swap derivative, two counterparties exchange cash flows from an underlying asset with two different properties at future dates with the terms of the underlying asset agreed upon on the day of the contract. The two parties in a swap transaction are both buying and selling a financial asset at the same time. Swaps, just like forward and future contracts, are usually written to hedge against uncertainties in the prices of financial assets. The cash flows exchanged in a swap derivative depend on the underlying assets and include principal & interest payments, coupon payments and cash flows from sales of commodities such as crude oil. One party in a swap transaction usually exchanges the fixed price of the underlying asset for a floating price of the same underlying asset from the other party. The fixed price of the underlying asset is usually benchmarked against a well-known benchmark price/rates Swap derivatives are usually traded over-the-counter. The major types of swaps are interest rate swaps, currency swaps and commodity swaps.

1. Interest Rate Swaps

In an interest rate swap, a party exchanges fixed principal and interest rate payments for a floating principal and interest rate payments from another party at various future dates agreed on the day of writing the swap contract. Financial managers of firms use interest rate swaps to hedge against interest rate risks on their loans to minimize disruptions in their financial forecasts. Banks usually act as dealers in swap transactions and are thus the other counterparties in an interest rate swap transaction. A bank writes an interest rate swap for a firm that wants floating principal and annual interest payments on a loan amount for a specified period of time. The floating interest rate is usually benchmarked against a standard rate such as LIBOR (London Inter Bank Offer Rate). On the other hand another firm deposits the same amount with a bank with a loan agreement to earn fixed principal and interest payments over the same period. In effect the two transactions are an interest rate swap with the second firm exchanging a fixed principal and annual interest rate payments with a floating principal and interest rate payments from the first firm. It is also possible but time taking for the two parties to enter into an interest rate swap agreement without involving a third party.

2. Currency Swaps
Currency swaps are like interest rate swaps but differ from interest rate swaps because the loan amounts are denominated in two different currencies. One party exchanges loan amount, with principal and interest payments based on a fixed interest rate and on a particular currency, with another party with principal and interest payments based on a floating interest rate and on a different currency. Currency swaps can be used by firms, especially multinational firms, to reduce both interest and foreign exchange rate risks. For example two firms operating in both United Kingdom and United States can exchange principal and interest payments with one firm exchanging fixed interest rate US Dollar-denominated principal and interest payments with a floating Pounds-denominated principal and interest payments benchmarked on LIBOR (London Inter Bank Offer Rate) from another firm. Banks also act as dealers in currency swaps.

3. Commodity Swaps
As discussed earlier, prices of derivatives are derived from the prices of underlying financial assets such as commodities, foreign exchange, interest rate, common stock and stock indices. A swap transaction with a commodity such as crude oil as the underlying asset is called a commodity swap. In a commodity swap, one party exchanges the commodity with a fixed price with another party with a floating price of the same commodity over a given period of time. The floating price of the commodity is usually the prevailing or the market price of the commodity obtained from the commodity's standard market.
Innovative financial instruments have been developed employing the risk management features of different derivatives. For example a forward swap contract combines forward contract features with swap derivative features. Here instead of exchanging prevailing or spot prices of underlying assets, their forward prices are exchanged instead. Another compound derivative is swaption which combines a swap derivative with an option contract (option contract is discussed in the next session). Yet another variation of swap derivative is credit default swap (CDS) where the seller of the CDS agrees to swap the loan default from the issue of a corporate bond with the payments from the buyer of the CDS. The seller receives regular payments from the buyer and guarantees the loan by paying the face value of the loan in case of default. Various studies have valued the swaps discussed above and other variations including discussions on their effects on firm value (Chen & Chaudhury, 2002; Choudhry, 2006; Flesch, 2009; FREY & RÖSLER, 2014; Fung, Wen, & Zhang, 2012; Gil-Bazo, 2006; Lin & Yi, 2005; Lipton & Savescu, 2014; Wei, 2001; Yang & Han, 2013)

2.1.4. Options
An options contract is a key derivative financial instrument that has attracted the interests of both finance theorists and practitioners in recent years. While the derivatives discussed earlier in this dissertation (forward, futures and swaps contracts) are obligations in that the parties involved must either buy or sell the underlying assets at maturity, options on the other hand is a right. An options contract gives the right to buy or sell an underlying financial asset by one party from another party on or before the maturity period of the contract. The buyer of the options contract pays the writer for the right to buy or sell the asset on or before a specified date agreed upon on the day of the contract. In the other derivatives, the payoffs to the buyers are usually symmetric as the buyers gain and lose equal amounts for the same increase and decrease in the prices of the underlying assets. For example in a forward contract where the buyer agrees to pay the seller US$60 per barrel of crude oil in three months' time, if the price of crude oil in three months' time is US$55 per barrel, the buyer loses US$5 per barrel and if the price is US$65, the buyer equally gains US$5 per barrel. On the other hand, the payoff is asymmetric in an options contract as the buyer's loss is limited for downside risk while the payoff is unlimited for upside potential. To enjoy this right, the buyer of the options' contract pays the seller an amount, called the options premium or the options price. The evolution of options pricing theory and the various applications of the theory are discussed in the next section.

2.2. Options Pricing Theory

2.2.1. The Evolution of Options
An options contract is the right, and not an obligation, given by one party to another party to buy or sell an underlying asset at a specified price called the strike or the exercise price on or before a maturity date at the price agreed on the date of the contract. A call option gives a party the right to buy a financial asset from another party on or before the maturity date of the contract at a strike price agreed on the date of the contract. A put option on the other hand gives a party the right to sell an underlying asset to another party on or before the maturity date at a specified exercise price. The underlying assets include common stocks, stock indices, commodities, foreign exchanges and interest rates among others. Option contracts have also been written on other derivatives, this means we now have option contracts on forward, futures, swaps and even on another option contracts. Unlike forward, futures and swap derivatives, a price, called the option price or premium, is paid by the buyer in a call option and the seller in a put option to enjoy the right. Options contracts, just like the other derivatives, are used for hedging and for speculations by individual investors, portfolio managers and firm financial managers. Options contracts offer the buyers and sellers protection from downside risk while the investors retain the benefits from upside potentials. A European option can only be exercised on the maturity date while an American option can be exercised on any date on or before the maturity date of the options contract.
Options contracts are innovative financial instruments created by financial and investment managers to mitigate risks to exposure to volatile changes in prices of underlying assets by financial and investment managers and to earn speculative returns by speculators in financial markets. Until the establishment of the Chicago Board of Options Exchange (CBOE) in 1973, options contracts were mainly traded over-the-counter (OTC). With the establishment of CBOE, investors started trading standardized options contracts on an organized exchange. CBOE and other electronic options exchanges that were later established in other financial cities of the world,

created secondary markets for the trading of options contract and thus greatly improved the liquidity of options contracts. Trading of option contracts on OTC requires one party to find counterparty who wants the same underlying asset in the same quantity at the same exercise price and maturity period. Although the emergence of options dealers reduced the challenges of finding counterparties, the liquidity of options still remained a big challenge until the establishment of options exchanges. Nowadays, it is now common to see various options contracts with different underlying assets being traded daily on organized exchanges,

