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Real Option Analysis for Valuating Investments in Information Technology Projects

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Abstract: This study presents an overview of ROA (Real Option Analysis) for valuating investments in IT (Information Technology) projects. For this purpose, we show how ROA assists the people in charge of the IT to take the most profitable investment decisions and how it encourages managerial flexibility. Then, we detail the mathematical basis of ROA in particular the asset variation modeled by Brownian motions and the computation of the net present value of IT projects. We also classify the ROA literature with the focus of the technique used. Lastly, we discuss the limits of the theory behind ROA. We distinguish between the limits coming from the assumptions related to the mathematical model and the limits coming from the use of intangible criteria in the pricing process. We finally conclude by reporting arguments and counter arguments of an approach based ROA from the analysis of the literature.

Key words: Information technology, real options, information systems, project management, approach, literature

INTRODUCTION

The idea of transferring ROA to real investments traces back to Myers (1974) whereas the application of ROA to the valuation of IT projects started in the early 1990's. The real option theory exploits pricing models derived from finance to model the variation of IT assets. In practice, it includes all intangible assets such as human, technical and informational resources that influence the ongoing IT projects. ROA aims at providing a good estimation of the cash flow of IT projects and thus, helping the decision makers to take the right investment decisions. ROA also presents an attractive alternative because it explicitly accounts for the value of future flexibility in management decision-making (Bardhan *et al*., 2004).

The real option theory suggests that management should proactively manage strategic investments by creating opportunities for mid-course corrections to investment strategies (Teece, 2007). By using managerial flexibility to deal with risk, managers can avoid risk or bring it down to acceptable proportions, for example by delaying decisions, transferring risk to a third party or by redirecting the course of the project (Fichman *et al*., 2005). Hence, the real options perspective is a promising complementary theory to existing theories by offering both financial and economic perspective on risk management logic as observed in practice.

ROA in its standard version uses an annual estimation of real options and the possible investment can take place at different points in time which is why the investment should rather be modelled as an American option (Taudes, 1998). American real options related to IT projects allow investing before the option expires, unlike European options which cannot be exercised before the maturity. In this study, we will consider only American call options, since, it is the most predominant options used in the literature. The valuation of the underlying options thus defined in ROA traditionally relies on the standard BSM (Black Scholes Model), described Black and Scholes (1973). A quantity called NPV (Net Present Value) is computed as a stochastic optimization problem. The objective is to maximize the NPV in most cases. BSM is based on continuous time and assumes that the benefit follows a Wiener process in which options evolve according to continuous stochastic processes, more precisely GBM (Geometric Brownian Motion) processes.

The possibility to stage, abort or defer expected investments in an IT project is represented by real options. The incertitude of the cash flow of an IT project can thus be corrected by applying the right option at the right time. With ROA, The decision makers can determine the optimal time to invest and identify the most profitable option for IT projects. However, the application of ROA is based on several assumptions, which are not always verified (Ullrich, 2013).

Foundation of real options: A real option itself is the right but not the obligation to undertake certain business initiatives such as deferring, abandoning, expanding, staging or contracting a capital investment of a project. IT

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Table 1: Types of real options for IT projects

Options	Description
Option to expand	When the progress of an IT project is better than what has been expected, the decision maker could invest in more resources ensuring the proper completion of an IT project
Option to withhold	Depending on the board elements, the decision maker could draw a pessimistic vision and decide to withhold future expected investments
Option to wait and see	The manager could delay an action awaiting more reliable information
Option to abort	If the expected market environment is totally unfavorable, the decision maker could abort investments in IT projects to avoid further losses
Option to defer	The manager could defer investments to some future time when the investment conditions look stable
Option to stage	If there is established inadequacy of the cash flow, the implementation of a project can be carried out in stages
Option to switch	In order to address a resource optimization problem, the input resources can be replaced depending on the course of a project
Option to adjust	The decision maker could decide to reduce or increase expected investments in IT projects
Option to learn	When there is a lack of information, the manager could decide to exercise a learning option

projects may be subject to investment restrictions or otherwise expanding investments. Trigeorgis (1996) presents a good overview of the main real options for IT projects management. Fichman *et al*. (2005) extend the works of Trigeorgis promoting management flexibility in the identified real options. Among these options, there is the option to expand, withhold, abandon and 'wait and see' as listed in Table 1. These options enable to invest before their expiration and the investment decision depends on the attractiveness of their IT project.

