MANAGERIAL RISK IN INFORMATION TECHNOLOGY INVESTMENTS: EFFECTS OF FRAMING, NARROW FRAMING AND TIME INCONSISTENT PREFERENCES ON REAL OPTIONS EXERCISE DECISIONS

by

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ABSTRACT

SARAH S KHAN. Managerial risk in information technology investments: effects of framing, narrow framing and time inconsistent preferences on real options exercise decisions. (Under the direction of DR. MOUTAZ J. KHOUJA and DR. RAM L. KUMAR)

Real options theory has been advocated as a solution to risky IT investment decisions. IT investments decisions are risky due to uncertainty around future outcomes and the inability of traditional financial measures (like NPV, IRR) to account for inherent managerial flexibility. On the one hand, it is argued that real options analysis captures and formalizes managers' intuition, hence creating a disciplined decision making process. On the other hand, the intuitive valuation of the options is criticized due to the prevalent effects of various judgmental biases. In this dissertation, we explore three potential biases that can affect the real option exercise decisions in terms of either suboptimal option exercise choice due to framing and narrow framing effects, or suboptimal exercise time due to time inconsistent preferences of IT managers. We test for framing effects in individual IT project decisions and narrow framing effects in IT portfolio decisions, by conducting an online experiment among top and mid-level IT professionals. The results show that IT professionals are prone to framing real options at exercise time and simplifying complicated real option exercise decisions by isolating them in IT portfolios. Further, their decisions are influenced by their personal risk preferences.

We analyze the effect of time-inconsistent preferences of present-biased managers on the exercise time of real growth and abandonment options and the realized values using a discrete time option valuation model. The results show that present-biased managers are more likely to exercise growth options early when the net payoffs are low, the growth option payoffs have high volatility, and the risk free discount rate is small. Also, present-biased managers are more likely to exercise abandonment option late when the net payoffs from continuing the project are high, salvage value of the project is low, and the rate of change in the salvage value over the period of time is low. In addition, present biased managers are more likely to exercise a growth option early in its life when the project is performing well. We provide implications for practice and IT governance.

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IT	Information Technology
NPV	Net Present Value
IRR	Internal Rate of Return
ROT	Real Options Theory
ROA	Real Options Analysis
3SLS	Three Stage Least Squares

CHAPTER 1: INTRODUCTION

All of us appreciate having options while making decisions. This is particularly true in case of difficult decisions involving high stakes. Such decisions include money back guarantees, exchange options for our purchases, option to withdraw from a course in school, liquidity in our investments and variety of products to select from. These daily life options are usually obvious and we tend to take them into account while making decisions. These options provide the decision maker with an hedge against negative outcomes, also known as risk. The case of Information Technology (IT) investment decisions is similar, where some security is appreciated for the risk involved in the investment, because IT investments are considered high risk endeavors.

> *There is one important caveat to the notion that we live in a new economy, and that is human psychology . . . which appears essentially immutable.*
>
> *Alan Greenspan*
> *Speech at the UC at Berkeley*
> *September 4, 1998*

IT investments have been a focus of research due to their importance in organizations and as a result, the amount of resources organizations allocate to them. Large scale IT projects are especially categorized as high risk- high return endeavors (Benaroch, Jeffery, Kaufman and Shah, 2007). It is difficult to accurately estimate cash flows for these projects due to their intangible nature, and these projects have a long term impact on organizations' strategic standing (Campbell, 2002; Kumar, 2002, Lederer and Prasad, 1993). Hence, inherent uncertainty and incomplete knowledge in many IT investments (Sullivan et al., 1999) pose a limitation in assessing their true value. This makes the justification and evaluation of these irreversible investments difficult. (Benaroch and Kauffman, 1999).

IT investments are typically evaluated through simple yet less structured financial techniques like cost benefit analysis, critical success factors, internal rate of return (IRR), and net present value (NPV) (Benaroch and Kauffman, 1999). On the one hand, such methods are easy to use, but on the other hand, these methods are criticized for not accurately estimating the true benefits of these investments. For example. NPV method is repeatedly criticized for undervaluing the IT investments (Kambil et al., 1993; Kester, 1984), along with its inability to take into account the managerial flexibility in IT investments to change the course of the project. Managerial flexibility means changing the course of the project based on its performance as well as changing business needs. Also, IT investment decisions are risky because significant uncertainty prevails around future payoffs from the investment and information available at the time of decision is ill-structured. Hence it becomes challenging for the IT managers to evaluate the IT investments under these circumstances, where the limitations of net present value (NPV) approach does not make the situation easy.

These limitations of traditional capital budgeting approaches and challenges of IT investment decisions led towards the exploration of valuation methods that could appropriately value managerial flexibility. One of such approaches included applying the real options theory (ROT) from finance for assessing the value of IT investments (Taudes, 1998; Benaroch and Kauffman, 1999; Keil and Flatto, 1999; Taudes et al., 2000; Benaroch, 2002). It is due to the theory's ability to handle uncertainty by accounting for the embedded flexibility in IT projects where managers can exploit the future opportunities created by the these projects while curtailing the inherent risks (Benaroch, 2002; Bowman and Moskowitz, 2002).

IT project possesses a real option when it offers the opportunity, but not the obligation, to take some action in the future in response to endogenous (within the firm) or exogenous (in the business environment) events (Benaroch & Kauffman, 1999). Real options valuation extends the use of financial options pricing models to value nonfinancial assets. Real options value goes beyond NPV to include the values of the options that are created when a series of repeated decisions can be made sequentially concerning an ongoing capital-investment stream. Thus by allowing for managerial flexibility in decision making, real options approach allowed more accurate valuation of capital investments by limiting the inherent risk (Benaroch & Kauffman, 1999; Tiwana et al. 2006).

Several studies have focused on using the real options theory in IT investment and project management. These applications range from conceptualization of IT investments in the real options context (Kumar 1996; 2002), valuation of the real options (Taudes, 1998; Benaroch & Kauffman, 1999; Keil & Flatto, 1999; Taudes et al., 2000; Benaroch, 2002) and intuitive recognition and valuation of real options, also known as real options thinking (Fitchman et al., 2005; Tiwana et al., 2006). A recent stream of research has started to explore if managerial intuition is in agreement with the ROT. Some studies show that managerial intuition typically responds in the correct direction to the factors that determine normative real options values, even without explicit real options methods or training (Bowman and Hurry, 1993; McDonald, 2000;

McGrath, 1997; McGrath, 1999, Miller & Arikan, 2004). According to this school of thought, formal real options analysis adds logical support and quantitative precision to managerial intuition but does not differ qualitatively. But another school of thought argues that intuition is not always qualitatively consistent with real options analysis (Busby and Pitts, 1997; Lankton & Luft, 2008; Tiwana eta l., 2006, 2007; Millar and Shapira, 2004). Also, prior field and survey studies find that consistency between managerial intuition and real option values varies across option types and settings (Benaroch et al., 2006; Busby & Pitts, 1997; Lankton & Luft, 2008; Tiwana et al., 2006; Tiwana et al. 2007). Our motivation comes from this stream of research.

In this dissertation, we take lead from the current IS literature on the recognition and valuation of real options in IT investments and projects, and managerial biases affecting their recognition as well as value. This stream of literature gives us insights on the intricacies involved while qualitatively recognizing and valuing real options in an IT investment before committing to them, and how susceptible this process of estimated value of real options is to the managerial biases. We move away from the qualitative recognition and valuation problem and build our case on the realized value of real options. Other things held constant, real options' value depends on its optimal exercise (Kumar, 2002). Optimal exercise of an option includes deciding on whether to exercise the option, and if it needs to be exercised, then exercising it at the time when it is most valuable. This makes studying the real option exercise decisions as important as their recognition and valuation. Finding no evidence of such studies in the IS literature, we explore what biases can impact these cognitively challenging decisions? Hence, we try to understand what anomalies underlie real options exercise decisions.

In this dissertation, we identify three managerial biases that can affect real options value by impacting the respective exercise decisions. We take help from behavioral economics to identify these potential anomalies, which are, framing effects in individual IT projects, narrow faming effects in IT portfolios and effects of time inconsistent preferences on real option exercise decisions. We propose to use these theories to fulfill the objective of this dissertation while utilizing two methodological approaches i.e. survey experiment and analytical models with numerical analysis.

Results from this research will change how the use of real options is perceived and justified in IT investments context. Theoretically, these results will highlight the importance of real option exercise decisions, where their mere recognition is not enough. Also it will add to the understanding of real options use in complex scenarios of IT portfolio management. In practice, results from this study will show that use of real options is a complicated valuation method, which is prone to judgmental anomalies. Use of real options in practice requires training and experience, and mere intuitions can lead to underutilizing the full potential of this approach. Hence, flexibility in decision making via real options does not always mean freedom in IT projects selection and management, but require training, experience and control measures to make a better use of real options approach.

This research also highlights the importance of human decision making in complex situations concerning IT investments and project management. These decisions are taken in volatile environment with high uncertainty and immense pressure, especially when firms' competence is at stake. Recognizing where the decision makers can go wrong, is a first step towards devising better IT investment management techniques, especially that controls for human biases.

The rest of the document is structured as follows. Next it presents the literature review on real options in the IT context. The following three chapters give details on individual studies; consisting of respective underlying theories, hypotheses/propositions, methodologies, and results. Chapter 6 concludes this document.

CHAPTER 2: LITERATURE REVIEW

The purpose of this chapter is to document the evolution of our understanding of real options in IT investments i.e. *the real option theory in IT*. It develops a detailed taxonomy and tracks the direction of this research stream along with facilitating the overview of the real options theory in IT. The chapter is organized as follows. In the first section, conceptualization of real options in the context of IT investments is described. Section 2 discusses literature on real options quantitative valuation in IT investments. Section 3 focuses on the application of real option methodology for IT investments followed by evidence of application from literature in Section 5. Section 6 summarizes literature on real option thinking and impact of managerial intuition. Section 7 concludes the chapter.

2.1 Conceptualizing Real Options for IT Investments

A real option is commonly defined as "any decision that creates the right, but not an obligation, to pursue a subsequent decision" (Janney and Dess, 2004). In the same vein, Real Options Analysis (ROA) is defined as a method to evaluate investment decisions under uncertainty, irreversibility of cost and high managerial flexibility in structuring the investment (Dixit and Pindyck, 1994). Real options are used as a formal modeling tool for specific decisions, as well as informally for framing decisions in a different light (Janney and Dess, 2004; Kogut, and Kulatilaka, 2001), and their conceptualization for IT investments is no different. On the one hand they are used as a formal modeling tool for managing IT investments (e.g. Dos Santos, 1991; Benaroch and Kauffman 1999; 2000) and on the other hand, they are used intuitively to value flexibility in the IT investment (Fitchman et al., 2005; Benaroch et al., 2006). A key premise of real options analysis is the economic value associated with resolving uncertainty associated with any decision. While doing so, upside potentials of the decisions are left open while losses are capped. Hence real options analysis is a decision making tool, mostly used in the face of uncertainty.

It is important to note the main difference between real options and financial options. Although both concepts are applied for valuing the risk hedging strategies, yet real options are different from financial options on one ground i.e. the asset underlying the option. In case of financial options, the asset underlying the option is an intangible and tradable financial asset like stocks. As for the real options are defined on real asset, typically not tradable.

2.1.1 IT Investments and Traditional Financial Measures

IT investments are characterized as essential yet hard to justify investments in organizations. They hold certain traits that distinguish them from standard financial investments (Table 2.1). Especially large scale projects are categorized as high risk-high return endeavors (Benaroch et al., 2007) due to their long term impact and the difficulty in estimating project cash flows accurately (Campbell, 2002; Kumar, 2002, Lederer and Prasad, 1993). Also, inherent uncertainty and incomplete knowledge in many IT investments (Sullivan et al., 1999) pose a limitation in assessing the true value of these investments. This makes the evaluation of these irreversible investments under uncertainty (Benaroch and Kauffman, 1999) difficult. Hence it is the IT investment decision problem that leads towards exploring techniques that could facilitate these decisions.

Table 2.1: Distinguishing IT Investment Characteristics

IT Investment Characteristics	References
Difficulty in justifying leading edge automation projects, large scale systems architectures development or communications network based on traditional capital budgeting measures including return on investment (ROI) or net present value (NPV). The basic underlying reason is difficulty in quantifying the intangible benefits.	Clemons and Weber, 1990; Campbell, 2002; Dos Santos, 1991; Kumar, 2002, Lederer and Prasad, 1993)
Uncertainty and incomplete knowledge around payoffs from investment and costs over the period of time	Dos Santos, 1991; Sullivan et al., 1999
Flexibility in IT projects where its course can be changed based on its feedback with respect to its environment	Dos Santos, 1991; Kumar, 1999
Irreversibility of IT investment	Benaroch and Kauffman, 1999; Clemons and Weber, 1990; Dos Santos, 1991; Kumar, 1996

With these traits, traditional financial measures, including most commonly used NPV analysis, does not work very well. There are several reasons for it. First, NPV does not take into account the managerial flexibility of changing the course of the IT project during its life (Dos Santos, 1991; Kumar, 1999). Second, to calculate NPV, appropriate discount rate determination is a challenge (Dos Santos, 1991). Third, NPV approach assumes all the investment must be done upfront, irrespective of the project's performance. In reality, at several points in a project life cycle, managers can change the course of the project based on factors like its performance, changing business needs, changing user needs etc. This flexibility is referred to as *managerial flexibility*.

Limitations of the traditional capital budgeting approaches led towards the exploration of valuation methods that could appropriately value managerial flexibility and incorporate flexibility. Also, the recognition of the importance of utilizing the theory of irreversible investment under uncertainty (Dixit and Pindyck, 1994) in the IS research (Clemons 1991; Dos Santos, 1991; Kambil et al., 1993; Kumar 1996) lead to the identification of the option-like characteristics of IT project investments.

2.1.2 Real Options in IT Investments

IT project possesses a real option when it offers managerial flexibility, to change the course of the project in response to endogenous (within the firm) or exogenous (in the business environment) events (Benaroch and Kauffman, 1999). Thus by allowing for managerial flexibility in decision making, real options approach allows more accurate valuation of capital investments while curtailing the inherent risk (Benaroch and Kauffman, 1999; Tiwana et al. 2006).

Several studies (Clemons, 1991; Dos Santos, 1991; Kambil et al., 1993; Kumar, 1996; 2002) used illustrative examples to propose the idea of using real options theory in IT investments, especially to manage risk by identifying and accounting for the inherent flexibility in decision making. Majority of the IS literature focuses on real options analysis for large and risky IT investments with known risks, under the assumption that some embedded real options already provide management with strategic and operational flexibility needed to respond to the risks (Benaroch et al., 2007). Table 2.2 is adopted from Benaroch et al., (2007) and modified, to give brief descriptions of the types of real options identified in IT context along with the related risks they provide hedge against.

Table 2.2: Real Options Types and Related Risk (Benaroch, et al., 2007)

Option	Explanation	Representative IS studies	Risks present
Defer	Flexibility to defer investment commitment is attractive when it enables learning about the nature of uncertain payoffs (and immediate lost cash flows are small).	Benaroch and Kauffman (1999, 2000)	• Customer usage/acceptance • Vendor adoption • Restrictive legislation
Explore (pilot prototype)	Flexibility to partially invest in a pilot or prototype effort enables learning about the extent to which technical and organizational risks affect the ability to complete (and realize the expected benefits of) a full-scale investment.	Amram and Kulatilaka (1999a), Kambil et al. (1993)	• IS skills and experience • Technology maturity • IT infrastructure adequacy • Organizational adoption
Stage (stop – resume)	Flexibility to stage an investment and kill it midstream (after gateway reviews) is valuable when there are risks due to technical complexity risks, user involvement, architectural compliance, and so on.	Benaroch (2002)	• Infrastructural fit • Managerial support, organization adoption
Change scale	Flexibility to alter—expand or contract—the scope of an investment adds value when it allows reacting to observed conditions concerning technical risk, user involvement risk, and so on.	Gaynor and Bradner(2001), Kulatilaka et al. (1999)	• Project size and complexity • Technology maturity • Emerging standards
Exit (switch–use)	Flexibility to exit an investment and put its resources to alternate uses provides partial insurance against failure due to client acceptance risk, organizational adoption risk, etc.	Bräutigam et al. (2003)	• Customer usage/adoption • IT infrastructure adequacy
Outsource development operations	Flexibility to outsource development is valuable when development failure risk can be transferred to a third party. Outsourcing a business process is contingent on when business conditions (process transactions load) are sufficiently unfavorable (favorable); transfers benefits risk to a third-party service vendor.	Lammers and Lucke (2004), Whang (1992)	• IS skills and experience • Cost escalation • Customer demand/usage • Uncertain investment benefits
Lease	Flexibility to lease resources is valuable when investment can be abandoned to save residual resource costs, when abandonment occurs during development, or after investment is operational.	Clemons (1991), Clemons and Weber (1990)	• Customer adoption • Organizational adoption • Development failure
Strategic growth (Expansion)	Flexibility for favorable investment outcomes (due to positive risk) is valuable when the investment creates.	Taudes et al. (2000), Zhu (1999)	• Above expected customer adoption/usage rate
Learning	Flexibility in learning about new and risky technologies	Goswami et al. (2008)	• Uncertain benefits • Uncertain feasibility

IT real options are classified in two groups based on the type of flexibility they provide (Trigeorgis, 1993). The strategic growth (expansion) options are classified as *growth options* (Benaroch, 2002), while the rest are categorized as *operational options*[1]. From an options perspective, IT investment project is seen as creating a base asset with some expected value; for example, the baseline implementation of an enterprise resource planning (ERP) package (Tiwana et al., 2006). *Operational options* relate to flexible actions that managers can make to reduce the potential for losses (usually) or increase the potential for gains (occasionally) on that base project. *Growth options*, capture the possibility of building additional assets on top of the base asset if the initial project were to be completed. For example, building a data warehouse to facilitate the analysis of data captured in the ERP system. Operational options give managers the flexibility to change the features of a base project by modifying its timing, scale, or scope, and strategic growth options give an opportunity to create one or more additional but related assets beyond the asset produced by the base project (Benaroch, 2002). It is important to note that in the case of operating options, there is only one asset under evaluation (i.e., the base system), while in the case of strategic growth options, there are multiple assets to consider (the base system, plus one or more future investment in assets that build on the base system).