Options contracts are written on various securities. A call option on a common stock gives the buyer the right to buy the common stock at a particular price on or before a maturity period. If it is a European call option, the buyer can only exercise the right on the maturity date of the contract and not earlier than the date. On the other hand, the American option holder can exercise the right on any date before the maturity date of the contract. For example a European call option on Mobil Oil stock with exercise price of N170 with three months maturity period means the option holder can only exercise the right to buy the stock on the maturity date of the contract. If the price of Mobil Oil stock in three months' time is less than N170, the option is left to expire without being exercised by the holder. For example if the price of the stock is N160, the option is not exercised and the payoff to the holder of the option is zero. On the other hand if the price of Mobil Oil stock is more than N170, say N180, the holder exercises the right to buy the stock by paying the exercise or the strike price of N170 to the other party on the expiration date. The payoff to the option holder is therefore N180 – N170 or N10. To enjoy this right the options holder must have paid the option price or premium to the other party on the date of the options contract. For a call option, as long as the price of the common stock is more than the exercise price, the call option is said to be in-the-money. The holder gains from exercising the right to buy the common stock. The option is however out-of-the-money whenever the price of the stock is less than the exercises price because the holder does not exercise the right at these prices. The option is at-the-money when the stock price is equal to the exercise price.

The reverse is the case for a put option. The holder of a put option pays the counterparty for the right to sell the underlying asset to the party at a specified exercise price on or before the expiry date of the put option contract. For example, the put option to sell a commodity such as crude oil by an oil producing firm to a steel manufacturing firm at an exercise price of US$55 per barrel with 60 days' expiry date. If the put option is European, on the expiry date the holder of the put option, the oil company, has the right to sell the agreed quantities of the crude oil to the steel manufacturing firm if the crude oil price is less than US$55 per barrel. On the other hand if the price of crude oil is more than the US$55 per barrel exercise price, the oil firm sells the crude in the open market at the prevailing price instead of selling it to the steel company. The oil firm has therefore hedged against the uncertainty in crude oil price by paying an option premium to enjoy the downward protection and the benefits of upside potential. Crude oil price speculators have also used the uncertainty in the crude oil prices to buy and sell options contracts by speculating on the movement of prices and earning returns from favourable movements of oil price. Portfolio managers have also introduced options contracts into their portfolios to achieve the desired risk-return relationships. Options contracts are also written on stock indices, foreign exchanges, interest rates and on other derivatives. Investors have been able to include options contracts into their portfolios without having to either buy or sell the underlying assets. Until the breakthrough in 1973, the key challenge in options trading had been the determination of the option price or premium without the arbitrage opportunities occasioned by mispricing.

2.2.2. The Pricing of Options Contracts

Over the years, finance theorists have developed generally acceptable formulae for pricing of regular financial assets including bonds and common stocks. The pricing methodology has been based on the estimates of future cash flows from the assets and then using the appropriate discount rates to estimate the present values of the estimated future cash flows. For example for the valuation of common stocks, valuation methods such as dividend discount model, discounted cash flow model and other methods that are based on comparables such as price-to-earning (P/E), price-to-book (P/B) and price-to-sales (P/S) are used. The valuation methods thus depend on the future expected cash flows from the financial assets and the risk-adjusted discount rate to be used to discount the future cash flows. The pricing of financial assets thus traditionally depend on the estimates of cash flows from the assets and the estimates of the risks involved in earning the cash flows. Most of the financial assets are tradable assets; therefore the volatilities of their historical prices are used to estimate the inherent risks in their cash flows. In valuation of financial assets, the rate of return on government treasury bills is usually used as the base rate or the risk-free rate of return. It is expected that the rates of return on other risky assets should be a premium on the risk-free rate. The traditional valuation methods thus depend on estimates of future cash flows (or rate of growth in cash flows), the risk-adjusted discount rate (or the risk-free interest rate for already risk-adjusted cash flow) and the volatility of returns. This approach has also been used in the valuation methods for derivatives such as forward, futures and options contracts. However because of the nature of cash flows from option contracts and the risk management features of the contracts, the development of a generally acceptable pricing method for options evaded the finance theorists for a very long time.

The payoff to options contract is asymmetric and therefore challenging to estimate the cash flows from options contracts and the risk-adjusted discount rates to use in the valuation process. Since the price of an options contract is derived from the price of the underlying asset, the primary driver of options price is therefore the price of the underlying asset. For an options contract with a given exercise price and maturity period, the higher the price of the underlying asset, the higher the payoff from a call option and the higher the option price. The reverse is the case for a put option. Estimates of future values of underlying assets are therefore expected to be good predictors of option prices. However the volatility in prices of the underlying asset which affects the asset pricesaffects the option prices in a non-uniform way. The higher the volatility of the underlying asset in an options contract, the higher the chance that the price of the underlying asset will exceed the exercise for a call option or be less than the exercise price for a put option. Therefore the higher the volatility in options contracts, the higher the options price. The third variable that affects the price of an option contract is the exercise price. For a given price and volatility of the underlying asset, the higher the exercise price, the less the likelihood of

exercise by a call option holder while the lower the exercise price, the more likely a call option holder will exercise the right on or before maturity. The reverse is the same for a put option. Another factor that also affects the prices of option contracts is the maturity period. Given a longer maturity period, it is more likely that the prices of the underlying assets in a call options will be higher than the exercise price and thus be exercised when compared to a shorter expiry date. Maturity period is therefore positively related to option price. The fifth variable that affects the prices of options, as will be seen later, is the risk-free rate.
The pricing of options contracts remained unresolved issue in finance until 1973 when Fischer Black and Myron Scholes developed the now generally acceptable option pricing formula. The option pricing formula is based on the principle of replicating portfolio. They were able to replicate the payoff from an option contract using a portfolio containing two securities: a common stock and a risk-free bond. They postulated that the payoff of a European call option can be replicated by buying a ratio of the number of the common stock in the options contract and borrowing the balance of the amount at risk-free rate. It was shown that the present value of the replicating portfolio will be equivalent to the option price because their future cash flows are the same. Based on this principle, any option contract can be priced by estimating the present value of future values from the equivalent replicated portfolio. A formula was developed for the estimation of the ratio of the number of common stocks in the replicating portfolio. Black & Scholes later developed the general option pricing formula for European call option using risk neutral principle and stochastic calculus. The developed options formula depends on objective and measurable variables: the present value of the underlying asset, the exercise price, the maturity period, volatility and the risk-free rate. The formula was programmed into an option calculator and has since been used by options traders on the floors of options exchanges. The traders only need to supply the values of the five variables and the calculator will estimate the price of the option.