The option to expand and the option to withhold act on future expected investments, e.g., the reduction of expected investment in technical resources due to cost changes. These two options aim to adapt the investments based on the market conditions. The 'wait and see' option is valuable in that it will provide the decision maker with an opportunity to defer investing. Indeed, the right timing for making the investments is particularly crucial to achieve higher returns. The abandon option could occur if the expected market environment is totally unfavourable and thus, expected investments on the overall resources of a project are abandoned. Since, the investments in IT projects cover all IT resources, the presented options are not limited to the financial resources, it may encompass technical, human or informational resources and aims to cost and time savings.

The introduction of a new option in a given model needs a study of compatibility with the existing options of the Model. In the identified real options taken from the literature, we notice some redundancy, for example, the option to 'wait and see' consists of the combination of the option to learn and the option to defer. Another example is the option to adjust which combines the option to expand and the option to withhold. Regarding the option to switch, it is responds to the need of a proactive management of the IT while the option to stage responds to the need of cash flow optimization. Finally, the introduction of a new option depends essentially on the context of the organization and its needs.

Literature review: In the literature, many tools have been developed to help people in charge of the IT manage uncertainty and risk in their investments (Brandao and Dyer, 2005; Benaroch and Kauffman, 1999; Wu *et al*., 2009; Ball and Deshmukh, 2013; Munoz *et al*., 2011; Bakke *et al*., 2016; Angelou and Economides, 2008; Ghorfi *et al*., 2017; Collan *et al*., 2003; Crasselt and Lohmann, 2016). The standard BSM Model is often extended by applying complementary tools such as decision trees, analytical hierarchical processes, multiple-criteria decision analysis and the construction of learning option.

Classification of the literature: As suggest by Ullrich (2013), we propose to classify the articles that monetarily valuate IT investments with the help of ROA into three categories: those about investments in standard software, those about investments in individual software and those about investments in new technologies. Table 2 summarizes the identified literature regarding the real options technique they use J. Eng. Applied Sci.

Classification of the literature: Hilhorst *et al*. consider individual preferences besides a market valuation and evaluate project-specific risks using a decision tree to compute the expected option value. Angelou and Economides (2008) apply the 'analytical hierarchy process' through which the quality of different sources of uncertainty can be considered and calculate the option value considering uncertain cash outflows using a single step binomial tree. Wu *et al*. (2009) acknowledge that traditional option pricing models in general do not have the ability to correctly account for the complexity of IT investments. Therefore, in their study, the researchers formulate the determination of the option value as a stochastic optimisation problem. Thus, the assumptions of ROA become irrelevant to them. Ball and Deshmukh (2013) highlights cooperative real options with incentive pricing scheme into a multi-agent system and compute the expected option value using a binomial decision tree for each task. Ghorfi *et al*. (2017) consider four real options to track the evolution of IT projects. With the help of a Monte Carlo simulation, they calculate optimal time of investing in different scenarios.

In their part, Bardhan *et al*. (2004) account for the uncertain costs of software development projects by applying the Margrabe model and therefore by modelling the cash outflows as a random variable following