This classification of real options facilitated the conceptualization of the phenomenon as a risk management tool for IT investments with inherent uncertainty. It was then carried forwarded by IS literature to solve various problems in IT investment management i.e. identification and recognition of real options (Benaroch, 2002),

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[1] Some studies like Tiwana et al., (2006) view option to defer as growth option and not operational option.

valuation of IT investments with embedded real options in different scenarios (e.g. Dos Santos, 1991; Kumar, 2002; Benaroch and Kauffman, 1999; Su et al., 2009) etc. For valuation purpose, *growth options* are considered having call option like characteristics (right to buy an asset in future), where *operational options* are considered having put option like characteristics (right to sell an asset in future).

2.1.3 Discussion

Adaptation of real options theory for IT investment decision from real options literature in other disciplines has made it easier to justify and consider risky IT projects, which was difficult before (Dos Santos, 1991). The conceptualization and classification of real options in IT investments facilitated the understanding of this theory as a justified risk management tool for IT investments. Most of the real options seen in IT literature are adopted from other fields like finance, strategic management, manufacturing, and R&D. They include real options such as abandon, defer, growth, scale, stage etc. Apart from these options, additional real options are also found in IT literature. For example, option to lease (Clemons, 1991; Clemons and Weber, 1990) and learning option (Goswami et al., 2008). Learning option is quite similar to option to defer, where the intention is to delay the investment until uncertainty is resolved via learning or waiting.

Within the real options classification as either call or put option in the IT literature, some confusion is seen. Option to defer investment is considered to possess characteristics of a put option (Benaroch, 2002) as well as of a call option (Kumar, 2002; Tiwana et al., 2006). Similarly, option to abandon and option to switch use are considered as having the same characteristics (Benaroch et al., 2007), where the resources are put to an alternative use. But these two real options are considered as separate (Tiwana et al., 2006; 2007). It seems to be a matter of context in which the real options have been conceptualized and discussed.

2.2 Valuation Approaches

Several models have been proposed to quantitatively valuate real options in IT investments settings. The concept behind capturing managerial flexibility in decision making is to take into account the value of embedded options that provide decision making flexibility along with NPV of expected cash flows (Trigeogris, 1995), and increase the value to strategic NPV. Formally, it is seen as:

$NPV_{Active} = NPV_{Passive} + f$ (value of the bundle of real options embedded in the project, from active management).

Where, NPV_{Active} of project is the net strategic value of the project, which is equal to the traditional or $NPV_{Passive}$ plus the value of managerial flexibility—the latter being a function of the value of the bundle of options embedded in the project (Benaroch, 2002). In this section, we will review the various valuation methods proposed and used for IT investments in the IS literature.

2.2.1 Binomial Option Pricing Model Approach (Discrete Time Model)

Cox, Ross and Rubinstein (1979) approach of option pricing via binomial model is seen in IT real options literature. Because of its simplicity, requirements for estimating less parameters and closed form, this discrete time model is easy to apply. But this formula can be applied only to single stage investments. Also this formula assumes that project values are in equilibrium after a period.

The binomial model assumes that V (uncertain underlying asset, usually present value of payoffs) follows a binomial multiplicative diffusion process. Starting at time $t_0 = 0$, by time $t_1 = t_0 + \Delta t$, V may rise to uV with probability q or fall to dV with probability $1-q$, where $u = e^{\sigma\sqrt{\Delta t}} > 1$, and $d < r < u$, with r being the risk free rate. With $\Delta t = T/n$, a binomial tree for the underlying asset is built for n time periods. The approximation for q in this model is taken as p, computed as $p = (r- d)/(u - d)$. The value of a call option on V is calculated via backward induction by:

$$V = \frac{pC_u + (1-p)C_d}{r}$$

Where:

C_u= max [0, uV-I]
C_d= max [0, dV - I]

Kambil et al. (1993) used the binomial model to value IT investment in hand held computers, by defining a pilot option in it. Making the pilot project analogous to a call option, they show how incorporating decision making flexibility in project valuation helps in justifying IT projects. Later Benaroch et al. (2006) used the same model to show its appropriateness in valuing nested options in IT projects, where Black-Scholes model (Bardhan et al., 2004) seem to overvalue them by 100%. They achieved it by developing a custom tailored binomial model for generic IT investment embedding nested options as baseline, along with a more accurate Black-Scholes model for nested options.

Benaroch (2002) uses an extension of binomial model i.e. log-transformed binomial model (Trigeorgis, 1996) to value real option in an internet sales channel investment with multiple shadow options. Log-transformed binomial model prevents *p* from becoming negative or exceeding 1, in case of small time steps or small volatility around payoffs *V*.

2.2.2 Asset- for- Asset Exchange Approach (Continuous Time Model)

One of the first efforts to value real options quantitatively in IT investment setting used a famous asset-to-asset exchange model, also known as Margrabe model. With an underlying question of, should the firms invests in projects involving new technologies, Dos Santos (1991) demonstrated how such investments can be justified by reframing into staged investments, where most of the value is contingent on the future stages of the project with investment opportunities. Investing in new technology is perceived as buying a call option on future investment opportunities where the firm has an opportunity to invest in future projects i.e. second stage projects. Therefore, the value of the future projects that become available as a result of an IT investment in a new technology is required for the economic justification of the investment. Also, such call options being similar to the ones on traded securities, can be valued using Margrabe model of real option valuation. The model is given as:

$$V = B_1 N(d_1) - C_1 N(d_2)$$

Where:

$$d_1 = \frac{ln(\frac{B1}{C1}) + \sigma^2 t/2}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

B_1 = current value of the expected benefits of the second-stage project

C_1 = Current value of the expected development costs of the second-staged project

$N(.)$ = cumulative standard probability density function

σ^2 = instantaneous variance of the ratio $\frac{B}{C}$, computed as:

$$\sigma_{B1}^2 + \sigma_{C1}^2 - 2\,\sigma_{B1}\sigma_{C1}\rho_{BC}$$

σ_{B1}^2 = variance of the rate of change of revenues of the second stage project
σ_{C1}^2 = variance of the rate of change of development costs of the second-staged project from follow up investment
ρ_{BC} = correlation between development cost and revenues from the second stage project

Dos Santos showed that using the Margrabe model for real option valuation eliminates the need to estimate a risk-based discount rate, which is a major drawback of NPV approach. Also not all the possible outcomes of the projects are required to be quantified with underlying real options, like in the case of decision trees. With good estimation of model parameters, this model gives a good value estimate for the investment.

Building on the relationship between project risk and real option values, Kumar (1996) illustrated that the pattern of variation in option values (as a function of variance rate of change in second-stage project costs or benefits) differs from well-known results in financial options theory (Black-Scholes model). The study shows that the options values of second-stage projects could increase or decrease with an increase on variance of rate of change of project benefits, depending on the sign of $\sigma_{B1} - \rho_{BC}\sigma_{C1}$. Hence justifying that it is not always attractive in terms of options value to select riskier second-stage projects. Later, Kumar (2002) proposed a real options framework for managing risk in IT projects in general. With the underlying concept of managerial flexibility and option valuing model being the same, the study differentiated the underlying risks in IT projects as the ones resolved by action and others that require hedging. Further hedging strategies were proposed by deferring the investment, abandoning the investment and changing the ongoing project’s scale.

The application of Margrabe model is not limited to valuing flexibility in IT projects. Kumar (1999) used this model to value flexibility resulting from DSS use by conceptualizing it as the change in value of a portfolio of options. This way, understanding the effectiveness of a DSS in terms of the value provided by its use became obvious.

2.2.3 Black-Scholes Model Approach (Continuous Time Model)

Most of the research in IT real options valuation seems to be using famous financial option valuation model of Black-Scholes (Black and Scholes, 1973). As compared to the Margrabe model, it assumes that the cost of the project is known with certainty (deterministic). Therefore total uncertainty in the project is due to the uncertainty around payoffs. Also, the discount rate is not zero but risk free rate (i.e. the rate on the US treasury bills). The Black-Scholes model for a European style call option looks like:

$$V = BN(d_1) - I\, e^{-rT} N(d_2)$$

Where:

$$d_1 = \frac{ln(\frac{B}{I}) + (r + 0.5\sigma^2)T}{\sigma\sqrt{T}}$$

$$d_2 = d1 - \sigma\sqrt{T}$$

B = Present value of investment returns
I = Cost of investment
r = risk free discount rate
σ^2 = variance around future payoffs
T = Option expiration time.
$N(.)$ = cumulative normal distribution.

Real option valuation using Black-Scholes is first seen in scenarios involving justifying infrastructure investment decisions. Panayi and Trigeorgis (1998) evaluated a telecommunication IT infrastructure project (for Cyprus telecommunication Authority) with two stages i.e. an initial stage with development of infrastructure and second stage with expansion of network. The value of the whole project includes the value of the growth option for the second stage, which is computed using Black-Scholes as a European call options maturing at the year of network expansion. Later Miller et al. (2004) used Black-Scholes model to price growth and compound real options in case of Korean IT infrastructure.

Benaroch and Kauffman (1999, 2000) used this model to value the project involving deployment of point of sale debit service system in an electronic banking network. The famous Yankee 24 case, the option to defer investment was modeled as a pseudo-American call option with dividends. The value of the underlying asset in a particular period was computed by subtracting the present value of the cash flows foregone during waiting from the present value of the project cash flows at time zero. Taudes et al. (2000) used Black-Scholes model in a real case study involving software platform decision. The problem under study was whether to use software platform SAP R/2 or switch to its newer release SAP R/3. Campbell (2002) used the same model to quantify deferral option and an optimal time to exercise it, by conceptualizing it as an American style call option. Su et al., (2009) used Black-Scholes to value real options underlying service organizations and their transformation in an uncertain business environment.

Bardhan et al. (2004) extended research on real option in case of IT investments by providing a new method for making IT valuation and investment decisions for project portfolio management. By examining a large U.S. based energy utility firm considering investment in a portfolio of 31 projects to provide a range of Internet-enabled energy services to customers, they developed a nested options model by incorporating the impact of project interdependencies to calculate the option value of all projects. The general portfolio valuation model looked like:

$$V(cluster) = PV\{Phase\ 1\ projects + Call\ Value\ [Phase\ 2\ projects + Call\ Value\ (Phase\ 3\ projects)]\}$$

The underlying call option valuation, although claimed to be done using Margrabe model in the paper, is actually done using Black-Scholes model (with uncertainty around benefits and cost discounted at a risk free rate). They argue that the real options model provides a better understanding of project interdependencies on valuation and prioritization decisions, and provides insights into the business value of IT infrastructure projects that provide the managerial flexibility to launch future projects. They also presented a real options portfolio optimization algorithm for dynamic multi-period portfolio optimization by incorporating the project values based on Black-Scholes valuation in a portfolio management model with budget constraints.

2.2.4 Expected Utility Model

Growth options' valuation is also conceptualized to its simplest form, looking like an expected utility function. Lankton and Luft (2008) used the expected utility function to value a simple growth option. They defined growth option as "A growth option has positive value if the expected utility (EU) of the initial investment, plus the EU of the follow-on investments later if they prove valuable, is greater than the EU of not making the initial investment".

$$EU(Initial\ investment) - EU(no\ Initial\ investment) = [p(d - e) + (1 - p)(-e)] - 0 = pd - e$$

Where:

EU = expected utility
p= probability the follow-on investment has positive value
d= payoff from follow-on investment
e = initial investment value

They have also modeled the deferral option in a similar manner.

2.2.5 Other Valuation Approaches

The real option valuation in IT context is not limited to Black-Scholes model, Margrabe model and Binomial model. Some studies have used combinations of these models to conceptualize/ value real options in particular contexts. For example, Taudes (1998) examined the methods for evaluating sequential exchange options in order to obtain estimates for the value of software growth options in EDI platform. The study defined software growth options as IS functions that are embedded on an IT platform (EDI in this case) and that can be employed once the particular base system is installed and their use is economically justified. The paper utilized four valuation models to evaluate a better model for sequential software growth option (European style). The models include Geske's formula (Geske, 1979) and Carr's formula (Carr, 1988) along with Black-Scholes and Margrabe formula. Geske's formula for sequential exchange opportunities is similar to Margrabe model, except it has an additional parameter q, depicting efforts for implementation of base efforts. With q = 0, Geske's formula reduces to Margrabe. Valuation of software growth options with several alternative implementation decisions, can be done by assuming that the IS function under consideration can be implemented at any time within a given planning horizon T. This is achieved by approximating the growth options as pseudo-American exchange options (an option with constant dividend yield), and valuing them using Carr's formula i.e.

$$F_c(V, I, q, t_1, t_2, \sigma^2, \sigma_I^2, \rho_{VI}, r) = VB\left(d_1\left(\frac{Rexp^{rt_1}}{R^*}, t_1\right), d_1(Rexp^{rt_2}, t_2)\right) -$$

$$Iexp^{-rt_2}B\left(d_2\left(\frac{Rexp^{rt_1}}{R^*}, t_1\right), d_2(Rexp^{rt_2}, t_2)\right) - qIexp^{-rt_1}N\left(d_2\left(\frac{Rexp^{rt_1}}{R^*}, t_1\right)\right),$$

Where

V = value of the IS function under study, expected present value of net benefits of usage;
I = cost of implementing the IS function under study,
$R = V/I$
q = fraction of I needed for implementation preparation
t_1 = decision time for implementation preparation (start of productive use)
R^* = value of R above which the (simple) exchange option should be acquired at t_1 obtained by solving
$F_M (V, I, q, t_2 - t_1, \sigma^2, \sigma_I^2, \rho_{VI}, r)$ - E = 0 for R
where F_M is given by Margrabe's exchange option formula in equation below;
$F_M = (V, I, q, t_2, \sigma^2, \sigma_I^2, \rho_{VI}, r) =$
$VN (d_1 (R\ exp^{rt}{}_2, t_2)) - I\ exp^{rt}{}_2\ N (d_2 (R\ exp^{rt2}, t_2)$
t_2= implementation decision time
σ^2 = instantaneous variance of V
σ_I^2 = instantaneous variance of I
ρ_{VI} = correlation between V and I
$N(.)$ = cumulative standard normal distribution function;
$B(.,.)$ = bivariate cumulative standard normal distribution function with correlation coefficient $\sqrt{\frac{t_1}{t_2}}$
$d_1 (\theta, \tau) = (\text{In}\ \theta + \frac{1}{2}\omega^2\tau) / \omega\sqrt{\tau}$
$d_2 (\theta, \tau) = d_1 (\theta, \tau) - \omega\sqrt{\tau}$
$\omega^2 = \sigma^2 + \sigma_I^2 - 2\sigma\sigma_I\rho_{VI}$, instantaneous variance of R
r = risk-free interest rate.

Schwartz and Zozaya-Gorostiza (2003) developed two models for the valuation of IT investment projects i.e. development projects and acquisition projects. The distinction between these two projects is done based on the time it takes to start benefiting from the IT asset once the decision to invest has been taken. Both the models account for the uncertainty in costs as well as benefits associated with the investment opportunities. In case of costs uncertainties, the model accounts for technical cost uncertainty, input cost uncertainty and investment cost uncertainty. The benefits are represented as a stream of stochastic cash flows from investment, and not the value of underlying asset. With the stochastic cost and benefits, the value of investment opportunity is derived by first applying Ito's lemma to get the differential equation and then applying Bellman equation of optimality to obtain the investment value, accounting for both cost and benefit uncertainty. The difference between development and acquisition projects comes in while estimating benefits, where acquisition projects include the value of underlying asset along with value of future cash flows from its use. Their model for development projects is as follows:

$$F(V, K) = \max_{I} \left[\begin{array}{c} \frac{1}{2}\sigma_V^2 V^2 F_{VV} + \frac{1}{2}\beta^2 IK\, F_{KK} + \frac{1}{2}\gamma^2 K^2 F_{KK} \\ + \rho_{VK}\,\sigma_V \gamma VKF_{VK} + (\mu_V - \eta_V)\, VF_V \\ - (I - \delta K - \eta_K)\, F_K - (r_f + \lambda)\, F - I = 0 \end{array} \right].$$

B.C.