2.2.3. Applications of Options Pricing Theory

The breakthrough in options pricing theory has far-reaching effects on the valuations of option-like assets and liabilities in finance. Some financial assets and liabilities were discovered to have options embedded in them and with the success of the options pricing theory, the valuations of these securities using the pricing formula marked different milestones in the theory and practice of finance. These assets and liabilities include already existing securities with option-like features and new ones that are developed with embedded options. These option-like assets and liabilities include callable bonds, convertible bonds, warrants, collateralized loans and equity in a levered firm.

1. Callable Bonds

Callable bonds are bonds with embedded call options. The issuer of a callable bond has the right to buy back the issued bond from the holder on or before the maturity date of the bond. The issuer of the bond usually exercises this right when the interest rate falls and therefore makes more financial and economic sense to refinance the issued bond at the prevailing lower interest rate. To be entitled to this right, the issuer of the bond pays the buyer an option premium or price which is usually built into the price of the bond when it is issued. Literature in finance, in general, and particularly in options pricing has been extended with studies on valuation of callable bonds both in theory and in practice (Bliss & Ronn, 1998; Kalotay, 2008; King, 2007; Lim, Li, & Linetsky, 2012; Longstaff, 1992; Marshall & Yawitz, 1980; Xie, 2009) including the investigations of option values implicit in callable treasury bonds (Jordan, Jordan, & Jorgensen, 1995; Jordan, Jordan, & Kuipers, 1998).

2. Convertible Bonds

Convertible bonds are option-like financial instruments that give the holders of the instrument the right to buy the specified amount of the common stock of the bond issuer on or before the maturity period of the bond. The holder exercises the right when the price of the issuer's common stock increases and gives more returns than when the holder continues to hold the bond. The buyers of convertible bonds pay an option price or option premium to enjoy the right. The option values are included in the prices of the issued convertible bonds. The exercise of the options embedded in convertible bonds alters the capital structure of the issuing company and are used by firms to hedge against the uncertainties in their share prices. The valuations of different forms of convertible bonds using various option pricing techniques have continued to be the subjects of financial studies (Ayache, Forsyth, & Vetzal, 2003; Ballotta & Kyriakou, 2015; Batten, Khaw, & Young, 2014; Brennan & Schwartz, 1977; Brennan & Schwartz, 1980; Carayannopoulos & Kalimipalli, 2003; Finnerty, 2015; Firouzi & Ayache, 2015). Other related studies include estimation of premiums on convertible bonds (Jennings, 1974; Weil, Segall, & Green, 1968; Weil, Segall, & Green, 1972) and other convertible bond valuation approaches (Kimura & Shinohara, 2006; Landskroner & Raviv, 2008; Liu, Tao, Ma, & Wen, 2014; Siddiqi, 2009; Sîrbu, Pikovsky, & Shreve, 2004; Zhang & Liao., 2014; Yagi & Sawaki, 2010)

3. Warrants

Warrants are option-like financial securities. Warrants are financial instruments that give the buyer the right to buy the common stock of the issuer at a given exercise price on or before a specified maturity period. Warrants are just like option contracts because the holder pays a price or a premium to enjoy the right to buy the common stock of the issuing firm at a future date. When the buyers of warrants exercise the rights to buy the specified quantities of the common stock, the issuing firm issues new shares to meet the new demand for the shares of the firm at a price that equals the exercise price of the warrants. Warrants can be used by investors to mitigate the risk in the price of the underlying asset which in this case is the common stock of the issuing firm. If the future performance of the firm is unfavourable, the warrants are left unexercised and the payoff to the buyer is zero. However if the performance of the firm exceeds expectation and the share price rises above the exercise price, the holder of the warrants exercises the

right to buy the stock and the firm issues new shares thus increasing the amount of share outstanding of the firm. Warrants are different from the regular call option on common stock in that the exercise of the right on a regular call option on a stock does not entail issuance of new shares by the firm whereas when warrants are exercised, the issuing firm will have to issue new shares.
Convertible preference shares have similar option like features in that the holders can convert the preference shares to regular shares on or before the specified future date. Convertible preference share holders pay an option price or a premium to enjoy the right to convert the shares to the common stock of the issuing firm on or before the expiry date of the convertible security. The option prices are usually in form of premiums over the prevailing share price of the issuing stock when the convertible shares are issued. Warrants can be issued to top executive as incentives to improve firm performance. Researchers have therefore attempted to develop various valuation methodologies for different forms of warrants (Burney &Moore, 1997; Galai & Schneller, 1978; Kremer & Roenfeldt, 1993; Kuwahara & Marsh, 1992; Leonard & Soft, 1990; Ukhov, 2004; Xiao, Zhang, Zhang, & Chen, 2014; Yagi & Sawaki, 2010). Other related studies have explored the factors affecting the values of warrants and the effects of warrants on other topics in management (Amihud, Lauterbach, & Mendelson, 2003; Bajo & Barbi, 2010; Crouhy & Galai, 1994; Koziol, 2006a; Koziol, 2006b; Koziol, 2010; Ma & Goldman, 2012) including studies on the effects of longevity and other factors on values of warrants (Miller, 1971; Rush & Melicher, 1974).

4. Leveraged Equity and Risky Debt
The equity in a levered firm has also been analysed to contain option-like features. Just like other option-like securities, equity in a levered firm can be examined to identify the key variables in an option and then apply the option pricing theory to value it. The key variables include the underlying asset, the volatility of the underlying asset, the exercise price, the maturity period and the risk-free rate of interest. A leveraged equity can be regarded as a call option on the value of the firm with the exercise price as the face value of the zero coupon debt issued by the firm while the expiry date is the maturity period of the debt. For a firm financed by both equity and debt, the value of the equity can be regarded as the option price to be paid up front. The underlying asset is the value of the firm. The initial value of the underlying asset is the initial sum of the equity and debt of the firm. The exercise price is the value of the zero coupon debt at maturity. The equity holders only have residual claims to the value of the firm at maturity. The debt holders are therefore paid first while the residual value of the firm goes to the equity holders. The equity holders have downward protection as their payoff is limited to zero at maturity but they benefit maximally from upside potential. Extant studies on the valuation of firm equity and risky debts have explored the option pricing approach to the pricing of equity in a levered firm (Aggarwal & Zhao, 2008; Ataullah, Higson, & Tippett, 2006; Chesney & Gibson-Asner, 1999; Grass, 2010; Myers, 1977)

5. Collateralized Loans
The characteristics of loans issued by banks and guaranteed by collaterals are also option-like. Loans in which creditors cannot resort to other assets of the debtors other than the pledged collaterals are options on the value of the collaterals. For these nonrecourse loans, the collateral is the underlying asset; the exercise price is the loan amount to be paid back (principal plus interest) at the end of the maturity period. The collateralized loan is a put option which gives the creditor the right to sell back the collateral to the debtor at the end of the loan maturity period at an exercise price which equals the principal plus interest. If the debtor defaults, the creditor exercises the right to sell the collateral at the prevailing price to recoup the loan amount. Banks can therefore use the option price methodology to price the loans to be granted to debtors. Debtors can also use the same methodology to determine the optimal time to default on a loan depending on the market value of the pledged collateral.Stewart C. Myers coined the term real options in his attempt at using financial option pricing approach to value corporate borrowing (Myers, 1977). Other innovative derivatives are now being derived from collateralized loans and are commonly referred to as collateralized debt obligations (CDOs).
In addition to the option-like assets and liabilities mentioned above, option pricing applies to many other different corporate finance topics such as dividend policy, capital structure, mergers and acquisitions, investment policy, spin offs, divestitures and abandonment decisions (Copeland, Weston, & Shastri, 2004). The extension of option pricing methodology to the valuation of ‘real’ assets or investment projects however marked another milestone in the theory and applications of OPT.