Table 2: Classification of the identified literature

Categories	Articles	Description	Focus of technique
Investments in standard software	Hilhorst *et al.* in 2006	Implementation strategy for the introduction of a capability management information system	Option based risk management+decision tree
	Angelou and Economides (2008)	Prioritising a portfolio of IT projects with interdependencies to follow-up projects of a water supply	Analytical hierarchy process+binomial tree
	Wu *et al.* (2009)	Implementation of an enterprise resource planning software	Stochastic optimization problem
	Ball and Deshmukh (2013)	Coordinating supply chain and resource allocation	Multi agent system+Binomial tree
	Ghorfi *et al.* (2017)	Implementation of IT governance best practices	Monte Carlo+Scenario analysis
	Bardhan *et al.* (2004)	Valuation of the IT project portfolio of an energy provider	Margrabe model+learning option construction
Investments in individual software	Munoz *et al.* (2011)	Valuation of project investments in wind power generation	Piecewise NPV estimation+Trinomial tree
	Bakke *et al.* (2016)	Evaluating the profitability of investing in electric energy storage	Markov switching+Least squares Monte Carlo
	Benaroch and Kauffman (1999)	Deployment of point-of-sale debit services by an electronic banking network	Black approximation+optimal timing of the investment
Investments in new technologies	Collan *et al.* (2003)	Enhancing the precision of cash flows of projects in ROA	Fuzzy BSM
	Crasselt and Lohmann (2016)	Tackling short term decisions in ROA	Short term option+Binomial tree

a stochastic process. Munoz *et al.* (2011) do not assume that the NPV abides a GBM process with constant parameters. To estimate these parameters, the researchers introduce a piecewise estimation. Bakke *et al.* (2016) determine the option value and optimal investment time for a battery bank. Their model combine regression analysis with a Monte Carlo simulation in a ROA framework.

Benaroch and Kauffman (2000) assume the cash outflows for the investment to be certain in their article and use a traditional Geometric Brownian Motion (GBM) in order to determine the optimal timing of the investment. Collan *et al.* (2003) introduce a new fuzzy real option valuationn method which is built on the use of fuzzy numbers and possibility distributions in order to tackle imprecision and uncertainty in a direct and explicit way. Crasselt and Lohmann (2016) consider the necessity to estimate option values at every decision point as a major drawback and therefore, propose a simplified options-based decision rule using a binomial decision tree.

MATERIALS AND METHODS

Mathematical model: In this study, we highlight the ideas and principles of Brownian motions applied to the valuation of IT asset. In the first part, we recall some basic definitions of probabilities and stochastic calculations in order to explain the valuation of financial assets through Brownian motions. Then, the second part underlines the transition from financial to IT assets.

Brownian motions to model financial assets: Let us consider a random variable X. Now introducing another parameter t referring to time, X_t is called a stochastic or random process. We assume that all X_t are Gaussian distributions (Normal laws) with a mean μ and a variance σ:$X \sim N(\mu, \sigma)$, this process is now called a Wiener process.

A standard Brownian motion B_t is a wiener process defined with the following expectation and covariance: $E[B_t] = 0$ and $Cov(B_t\text{-}B_s) = min(t, s)$. This process has independent and stationary increments:

- For $k>l>j>i$: $Cov(B_k\text{-}B_l, B_j\text{-}B_i) = 0$ (independent increments)
- For $t>s$: The variance, $Var(B_t\text{-}B_s) = t\text{-}s$ (stationary increments)

A Brownian motion xt with a drift parameter μ and a diffusion coefficient σ is defined as follow:

$$x_t = \mu_t + \sigma B_t \quad (1)$$

Where:

B_t = Standard Brownien motion
μ = Drift parameter
σ = Diffusion coefficient

This process abides to a normal distribution $x_t \sim N(\mu_t, \sigma^2 t)$ and has independent and stationary increments. The idea behind the standard BSM Model is to model the variation of a financial asset st by a Brownian motion. The return on investment r_t of asset st is assumed following a Brownian motion as shown in Eq. 2:

$$r_t = \frac{s_{t+dt} - s_t}{s_t} = \mu_t + \sigma B_t \quad (2)$$

This assumption is called the assumption of stochastic process and constant variance (i). Hence, we built a simple Brownian model of asset price movements. Further information on Brownian motions within finance can be found by Shreve *et al*. (1997). We note that from the previous equation, return r_t abides a Brownian motion whereas asset s_t abides a geometric Brownian motion. We can verify this with a Taylor expansion of the log function assuming a low variation of the asset:

$$r_t \approx \ln(r_t+1) = \ln\left(\frac{s_{t+dt}}{s_t}\right) \quad (3)$$

Thus, we obtain the value of the asset:

$$s_t = s_0 \exp\left((\mu-\frac{\sigma^2}{2})t+\sigma B_t\right) \quad (4)$$

Where:
s_t = Asset value
r_t = Return on investments
$\sigma^2/2$ = Risk premium of uncertainty
B_t = Standard Brownian motion