F (V, 0) = V,
F (0, K) = 0,
= 0

V = value of the asset received on successful completion of the project
K = remaining cost to completion of the project assuming that investment could be done instantaneously
I = initial cost
= Poisson probability of a catastrophic event causing the project to be permanently abandoned
β = technical uncertainty parameter
γ = input cost uncertainty parameter
= instant standard deviation of the proportional changes in V,
μ_v = drift parameter reflecting changes (positive or negative) in the value as time proceeds

dy = increment to a Gauss-Wiener process that is uncorrelated with the technical uncertainty in expected costs, but that may be correlated with overall economic activity.
= risk premium associated with V
= risk premium associated with K
= change in cost experienced by IT assets over time
r_f = risk-free interest rate

Dai et al., (2007) move away from financial models of real options and incorporated options thinking in cost-benefit analysis to permit the analysis of real options in the context of corporate strategy. They consider current and future costs and benefits as well as market factors influencing these costs and benefits relating to IT infrastructures. They constructed a two-stage model that considered relationships among the factors to guide future improvements in decision making relative to option value-bearing IT infrastructure investments. In Stage 1, a firm invests in an IT project to implement an IT infrastructure technology with an initial cost of *K*. With the IT infrastructure implemented in Stage 1, the firm is able to provide a desired product or service in Stage 2 by developing additional IT resources, which represents a growth option. Developing these new IT resources typically requires follow-up investment, which is analogous to what investors must pay to exercise call options on stocks to balance risk and returns in portfolio management. With infrastructure in place, the value of overall IT investment is given by:

$$V^{\text{INVESTMENT}}(\theta) = E(\pi^{\text{INVESTMENT}} | \theta \geq \theta_1) \cdot \text{prob}(\theta \geq \theta_1) - K$$

Where

$$\pi^{\text{INVESTMENT}} = \begin{cases} 0; & \theta < \theta_1 \\ \frac{(p-c)^2\theta^2 - 4fp(p-c)}{4f}; & \theta \geq \theta_1 \end{cases} \quad \text{with} \quad \theta_1 = \sqrt{\frac{4fp}{p-c}}. \quad \text{and } d = \quad -p$$

$a_1,\ldots,a_7$	Parameters for deriving the second stage profit with skewed demand
c	Constant variable cost for offering the desired product or service at Stage 2
d	Demand for the product or service offered at Stage 2
f	Constant fixed cost for offering the desired product or service at Stage 2
$G(\theta)$	Expected value of the IT infrastructure, based on stochastic demand, θ
K	Investment cost for developing IT infrastructure at Stage 1
p	Price for the product or service offered at Stage 2
s	Attribute level (e.g., quality level) of the product or service offered at Stage 2
z	Cross-elasticity factor, representing interfirm competition in non-IT areas
$\pi^{\mathrm{INVESTMENT}}$	Profit at Stage 2 when firm invests in the IT infrastructure at Stage 1
$\pi^{\mathrm{NOINVESTMENT}}$	Profit at Stage 2 when firm does not invest in the IT infrastructure at Stage 1
$V^{\mathrm{INVESTMENT}}(\theta)$	Expected value of overall IT investments when firm invests in IT infrastructure at Stage 1
$V^{\mathrm{NOINVESTMENT}}(\theta)$	Expected value of overall IT investments when firm does not invest in IT infrastructure at Stage 1
θ	Stochastic portion of demand for product or service. Interpreted as the degree to which customer desires a one unit increase in the attribute level ($\theta > 0$)
θ_0	Expected value of demand, θ
σ^2	Demand variance of demand, θ
θ_1	In the base case, level of customer desire for the product attribute, above which the firm can gain a positive profit at Stage 2 by offering the product, given that it invested in IT infrastructure at Stage 1
θ_1'	In the base case, the level of customer desire for the product attribute, above which the firm can gain a positive profit at Stage 2 by offering the product, given that it did not invest in the IT infrastructure at Stage 1
θ_2	In the duopoly case, the level of customer desire for the product attribute, above which both firms can gain a positive profit at Stage 2 by offering the product, given that one firm invests in the IT infrastructure at Stage 1
θ_3	In the duopoly case, the level of customer desire for the product attribute, above which both firms can gain a positive profit at Stage 2 by offering the product, given that neither firm invests in the IT infrastructure at Stage 1
λ	Cost advantage of the IT infrastructure ($\lambda > 1$)

2.2.6 Discussion

Several models are proposed for the valuation of IT real options. Most of them are adopted form other fields, yet some efforts are seen towards developing models custom tailored for IT projects. At this point, it will be good to evaluate these models.

Most of the IT literature used Black-Scholes model to value the real options. As seen in Table 2.3, majority of studies talking about real options valuation in IT context prefer to use Black-Scholes model over Margrabe, binomial or any other custom built model. May be it’s because of the simplicity of using the model and custom tailoring it for specific scenarios like sequential options or compound options, that this model is preferred.

Table 2.3: Real Option Valuation Models Usage in IT Literature

S.No	Author	Paper Title	Option Valuation model Used			
			Margrabe	Black-Scholes	Binomial	Other
1	Dos Santos, 1991	Justifying Investments in New Information Technologies	1			
2	Kambil and Henderson, 1993	Strategic Management Of Information Technology Investments: An Options Perspective			1	
3	Kumar, 1996	A Note on Project Risk and Option Values of Investments in Information Technologies	1			
4	Panayia and Trigeorgis, 1998	Using An Options Approach To Evaluate Korean Information Technology Infrastructure and International Bank Expansion		1		
5	Kumar, 1998	Understanding DSS value: an options perspective	1			
6	Taudes, 1998	Software Growth Options	1	1		1
7	Benaroch and Kaufman, 1999	A Case for Using Real Options Pricing Analysis to Evaluate Information Technology Project Investments		1		
8	Benaroch and Kaufman, 2000	Justifying Electronic Banking Network Expansion Using Real Options Analysis		1		
9	Taudes et al., 2000	Options Analysis of Software Platform Decisions: A Case Study		1		
10	Campbell, 2001	Real Option Analysis of the timing of IS investment decision		1		
11	Kumar, 2002	Managing risks in IT projects: an options perspective	1			
12	Benaroch, 2002	Managing Information Technology Investment Risk: A Real Options Perspective			1	
13	Schwartz and Gorostiza, 2003	Investment Under Uncertainty in Information Technology: Acquisition and Development Projects				1
14	Bardhan et al., 2004	Prioritizing a Portfolio of Information Technology Investment Projects		1		
15	Miller and Arikan, 2004	Using An Options Approach To Evaluate Korean Information Technology Infrastructure		1		
16	Benaroch et al., 2006	On the Valuation of Multistage Information Technology Investments Embedding Nested Real Options			1	
17	Dai et al., 2007	Valuing information technology infrastructures: a growth options approach				1
18	Su et al., 2009	Shared Services Transformation: Conceptualization and Valuation from the Perspective of Real Options		1		
Total Number of Times Models are used			**5**	**9**	**3**	**3**

Each model proposed, especially the ones adopted from other fields are based on some underlying assumptions. For example, the most commonly used Black-Scholes model applies to only European type options (i.e. options with fixed maturity). Whereas real investments are more like American options, with no fixed maturity date, where project manager has flexibility over when to exercise the option. This makes the generalizability of Black-Scholes option pricing formula doubtful. Another assumption underlying Black-Scholes formula is that the underlying asset is tradable. However, real assets, especially in case of IT projects are typically not traded e.g. cost, cash flows etc. Benaroch (2002) argues this point with the help of Amram and Kulatilaka (1999) to show that the concept can be extended to the non-traded assets as well. Black-Scholes model also assumes that cost of exercising an option is deterministic.

In most IT investment scenarios, cost of investment is uncertain as well (Dos Santos, 1991; Kumar, 2002). This limitation of Black-Scholes is accounted by Margrabe model, where cost of investment is taken stochastic along with the payoffs. As compared to binomial model which is a discrete time model, Black-Scholes is a continuous time model. Benaroch et al., (2006) shows that if binomial model is converted into continuous time, the results produced by it should be similar to the results produced by Black-Scholes model. It's all because of the underlying distribution assumption of payoffs for each model i.e. in binomial model the assumption is that payoffs are distributed binomially whereas in Black-Scholes, the assumption is that payoffs are distributed log normally.

IT investments usually do not have a single underlying option but could have series of cascading compound options due to exposure to multiple risks. Black-Scholes model tend to be limited in valuing such options (Schwartz and Gorostiza, 2003) because it ignores the interaction effects on option values in a series of cascading options. Benaroch (2002) provides a solution to it by introducing a general lattice model that simplifies the valuation of cascading options i.e. log-transformed binomial model.

Such underlying assumptions make the selection of a correct option valuation model critical. Benaroch (2002) gives a brief on which model is appropriate based on two variables i.e. simple vs. compound option and cost as being stochastic or deterministic. Table 2.4 is adopted from Benaroch (2002) giving a brief on this area.

Table 2.4: Real Option Valuation models and IT Investment Traits (Benaroch, 2002)

	Only V is uncertain	**V and I are uncertain**
Investment embeds a simple option	Black-Scholes and binomial models (Benaroch and Kauffman, 1999)	Margrabe model (Dos Santos, 1991)
Investment embeds compound options	Log-transformed binomial model (Trigeorgis, 1996)	Expanded log-transformed binomial model (Gamba and Trigeorgis, 2001) Margrabe model adapted for sequential opportunities (Carr, 1988; Taudes, 1998)

2.3 Applying Real Options to IT Investments- OBRiM Approach

Real options are not inherent in any IT investments. They need planning and careful identification to be imbedded in order to hedge the inherent risk in that investment (Benaroch, 2002). This argument is aligned with the real options concept of “shadow options” i.e. options that are hidden until they are identified (Clemons and Weber, 1990). When various real options are ready to be discovered in an investment with multiple risks, there can be numerous ways to reconfigure the investment using different series of cascading (compound) options (Benaroch, 2002). This problem took the IT real options literature beyond the conceptualization and valuation problem, into the effective application problem.

Benaroch (2002) presents option based risk management (OBRiM) framework, which uses real options theory and fundamental principles from the area of financial risk management as a theoretical backdrop to actively configure IT investments for the purpose of managing the balance between their value and risk. They use real options analysis to decide on how to optimally configure an IT investment by creating the set of options that maximally contributes to that investment value. To maximize IT investment value, they argue that managers must size up the relevant risks and proactively build flexibility into an investment while continually evaluating new risk information and taking corrective actions within the bounds of the flexibility built into the investment. Figure 2.1 gives a graphic illustration of the framework.

The major arguments of this framework, as highlighted by further studies (e.g. Benaroch et al., 2006, 2007) are:

- Real options can be interpreted as high-level strategies for managing risk, with the associated strategic action and a managerial decision that are made possible.
- Flexibility must be proactively embedded in an IT investment based on the specific risks one seeks to control (As proposed by OBRiM set of risk option mappings).
- The real options mapped to for the risks present permit generating alternative investment configurations where each configuration embeds a different combination of these real options.

- Different combinations of real options affect IT investment value differently due to varying associated cost and potential to handle risk (of same kind). An economically superior configuration can be found by quantitatively evaluating the different investment configurations using option pricing models.

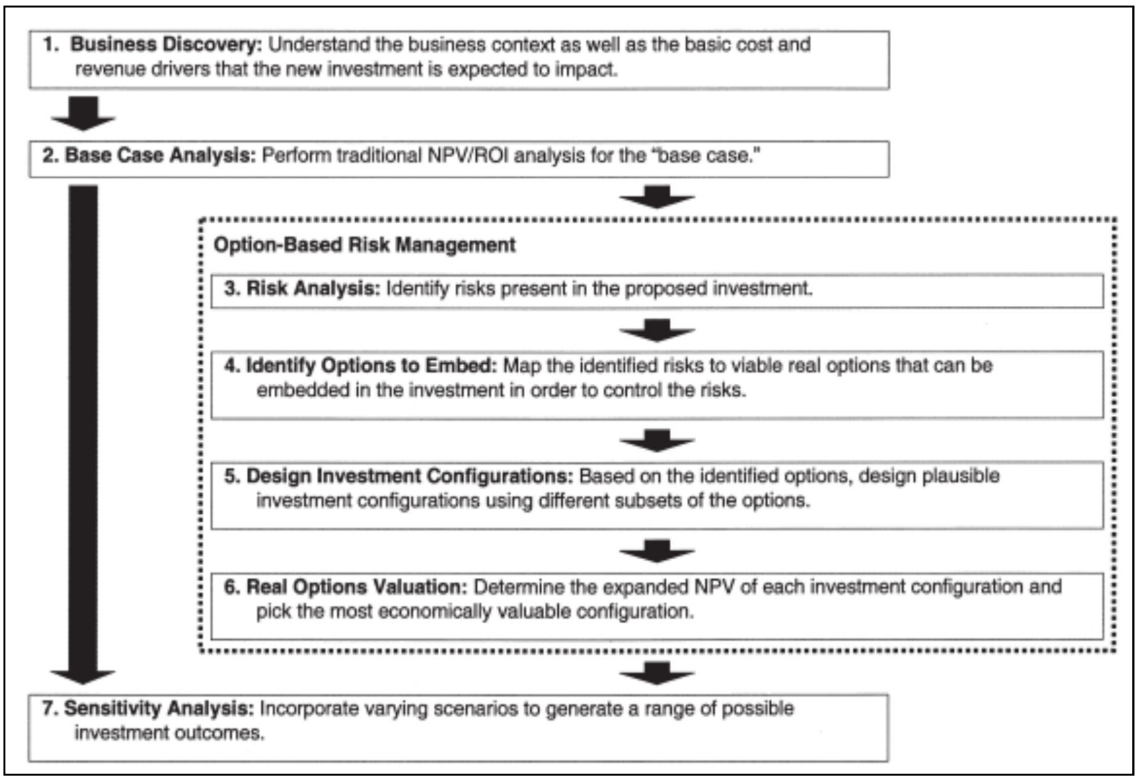

Figure 2.1: OBRiM Framework (As illustrated by Benaroch et al., 2007)

Further support for OBRiM framework followed. Benaroch et al. (2006) empirically tested the presence of risk mappings on which option based risk management (OBRiM) is based. With the analysis of the risk management plans developed for a broad portfolio of 50 IT investments in a large Irish financial services organization, they found ample empirical support for OBRiM's risk-option mappings i.e. IT managers follow the logic of option-based risk management, although purely based on intuition. The study used a logistic regression to test the relationship between the risk factors identified and the real options present in projects exposed to these risks. The results suggested a strong relationship between the two. A higher level of specific risks for which mitigations were planned was found to be associated with an increased presence of specific options (forms of flexibility) that facilitated deployment of the mitigations. The results validated the majority of risk-option mappings posited by the OBRiM framework, supporting the overall logic of option-based risk management. With these findings, they argued that reliance on this logic based on intuition alone could lead to suboptimal or counterproductive risk management practices. But with the strong empirical evidence for OBRiM, while supporting the argument that the scope of real option theory can and ought to be expanded to the management of IT risk.

Benaroch, et al. (2007) took validation of OBRiM one step further. By conducting a filed study among multiple managers involved in a data mart consolidation project (conducted by a major airline firm and a data warehousing systems vendor), they evaluated the viability of applying an option-based risk management (OBRiM) framework and its accompanying theoretical perspectives and methodology to real-world sequential IT investment problems. They applied OBRiM to identify several specific classes of real options, including the implicit options of deferral and abandonment, and the explicit options of piloting and staging in the project. The approach proved to be useful and revealing for staff members at the field study sites who were studying how to achieve an optimal configuration for their data mart consolidation project so that it would embed the most value-bearing real options. The results highlighted some benefits of the application of this approach i.e. the ability to generate meaningful option-bearing investment structures, simplification of the complexities of real options for the business context, accuracy in analyzing the risks of IT investments, and support for more proactive planning.

Although these evaluative studies showed that OBRiM has the potential to add value for managers looking to structure risky IT investments, yet some aspects still require refinements, e.g. estimate of risk and uncertainty through incomplete contracts in multi-party projects.

2.4 Application of Real Options to IT Investments

The application of Real Options theory in the context of IT investments includes numerous examples to illustrate the theory's applicability. Dos Santos (1991) used an example of ISDN network to illustrate the benefits from second stage projects affecting the value of the whole project. Kambil et al. (1993) discussed the implementation of handheld computer application at Healthways and valuing the project with its embedded piloting option. Taudes (1998) illustrated the valuation of sequential software growth options in IT platforms in case of EDI implementation. Kumar (1999) determined the DSS value via flexibility provided through its implementation in case of commodity training and marketing areas. Benaroch (2002) used the example of Internet Sales Channel investment to conceptualize and build the case for the use of real options for risk management in IT investments. Kumar (2002) used the example of CASE tools acquisition to value embedded abandon, scale and deferment options in the decision. Campbell (2002) used the example of Human systems Inc. and online logistics to illustrate the valuation of option to defer the decision.

Panayi and Trigeorgis (1998) used the real example of CYTA (Cyprus telecommunication authority and telecom infrastructure) to describe the valuation of multi stage real options in an IT infrastructure investment. Benaroch and Kauffman (1999, 2000) used the example of Yankee 24's POS deployment problem to value the underlying option to defer the investment. Later, the same data was used by Schwartz and Zozaya-Gorostiza (2003) to test their IT investment models for IT development and acquisition cases. Taudes et al. (2000) discuss the practical advantages of using option pricing models to support IT investment decisions for the selection of a software platform. They used a real-life case study of a European Auto part Manufacturer, facing a decision of SAP system upgrade from R/2 to R/3 to value the underlying options.