3. Real Options Theory and Its Application in Management

3.1. Real Options Theory
Ever since the term “real options” was coined in 1977, its study has attracted interests among researchers and practitioners that have followed the defining developments in options pricing theory. Finance researchers had therefore looked forward to another breakthrough in real option pricing technique and its wide application in the field of finance. In the same way option pricing formula is used by option traders daily on the floors of option exchanges, theorists had expected that real options technique would soon replace the traditional discounted cash flow in the valuation of investment projects. Real options theorists argue that option pricing methodology is also applicable in the valuation of capital investments by firms. It is argued that investments projects are option-like investments and therefore can be valued using OPT.Capital projects are characterized by irreversibility and uncertainty. In financial options, returns on financial assets can be maximized in the presence of uncertainty by embedding options on these assets to manage the risks inherent in the assets’ prices. In a similar way, various options, in forms of strategic and operational flexibilities can be embedded into investment projects to manage inherent risks in the development and use of the assets and thereby maximize their values. Extant literatures on real options have identified various common real options and option-like strategic investments.

3.1.1. Common Real Options

LenosTrigeorgis, a leading real options theorist, identified the common real options that can be incorporated into firm's investment projects. These include options to wait or defer, time-to-build option, option to alter operating scale, option to abandon, option to switch, growth option and multiple interacting option (Trigeorgis L. , 1993b). These various option types have been found to be incorporated into investment projects increasing their values in the process. Embedding real option into investment projects, the author argues, expands the values of the projects and hence the value of the firm. These options expand the values of investment projects under uncertainties because they build managerial flexibilities into the development and operation of the capital assets. Building these real options into investment projects give the managers the right to exercise or take some decisions in the future given the resolution of the uncertainties. The starting point in the use of real options methodology is the identification of the real options that can be embedded into the capital projects including the estimation of options variables in the project. The present value of the underlying asset is the same as the present value of the investment project. The exercise price depends on the real options being valued in the project and is usually the cost incurred to exercise the option embedded into the project. The maturity period is the period between when the real option is built into the project and when the real option is exercised. The risk-free rate remains the interest rate on the government treasure bill /bond. Estimating volatility of the underlying asset has however remained the key challenge in real options application. The different methods used to estimate the project volatility is discussed in the next section of the dissertation.
The common real options identified in the literature and examples of their applications are discussed below:

1. Option to Wait or Defer

Under demand uncertainty for the products of the firm and/or the cost of developing an investment project, firm managers can embed this option into their capital investments. For new products with uncertain demands and for commodities such as crude oil and real estate, managers can wait for the resolution of uncertainty before developing the asset. The preliminary assets such as exploration license or land for real estate can be procured while the managers wait for some time or the maturity period of the option to wait or defer before developing the asset. A cost, in form of lost revenues while waiting, is incurred to enjoy the right to exercise the option in the event of favourable condition. The exercise price is the cost of development of the asset while the expiry period of the option is the time period of waiting. The option pricing approach is used to estimate the option value of waiting. The option to wait adds value to the project if the estimated option value is more than the lost revenue that would have accrued to the firm if there has been no waiting or if the traditional net present value approach had been used. Extant real options studies have valued options to wait or defer in investment projects (Joaquin & Khanna, 2001; McDonald & Siegel, 1986; Miljkovic, 2000; Paddock, Siegel, & Smith, 1988; Titman, 1985; Yongma, 2014)

2. Time-to-build Option

This is otherwise referred to as the option to stage investment. The incorporation of this type of real options is intuitive. Project managers may break large investment projects into stages in order to transfer the experience from earlier stage(s) to later stage(s). Staging large capital investments gives the managers the right to develop subsequent stage(s) of the project depending on the resolution of uncertainties in future revenues and/or costs of project development. Option price or premium in form of the development costs of the first stage gives the right to incur development costs on the next stage. The exercise price is the cost of developing the subsequent stage(s) while the maturity period is the time period between when the time-to-build option is built into the project and the date of exercise of the staging option. Time-to-build options are quite valuable in large capital-intensive infrastructure projects such as roads, rails, ports, energy plants, water plants and telecommunications. The projects are developed in stages to resolve technical uncertainties and uncertainties in the demand for the projects' products and/or services. Time-to-build real option pricing methodologies have been developed and valued using case study applications in a number of real option studies (Berry & Zuo, 2010; Majd & Pindyck, 1987; Milne & Elizabeth, 2000; Pacheco-de-Almeida & Zemsky, 2003; Rodrigues & Armada, 2007; Trigeorgis L. , 1993a).

3. Option to alter operating scale

Another form of real options is the option to alter operating scale of a capital investment project. The real options can be in form of option to expand or contract the scale of operation of the capital project. If this option is built into the project during the planning stage, the managers can exercise this right by incurring costs (call option) to expand the project or sell parts of the projects by contracting the scale of operation (put option). The options are usually valuable for capital-intensive irreversible projects in the face of uncertain demand in the projects' products and/or services. The firm managers incur some costs or option prices or premium to build the scale flexibility into the investment projects. These options are common in energy and manufacturing firms' operations where the demands for the products are uncertain and change cyclically. Instead of building plants that are inflexible to changes in demands for the plants' products, the firm manager can incur upfront cost to embed option to alter operating scale of the asset. A number of real options studies have examined options to expand or contract operating scales in capital investment projects (Brennan & Schwartz, 1985; Charalampopoulos, Katsianis, & Varoutas, 2011; Kogut, 1991; Lawryshyn & Jaimungal, 2014; McDonald & Siegel, 1985; Page, 2012; Pederson & Zou, 2009; Sewalk & Dai, 2014; Varma, 2011; Yuan, 2009)

4. Option to Abandon

In some cases, it may not be economically viable to continue to use some assets for a firm's operations. The put real options to sell a capital asset in future for the asset's salvage value may be highly valuable. In the presence of uncertainty in the future cash flows to be derived from the operations of a capital asset, option to abandon can be built into the asset for protection against future losses. The exercise price in this option is the salvage or resale value of the asset. The firm exercises the right to abandon whenever the salvage value is greater than the discounted future cash flows from the asset. This option can be valuable and can turn a negative NPV into a viable project if this option is built into the asset. Option to abandon can be incorporated into large scale infrastructure project. Instead of limiting future cash flows to only cash flows from products and/or services, cash flows from salvage values of the assets can also be considered and this option built into the project. In real options literature, options to abandon have been shown to add values to investment projects by providing downward protections to future operating losses (Berger, Ofek, & Swary, 1996; Clark, Rousseau, & Gadad, 2010; Huang & Chou, 2006; Williams, 1991)