Equation 4 describes the value of a financial asset s_t which abides a geometric Brownian motion. The solution of this equation relies on ITO formulas (Shreve *et al*., 1997). The diffusion coefficient represents the volatility of asset s_t in the standard BSM while the drift parameter represents the expectation of return r_t. The volatility can also be defined as the standard deviation of return r_t. The necessary assumptions for the transition from financial assets to real assets of IT projects are reported in the next study.

Net present value of IT assets: The condition of the transition from valuating financial assets in the stock market to valuating real assets of IT projects is the assumption of complete market. This assumption implies that there is a single price of an asset as well as there is a single return on investments for each asset. This means that there is no profitable arbitrage. Even if markets are incomplete for the great majority of the projects, this assumption is often used in the field of continuous time real option valuation and allows the determination of the correct discount rate for the projects (Brandao and Dyer, 2005).

In the standard BSM Model, the value of a call option is defined by its discounted excepted terminal value $E[s_t]$ (Benaroch and Kauffman, 1999). The minimum return of the share is assumed to be a fixed-rate asset which has a constant yield. This arises from the assumption of non-fluctuating interest rates. The current value of a call option is thus given by:

$$C_t = e^{-r_f t}E[s_t] \quad (5)$$

where, r_f is risk free interest rate. In the case of an IT project, C_t represents the cash flow of the project. After exercising a real option, the net present value measures the profitability of investments during the life of the option. The option is profitable for a project when and only when the NPV is positive and greater than the one of other options. In the case of continuous time with the assumption of the certain duration of the option and the assumption of risk-neutrality, the NPV is given by the following Eq. 6:

$$NPV = \int C_t dt = E_Q[\int S_t e^{-r_f t} dt] \quad (6)$$

Where:
E_Q = Risk neutral expectation
NPV = Net Present Value

The net present value of share st given by the previous equation depends on the initial price s_0 and the three parameters r_f μ and σ. However, it may include other parameters such as income, costs, amortizations, loan and taxes. Then, the option price and is often expressed as a function of a share s_t following a GBM and other parameters which vary over time:

$$P_t = u(s_t, t) \quad (7)$$

Where:
u = Function of s_t and t
P_t = Option Price

Thanks to the ITO formulas, the new expressions of volatility σ and drift parameter μ are given by Eq. 8 tacking into account all parameters of Eq. 7. Finally, the option price and the net present value are given by Eq. 9 and 10:

$$\mu_0 = \frac{\frac{\partial u}{\partial x}+\mu S_t\frac{\partial u}{\partial s}+\frac{1}{2}\sigma^2 S_t^2\frac{\partial^2 u}{\partial S^2}}{u(t, S_t)}, \sigma_0 = \frac{\sigma S_t \frac{\partial u}{\partial S}}{u(t, S_t)} \quad (8)$$

$$P_t = P_o \exp(\mu_o - \frac{\sigma_0^2}{2})t+\sigma_o B_t \quad (9)$$

$$NPV = E_Q[\int P_t e^{-r_f t} dt] \quad (10)$$

Where:
P_t = Option Price
μ_0 = Drift parameter after exercising the option
σ_0 = Diffusion coefficient after exercising the option

The final net present value depends on μ_0, σ_0 and r_f and is the basis to determine the most profitable option among the options of the adopted ROA Model. In the literature, the researchers generally use MIP (Mixed Integer Stochastic) programing combined with decision trees to identify the most profitable option (Brandao and Dyer, 2005; Wu *et al*., 2009; Ball and Deshmukh, 2013). Other approaches (Munoz *et al*., 2011; Bakke *et al*., 2016) relies on regression analysis and Monte Carlo simulations to select the most profitable option.