Kenneally and Lichtenstein (2002) tested the assumption that IS projects embed significant optional value by studying the portfolio of current and recent IS projects in a European manufacturer's plant setting. By interviewing seventeen project managers concerning thirty-one projects they found strong support to the prediction that IS projects include considerable optional value. Most of the projects under review were found to embed forty seven options, many of them with benefits comparable to the value of the original projects. The study concluded on the notion that real option evaluation is useful for IS projects in general, and should not be confined to special cases. It also concluded that real option thinking may be of particular value in recognizing the reduction and deferral options (which were found difficult to identify with short time to expiration). Thus proactive management of reduction and deferral options should increase the flexibility and value of IS projects. Similar effort was seen by Bräutigam et al.(2003), where they proposed a framework aiming at facilitating the process of real option valuation and to making it more time efficient. The framework encompasses the valuation of real options as well as the organizational, strategic, and controlling aspects necessary for the application of real option valuation accurately. Specifically it focused on uncertainties underlying any real option where these uncertainties were used to identify options as well as to link the interactions of uncertainties with the interactions of options. The applicability of the framework was demonstrated in the case of a German e-commerce firm.

Bardhan et al. (2004) provided a nested options model for making IT valuation and investment decisions for project portfolio management. They have examined a large U.S. based energy utility firm considering investment in a portfolio of 31 projects to provide a range of Internet-enabled energy services to customers. Hilhorst et al. (2008) used a data from a European based firm to value embedded stage option in the implementation of HRM system. Recently, Su et al., (2009) applied a real options framework to a shared service transformation by conceptualizing it as a European call option at Global Multimedia Company. All these examples show the progress made over the last two decades in extending the real options theory to IT, by utilizing hypothetical as well as real examples.

2.5 Real Options Thinking and Real Options Analysis

Real options analysis is considered as an appropriate tool for IT investment valuation (as demonstrated by studies discussed before), but many IT managers find it complex and costly endeavor. As a result, evidence of substitutes to the approach is found where managers utilize insights from real options theory to arrive at similar conclusions by other means (Sammer, 2002). Fitchman et al., (2005) positions this concept as a new way of thinking about the IT projects structure and management. Referring it to as “real options thinking”, they state that managers do not need to acquire option quantification skills to put options thinking to work. Instead by utilizing the real options as a heuristic framing tool, they can identify and value flexibility within an IT investment.

Empirical evidence of managerial decision making under risk for IT specific situations shows that IT managers follow the logic of options-based risk management, although purely based on intuition (Benaroch et al., 2006; Busby and Pitts, 1997; Fichman et al., 2005). On the one hand, the benefits of the approach can be reaped by using real options concepts to actively create and extract the value of embedded options in the IT project that can otherwise be difficult to see (Fichman et al., 2005). On the other hand, the intuitive decision making based on real options leads to sub optimal and counterproductive risk management practices (Benaroch et al., 2006). Following the stream of this philosophy, recent research has focused on exploring the variation in consistency found due to the presence of intuitive judgment along with the quantitative real option valuation.

2.6 Real Options and Managerial Intuitions

Some studies showed that managerial intuition typically responds in the correct direction to the factors that determine normative real options values, even without explicit real options methods or training (McDonald, 2000; McGrath, 1997; 1999). Formal or heuristic real options analysis adds logical support and quantitative precision to managerial intuition but does not differ qualitatively from it. But intuition is not always qualitatively consistent with real options analysis (Lankton and Luft, 2008).

Prior field and survey studies found that consistency between managerial intuition and real option values varies across option types and settings (Benaroch et al., 2006; Busby and Pitts, 1997; Lankton and Luft, 2008; Tiwana et al., 2006; 2007). Also, several biases come into play that causes this gap.

Tiwana, et al. (2006), explored the effects of real options on escalation of commitment in IT projects. They recognized the impact of various real options on the decision making of IT managers and how it changed their perception about the project value. This lead to the continuation of the project even when traditional valuation methods i.e. NPV, showed it infeasible to continue. The study built its questions on the argument that project managers take into account the value of real options implicitly when it's not a part of formal valuation procedure, along with exploring how strongly option value translates into an increased propensity to continue a troubled project. This gives an indication of how pervasive the phenomenon of warranted continuation[2] is due to recognition of options might be in practice. The study also explored differences underlying perceived value of real options (i.e., to switch use, change scale, stage investments, abandon, or strategically grow a project) in escalation situations. Hence, this study provided some initial insights into possible biases in how options are valued.

The results showed that presence of real options do contribute towards escalation of commitment in troubled projects. Also, among all identified real options in IT context, growth options are valued the most. Switch use option is found second to growth option and the abandonment option had the least perceived value among

[2] Also referred to as warned escalation, refers to situations in which the decision to continue a project is reasonable because, even though negative events have transpired since the project was initiated, the expected future benefits of continuing outweigh the cost (Keil and Flatto, 1999)

mangers. It is argued that this option is likely to be exercised only on the least successful projects. Consistent with the framing argument, managers associate low value to abandoning the project because they are less appreciative of options that only serve to curtail severe losses. In practice, it is difficult to exercise this option because it causes morale and credibility problems among team members and other stakeholders, who generally become personally invested in seeing the project completed. On the contrary, exercising growth and switch use options may have positive impact on morale and evoke a sense of accomplishment among project stakeholders. The study concludes that neither reducing the scale of a project nor staging investments is likely to be viewed as negatively as exercising the option to abandon, because in both cases, the degree of perceived failure may be less than that associated with the abandonment option. Reducing the scale of the project that project may still be implemented, though on a smaller scale than originally anticipated, and option to stage implies that it has been acknowledged all along that continued funding is contingent upon achieving interim milestones.

Tiwana et al., (2007) looked at the effects of bounded rationality on intuitive valuation of real options. They make an argument about managers not valuing options rationally because they are boundedly rational and they cope with decision-making complexity by using only a subset of the available information. The results showed that IT managers tend to systematically show bounded rationality bias in real option valuation. This affected the requirement of real options thinking, that suggests that managers must take into consideration the value of real options in making judgments about the value of new capital investments. The situation was found to be true for four kinds of options i.e. growth, scaling, switching and abandonment. In case of scale options, it was also observed that managers value the flexibility to change scale irrespective of project NPV. While in case of staging and deferral option, the results showed that managers do not value these options even if the NPV is low. Another important outcome of the study was the revelation of managers' preferences in general when it comes to real options. Managers weighed option to switch most heavily, followed by almost equal weightings on growth and scaling options, while weighing the abandonment option lowest.

Lankton and Luft (2008) predicted option-type-specific differences between intuitive judgments and real options predictions while using regret theory and competitive behavior theory. According to the study, payoffs from investments in IT are often subject to significant uncertainties, and the newsworthiness of major technologies (e.g., enterprise resource planning systems, e‑commerce, open source software) often means that information about the successes and failures of these technologies is available to firms that have not (yet) invested in them. These two factors provide the conditions for anticipated regret to affect IT investment decision making. The results showed that as uncertainty increases, individuals judge deferral options as more valuable but growth options as less valuable thus claiming that the deferral option judgments are consistent and the growth option judgments are inconsistent with real options theory. The results also showed that competitor's presence decreases judged deferral option values while increasing growth option values, even when a normative response to a rational potential competitor would result in no change in the option values. These results are consistent with behavioral economic theories as well as rules of thumb i.e. increased uncertainty leading to conservative investments and aggressive investments due to the presence of potential competitor, even if the uncertainty is high.

In a recent study on RFID adoption, Goswami et al. (2008) explored the role of embedded real options in the technology on the intention to adopt the technology. The real options analyzed were growth, learning, defer and stage. Further they explored the factors affecting the recognition of the embedded real options, including managerial mindfulness, institutional influences and institutional regulations. It showed that embedded growth and deferral options have a strong effect on RFID adoption as compared to learning and staging options, where they had no significant effect. Further, recognition of growth option was affected by only institutional influences, whereas recognition of deferral option was affected by only institutional regulations. Even though learning and staging options had no impact on RFID adoption intent, yet their recognition was affected by the managerial mindfulness.

2.6.1 Discussion

From the studies discussed above, it is evident that intuitive judgment of IT managers does effect real option valuation, and the outcomes are different under different scenarios. According to Tiwana et al., (2006), managers tend to value growth option more than operational options (Figure 2.2), where growth option is conceptualized as a call option and operational options are conceptualized as put options. Reasons ascribed to such outcome include:

- Growth options capture the complete value of one or more additional assets, rather than modifying the value of a single asset as with operational options.

- Due to the framing effects, managers prefer options (growth) that decrease the probability of any loss over those (operational) that decrease the severity of potential losses, should a loss occur. Same reason is predicted for valuation of different operational optional (excluding deferral).

These findings raise a need for not only testing if it is really the framing effects that are causing this outcome, but also extending the concept beyond escalation situations.

Strategic	Operational				
Growth	Switch	Scale	Stage	Abandon	Defer
Call Option	Put Option				
More attractive →				Less attractive	
High Value →				Low Value	

Figure 2.2: How managers value real options?

Valuation of real options beyond escalation situation was seen in Tiwana et al., (2007), by exploring when managers tend to associate real option with a project. The study drew the conclusion that managers are more likely to associate real options with project value for projects with low, but not high, NPV, thus implying that due to bounded rationality, options thinking comes into play as the uncertainty increases during the course of project (Figure 2.3).

Option Type					
Switch	Growth	Scale	Abandon	Stage	Defer
Low NPV →			High NPV	No NPV effect	
High Uncertainty →			Low Uncertainty	No Value	

Figure 2.3: When managers value real options, in the presence of uncertainty?

The study gave an insight on how uncertainty plays a role in not only recognition and valuation of real options, but also in how the preferences of managers change for each type of option. Hence the real option valuation can be mapped through other theories relating to decision making under uncertainty. Although the study is sound on theory and methodology, it has some inherent limitations. Due to the cross-sectional nature of data used in the study, results of this study do not provide insights into the dynamics of evolution of real options by testing how real option value changes across different stages of a project. Also only knowledge intensive and complex IT projects are examined in the study, thus making the generalizability of the results skeptical for other types of projects that do not share these characteristics. Over all, it gives a good indication that further similar concepts, relating to investors psychology can be applied on the real option valuation dilemma.

Lankton and Luft (2008) took the literature one step closer to psychology of IT managers by predicting option-type-specific differences between intuitive judgments and real options predictions while using regret theory and competitive behavior theory. The study showed the conditions for anticipated regret to affect IT investment decision making, in the case of two types of real options i.e. growth and deferral, while controlling for potential competition (Figure 2.4). Due to the anticipatory nature of outcomes involved when it comes to options thinking, further impacts of regrets need exploration i.e. how else such an emotional state can effect options thinking among IT managers.

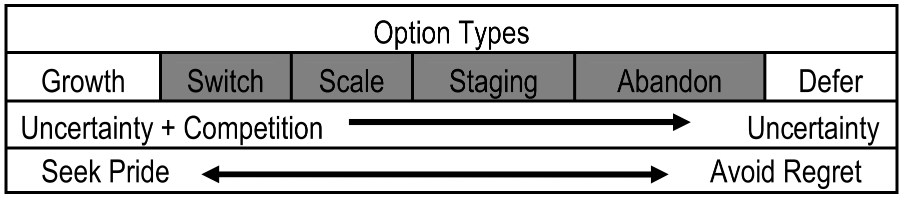

Figure 2.4: Role of Uncertainty and Competition on Options Valuation

Goswami, Teo and Chan (2008) conceptualized the intuitive valuation of real options in a different setting i.e. new technology adoption, specifically RFID. By aiming at finding if institutional factors and managerial mindfulness affect the capability of managers to recognize the "shadow options" in the projects involving RFID, this study gave a new insight into further factors that can impact the real options thinking. Also, growth and deferral options being prominent in contributing towards RFID adoption intuition (Figure 2.5) strengths the pre-established result about these options being valued more by IT managers as compared to other real options. It will be interesting to see the real option valuation done by managers in the absence of growth or deferment or both options. There is a possibility that other real options don't seem valuable due to the managerial bias towards these two options. However in their absence, the results might be different, especially in the case of new technology adoption.

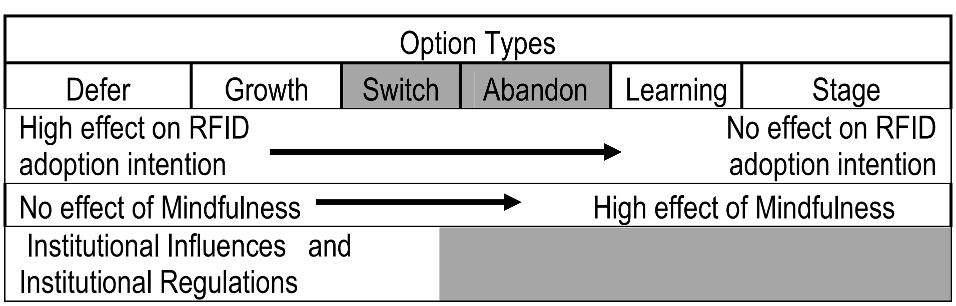

Figure 2.5: Role of Real Options in RFID Adoption

2.7 Conclusion

Our understanding of real options for IT investments is evolving. Although there is considerable help available from other fields that has used real options, yet the nature of the IT investments and risks underlying them makes these investment a special case. That is why we see proliferation in conceptualization of the real options in the context of IT, valuation methods and management and implementation issues involved.

For the option valuation, strong arguments are provided in favor of the adoption of quantitative methods from financial options and real options in other fields. Yet, the generalizability of one method is not possible. Even if we are able to adopt all the methods, the dynamism in the field requires research to fine tune and improves these methods. Therefore, efforts like Schwartz and Gorotiza (2003); Hillhorst (2008) etc. are much needed. There is also a potential for integrating ROA with Decision Analysis (Smith and Nau, 1995) for the better approximation of managerial flexibility and overcoming the limitation of the traded assets underlying the real options (especially in case of Black Scholes model).

Real options theory has two distinctive aspects to it: real options thinking and real options analysis. Real options thinking includes literature on intuitive valuation of real options in IT investments/ projects and effects of biases on intuitive valuation of real options. Real options analysis on the other hand, includes literature on the conceptualization of real options in various IT investment scenarios (i.e. kinds of real options that can exist in an IT investment scenario), quantitative valuation of real options (i.e. the various models discussed in the paper) and the application of real options analysis in IT investment scenarios (including hypothetical examples, real examples and OBRiM framework). Figure 2.6 gives a pictorial depiction of real options theory in IT.

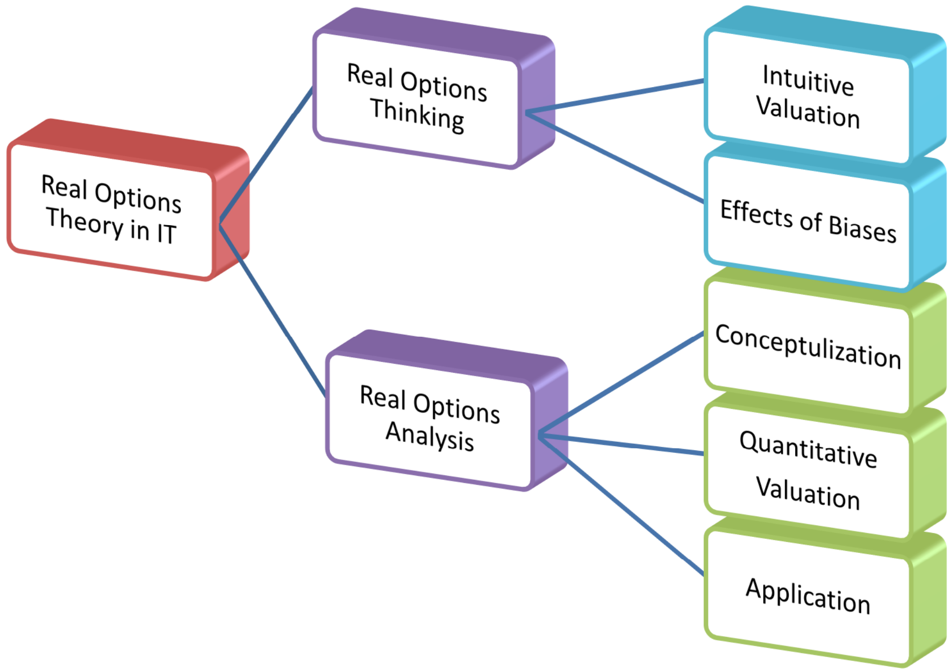

Figure 2.6: Real Options Theory in IT

Keeping in view the recent developments in this area, we can conveniently say that real options are shown to be suitable for IT investment management. The literature gives a good insight into real options analysis as well as real options thinking. Real options analysis explains the conceptualization, quantitative valuation and application of real options for IT investments, whereas real options thinking explores intuitive valuation of option like characteristics in IT investment by IT managers and effects of various biases on it.

Literature on real option thinking unanimously agrees that when real options are used intuitively to value flexibility in IT investments; they tend to give biased results.

Similar results were found in case of organizational capabilities as real options (Kogut and Kulatilaka, 2001). If real options' thinking is prone to biases, then there is a possibility for a laundry list of synchronized biases that are not explored yet. For example, if growth options are valued more than option to abandonment, what effect this outcome can have in the case of a portfolio of projects with multiple options? Or if similar heuristics lead the decision maker to be risk sensitive while exercising real options, based on their perceived value, preferences similar to Prospect theory (Tversky and Kahneman, 1992)?