5. Option to Switch Between Inputs and/or Outputs

In addition to incorporating scale flexibility into capital investment assets, it is also possible to embed input/output flexibilities into investment projects. There are some plants that can be built with the option of switching between inputs depending on the prices of raw materials or inputs used in the production of finished products by the plants. For example a power generating plant can be built with the option to switch between oil and gas depending on the prevailing prices of these input products. If the option to switch between the inputs is built into the plant, the firm managers can exercise the right to switch from one input to another input on or before the end of the productive years of the asset. In addition to option to switch between inputs, real options to switch between outputs can equally be incorporated into capital assets at the planning stage of the asset. This can be valuable in manufacturing industry where manufacturing plants are built with the option to switch between two or more finished products depending on sale prices and demands of the products. Upfront costs or option prices or premiums are incurred by the firm to enjoy the future right to switch between the inputs and/or outputs.These options have been shown to be highly valuable under uncertain prices of inputs / outputs (Bastian-Pinto, Brandão, & Hahn, 2009; Bastian-Pinto, Brandão, & de Lemos Alves, 2010; Brandao, Master Penedo, & Bastian-Pinto, 2013; Dockendorf &Paxson, 2013; Henseler & Roemer, 2013; Johnson, 2010; Kulatilaka & Marks, 1988; Siddiqui & Takashima, 2012)

6. Growth Option

Some key investments are needed by firms to enjoy the opportunities for future investments. If these key investments are not made, firms may not enjoy the future revenues from follow-on investments that will be made based on the assets that are already in place. Most investments in infrastructure projects by firms are rights to further invest in the future depending on the resolution of future uncertainties in revenues and/or costs. Investments in research and development (R&D) by firms also fall under this category. Firms incur costs in research in order to generate research outputs for new products or improvements of existing products. If developments of these research outputs are viable, firms further incur development costs to turn the research outputs into new/modified products. The initial investments in research give the firm the right to exercise the option for follow-on investment and to earn future revenues from the products and/or services. If further developments of research results are not viable, the option is left unexercised. Investments in infrastructure such as transport (roads, rails and ports) and telecommunications also give the rights for follow-on investments that are later exercised under favourable economic conditions. These real options are referred to as growth options because they provide growth opportunities based on initial investments. Extant real options studies have identified and valued growth real options in firms including effects of the options on firm values (Abel & Eberly, 2012; Albuquerque, 2014; Alessandri, Tong, & Reuer, 2012; Baldi & Trigeorgis, 2009; Fujiwara, 2012; Loch & Bode-Greuel, 2001; Ming-Cheng & Yen, 2007; Reuer & Tong, 2007; Taudes, 1998; Tong, Reuer, & Peng, 2008)

7. Multiple Interacting Real Options

More than one real options type is usually present in real life projects. The above real options, when valued in multiple time periods, are themselves compound options because they are embedded in real life investments as option on option. Option to wait in time period 2 is a real option on option to wait in time in time period 1. The option to develop stage 2 of a staged investment is an option on option to develop stage 1. Options to alter operating scale, abandon and/or switchare option on the initial option to invest on the project. In the same way, option to invest in follow-on investment in a growth option is an option on the initial option to invest in the initial infrastructure or in a R&D project. These real option types exist together in investment projects interacting together to affect the values of the projects. Unlike financial options where more than one option on the same underlying asset can be valued separately with no interaction, interactions of real options on capital projects affect their values. A financial call option and a put option written together on a common stock do not affect the individual values of the options. They can be valued separately and added together. However the real option to wait, time-to-build and growth options in an infrastructure project cannot be valued separately and added together. The incorporation of the options affect the value of the infrastructure assets and therefore their interaction effects need to be considered when they are valued together in a project. This further supports the inadequacy of the Black-Scholes option formula for the valuation of real options in capital projects. Although attempts are being made by real options researchers to develop generic formula for real option valuation, only project-based real options valuation technique can take care of complex nature of multiple interacting real options in real-life investment projects. Although this complex mathematical rigour has slowed down the adoption of real options methodology in practice, the intuitive applications of real options in theory and in practice have however been encouraging to the real options promoters.

3.1.2. Option-like Strategic Investments

Amram and Kulatilaka in their book (Amram & Kulatilaka, 1999) explored capital investments by firms classifying them as option-like strategic investments. Studies on real options framework continue to bridge the gap between finance and strategy in management studies. When capital investments are analyzed using real options methodology, their strategic values are more appreciated as opposed to analyzing them with the traditional capital budgeting tools. The use of the traditional discounted cash flow approach treats capital investment decisions as mostly financial decisions based on whether or not the project will add value to the firm based on the forecast cash flows and the opportunity cost of capital. The decisions do not mostly consider follow-on actions that can be taken in the future to optimize the values of the option. To enjoy the right to take these future follow-on decisions, some forms of strategic and operational flexibilities need to be built into the projects at the onset and at a price. Amran & Kulatilaka identified these option-like features present in firms' capital investments that make them suitable for real options analysis.
The authors state that real options analysis is needed in the following situations:

1. When there is a contingent investment decision

Option pricing theory is based on the analysis of contingent claims. Contingent claims are payoffs or cash flows from an investment in an asset that depend on the outcomes of uncertain conditions. Most capital investments by firms are followed by follow-on investment decisions. Even the so-called one off decisions can be structured in ways that allow them to be followed by subsequent investment decisions thereby optimizing their values in the process. Although the authors say that capital investments with a contingent investment are more suitable for real options approach, strategically virtually all long term capital investments can be structured in a way that will allow them to be followed by contingent investment decisions.

2. When uncertainty is large enough that it is sensible to wait for more information, avoiding regret for irreversible investments

This underscores the value of waiting or the value of the real options to wait or defer investment. The questions of whether there is added value in waiting and how long a firm waits for more information have been examined by a number of real options theorists. This key proposition by the authors opened up follow-up studies on the determination of the optimal time to initiate the development of a capital project by a firm. While the level of uncertainty involved may not require the incorporation of option to wait or defer, other real options types may however need to be incorporated to optimize the value of the project even at that level of uncertainty.

3. When the value seems to be captured in possibilities for future growth options rather than current cash flows

Investments such as R&D fall under this category. R&D and other related-investments such as investments in employee training are negative NPV investments when considered alone. However when the possibilities of follow-on investments are analyzed together with the initial investments, firm managers will be in a better position to determine whether or not to embark on such investments. Traditional capital budgeting tools are not robust enough to analyse these kinds of investments and will require a technique such as real option approach that considers the strategic follow-on investment decisions that can be taken in the future.