RESULTS AND DISCUSSION

There is certain limitations in a real option reasoning for the valuation of IT investments. We distinguish two types of limitations:

- The assumptions of the mathematical model
- The intangible criteria in the pricing process

The mathematical assumptions: The major drawbacks due to the mathematical assumptions are: the stochastic process and constant variance assumption implies that volatile changes in the value of cash flow cannot be taken into account. The assumption of the complete market legitimates the application of option pricing models even though the underlying market is not traded. Indeed, the absence of profitable arbitrage makes difficult the price regulation.

The assumption of non-fluctuating interest rates implies that volatile changes in the value of interest rates cannot be taken into account. The assumption of the certain duration of the option supports the idea of the certain cash outflows and the certain duration of the base project. The risk-neutrality assumption considers that the projects remain risk less because of constant rebalancing of discount rates.

The intangible criteria: The integration of non-financial resources creates intangible value drivers. Indeed, the decisions of investing in human, informational and technical resources cannot be calculated from a pure financial vision which only relies on analyzing the return on the resource investment. Other parameters such as the availability and the state of the resource are hard enough to embed into the pricing process. In the literature, many researcers try to enhance the financial valuation of non-financial resources in order to obtain a more accurate model approaching reality as closely as possible (Wu *et al*., 2009; Ball and Deshmukh, 2013; Ghorfi *et al*., 2017). However, if the valuation process ignores the value of intangible assets, this may jeopardize the real option valuation as a whole and therefore the investment decisions.

ROA aims at finding a balance between tolerated risks and benefits in IT projects. In the case of sudden changes, the acceptation of changes is largely depending on non-financial criteria (Fichman *et al*., 2005). In this case, the level of maturity of processes and resources to respond to changes is an important factor. Among intangible criteria, there is also knowledge sharing, innovation, employee relationships, etc. Since, these criteria are intangible, their valuation is inevitably associated with individual judgments. Then, the integration of these intangible criteria in ROA is one of the most important challenge to reach a precise valuation of investments in IT projects.

Challenge and counter arguments: In this study, we report the main criticisms related to the use of ROA. These criticisms are derived from the analysis of the literature (Benaroch and Kauffman, 2000; Kumar, 2002; Fichman, 2004; Scialdone, 2007; Kumar *et al*., 2008). The assumptions of ROA may differ from one model to another. However, there is common challenges when applying a ROA based model. Table 3 is built on the works and highlights the main arguments against ROA and the counter arguments. We notice that the presented list is not exhaustive.

Table 3: Arguments against ROA and counter arguments

Challenges	Counter arguments
There is a lack of transparency in options models	ROA is typically complemented by transparent approaches such as decision trees, scoring models, simulations which can give a rough approximation of option value
Absence of a traded market for IT assets, makes difficult to estimate the expected value of future cash flow of a project	NPV of the project can be considered the best estimation for the value of the project as if it were traded on the market
	The classic NPV approach is no more effective than the real options valuation for the estimation of future project cash flows
Option valuation uses a risk-neutral approach	While it is possible to build of a portfolio of assets that tracks the risk characteristics of the investment, option valuation is the same in the risk-neutral world and the real risk-averse world
	In the event of not being able to build a tracking portfolio, option valuation remains a good approximation that captures flexibilities of the investment decision that are not considered by the classic NPV approach
Absence of a traded market for IT assets, makes difficult to estimate the volatility of a project	In order to determine whether a project can tolerate different sets of assumed levels of volatility, a sensitivity analysis can be performed
	Meanwhile, analysts can use conservative values of volatility until they gain enough experience

CONCLUSION

In this study, we provided an overview of ROA for valuating investments in IT projects. We described the types of real options and the mathematical model of ROA. Then, we moved on analyzing the literature with a focus on the techniques used. Based on the assumptions of the mathematical model, we highlight the main limits of the theory behind ROA. In addition, we showed how intangible criteria influence the pricing process of ROA. Finally, we reported the criticisms related to the use of ROA based on the analysis of the literature. We also reported the counter arguments.

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