The real option's value is realized when it's either exercised or not, based on the project's progress. In case if real options are used as an approximation for actual heuristics, it can be argued that the real option's realized value might be biased due to the biased exercise decision of these options? This may be true especially, when there is no predetermined time to exercise a real option in the case of IT investment because most options are like American style options (where an option can be exercised any time before its expiration). While the literature has been focusing on the valuation problem in the real options thinking, there is a great potential for exploring the option exercise problem in real options thinking i.e. what biases may affect them? Hence, this dissertation is directed towards this objective.

Most of the findings in the current literature about real options thinking are ex post and explain observations incompletely. They include either limited or many option types and valuation-relevant variables. Without knowing more about why such inconsistencies occur in a coherent manner, it is difficult to identify the conditions under which they are likely to occur in the future and how best to reduce them. In order to do so, stronger theory base is required that not only provides a common base to understand the gaps between managerial intuition and real options, but also explains this complex phenomenon in a relatively simple manner. This marks yet another objective of this dissertation, where we take help from “prospect theory” to explore some anomalies in real option exercise decisions.

CHAPTER 3: STUDY 1 – FRAMING AND NARROW FRAMING EFFECTS ON IT REAL OPTIONS

3.1 Introduction

Building on the intuitive recognition and valuation of real options by IT managers, recent studies have tried to explore the presence and effects of various systematic biases on real options (e.g., Tiwana et al., 2006; 2007; Lankton and Luft, 2008; Goswami et al., 2008). These studies focused on the effects of various biases on real option valuation, showing the method's vulnerability to human decision making. But these studies had a limited scope, i.e., a single project and in the presence of a single real option. In this study, we try to explore, the presence of systematic biases in a more realistic setting, i.e., a portfolio of projects with multiple embedded real options, along with the single project scenarios with a single embedded real option. We also aim at capturing the effects of these biases on actual managerial decisions at the time of option exercise. Furthermore, we explore the factors that can contribute towards minimizing the biases. Finally, we look at the relationship between risk behavior of individual decision makers and the risk behavior found in IT investment decisions.

3.1.1 Motivation

The motivation of this study is to capture the actual decision making process behind real option exercise decision along with the factors that impact the decision. Our motivation for this study comes from the existing literature on real options indicating the vulnerability of real options being subjectively valued by IT managers. Studies have shown how real options are valued based on subjective frames in general as well as in IT projects. We draw on Tversky and Kahneman's (1981) idea of framing to suggest that managers will demonstrate systematic biases while making real option exercise decisions in an IT project setting. By also looking at the concept of narrow framing, we hypothesize that in a portfolio setting, IT managers' tendency of framing some options as gains (e.g., growth) and others as loses (e.g., switch or abandon) (Millar and Shapira, 2004; Tiwana et al., 2006) with respect to the NPV of the project as a reference point, will result in varying risk behaviors at option exercise time. Further, it will lead them to take isolated real option exercise decisions in a portfolio, hence, impacting the overall portfolio's economic value.

The focus of this study is not only on problem recognition but also on finding methods to mitigate these problems associated with real options exercise decisions. We study whether inherent characteristics in IT portfolios or restatement of the decision scenario can reduce the narrow framing effects. Also we investigate the role of individual risk behavior. Hence, with this study, we intend to answer the following questions:

1. Do framing effects exist at real options' exercise time in IT projects?
2. Do narrow framing effects exist at real options' exercise time in IT portfolios?
3. What factors have the potential to impact narrow framing effects in IT portfolios?
4. Does individual risk behavior of IT managers cause framing and narrow framing effects on real options' exercise decisions in IT projects?

Our results indicate that framing of real growth options as gains and real abandonment options as losses does lead to suboptimal exercise decisions. These biases are more prevalent in large projects than in small projects. Also, biased decision making intensifies in a portfolio of projects, where individual and firm level characteristics contribute significantly.

3.1.2 Contribution

Our study contributes to the literature in several ways. First, it is one of few studies focusing on real options exercise decisions, instead of real options valuation problems. IT real options exercise decisions are challenging due to prevalent uncertainty about commitment to the option, and the fact that managers are expected to take into account all the possible outcomes and future opportunities before making a decision. Also, the realized value of real options depends on its optimal exercise. If managers are involved in framing in IT projects, their bias of showing different risk behavior may lead to suboptimal option exercise decisions. Also, if managers are involved in narrow framing in IT portfolio decisions, their bias of separating interconnected decisions may lead to isolation cost due to a suboptimal option exercise decision.

Second, we are contributing to the literature and practice of IT project portfolio management. Although most organizations today are adopting the idea for managing their IT investments, IT project portfolio management is a relatively new research area. By knowing the potential pitfalls, management techniques to avoid them can be devised and in turn, IT managers can better equip themselves to make the best use out of real options.

Third, we try to extend the literature on behavioral decision making by studying the effects of framing and narrow framing in a real options setting. Framing effects and narrow framing have been studied extensively in the fields of psychology, consumer behavior, investment behavior and financial markets. Yet, the presence of these phenomena in a real options setting has not been investigated.

The chapter is structured as follows: First, we review the relevant real options, framing, and narrow framing literature. Then, we develop hypotheses based on the literature, followed by the details on methodology and data. We finally present the results, discussion, implications and conclusions.

3.2 Theories

3.2.1 Information Technology Management and Real Options

A real option has two stages: commitment stage and an option exercise stage (Amram and Kulatilaka, 1999). At the commitment stage, the option holder commits to the option by determining its value and paying an upfront price for it. At the option exercise stage, value of the option is realized by making an exercise decision. Most of the IS literature on real options has focused on their valuation at the commitment stage. For example, several studies (Clemons, 1991; Dos Santos, 1991;Kambil et al., 1993; Kumar, 1996; Kumar, 2002) used illustrative examples to propose the idea of using real options in IT investments, categorization of real options for IT investments (Benaroch, 2002), study valuation methods for real options in an IT context (Benaroch 2002; Benaroch 2006, 2007; Su et al., 2009; Hilhorst et al., 2008) and investigate behavioral biases affecting the valuation of real options (Lankton and Luft, 2008; Tiwana et al., 2007; Tiwana et al., 2006).

IS literature has proposed to apply financial options pricing models to value the embedded real options in IT projects. Commonly seen models include binomial

(Benaroch, 2006), Black-Scholes, and Margrabe (Kumar, 1996, 2002; Bardhan et al., 2004). In case of financial options, the values of the key parameters for these models is available ex ante or is easily calculated because assets underlying these options are traded in the market with complete information. As for the real options case, the values of key parameters for these models are usually not available. For example, the real option exercise price, option expiration time, value of asset underlying the real option, etc. may not be known. Table 3.1 gives a comparison between a financial option and a real option on an IT asset.

Table 3.1: Comparison of Financial Call Options with Real Options on IT Asset

Option Parameter	Financial Call Option	Real Option on IT Asset
Option Exercise Time (T)	Exercise date fixed when option is issued. A fixed date for European style options and flexibility in exercising before expiration for American style options	Unspecified date. Estimated based on experience with prior projects or managerial opinion (Kumar, 2002)
Strike / Exercise Price (K)	Exercise price is determined before option is issued, which does not change over the life of the option	Usually taken as the cost of IT project phase (Benaroch 2002, 2006; Kumar, 2002). It is uncertain at the time of option acquisition (Kumar, 2002)
Uncertainty about full scale commitment (sigma)	Calculated based on the price uncertainty of traded financial asset. It dissipates fully by the expiration date of option	Based on uncertainty in project cost/ benefits resulting from the IT project (Kumar 2002). Some uncertainty persists over time leading to downside risk at exercise time (Tiwana et al., 2006)
Benefits (S)	The market value of the financial asset	The benefits resulting from the IT project (Kumar, 2002) or the value of the underlying IT asset (Benaroch, 2002). This may be uncertain and could in turn be another option to invest in the next phase of the project (Kumar, 2002)

Real options provide a tool for hedging unsystematic risk inherent in IT projects (Kumar, 2002) by giving a flexibility of altering the course of a project as information is revealed. But, unlike financial options, where market information on the underlying asset resolves the uncertainty by the exercise time, significant uncertainty persists at the option exercise time about the outcome (Coff and Laverty, 2007). Two main sources of uncertainty surrounding the exercise decision are technological changes and business environment changes (Keil et al., 2007). Technological uncertainty includes unexpected problems in the underlying project hardware, system software, programming languages, and database technologies (Nidumolu, 1995; McGrath, 1997). Business uncertainty arises from unpredictable changes in a project's business priorities during its implementation (Nidumolu, 1995; Tiwana, Bharadwaj, and Sambamurthy, 2003). Therefore, at option exercise time, IT managers have to evaluate the situation with uncertain elements, and make a choice between exercising an option and letting it expire.

Due to the difficulty in determining the value of key parameters to value real options, using an options heuristic is considered a more practical approach instead of conventional quantitative valuation approaches (Bowman and Markowitz, 2001; Kogut and Kulatilaka, 2001; McGrath and McMillan, 2000). But these heuristics come at a cost of rigor. IT investment decisions are no exception; managers rely more on intuitive judgments as a heuristic, rather than using formal quantitative models (Fitchman, 2005; Lankton and Luft, 2008). Costs of these heuristics include the likelihood for incorrect option exercise decisions. Especially in the face of persistent uncertainty around project outcomes at exercise time and with the absence of a time frame for exercising a real option on the underlying IT asset, it's left to the manager's discretion if the exercise decision needs to be made.

On the one hand, it is argued in the real options literature that option analysis captures and formalizes the managers' intuition, hence, creating a disciplined decision making process (Amram et al., 1999). On the other hand, the intuitive valuation of the real options is under high scrutiny in the IS literature due to the prevalent effects of various judgmental biases. Also, irreversibility of these investments in terms of development and implementation costs makes the timing of these option decisions very critical. We inquire into this domain further in this study by exploring the effects of framing and narrow framing on real option exercise decisions. We focus on two most commonly found real options in IT projects, i.e., growth and abandonment options.

An IT project can have an embedded growth option that may necessitate several platforms or enable implementation of other projects (Taudes et al., 2000). Examples include: investments by firms in C-language-based projects, client-server applications, and graphical user interfaces providing the knowledge to later exploit object-oriented programming innovations (Fichman and Kemerer, 1997); investment in web-based technologies by utility firms provide them the software platform to exploit various e-services tailored to their customers (Bardhan et al., 2004); investment in new telecommunication infrastructure provided a telecom firm with future capability to adapt to changing needs and allowed it to take advantage of future development opportunities and follow-on projects in an uncertain environment (Panayi and Trigeorgis, 1998); investments in an ERP system by a firm might provide a necessary foundation for workflow or supply chain management systems in the future (Tiwana et al., 2006).

A project can also have an embedded option to abandon, where the application can be halted permanently before its completion, depending on the circumstances, like for example good quality applications that have lost their value for the organization (Weil and Vitale, 1999). An abandonment option can be associated with a switch-use option in the IS literature (Benaroch, 2002), where abandonment options become more valuable if the resources from the abandoned project can be put to another use. The value is generated by minimizing losses on overall investment through reducing resource waste. Alternatively, the abandonment option and the option to switch-use can be treated separately, where value from an option to abandon is generated by the flexibility to curtail losses, instead of minimizing them. Although, in both cases, the abandonment option is valuable, empirical evidence shows several reasons for this option to be least valued by managers, even when it is appropriate to exercise the option (Busby and Pitts, 1997; Miller and Shapira, 2004; Tiwana et al., 2006). These include political implications of cancellation of the project, personal reputation of managers, negative impact on staff morale, etc. (Keil et al., 2000).

3.2.2 Information Technology Portfolio Management

A project portfolio is a collection of individual projects. In case of IT, a collection of individual IT projects managed collectively comprises an IT portfolio. The major classifications that are found for IT portfolios in the IS literature are application portfolios (Ward, 1990; Weil and Vitale, 1999) and multi-stage projects portfolios (Panayi and Trigeorgis, 1998; Bardhan et al., 2004; Benaroch et al., 2006). Application portfolios constitute various IT applications that have a potential to add value to the firm. Each IT application in the portfolio is usually independent of the other applications and each can serve a specific purpose. For example, an application can be of strategic nature (like order management systems, links with suppliers, sales and demand forecasting, etc.), or can be supporting key operations (like budgetary control, accounting, inventory management, etc.). The common factor for which such a wide variety of applications are combined in a portfolio form is that they can be supported by a single software platform (Taudes et al., 2000). Also, all of them are competing for limited organizational resources (Ward, 1990). Various methods are proposed for evaluating projects in these portfolios (Ward, 1990; Weil and Vitale, 1999), where each project investment is profiled based on its risk and value characteristics over a period of time (Weil and Vitale, 1999). Investment decisions are then made based on these profiles of individual projects within the portfolio. This portfolio approach further helps in determining the overall value added by IT investments to the firm's performance (Ward, 1990).

Multi-stage IT portfolios are constituted of multiple interdependent projects (Panayi and Trigeorgis, 1998; Bardhan et al., 2004). Usually, two kinds of interdependencies are found among projects in such IT project portfolios. First is an *input/output interdependency,* where completion of one project is required to carry out the future projects, i.e., sequencing (Bardhan et al., 2004; Benaroch et al., 2006). For example, in order to launch e-services, a web infrastructure has to be in place. The second kind of interdependency is the *resource interdependency*, where multiple projects are sharing resources like skilled people, hardware and finances (Thorp, 1999). These multi-staged IT project portfolios are made of large projects like IT infrastructure, where the base project by itself does not create much value but it has a potential to enable other projects that could add significant value overall. Also, such projects are constrained by sequencing, where completion of one project is essential to initiate the contingent projects. These interdependencies impact the value of not only the project but the whole portfolio of projects. In multi-staged IT portfolio, each stage is evaluated before further investment is made. This leads to the embedded compound growth options in such portfolios, i.e., options whose exercise brings forth more options along with generating value for the firm in terms of cash flows and strategic advantage (Panayi and Trigeorgis, 1998; Bardhan et al., 2004).

The overall objective of IT portfolio management is to maximize the value of the portfolio by balancing the combined risk and value of the projects. There can be several sources of risks within an IT portfolio, including, project size, experience with technology, project structure (McFarlan, 1981) and technical quality (Weil and Vitale, 1999) among others. Ultimately, these factors determine how volatile the benefits are from the investments. As for the value of the projects, it is usually determined by the system's importance to a specific business unit in the organization, perceived management value of the system and level of use of the system (Weil and Vitale, 1999). Based on that, IT projects can have one of the following risk and value profile, i.e., high risk-high value, high risk-low value, low risk-high value and low risk-low value.

In this study, we focus on two types of IT portfolios, i.e., IT portfolios with no interdependency among projects, and IT portfolios with resource interdependency among projects. In these portfolios, the key challenge is to keep the resource allocation at its best based on the risk-value profile of the portfolio. This in turn makes the investment decision dependent on the perception of real options embedded in projects and their exercise decision. Sub-optimal exercise decisions can impact the portfolio's health in the form of sunk costs with early investments, lost opportunities, and too much investment for too little value. The absence of methods in place for portfolio evaluation makes optimal option exercise decisions challenging.

3.2.3 Framing Effects and Narrow Framing

For strategic decisions involving high stakes, managers are expected to make decisions objectively and inclusively by considering all the alternatives and integrating a variety of information (Bukszar and Connolly, 1988). In reality, as the task becomes cognitively challenging, managers arrive at their decisions by considering a broad range of facts and then by conducting a detailed examination of a subset of facts (Etzioni, 1989). While doing so, empirical studies have shown that they fall prey to the effects of narrow framing based on how individual subsets are framed (Tversky and Kahneman, 1981; Kahneman, 2003; Thaler, 1985; Kahneman and Lovallo, 1993). This section reviews the literature on framing effects and narrow framing along with their application in various fields.

Frames are cognitive shortcuts that people use to understand complex information and to simplify complicated phenomena into more easily understandable components (Liu et al., 2010). The first conception of frames in terms of decision making came from Tversky and Kahneman (1981), who described decision frames as the decision-maker's conception of the alternatives and contingencies associated with the alternatives and outcomes. Through experimental evidence, they showed that the decision frames that a decision maker adopts rely on factors like formulation of the problem, norms, habits, and personal characteristics of the decision-maker.

Generally, framing effect occur when the willingness to undertake a risky task depends on whether potential outcomes are positively or negatively framed. Also known "*risky choice framing*", Tversky and Kahneman (1981) showed preference reversal among people's risk preferences where they are willing to take more risks with negatively framed outcomes than with positively framed outcomes. In their famous Asian disease problem, two groups were given the same situation, but framed in two different ways, i.e., gain (lives saved) frame vs. loss (lives lost) frame (Figure 3.1).

Imagine that the United States is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows:	
Save Frame	**Loss Frame**
If Program A is adopted, 200 people will be saved (72%)	If Program A' is adopted, 400 people will die (22%)
If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved (28%)	If Program B' is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die (78%)

Figure 3.1: Asian Disease Problem, Tversky and Kahneman (1981)

Both the options are mathematically equal, where the expected values are the same. Theoretically, the same proportion of subjects should have selected option “A” as selected option “A`”, or should have selected option “B” as selected option “B`”. Instead, the majority of subjects showed preference reversal by showing risk-averse behavior in the gain frame and risk seeking behavior in the loss frame. In other words, they were risk-seeking when a "lives lost" frame was employed (B` was favored over A`) but under the "lives saved" frame, they were risk-averse (A was favored over B).