4. When uncertainty is large enough to make flexibility a consideration

A recurring term in real options theory is uncertainty. In a world of certainty there is no need for real options theory. However it is well known that the only thing that is certain in life is change. Virtually all investments, financial and nonfinancial, are subject to some degree of uncertainty. The only financial investment that is termed risk-free in finance is investment in a Government-issued Treasury bill or bond backed by the sovereignty of the nation concerned. Even the investment is not absolutely risk-free because a number of nations have been recorded to default on their debt obligations. The question is not whether or not strategic or operational flexibility will add value to investment projects but whether the value to be added will surpass the cost to be incurred in embedding the flexibility or real options into the project. It is therefore necessary to weigh the option price or the cost to be incurred with the values the real options will add to the project.

5. When there will be project update and mid-course strategy corrections

It is hardly possible to have perfect information before embarking on any capital project. Firms therefore need to embark on capital investments with limited information on what the future holds for the firm. Incorporating options for future investment decisions to respond to unfolding events are therefore necessary to give the firm downside protection while at the same time offering opportunities for upside potentials. If these flexibilities, in form of real options, are not built into the projects, the firm may need to totally abandon the ongoing project and embark on fresh investment decision rounds subject to another round of uncertainty. Incorporating real options therefore affords the firm the opportunity to update the project in future and to embark on mid-course strategy corrections.
Although the authors have come short of saying that all capital investments by firms can be subjected to real options analysis, in reality virtually all the capital investments embarked by firms can be analyzed using real options analysis. Follow-on studies on real options continue to show that real options apply in very wide area of business management. With the rising profile of strategic management studies, it can thus be argued that virtually all firms' capital investments are strategic in nature and therefore candidates for real options' thinking and/or valuation.
The strategic investments identified by the authors are reviewed as follows:

6. Irreversible Investments
In real options theory, two key recurring terms are irreversibility and uncertainty. Firms' investment projects are largely irreversible and therefore need to be properly analyzed and valued before they are embarked on. The common real options identified earlier can be built into these investments to optimize their values. Option to wait or defer, for example, can be incorporated to allow uncertainty surrounding future cash flows from the project to be resolved to some degree. For example irreversible investments in a particular sector of an economy may need to wait for clear policy direction of the government. Other real options that can be built into the irreversible investment are time-to-build or staging option and growth options. While others are waiting for the government policy, a firm can initiate some form of investment that can be improved on or readjusted once the operating environment becomes clearer.

7. Flexibility Investments
Incorporating real options into investment projects gives managers the right to make the investments flexible. Flexibility investments respond better to changing business environment and therefore more desirable for firms hoping to maximize returns on their investments. Firm managers need to take conscious steps to embed strategic and/or operational flexibilities into investment projects. Common real options provide the firms with these opportunities. Option to alter operating scale and switching real options are examples of real options that can turn firms' capital investment into flexibility investments. Option to expand or contract the operating scale of a plant or related investment when built into the capital project enables the firm to take flexible investment decisions in the future. In the same way, option to switch between inputs or outputs gives the firm the opportunity to enjoy flexibility in inputs to firm's plant or flexibility in the products that are produced from the plants. The firm optimizes return on investment in the process.

8. Insurance Investments
Although real options can be compared to insurance policies, incorporating options into capital investments produces payoffs or cash flows with returns that are over and above returns from insurance policies. While insurance policy holders pay premium that restore their assets to their original forms in the event of loss or theft or any other unfavourable circumstances, option holders not only pay premium to preserve the value of the assets, the option prices give the right to payoffs far above their asset prices in favourable circumstances. In addition to insuring their plants, firm managers can also incur some costs in forms of real options to meet unexpected upsurge in the demand for their products for example. Spare facilities or convertible plants can be maintained to meet unexpected rise in demand for their products in the future.

9. Modular Investments
Modular investments are more or less growth and/or staging real options. Modular investments build strategy into the valuation of investment projects. They are therefore better analyzed using real options methodology. Capital projects implemented in modules give the firms the opportunity to respond better to unfolding realities. Development of subsequent modules can be fast-tracked, delayed or even abandoned totally depending on what the future holds for the firm. Other common real options such as option to alter operating scale and switching option can also be built into modular investments.

10. Platform Investments
Platform investments are basically capital investments with opportunities for follow-on investments. These investments typically have growth real options incorporated into them to give the firm the right to embark on subsequent investments in favourable economic conditions. Growth real options have been shown to dominate other real options incorporated into capital investment projects in a study of large Canadian firms (Baker, Dutta, & Saadi, 2011). Large capital-intensive investments are usually platform investments or can be broken down into platform investments and real option approach provides a more robust approach to analyzing them when compared to the traditional capital budgeting technique.

11. Learning Investments
Learning investments are embarked on to produce information on which the decision to embark on follow-on investments are made. They can be regarded as invisible or intangible platform investments in that they may not require procurement of physical assets. When considered alone and analyzed using the traditional investment appraisal tools, learning investments will result in negative NPV and will thus not be viable. However when options for follow-on investments that use the information revealed by the leaning investments are considered, the investments can have substantial values.

The robustness of real options approach and its potential wide applications to firms' investment projects have attracted finance and other management theorists to real options research. Although real options frameworks have successfully been used as a heuristic in management studies, a breakthrough in real options valuation similar to that of financial options will go a long way in fast-tracking the adoption of the approach in capital budgeting process by practitioners. Real options valuation studies however continue to hinge closer to a breakthrough in the development of generally acceptable and intuitive real options formula albeit at a pace slower than anticipated when the term was coined in 1977.

3.1.3. Real Option Valuation Techniques
Early extensions of option pricing theory to other areas of finance make use of Black & Scholes option formula. These include the application of OPT to the valuations of collateralized loans and equity in a levered firm. The option pricing formula is directly applied in the scenarios after identifying the five key option pricing variables. These variables include the value of the underlying asset, the

volatility in prices of the underlying asset, the exercise price, the maturity period and the risk-free rate of interest. In using the Black & Scholes formula, the variables are identified and estimated and their values used to compute the option prices. Real option valuation evolves from the use of Black & Scholes formula in the valuation of common real option values in capital investment projects. Capital investment projects are analyzed to identify the variables to be used in the estimation of the option prices. The present value of the investment project is used as a proxy for the value of the underlying asset in the formula, the exercise price is estimated as the cost of the development of the asset when the real option is exercised and the maturity period is usually the time period between when the decision to invest is taken and the time when the embedded real option is exercised. While the risk-free interest rate is usually estimated from the historical prices of Government Treasury Bill/Bond rate, real option theorists are yet to agree on methodology for estimating project volatility in a real option valuation.