The formulation of frames is dependent on the reference point to which the decision maker become conveniently adopted. This leads them to start relying on narrow frames relative to that reference point (Kahneman and Tversky, 1981; Kahneman, 2003). Narrow framers make their decisions through selective simplification and engage in suboptimal decision making under risky situations. For example, the reference point in the previous example was lives saved (Tversky and

Kahneman, 1981). Typically, the reference points vary from situation to situation. For example, for managerial decision making, the reference point is the organizational resources at stake (Hogarth, 1987). In a trade situation, reference point for the seller is found to be the amount received, whereas it is the amount paid for the buyers (Huber, Neale and North-craft, 1986), which leads to sellers being less risk taking than buyers. In the case of IT investment, a project's NPV is the reference point that managers conveniently adapt to (Fichman et al., 2005) that guides their decision about the project. In other words, the decision-makers' perceptions become narrowly anchored on a reference point they use to assess changes in wealth rather than the final states of wealth (Tversky and Kahneman, 1981), therefore leading them to decision making in isolation (Tversky and Kahneman, 1981). The situation becomes more prevalent in case of decisions made intuitively rather than through effortful reasoning (Kahneman, 2003).

A similar conception of narrow framing is given by Thaler (1985), who suggests that framing simplifies complicated problems into simpler sub-problems, and decomposes investment problems into mental accounts. When doing their mental accounting, people engage in narrow framing, that is, they often appear to pay attention to narrowly defined gains and losses (Barberis and Huang, 2001), as described by Tversky and Kahneman (1981). Again, the behavior over gains and losses follows the prospect theory predictions, i.e., risk-averse over gains and risk-seeking over losses. Also, while comparing gains and losses, people tend to be more sensitive to losses than gains, leading to loss-averse behavior (Kahneman and Tversky, 1979). The application of mental accounting and loss aversion, also known as myopic loss aversion is mostly seen in the area of individual stock investment behavior (Barberis and Huang, 2001; 2008)

There is ample literature about narrow framing (Table 3.2). As mentioned before, Tversky and Kahneman (1981) first introduced the concept of narrow framing by experimentally demonstrating the tendency of people to simplify complicated phenomena into easily understandable outlines and engaging into decision making in isolation. While doing so, they showed risk-averse behavior over positively framed scenarios and risk seeking behavior over negatively framed scenarios, where scenarios were presented as a concurrent decision problem. Such tendencies lead towards the selection of sub-optimal choice on their part. Later Kahneman and Lovallo (1993) showed the existence of narrow framing for decision making under risk while showing that under these circumstances, people make decisions one at a time. They are prone to neglect the relevance of future decision opportunities as well as interdependence among their decisions, which leads to isolation costs. The results were generalized to individual decision makers as well as organizational decision making.

Thaler (1985) extended the concept of narrow framing to marketing in the form of mental accounting, and developed new concepts in three distinct areas, i.e., coding of gains and losses by consumers, how they evaluate purchases while using transaction utility instead of standard utility, and budgetary rules followed by them. Later, Thaler (1999) further explored the relationship between narrow framing and mental accounting and characteristics of mental accounting, also referred to as myopic loss aversion.

Table 3.2: Literature on Narrow Framing

Reference	Area of Application	Results
Tversky and Kahneman (1981)	Psychology of decision making under risk	Formulation of frames is dependent on the reference point to which decision maker become conveniently adapted. It leads them to start relying on narrow frames relative to that reference point.
Kahneman and Lovallo (1993)	Psychology of decision making under risk	Narrow framers are liable to consider problems as unique. They isolate current choices from future opportunities and neglect the connection in terms of future choice opportunities, which results in isolation costs.
Thaler (1985)	Consumer behavior and evaluation of purchases	Consumers indulge in mental accounting while deciding on various aspects of their purchases.
Thaler (1999)	Mental accounting process	Risk attitude of loss-averse investors depends on the frequency with which they reset their reference point.
Barberis, Huang, and Santos (2001)	Relation of narrow framing and loss aversion to the equity premium puzzle	Loss aversion due to narrow framing over financial wealth fluctuations in a dynamic equilibrium model captures a number of aggregate market phenomena.
Barberis, Huang, and Thaler (2006)	Investor behavior in stock market	Investors isolate their investment decisions in regards to their portfolio and do not take into account the degree of correlation between the portfolio components.
Barberis and Huang (2008)	Investors' utility function for asset allocation under narrow framing and loss aversion	Investors evaluate a gamble in isolation and are sensitive to losses.
Frazzini (2006)	Individual trading behavior in stock market	Investors evaluate a gamble in isolation and are indifferent to the correlation between their outcome and their total wealth.
Lim (2006)	Individual trading behavior in stock market	Individual traders exhibit mental accounting behavior in stock markets. They frame gains and losses separately, and are prone to executing trading decisions in order to sell more multiple losers on any given day versus selling winners.
Kumar and Lim (2008)	Individual trading behavior in stock market	Narrow framing traders exhibit the disposition effect more, and hold more undiversified portfolios in stock markets.
Baily et al. (2008)	Individual trading behavior in stock market	Investors who frame decision narrowly or prefer speculative securities poorly select mutual funds and trade excessively.
Magi (2009)	International portfolio choice	Narrow framing preferences in agents lead to home bias i.e., foreign assets seem less attractive than the one in the home country.
Liu et al. (2010)	Financial Options market	Traders in an options market show evidence of narrow framing by framing complicated investment decisions into simpler ones. Also, traders' professionalism, sophistication, and trading experience help to reduce investors' behavioral bias in the form of narrow framing.

Along with psychology and marketing, application of narrow framing in finance explained a wide variety of investor behaviors. For example, Barberis et al. (2006) suggest that investors engage in narrow framing by isolating their investment decisions in regards to their portfolio in terms of gain and losses. This way, they ignore the degree of correlation between the portfolio components. By demonstrating that investors evaluate a gamble in isolation and are sensitive to losses, Barberis and Huang (2008) showed that investors exhibiting narrow framing can explain equity premium puzzles. Frazzini (2006) reports that narrow framing can occur anytime or across different risky choices. In other words, agents evaluate a gamble in isolation and are indifferent to the correlation between their outcome and their total wealth. They also evaluate their outcome at given time intervals.

Kumar and Lim (2008) justified the disposition effect among individual traders through narrow framing and found that investors who frame decisions narrowly or prefer speculative securities select mutual funds poorly and trade excessively. Therefore, such traders are more likely to hold more undiversified equity portfolios. Along with excessive trading, investors with narrow framing also select high expense mutual funds that detract from performance (Baily et al., 2008). Magi (2009) gave explanation of aggregate portfolio behavior, in a framework where economic agents have *narrow framing* preferences. In case of diversification opportunities in the form of international portfolio choices, an individual’s limited capabilities of processing information lead to home bias. This means a foreign asset is perceived as less attractive than it would be if the investor had the optimal information skills and, hence, would be able to evaluate the two risky assets jointly.

Traders' behavior is also found to be in alignment with narrow framing in financial options markets. Liu et al. (2010) showed that traders in an options market show evidence of narrow framing by framing complicated investment decisions into simpler ones. Also, traders' professionalism, sophistication, and trading experience help to reduce investors' behavioral bias in the form of narrow framing.

Given that the real option exercise decisions are important in order to realize their value (Kumar, 2002), along with the evidence provided in the literature on biases affecting the real options value (Busby and Pitts, 1997; Howell and Jägle, 1997; Miller and Shapira, 2004; Tiwana et al., 2006; 2007; Lankton and Luft, 2008), we take one step ahead to test if the real option exercise decisions are affected by judgmental biases? We make use of Prospect Theory, and specifically "framing effects", because this theory has been used in real option valuation. We discuss the details in the following section. Also, as IT projects are commonly managed as a portfolio, we extend the use of the theory for collective decision making in real options scenarios, by taking into account the "narrow framing effects". The details on hypotheses development is given in the following section.

3.3 Hypotheses Development

Recent real options literature has focused on the behavioral aspect of the real options use (Table 3.3). The motivation of these studies has been to identify the characteristics of managerial intuition and real options analysis along with the reasons for prevailing valuation gaps in various contexts. As described in Table 3.3, these studies concentrated on the real options value and the identification of potential biases that can affect their perceived value.

Table 3.3: Literature on Intuitive Valuation of Real Options

Reference	Theory Used	Hypotheses	Type of Subjects
Busby and Pitts, 1997	Real Options Theory	How decision-makers in industry evaluate flexibility in capital investments.	Senior Finance Officers
Howell and Jägle, 1997	Human Information Processing	How managers intuitively value real growth options.	Managers
Miller and Shapira, 2004	Prospect Theory and Framing Effects	How purchasers/sellers of call and put option price it relative to their payoffs/losses	MBA Students
		Discount rates decrease with option duration, and the steepness of decline decreases with time.	
		Call/Put option sellers and buyers discount exercise price	
Tiwana et al., 2006	Escalation of Commitment	Presence of real options in a project increases the likelihood of warned continuation of an IT project with negative feedback.	Managers
	Prospect Theory and Framing Effects	Managers perceive strategic growth options embedded in an IT project as adding more value to the firm than operating options	
Tiwana et al., 2007	Bounded Rationality	Under uncertainty, managers associate embedded options (growth, switch, stage, scale, defer, and abandon) with IT project value in case of a low NPV.	Managers
Lankton and Luft, 2008	Regret Theory	Under uncertainty, deferral options are intuitively valued more than growth options in IT projects.	MBA Students
		The presence of competition decreases the value of deferral options and increases the value of growth option	

Literature studying the fit between managerial intuitive valuation of real options and real options analysis confirm that managerial intuition does not always conform to real options analysis. For example, Howell and Jägle (1997) showed that managers do not value growth options as much under high uncertainty. Tiwana et al. (2007) showed that managers only value an option in a project when the NPV of the project is low. Lankton and Luft, (2008) showed that under prevailing uncertainty about outcomes, deferral options are valued more than growth options, which is partly in line with the results of Howell and Jägle (1997). They also show that the situation reverses in the presence of competition.

In this section, we develop our hypotheses in light of recent findings on real options and literature on “framing effects” and “narrow framing”. Hypotheses for this study are divided into four types. The first set hypothesizes the effects of intuitive frames on real options exercise decisions in individual IT projects, due to resulting risk behavior, and the project size effects. The second set of hypotheses is built around the consequences of prevailing framing effects in IT portfolios in the form of narrow framing. The third set of hypotheses focus on the factors that have a potential of reducing narrow framing effects in IT portfolios. The last hypothesis tests the connection between the individual risk behavior and narrow framing effects.

3.3.1 Framing Effects

Real options literature shows evidence of general managerial perceptions of real options being in alignment with the predictions of prospect theory. Millar and Shapira (2004) showed that real call options are framed as gains and real put options are framed as losses by the real options buyers and sellers, during the real options’ risk evaluation. Due to these framing effects, real option buyers and sellers show risk-averse behavior for call options and risk seeking behavior for put options at the real options’ purchase time. These effects are reflected in the real option price and its exercise price that each party is willing to pay and receive. Tiwana et al. (2006) used the same reasoning to show that, in the context of IT investments, IT managers value real growth options more than operational options because real growth options share the same structure as call options, whereas the rest of the operational real options are like put options. Therefore, they perceive a growth option as adding more value to the project than operational options. These perceptions of real options in an IT investment are shown to drive commitment to projects embedding these options as well as contribute towards their continuation, even in the face of negative feedback (Tiwana et al., 2006). But this finding does not assure the optimal exercise of these real options at the exercise stage. On the one hand the IT manager is likely to commit to a project with an embedded real option or keep committing to the project as more real options emerge or the existing ones have time left to expire, because they are perceived as adding value to the project in terms of flexibility in changing the course of the project. On the other hand, from the framing theory perspective, IT managers should show either risk-averse behavior or risk seeking behavior at the option exercise time, depending on how they are framed, i.e., either as a gain or loss. For example, if growth options are framed as gains at the commitment stage, IT managers will show risk-averse behavior for decision scenarios involving exercising decision under uncertain outcomes situations. Hence, we hypothesize that:

H1: When IT managers exercise a growth option in a single IT project, there will be framing effects.

Several operational options exist against one real growth option, i.e., option to switch, stage, abandon, scale and defer. The IT literature points that an IT real option to abandon is least valued by the managers (Tiwana et al., 2006; Busby and Pitts, 1997) due to difficulty in exercising the option. Other factors identified include the "sunk cost effect" and 'face saving" (Keil et al., 2000) that may lead to delaying/preventing exercising the option to abandon among IT managers. Contributors towards the difficulty in exercising the exit option include disruption in ongoing project operations, negative impact on the team's moral and credibility, and the ability of the exit option to give no accomplishment as compared to other real options, except curtailing losses (Tiwana et al., 2006).

We extend our framing argument to the option to abandon. Similar to the growth option, an option to abandon is shown to drive commitment to an IT project or continuation of the troubled IT project, but its presence does not assure that the option value will be realized through its optimal exercise. Especially due to risk seeking behavior in situations framed as losses, IT managers will put off their exercise decision as much as possible, even when it's optimal to exercise it, i.e., with small odds of breaking even against taking a sure loss and saving resources. Hence, we hypothesize that:

H2: When IT managers exercise an abandonment option in a single IT project, there will be framing effects.

While evaluating gains as well as losses, people show loss-averse tendencies in general. It means that they are more sensitive to losses than to gains. Their displeasure associated with losing a sum of money is generally greater than the pleasure associated with winning the same amount. Aversion to losses is used to explain several decision making paradoxes including people's reluctance to accept fair bets on a toss of a coin (Tversky and Kahneman, 1981), the discrepancies between the amount of money people are willing to pay for a good and the compensation they demand to give it up (Tversky and Kahneman, 1986; Bishop and Heberlein 1979; Knetsch and Sinden, 1984), and a violation of consumer theory known as endowment effect, i.e., the selling price for consumption goods is much higher than the buying price, often by a factor of 2 or more. The reason is that the value of a good to an individual appears to be higher when the good is viewed as something that could be lost or given up than when the same good is evaluated as a potential gain (Kahneman, 2003; Tversky and Kahneman, 1991).

We make use of loss-aversion to explain the risk behavior related to real options. As, abandonment options are found to be least valued by the IT managers, we argue that it is due to their aversion to losses. We hypothesize that loss aversion[3] holds in real abandonment option exercise decisions. Reaction to losses associated with option to abandon, are more severe in IT investment decisions than reaction to gains associated with growth options. Hence, the suboptimal decision making at option exercise time for abandonment options is greater than in the case of growth options.

H3: When IT managers exercise a real option in a single project, framing effects will be greater in an IT project with an abandonment option than in an IT project with a growth option.

3.3.2 Framing Effects and IT Project size

Framing effects are more prevalent in situations framed as gains and losses involving small amounts than situations involving large amounts, given the actual quantities involved are similar in both situations. For example, the subjective value difference between a gain of $10 and a gain of $20 is perceived to be greater than the subjective value difference between a gain of $110 and a gain of $120. The same holds true for losses, unless the larger loss is intolerable. Hence, the marginal value of both gains and losses generally decrease with their magnitude (Kahneman and Tversky,

[3] Loss aversion is the tendency of people to strongly prefer avoiding losses to acquiring gains (Kahneman and Tversky, 1979)

1979).The reason for such variability is associated with the underlying weighing function that drives the subjective value of frames in the prospect theory. This S-shaped value function defined over gains and losses is concave for gains and convex for losses, where the effect of marginal change in subjective value decreases with the increase in distance from the reference point in either direction (Tversky and Kahneman, 1986).

IT projects vary in terms of their scope and investment costs. For example, according to the Amberdeen Group Inc. (2006) survey, an average total cost of an ERP system ranges from $0.4 Million to $2.2 Million, depending on the vendor and the size of the firm in terms of the system users. In alignment with the prediction of framing theory and the effects of subjective valuation of gains and losses on the quantities involved in the situation with respect to their distance to the reference point, we predict that the framing effects will be relatively more substantial in smaller IT projects with embedded growth and abandonment options as compared to their counterparts that involve higher costs. Hence, we hypothesize:

H4a: In IT projects with growth options, framing effects will be stronger in small IT projects than large ones.

H4b: In IT projects with abandonment options, framing effects will be stronger in small IT projects than large ones.

In the IS literature, evidence has been provided that an increase in the size of the project has led to more biased decisions. Especially in the case of IT projects with less potential of being productive, escalation of commitment is prevalent. Sunk cost effect (Keil et al., 2000) is successfully attributed to such a behavior, where decision makers tend to be more willing to continue a project when the level of sunk cost is high.

Although this finding is limited to software projects, it provides a counter argument for the effect of size of a project on real option exercise decisions. We also find evidence of difficulty in killing large projects. Examples include Denver's International Airport baggage system (Keil and Montealegre, 2000) and London's Taurus stock exchange project (Drummond, 1996). In those cases, the size of the project along with other factors, such as managers' reputation, the political ramifications of abandoning, and the possible effect of abandonment on staff morale (Keil et al., 2000) have been shown to increase the difficulty in abandoning the project. In case of option to abandon decision, larger projects will have more at stake at the exercise time, as compared to small projects, which might make a decision maker biased towards escalation of commitment.

For growth option exercise decisions, large projects require more investment and, hence, putting more at stake, as compared to small projects with growth options. Economic recession compiled with shrinking technology market has impacted the IT investments greatly across the world (Ante, 2008; Botello, 2009). These macroeconomic factors have a tendency of rendering organizations to be very careful and conservative about their investments including in IT. Investments in large projects with high uncertainty puts quite allot at stake. With organizations having less capability to take risk, and IT managers reputation depending on the performance of the project, might lead them to be conservative in their investment approach. We extend these arguments to both real options, i.e., growth as well as abandonment option decisions and propose the following competing hypotheses:

H4c: In IT projects with growth options, framing effects will be stronger in large IT projects than small ones.