Some unresolved issues on estimates of volatility and other issues have questioned the direct use of option pricing formula in real option valuation of capital investment projects. A number of applications have used the option pricing formula directly to value capital projects using the volatility in the share prices of the firm investing in the project or the volatility in share prices of similar firm as a proxy for the volatility of the project (Amram & Kulatilaka, 1999). It can however be argued that the volatility of a capital project will be quite different from the volatility of the firm investing in the project or any other similar firm. The fact that investment projects are not usually tradable assets has also been a strong argument against the use of option pricing formula to directly value real options in capital projects. Another argument is that interest rate used in real options valuations are not certain and need to be modelled along with the uncertain values of the underlying assets (Schulmerich, 2005). The users of Black & Scholes formula for real options pricing are however quick to point out that even with the shortcomings in the use of the formula, the methodology presents a more robust approach to valuing capital investment projects when compared to the traditional discounted cash flow approach. Empirical evidence to support this assertion is however yet to be provided. Two key real option valuation techniques that have featured prominently in real options literature are the analytic methods and the numerical methods.

1. Analytical Methods

Financial mathematicians and engineers have continued to find closed form solutions to the underlying financial problems in real options usually expressed as stochastic partial differential equations. The mathematical language to value uncertainty in mathematical finance is stochastic calculus. Black and Scholes' breakthrough in option pricing theory came with the solution to the age-long partial differential equation underlying the European call option. Myron Scholes (Fischer Black died in 1995) and Robert C. Merton, who extended the option pricing formula, were awarded the Nobel Prize in Economics in 1997 for the feat. Attempts to develop closed form real option pricing formula by real options theorists grounded in financial mathematics and engineering have continued since the term real options was coined in 1977 (Carr, 1988; Grenadier, Steven, & Malenko, 2010; Huang & Chou, 2006; Liu Y.-H. , 2010; Margrabe, 1978; Majd & Pindyck, 1987; McDonald & Siegel, 1985; McDonald & Siegel, 1986; Pindyck, 1990; Wong, 2011). Although real option valuation theorists have succeeded in using analytical methods to develop real option valuation formula for specific capital investment projects, attempts to generalize the developed formulas to capital investment projects have however been quite unsuccessful. The developed formulas are characterized by too many simplifying assumptions and only applicable to relatively simple cases of real options embedded in investment projects. The more attempts are made at developing closed form solutions to complex real options problems, the more complex and less intuitive the formula becomes and hence the lower its probability of being adopted in practice. This has encouraged the use of numerical approach to real option valuation while a breakthrough in real option pricing is being awaited.

2. Numerical Methods

The field of mathematics uses numerical methods to find approximate solutions to differential equations. In stochastic calculus of financial engineering, numerical methods are used to solve stochastic partial differential equations. The movement of prices of financial assets under uncertainty are represented by stochastic processes. Stochastic processes, including arithmetic and geometric Brownian motion, are used to model the evolution of random variables in finance. The modelling of the stochastic processes results in partial differential equations which can be solved to produce analytical solutions or approximated using numerical methods. The steps involved in developing valuation formula for real options, just like for financial option, involve the following:

- Deciding on the appropriate stochastic process to represent the evolution of the values ofthe underlying asset (the project values in real options)
- Developing a set of partial differential equations from the stochastic processes
- Solving or approximating the developed partial differential equations to obtain the real option pricing formula.

The two main numerical approaches that have been used in real option literatures are approximation of stochastic process of the underlying project value and approximation of partial differential equations. Real option numerical methods that approximate the stochastic process of the underlying asset are more intuitive and less complex than those that develop partial differential equations from the underlying asset before approximating the resulting partial differential equations. These numerical methods include binomial approximation and Monte Carlo simulations and have been used in real options studies directed at practitioners (Benninga & Tolkowsky, 2002; Herath & Park, 2002; Panayi & Trigeorgis, 1998; Smit, 1997; Sodal, Koekebakker, & Adland, 2009; Titman, 1985; Trigeorgis L. , 1991; Trigeorgis L. , 1993a). The numerical methods that approximate the resulting partial differential equations are finite differences (Implicit and Explicit) and numerical integrations. Studies on valuations of real options in capital investment projects have equally employed these methods (Brennan & Schwartz, 1985; Paddock, Siegel, & Smith, 1988; Rose, 1998)

3.2. Applications of Real Options

While the search for a breakthrough in real option valuation similar to that of financial options continues, management researchers continue to apply real options logic to other topics in management. Attempts are also made in real options literatures to value various real options identified in a number of management theories and/or practices. In addition to its area of origin, finance, real options theory has been quite useful in such other areas as operation management, marketing, human resource management, management information system, biotechnology &health management, real estates, agriculture, infrastructure & natural resource management and in other socio-economic phenomena.

3.2.1. Real Options in Operations Management

Operations management is closely linked to efficiency while efficiency is a key determinant of firm performance. For two firms with the same strategy and operating in the same environment, a key distinguishing factor is superior efficiency in the management of their operations. Operations researchers have employed the novel risk management features, in form of managerial flexibilities, in real options to offer support for existing theories in operations management and to incorporate and value real options in firms' production assets. These include using real options to value control charts decisions (Nembhard, Shi, & Aktan, 2002), production plants in three countries under exchange rate uncertainty (Wu & Lin., 2004) and cores for remanufacturing in service markets (Wei & Tang, 2015). Other real options applications include in the valuation of embedded options in supply chain decisions (Avanzi, Bicer, de Treville, & Trigeorgis, 2013),corn ethanol facilities (Maxwell & Davison, 2014) and real options in Six Sigma projects (Padhy & Sahu, 2011)

3.2.2. Real Options in Marketing

Real options framework and valuation approach have also been employed by marketing researchers in a number of their studies. The applications of real options in marketing include in the valuation of uncertainty in prospective and selling decisions (Adams, 2004) and customer lifetime value in business-to-business relationships (Roemer, 2006). Real options theory has also been used to provide further support and evidence for extant relationships in marketing for example the relationship between customer relationship management (CRM) outsourcing and customer satisfactions (Graf, Schlegelmilch, Mudambi, & Tallman, 2013).

3.2.3. Real Options in Human Resource Management (HRM)

The application of real options has also been extended to HRM studies. Real options valuation technique has been used, for example, in the valuation of employee training and also used to further explain the relationship between HR management and long-term organizational flexibility (Andoljżek, 2005). HR options are also shown to explain 37 percent and 42 percent of the variance in operational and financial performance of firms respectively (Sanyal & Sett, 2011). Other studies on the application of real options in HRM include the study of the relationship between employee incentives and real options logic in firm investment decisions (Wang & Lim, 2008) and the use of real options framework to model and financially value a cross-training policy of a firm (Nembhard, Nembhard, & Qin, 2005).

3.2.4. Real Options in Management Information System (MIS)

Information and communication technology (ICT) has transformed the ways firms do their businesses and has positively affected firms' effectiveness and efficiency. Investments in ICT have been shown to provide opportunities for other future investments and are thus strategic investments in which real options logic and valuation approach are applicable. MIS researchers, in their studies, have thus widely applied real options thinking and tools to value ICT investments and to examine their effects on firm values. Some of these applications include the valuations of option to delay mobile telecommunications network investment (Franklin, 2015), investment in radio frequency identification (RFID) under product uncertainty (Dimakopoulou, Pramatari, & Tsekrekos, 2014), electronic banking network expansion (Benaroch & Kauffman, 2000) and virtual world technological initiatives (Yang, Lim, Oh, Animesh, & Pinsonneault, 2012). Other studies use real options to explore relationships such as that between ICT investment decisions and managerial intuition(Lankton & Luft, 2008) and the relationship between exercise of electronic commerce investment options and firm performance (Otim & Grover, 2012).

3.2.5. Real Options in Biotechnology &Health Management

The inherent strategic and operational flexibilities in R&D investments and investments in production of drugs and other related products have encourage the application of real options in biotechnology and health management industries. The studies include the use of real options to value a multi-staged pharmaceutical R&D investments (Cassimon, De Backer, Engelen, Van Wouwe, & Yordanov, 2011) and the use of real options analysis in the valuation of open innovation initiatives in biopharmaceutical R&D (Lo Nigro, Morreale, & Enea, 2014). Other related studies include the application of real options in the valuation of human papillomavirus (HPV) vaccination strategies (Favato, Baio, Capone, Marcellusi, & Saverio Mennini, 2013) and a case study valuation of a pharmaceutical firm (Banerjee, 2003)

3.2.6. Real Options in Real Estates

Real options applications in real estate development include the empirical predictions of a real-option-pricing model on market values of lands and buildings (Tsekrekos & Kanoutos, 2013) and the valuation of the real option values in the development of vacant parcels of land (Grovenstein, Kau, & Munneke, 2011). Other real option studies include the study on the effect of real options to rebuild or enlarge existing buildings on the dynamics of house prices (Clapp, Eichholtz, & Lindenthal, 2013) and the effect of redevelopment options on urban land values (Womack, 2015).

3.2.7. Real Options in Agriculture

Applications of real options in agricultural science and agricultural economics include the real option valuation of investments in a farm-based anaerobic digester (Anderson &Weersink, 2014), a real options-NPV valuation of private land use decisions (Yemshanov, McCarney, Hauer, Luckert, Unterschultz, & McKenney, 2015) and real option valuation of bare land under uncertainties in log and carbon prices (Manley, 2013). Other valuation applications include the valuation of landowner's preservation option in agricultural conservation easements (Stokes, 2012),the option to delay investment in pasture (Tozer & Stokes, 2009) and valuation of timber harvesting real options (Khajuria, Kant, & Laaksonen-Craig, 2009). Real options framework has also been used to provide further support for some relationships in agricultural economics. These include the effects of farm product's price floors on farmland investment behaviour (Maart-Noelck, Musshoff, & Maack, 2013), the relationship between real option values and storage decision by farmers (Kim & Brorsen, 2012), economic incentive and migration of farm labour out of the agricultural sector (Önel & Goodwin, 2014) and effects of investment theory on farmers' (dis)investment behaviour (Ihli, Maart-Noelck, & Musshoff, 2014)

3.2.8. Real Options in Infrastructure and Natural Resource Investments

Investment in infrastructure and natural resources are usually capital intensive, mostly irreversible and are made under uncertainty in prices of infrastructural products/services and in prices of finished commodity products. Attempts have therefore been made to use real options methodology to value various real options that can be embedded in such investments. These include the valuation of abandonment option in an infrastructure project (Rakić & Rađenović, 2014), real option valuation of co-fired electricity generating plant (Xian, Colson, Mei, & Wetzstein, 2015) and a case study of real options approach to valuation of infrastructure investments (Power, Tandja M., Bastien, & Gregoire, 2015). Other applications of real options in infrastructure and natural resource investments include the real option valuations of bio-fuel plant under uncertain fuel prices (Li, Tseng, & Hu, 2015) and mining project (Zhang, Nieto, & Kleit, 2015). Real option theory has also be combined with portfolio theory and used to value a portfolio of electricity generation investments (Csapi, 2014).

3.2.9. Other Applications of Real Options

Real options theory has also be applied in other areas outside the usual topics of management. For example real options logic is applied to the issues of courtship in marriage (Dixit & Pindyck, 1994). In the presence of uncertainty in future happiness in marriage, prospective couples can pay an option price or premium in form of courtship to enjoy the right to tie nuptial knotand live happily thereafter. If the period of courtship reveals favourable future marital life, a formal marriage is exercised otherwise the partners can cancel future marriage plans. Real option approach has also been employed in the valuation of a college degree (Stokes J. R., 2013). Real option-like features include the uncertain future tuition and income and opportunity for follow-on investments in postgraduate degrees and their effects on the valuation of a college degree. These are usually not considered in the traditional approach to valuing a college degree. Another study has shown that cash has a real option value (Kisser, 2013). The author shows that high cash flow volatility can decrease the value of cash and uses real options to explore the effects of internal funds and external financing on firm's investment timing. Valuation of green building certificates has also been approached using real options framework (Vimpari & Junnila, 2014). The authors argue that green certificates have several characteristics similar to real options and show that real option approach is more suitable for valuation of the certificate when compared to the traditional discounted cash flow.

Other areas that real options methodology has been used include demographic studies, biodiversity and law. In the presence of uncertainty in economic conditions, a study formulates the demographic decision to have a child as a real option to wait to give birth or space births (Iyer & Velu, 2006). It is shown in the study that real options approach better explains the process of demographic decision making especially in the poor countries. In the area of biodiversity, it has been shown that the option to substitute species in the presence of uncertain values in future values of biodiversity can lead to optimal conservation decisions (Kassar & Lasserre, 2004).Law profession is not left out in the applications of real options. Litigation in law has been analyzed using real options framework (Grundfest & Huang, 2006). The authors argue that a real options analysis of the litigation process involves sequential information revelation and bargaining over the surplus generated by early settlement. Under uncertainty in the value of information to be revealed in the course of the litigation, growth options embedded in negative expected value lawsuits can make the litigations to be highly viable. Also in administrative law, the net expected value of a rule in agency rulemaking can be expanded by incorporating option-like schemes into the rulemaking (Lee, 2013).

4. Conclusion

The field of management has recorded a number of major theories that have transformed the field; key among the theories is options theory which originates from finance and its extension, real options. This paper has reviewed the evolution of real options from financial options and derivatives and their various applications in the fields of business and management. With the breakthrough in the derivation of options pricing formula in 1973, finance and other management theorists have been attracted by the far-reaching implications of the theory in diverse management disciplines. Various management studies have therefore explored potential applications of options theory leading to the coining of the term "real options" in 1977. The last four decades witness interesting studies on the subject and therefore calls for a revisit to the literature on evolution of real options from financial options. The paper explores the literature on real options; from its origin from financial options and derivatives to its applications in diverse management disciplines. The review shows that the subject will continue to attract interests from management theories because of its uniqueness in managing future uncertainties. There is also a great potential for further applications of the findings of real options' studies in practice with a far-reaching effects on management practice.

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