H4d: In IT projects with abandonment options, framing effects will be stronger in large IT projects than small ones.

3.3.3 Narrow Framing Effects – Portfolio of Independent Projects

Exercising real options in the absence of quantitative methods is risky due to the prevalent biases. In the case of IT investments, the situation is further complicated due to the effect of uncertainty around outcomes at option exercise time (Kumar, 2002; Tiwana et al., 2006), high option exercise cost which is based on the cost of current IT project/ project phase (Benaroch 2002, 2006; Kumar, 2002), and uncertain benefits from the underlying IT asset (Benaroch 2002; Kumar, 2002). The decision scenario becomes more complex in the presence of more than one IT projects, i.e., project portfolio setting with embedded options.

In the presence of framing effects in managerial valuation of real options in general (Millar and Shapira, 2004) and real options embedded in IT projects (Tiwana et al., 2006), their impact on portfolio decisions is still unknown. Narrow framing theory suggests that narrow framers make decisions through selective simplification and engage in suboptimal decision making under risky situations (Tversky and Kahneman, 1981; Kahneman and Lovallo, 1993). The simplification process is executed by isolating each decision, then formulating "frames" around each decision with a mutually exclusive reference point, and then becoming conveniently adapted to it (Tversky and Kahneman, 1981). In the investment portfolio setting, investors are found to isolate their decisions while ignoring the vital decision criteria like correlation among portfolio components (Barberis, Huang and Santos, 2001) and the connection between current choice and future opportunities (Kahneman and Lovallo, 1993). Hence, one of the implications of framing of situations is narrow framing in complicated decision scenarios.

To capture the implications of framing effects in IT portfolio decisions, we utilize the narrow framing theory. Our goal is to observe if managerial intuition of IT managers engage in narrow framing at option exercise time in an IT portfolio that is embedding different real options, due to the difference in the framing of real options. We keep our hypotheses limited to two types of real options for portfolio decisions: real growth option and real abandonment option. The underlying intuition is that the framing of real options incites different risk behaviors, which is observable in the option exercise choice. Hence, IT managers' tendency to frame real growth options as gains and real operational options as losses (Millar and Shapira, 2004) may lead them to narrow framing in portfolio decisions.

In an IT portfolio with multiple embedded real options, managers will frame a growth option associated with one project as gain and an option to abandon as loss. Therefore, managers are likely to show risk-averse behavior for the growth option and play it safe by not exercising it and risk seeking behavior for the option to abandon, again by not exercising it when it's feasible to do so. Due to the framing effects on individual real options in the portfolio, they would isolate each real option exercise decision by their frame and decide individually based on underlying risk predictions, while ignoring the overall impact of their decision on the portfolio, hence, engaging in narrow framing. Therefore, we hypothesize that:

H5a: When IT managers exercise real options in an IT portfolio, they will engage in narrow framing.

We extend our framing effects argument from single projects embedding real options to portfolio decisions. Portfolios are a collection of individual projects. If the IT managers engage in framing and show respective risk behaviors based on real option type in single projects, their decision preferences should not change in the portfolio setting. Managers framing single growth options will frame them in a portfolio as well. Similarly managers framing single abandonment options will frame them in a portfolio as well. Engaging in narrow framing indicates decision making in isolation in a portfolio. This outcome may be due to how real options are framed individually, in a non-portfolio setting. Hence, we hypothesize that:

H5b: Framing of real options in single IT projects will lead to narrow framing in IT portfolios.

We hypothesized earlier that loss aversion holds in real option exercise decisions. Reaction to losses, associated with the option to abandon, is more severe in IT investment decisions than for gains situations, associated with growth options. We extend the same reasoning to IT portfolios and hypothesize that the presence of abandonment options in IT portfolios contributes more towards a suboptimal decision in the portfolio, than the presence of growth options, because of the IT managers' aversion to losses.

H6: When IT managers exercise real options in an IT portfolio, framing effects will be greater for projects with an abandonment option than for projects with a growth option.

3.3.4 Narrow Framing Effects – Portfolio of Interdependent Projects

In an IT portfolio, projects are likely to share resources. These resources include financial resources, where a portfolio needs to be maintained out of a same budget pool, and human resources, where the same set of people are responsible to develop, implement and maintain the projects involved in the portfolio. With such resource interdependency among projects in the portfolio managed by IT managers, the challenge is to maximize the portfolio output while making efficient use of the scarce resources at hand. The embedded real options in the projects forming such portfolios give IT managers the flexibility of making decisions in order to achieve that goal.

In IT portfolios, resource interdependencies initiate competition for scarce resources (Throp, 1999). Also, such interdependencies act as constraints on the portfolio, which is a key step in portfolio alignment (Goldman, 1999). These findings point towards the notion that resource interdependencies among IT projects in a portfolio contribute towards its improved management, where efficient management of these resources becomes a key to maximize the output of the portfolio.

IS literature highlights the contribution of effective resource management in IS projects by promoting de-escalation of commitment in failing projects (Keil and Robey, 1999). Awareness of alternative uses of the funds supporting a project is shown to force the decision makers out of decision making in isolation (Keil and Robey, 1999; McCain, 1986; Northcraft and Neale, 1986). Especially for long term resource allocation decisions for projects with setbacks like decreased revenue, increased cost, and lower benefits, decision makers ignore the opportunity costs[4] and frame the situation as a loss, i.e., choice between certain loss and the possibility of larger or no loss. Making the opportunity costs more explicit, by highlighting the alternative uses of remaining resources, have proven to alter the framing of such decisions, hence, leading to decisions that more closely reflect the cost/ benefit prescriptions (Northcraft and Neale, 1986), instead of subjective decisions based on risk behaviors.

On the one hand, in alignment with the narrow framing theory prediction, where interconnection among investments is ignored by decision makers, IT managers' tendency of framing real options differently has a potential to lead them towards taking decisions in isolation in a portfolio setting. But on the other hand, the resource interdependency among projects has a potential for the IT project managers to improve their portfolio output by taking into account the complete portfolio outcome before making option exercise decisions for each real option, hence, reducing the potential narrow framing effects. We extend our prediction in favor of the IT portfolio findings and hypothesize that:

H7: Resource interdependency among projects in an IT portfolio will reduce the narrow framing effects.

3.3.5 Narrow Framing Effects - IT Project Size

We hypothesized earlier that framing effects are predicted to be more prominent in small sized IT projects with embedded real options as compared to their larger counterparts. Continuing on the same reasoning, it is arguable that such IT project size effects will be seen in IT portfolios as well. In alignment with the prospect theory we

[4] Opportunity costs here mean costs associated with forgone opportunities to utilize resources in more productive endeavors/ projects.

predict that the IT managers will be showing more narrow framing bias in IT portfolios involving smaller projects in terms of investment than the ones involving large projects in terms of investment size. For example, the gain of $ 10,000 will be more valuable in a project of size $100,000 as compared to the project of size $ 1 Million. Similarly the loss of $10,000 will be more valued by IT managers in a project of size $ 100,000 as compared to the project of size $ 1 Million. Such decreasing marginal value of gains and losses with respect to the project size could impact the narrow framing effects in an IT portfolio setting, by reducing the framing bias on IT projects constituting the portfolio. When the subjective value on pure gains and losses is reduced, there is a likely chance of IT managers to think inclusively about the portfolio before making the real options exercise decision. Hence, we hypothesize that:

H8a: Increasing project sizes in an IT portfolio will reduce the narrow framing effects.

We hypothesized earlier that an increase in the size of the project may lead to more biased decisions, for growth and abandonment options. We extend the same reasoning for IT portfolios consisting of growth and abandonment options. We propose the following competing hypothesis:

H8b: Increasing project sizes in an IT portfolio will increase the narrow framing effects.

3.3.6 Narrow Framing Effects – Simplifying the Real Options Outcomes

Narrow framing has costs associated with it, i.e., isolation cost due to exclusive decision making. In the case of IT real options, the isolation cost would be the suboptimal portfolio outcome based on the option exercise decisions. It means that IT managers' risk-averse behavior for situations framed as gains and risk-seeking behavior for situations framed as losses would lead them to ignore the overall impact of their exercise decisions on the portfolio. But, when the presentation of the same decisions is changed from the binary choice for each real option in a portfolio to a single choice among potential portfolio outcomes, where the economic value of the combined decision is obvious, they would select the choice where the portfolio's economic value is optimal. This prediction is in alignment with Tversky and Kahneman (1981) finding that, once the prospects are combined and dominance of the prospects is obvious, decision makers recognize the dominant prospect and select that. Therefore, we expect that:

H9: Simplifying the real option exercise decisions in an IT portfolio will reduce the narrow framing effects.

3.3.7 Narrow Framing Effects - Individual Risk Behavior

Narrow framing studies have found a connection between decision makers' professional characteristics (e.g., professional sophistication and experience) with their ability to narrow frame (Liu et al., 2010), but the framing studies as well as narrow framing studies results are typically presented independent of the individual risk behavior of the decision maker. One reason for such a trend is the underlying assumption of prospect theory that all decision makers are systematically biased in the same way and to the same extent when it comes to framing of situations (Kahneman et al., 1982). This assumption implies independence between the individual risk behavior of the decision maker and their ability of framing situations that lead to narrow framing.

It means that independent of individual risk behavior, people are biased for narrow framing.

The real options literature and the IT project management literature do not look at individual risk behavior. To get a deeper insight into the narrow framing phenomenon, we consider capturing individual risk behavior of IT managers that are important in this study. The reputation of IT managers at stake positions the IT portfolio management as an important decision scenario. On the one hand, the importance of the decision scenario should guide the IT project managers to rational decision making while managing the portfolio. On the other hand, real options are found to be framed by IT managers as gains and losses, based on the type of real option (Millar and Shapira, 2004; Tiwana et al., 2006) (risky choice framing). Narrow framers evaluate prospects subjectively leading to the underlying risk behaviors, based on how the prospects are framed. Hence, if there is evidence of a suboptimal option exercise decision found confirming the narrow framing effects in IT portfolio decision making, this should be irrespective of individual risk behavior of the decision maker. Our previous hypotheses are based on prospect theory's assumption that IT managers hold prospect theory preferences that will lead to narrow framing in an IT portfolio setting. We hypothesize that:

H10: Narrow framing effects in an IT portfolio are independent of the individual risk behavior of the IT managers.

3.4 Methodology and Data

To test the effects of framing and narrow framing, we used Choice-based Conjoint analysis (CBC), also known as Experimental Choice Analysis (ECA). The following sub sections discuss the rationale for the experiment method and details.

3.4.1 Experimental Choice Analysis

ECA is a conjoint analysis technique, based on the Information Integration theory (IIT) by Norman H. Anderson (1981). IIT focuses on the behavior of numerical data generated to capture the complex decision making process via its decomposition (Louviere, 1988). IIT has been dominantly used in the field of marketing research, but is also been proposed and used to study risky decision making (Louviere, 1988) due to the similarities it shares with axiomatic utility theory in economics, management science and statistics (Keeney and Raiffa, 1976).

Experimental choice analysis (ECA) is a stated choice model that relies on the discrete choice between alternatives by the respondents (Louviere et al., 2000), e.g., in our case, the decision to exercise or not to exercise a real option in a decision scenario. ECA integrates and applies theory and methods from conjoint analysis, probabilistic discrete choice theory and the design of discrete multivariate statistical experiments (Batsell and Louviere, 1991). We will justify our inclination towards conjoint analysis first, followed by our motivation for the selection of the choice analysis.

3.4.2 Why Conjoint Analysis?

There are three central elements in a conjoint research design: attributes, conjoint profiles, and utilities (part-worth and overall utilities). An *attribute* refers to a decision criterion that respondents might use to evaluate the dependent variable. The overall value assigned to the dependent variable is referred to as its *overall utility*. The contribution of each attribute towards the formation of the overall utility of a project is called its *part-worth utility*. Lastly, different combinations of attribute levels are called treatments or *conjoint profiles*. The conjoint technique requires respondents to make a series of judgments about a dependent variable based on a set of attributes from which the underlying structure of their cognitive system can be statistically inferred. For example, in our case, a series of conjoint project profiles with different combinations of attribute levels, i.e., risk, payoffs and underlying real options, can be presented to each respondent, and their responses can provide an assessment of the dependent variable i.e., real option exercise decision, for each project and portfolio profile. Some of the benefits that this conjoint experiment approach can provide over survey or role-playing experiments are as follows:

- Our hypotheses are grounded in behavioral decision theories and pursue a theory-testing goal. Conjoint-based research designs are especially suitable for such theory-testing endeavors (Graham and Cable, 2001).
- The conjoint method has been developed primarily to decompose respondents' utilities for multi-attribute decision making. In our case, the decision to exercise a real option involves a multi attribute criteria of the real option type, project's future payoffs, and uncertainty around the payoffs associated with each decision, project size, and the decision scenario (single project vs. portfolio). The conjoint design, therefore, will allow decomposing the contributions of these project attributes in arriving at a holistic project decision related to real option exercise decision assessment (Louviere, 1988).

- Studies examining behavior relating to professional situations, especially the ones where managers are likely to be sensitive or can get defensive might induce risk of some form of social desirability bias (Tiwana et al., 2006). Using a traditional survey-based approach would require to have managers retrospectively recall a recent event to assess the outcome, which might include an unfavorable event, thus affecting their responses. As the conjoint project profiles are hypothetical and do not require the respondents to recall their previous project, the design is immune to the threats of social desirability bias and retrospection bias.

3.4.3 Why Experimental Choice Analysis?

In traditional conjoint analysis, subjects are required to respond to multiple combinations of attribute levels, often generated by some statistical design procedure (like factorial design). Similar to conjoint analysis, ECA employs combinational design to generate multi-attribute stimuli. Conjoint analysis relies on one at a time preference ratings or rankings of one set of multi-attribute stimuli to estimate individual level utilities. In contrast, ECA estimates utilities from aggregates of individual choices or resource allocations among sets of multi-attribute choice objects from samples of individuals or segments. Therefore, unlike rating-based conjoint analysis, choice experiments use experimental design to place choice objects into choice sets.

Our intention is to capture the risk behavior of the respondents, related to real option exercise decisions, in a project and then in a portfolio setting based on how they are subjectively framed. This is only reflected in the choices they make for real options scenarios. Therefore, we chose choice-based conjoint instead of rating-based conjoint analysis. In choice-based conjoint analysis, choice probabilities can be predicted directly (Moore, 2004), which will reflect the underlying risk behavior of the respondents under particular real options scenario.

3.4.4 Experiment Design and Measures

We created single project and portfolio profiles for our experiment. They are described as follows.

3.4.4.1 Individual Project Profiles

Four IT project profiles were created to test for the framing effects. In each profile, information about a single IT project was given in terms of the embedded option in it and the risk and return of the project associated with available real option exercise decisions. To keep things simple, all the projects had only one embedded real option each, i.e., either a growth option or an option to abandon. Each embedded real option had two outcomes, i.e., a risky outcome with uncertainty around it and a riskless outcome with no uncertainty around it. Further, the projects were grouped as small projects or large projects, based on investment costs and payoffs involved. Hence, the projects varied in terms of the embedded option, and the size of the project. Table 3.4 gives a breakdown on the project profiles set up that tested the framing effects.

Table 3.4: Individual IT Project Profiles Breakdown

Project	Embedded Options	Size of Projects
1	Growth	Small
2	Abandon	Small
3	Growth	Large
4	Abandon	Large

For the growth option, usually the risky decision is to invest in the project further by exercising the option, which might lead to higher returns in the form of larger NPV, especially when there is uncertainty around the outcome at the time of option exercise. We control for this uncertainty in the form of probability of outcome in the experiment profile. On the contrary, the riskless decision related to the growth option is to let the option expire, which usually leads to certain but lower gains. We assume pure gains either way for growth options for simplicity. This situation is close to what is seen in reality, where growth options seem to be lucrative and are valued higher as compared to the rest of the real options (Miller and Shapira, 2004; Tiwana et al., 2006) due to the potential of larger future benefits, yet there is uncertainty involved in the future realized benefits at the time of real option exercise time, i.e., follow-up investment (Coff and Laverty, 2007). It can be argued that the uncertainty around outcomes can be reduced by deferring the investment. Our intention is to capture the investment behavior in the absence of the flexibility to delay the investment and to know the risk behavior of the IT managers under such situations. In reality, the flexibility to delay the investment is usually not availed by firms operating in a competitive market, where growth is vital for their survival (Lankton and Luft, 2008).

For the abandonment option, the risk is typically associated with continuing to invest in the project even when the project is not doing well with a hope that it will turn around. The uncertainty around the course of the project in the future as well as ambiguous benefits attached to it adds to its risk (Keil et al., 2007). There is always a possibility for the project to rebound, but the risk increases as the time passes. On the contrary, the relatively riskless option is to exercise the option to abandon, realize the cost and save the rest of the investment amount for other projects. This is typically true for situations where the resources used by the project are from a common pool and can be utilized easily elsewhere. We mimic this situation in our decision scenarios by positioning the exercise decision of abandonment option as a riskless decision with certain partial loss along with the risky decision to continue investing in the project with a slight possibility for it to breakeven. Even if the project has a potential to generate positive returns but with less likelihood, the decision scenario would still be the same, i.e., deciding between smaller but sure loss vs. probable but larger loss. We consider breakeven as the best probable outcome for simplicity.

Although, theoretically every investment project can have an option to abandon, in reality, there can be several restrictions forbidding this option to be exercised. Such restrictions include contractual agreements binding the project to be completed, regulatory ramifications associated with incomplete projects etc. We assume none of these restrictions are associated with the project.

3.4.4.2 Project Portfolio Profiles

To test the narrow framing effects and factors that can reduce them, three IT project portfolios were created. Each portfolio consisted of two IT projects, similar to the ones used to test framing effects. The portfolios varied in terms of the interdependency among the projects within the portfolio projects and the size of the projects involved in the portfolio in terms of investment costs. Table 3.5 gives a breakdown on the portfolio set up. The interdependency among the projects within a portfolio was created by explicitly stating about the resources available for the project portfolio and the presence of flexibility of using the resources interchangeably among projects.

Table 3.5: IT Project Portfolios Breakdown

Portfolio	Number of Projects	Embedded Options	Interdependency among projects	Size of Projects
1	Two	Growth, Abandon	No	Small
2			Yes	Small
3			No	Large

After presenting the participants with the portfolio profiles, a follow up decision scenario was presented to test the effects of combining and simplifying portfolio decisions. In this scenario, each choice was an aggregate outcome of option exercise decisions presented in the first portfolio, i.e., the NPV values adjusted for uncertainty in each project underlying the portfolio. Out of the four choices, one of the choices was the theoretically most probable choice as predicted by prospect theory, and another choice was the optimal choice. The determinant of narrow framing effects in small scale portfolio of independent projects was presence of the preference reversal among the choices made in these two similar scenarios that were presented differently (Tversky and Kahneman, 1981). The complete survey is presented in Appendix A.

3.4.5 Independent Variables

3.4.5.1 Option Type

We used two kinds of real options in our experiment profiles. In the growth option scenarios, the decision maker had a choice to invest further in a project that can add to the future IT capabilities of the firm or not to invest. In an option to abandon scenarios, the decision maker had a choice to abandon the project mid-way, or keep investing in it by not exercising the option.

3.4.5.2 Uncertainty and Payoffs

All decision scenarios consisted of future payoffs and uncertainty around them. In each project and portfolio profile, all the real options were positioned as high risk. The probable gains are much higher for a growth option as compared to certain gains, but with less likelihood. For an abandonment option, the probability of the project to become valuable again for the firm was low. We chose the payoff probabilities of 25% - 75% based on the original experiments of framing and narrow framing (Tversky and Kahneman, 1981). Also, cumulative prospect theory shows the threshold for risk behavior change is approximately 50%, where risk seeking behavior in gains and risk-averse behavior in losses are observed for outcomes with probability less than 50% and the reverse was observed for outcomes with probability more than 50% (Tversky and Kahneman, 1992). Options are valuable under high uncertainty as well, so we chose to keep the same uncertainty in all scenarios.

We created the experimental scenarios using realistic figures for payoffs, to make it look like an important investment decision. We used the actual costs of ERP systems given in the past few years. We think ERP systems are a good example of IT projects and project portfolios. Most enterprises utilize them and they are considered important investments due to the wide range of costs involved in them as well as the variety of applications that are enabled due to the implementation of ERP systems. The average costs we found for ERP systems ranged from approximately \$0.4 Million to \$2.3 Million, depending on the vendor and the size of the firm implementing the system

(Aberdeen Group Inc., 2006). In order to keep the scenarios simple, we kept payoffs in all the profiles close to these figures. The payoffs only vary for each real option scenario based on project size. The details on the project sizes are given below.

3.4.5.3 Project Size

To control the scenarios for the projects' size, we chose \$ 0.5 million for small projects and \$ 2.0 Million for large projects. All the scenarios were positioned as projects completed mid-way, where they are 50% complete and 50% of the resources are invested. This way, the earned value, i.e., budgeted cost of project multiplied by its completion percentage (Anbari, 2003), for small projects comes at \$0.25 Million and \$ 1.0 Million for the large projects. This earned value enabled us to create a suitable decision point in terms of planned value of the projects (i.e., value to be earned as a function of project work accomplishment up to a given point in time (Anbari, 2003). The IT managers had to decide about the future course of the IT projects, purely based on the embedded flexibility in them. Table 3.6 gives a breakdown on the payoffs used for large and small projects in the experiment, along with the respective uncertainty.

In accordance with Prospect theory (Kahneman and Tversky, 1979), the net payoff difference between risky and riskless options was kept the same in small and large projects, i.e., equal to \$ 200,000, to capture the difference between framing and narrow framing among small and large projects.

Table 3.6: Uncertainty and Payoffs used in Experimental Scenarios

Small Projects (0.5M)	**Growth**			**Abandon**		
	Exercise		**Expire**	**Exercise**	**Expire**	
	25%	$1,800,000	$250,000	$(250,000)	75%	$(600,000)
Expected Value	$450,000		$ 250,000	$(250,000)	$(450,000)	
Difference	$200,000			$(200,000)		
Large Projects (2.0M)	**Growth**			**Abandon**		
	Exercise		**Expire**	**Exercise**	**Expire**	
	25%	$4,800,000	$1,000,000	$(1,000,000)	75%	$(1,600,000)
Expected Value	$1,200,000		$1,000,000	$(1,000,000)	$(1,200,000)	
Difference	$ 200,000			$(200,000)		

3.4.5.4 Interdependency among Projects

Resource interdependency among the projects in one of the portfolios was created by specifying in the scenario that both the projects in this portfolio are utilizing the same resource pool in terms of funds and human recourses.

3.4.5.5Individual Risk Behavior

We used the Webber et al. (2002) risk attitude scale to measure individual risk. This scale was developed and tested based on the risk-taking behaviors literature to cover the full range of risk-taking situations encountered by young adults in Western cultures.

When it comes to individual risk behavior, individuals tend to show different risk attitudes in various domains (Webber et al., 2002). As our goal is to measure only the individual risk attitudes of the respondents, we included only the items measuring the financial risk behavior from the “Risk-Behavior instrument” in Webber et al. (2002)

in our survey. We measured only the individual financial risk for the participants, using the 8-item scale. The financial risk taking is measured using two subscales, focusing on investment and gambling problems. Each sub scale consists of 4 items, measuring the risk taking behavior in that domain. We included both of them in our survey because our scenarios require investment decisions by the participants and, due to the uncertainty around payoffs at the decision time, which resembles a gamble. The individual risk behavior items are included towards the end of the survey. Participants are asked to identify the 'likelihood" of them engaging in the activities described in the survey. The likelihood is measured on a Likert scale of 1-5 (Webber et al., 2002). The risk behavior items were presented in a random order following the original study, as no order effects were found in it.

3.4.6 Dependent Variables

3.4.6.1 Option Exercise Decision

Decision making under risk has been viewed as choices between prospects or gambles (Kahneman and Tversky, 1979). The closest approximation of capturing such a decision in an experiment is to treat it like a gamble (Kahneman and Lovallo, 1993), especially in organizations. In our experiment, we presented the real option exercise decision in each profile as a gamble. Real option exercise decisions are taken in the face of uncertainty where future payoffs depend on the exercise decision and unveil over the period of time. Given that uncertainty and dependency of payoffs on the decision are two major components of a gamble, we think it is the simplest yet most realistic way to represent a real option exercise decision.

Further, testing of framing effects requires the experiments to be built around a reference point, to which decision maker becomes conveniently adapted, leading them to start relying on narrow frames relative to that reference point (Kahneman and Tversky, 1982; Kahneman, 2003). For IT managers, the common criteria that is used to evaluate investment decisions is considered to be the project's NPV (Fitchman et al., 2005; Keil et al., 2007). Hence, we have used it as a reference point in our experiment. The reference point also serves as a boundary that distinguishes gains from losses (Tversky and Kahneman, 1992). Based on the reference point, the growth options in both portfolio profiles are presented as a prospect with possibility of minimum zero NPV and the abandonment options are presented as a prospect with possibility of maximum zero NPV.

3.4.7 Control Variables

To isolate the effects of framing and narrow framing in the study, several control variables were included in the survey, based on the literature. We controlled the experiment for gender based on differences found in risk behaviors in literature (Fellner and Maciejovsky, 2007). We also control for age, work experience of the respondents in years (Liu et al., 2010), industry sector of respondents' organization, respondents' country, and size of the respondents' organizations in terms of annual revenue. For industry sectors, we used simple distinction of manufacturing and services. We also controlled the experiment for the experience of the respondents with (i) IT investment decisions, (ii) IT investment decisions involving real options, and (iii) IT investment decisions involving IT project portfolios.

3.4.8 Data

We pilot tested the survey among MBA students at UNC Charlotte. A total of 37 usable responses were generated to test the quality of the survey and the clarity of the project/ portfolio scenarios. Minor modifications were made based on the feedback from the survey. The final survey was sent out to IT management professionals in the US and abroad. We used Dun and Bradstreet Executive's list 2010 (Tiwana et al., 2006; 2007) consisting of top and middle level management in US organizations involved in information and technology management, as well as Project Management Institute (PMI) US chapters and communities of practice. A total of 3500 surveys were sent out. We received 387 responses back, making our response rate 11.05%. The response rate declined due to lower response rate from Dun and Bradstreet Executive's list. Once possible explanation is that the list we got was not up to date. Out of these responses, 355 were complete. We had 223 responses from US respondents and 132 from International respondents. We used US responses to test the hypotheses in this study because the international sample consisted of multiple countries, leading to heterogeneity among the international respondents in terms of origin and culture. Also, our individual risk measures were primarily developed on US sample. The US sample size met the requirement based on our a-priori sample size estimation for the study given the effect size, error probability, and power for the parametric data analysis (Table 3.7). The data collected was based on different scales. Table 3.8 gives a summary of variables and their respective scales, used in the analysis.

Table 3.7: a- priori power Analysis to determine sample size

Test family : z-tests, Statistical test: two independent Pearson's r					
Input Parameters	Tails	One	One	One	One
	Effect size[5]	0.5	0.5	0.5	0.5
	Error probability α	0.05	0.05	0.05	0.05
	Power (1-β)[6]	0.8	0.85	0.9	0.95
Output Parameters	Critical z	1.64	1.64	1.64	1.64
	Total sample size	106	122	144	180
	Actual Power	0.8	0.85	0.9	0.95

Table 3.8: Variables and their Respective Scales

Variable	Scale	Values
All single and portfolio Projects	Binomial	1= Correct Decision 0=Incorrect Decision
Portfolio outcome	Binomial	1= Correct Portfolio Decision 0=Incorrect Portfolio Decision
Loss aversion	Binomial	1= Loss aversion in portfolio decision 0=Absence of loss aversion in portfolio decision
Combined Decision	Binomial	1= Correct Decision 0=Incorrect Decision
Individual risk measures	Likert Scale	Scale of 1-5
Age	Categorical	5=Above 50; 4=46-50; 3=41-45; 2= 36-40; 1=20 - 35
Gender	Binomial	Male – 1; Female - 0
Work Experience	Categorical	5=Above 20 years 4=16-20 3=11-15 2= 6-10 1=5 years or less
Industry Sector	Binomial	0= Manufacturing 1= Services

[5] Was calculated using expected significant t-values and *df*.
[6] Set to minimum expectable range (Cohen, 1988)

Firm Size	Categorical	4=More than $1 Billion 3= $500 Million - $1Billion 2=$ 1 Million - $ 500 Million 1= Less than $1 Million
Country	Binomial	US - 1 Non US - 0
IT Investment, Real Options and Portfolio Management Experience	Likert Scale	Scale of 1-5

Prior to run the analyses, all variables for single projects, portfolios and controls were examined for accuracy of data entry, outliers, and missing values using SPSS v17. All the values for all variables were within acceptable ranges suggesting that there were no data entry errors. There were some univariate outliers detected (Table 3.9). The descriptive statistics were computed with and without outliers and they stayed the same. Hence, the observations were retained in the data set.

Table 3.9: Univariate Outliers

Variable	**Outliers**
Work Experience	**15 (=<2)**
Real Options Experience	**19 (<= 1)**

The descriptive statistics of the data is given in Table 3.10. Due to the binary responses for project and portfolio profiles, normality of distribution, and multicollinearity were not checked. We checked for multicollinearity and normality of distribution for the control variables. Upon checking the VIF of control variables, control variable "age" was found to have a VIF equal to 2.82, showing multicollinearity. Also, bivariate correlation between "age" and "work experience" was approximately 0.8 (Table 3.11), Due to multicollinearity, we dropped "age" from the analysis. In terms of normality of data distribution, some variables were slightly skewed (Table 3.10). The skewness of data was not enough to merit data transformation. None of the Mahalanobis distance p-values (based on chi-square distribution) were found to be less than 0.001. Hence, there were no multivariate outliers.

Table 3.10: Descriptive Statistics, n=223

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	S.E.	Statistic	S.E.
Project 1(P1)	0	1	.49	.501	.045	.163	-2.016	.324
Project 2 (P2)	0	1	.81	.395	-1.568	.163	.462	.324
Project 3(P3)	0	1	.40	.491	.415	.163	-1.845	.324
Project 4(P4)	0	1	.59	.493	-.377	.163	-1.875	.324
Portfolio1-P1	0	1	.69	.465	-.807	.163	-1.360	.324
Portfolio1-P2	0	1	.69	.465	-.807	.163	-1.360	.324
Portfolio 1	0	1	.48	.501	.099	.163	-2.008	.324
Portfolio2-P1	0	1	.69	.465	-.807	.163	-1.360	.324
Portfolio2-P2	0	1	.70	.461	-.853	.163	-1.284	.324
Portfolio 2	0	1	.49	.501	.045	.163	-2.016	.324
Portfolio 3-P1	0	1	.48	.501	.063	.163	-2.014	.324
Portfolio 3-P2	0	1	.55	.499	-.190	.163	-1.982	.324
Portfolio 3	0	1	.25	.435	1.156	.163	-.671	.324
Simplified Decision	0	1	.92	.273	-3.099	.163	7.674	.324
Age	1	5	3.74	1.399	-.741	.163	-.835	.324
Gender	0	1	.77	.421	-1.301	.163	-.311	.324
Work experience	2	5	4.43	.955	-1.414	.163	.613	.324
Industry	0	1	.42	.494	.339	.163	-1.902	.324
Firm size	1	4	2.69	1.081	-.005	.163	-1.390	.324
IT Investment experience	1	5	3.52	1.266	-.493	.163	-.818	.324
Real Options Experience	1	5	3.45	1.218	-.441	.163	-.690	.324
Portfolio Management Experience	1	5	3.17	1.288	-.139	.163	-1.094	.324

Table 3.11: Pearson Correlation

	Project 1	Project 2	Project 3	Project 4	Portfolio 1	Portfolio 2	Portfolio 3	Simplified Decision	Age	Gender	Work Experience	Services	Firm Size	IT Investment Experience	Real Options Experience	Portfolio Experience
Project 1	1															
Project 2	-.022	1														
Project 3	.357**	-.019	1													
Project 4	-.028	.288**	.062	1												
Portfolio 1	.309**	.169*	.251**	.059	1											
Portfolio 2	.300**	.114	.302**	.173**	.488**	1										
Portfolio 3	.261**	.073	.457**	.270**	.381**	.427**	1									
Simplified Decision	-.007	.106	-.061	.055	-.015	.059	-.018	1								
Age	-.123	.090	-.153*	.011	.091	.012	.128	.229**	1							
Gender	-.066	.086	-.210**	.069	.069	.041	.094	-.005	.183**	1						
Work Experience	-.136*	.111	-.153*	.065	-.086	-.098	.110	.271**	.790**	.143*	1					
Services	.010	-.025	.035	-.038	.014	.137*	-.007	.084	.103	-.037	.090	1				
Firm Size	-.069	.049	-.055	.075	.065	.006	.061	-.009	.102	.121	.071	-.036	1			
IT Investment Experience	.027	.092	-.115	.086	.024	-.037	.083	.043	.238**	.239**	.253**	.152*	-.008	1		
Real Options Experience	-.077	.079	-.093	.002	.015	-.069	-.046	.070	.306**	.159*	.248**	.156*	-.061	.622**	1	
Portfolio Experience	.014	.093	-.025	.120	.066	.048	.098	.028	.257**	.207**	.265**	.090	.104	.751**	.598**	1

3.5 Results

3.5.1 Framing Effects

We used non-parametric frequency analysis to test H1- H4d. The data was first coded in binary, i.e., 1 for rational response and 0 for biased response. Testing for framing in projects with growth and abandonment options (H1 and H2), the participants were divided into four categories: (a) making a rational decision for the growth option, (b) making a risk-averse decision for the growth option, (c) making a rational decision for the abandonment option, and (d) making a risk-seeking decision for the abandonment option. Frequency analysis was used to evaluate the risk tendencies of the respondents under each decision scenario, followed by one sample t-tests (Table 3.12).

Table 3.12: Individual project scenario responses (n=223)

	No. of rational decisions (Percentage)	**No. of biased decisions (Percentage)**	**t-stat (p- value)**
Project 1 (small project -growth option)	109 (48.9%)	114 (51.1%)	14.569 (<.001)
Project 2 (small project – abandonment option)	180 (80.7%)	43 (19.3%)	30.484 (<.001)
Project 3 (large project- growth option)	89 (39.9%)	134 (60.1%)	12.143 (<.001)
Project 4 (large project- abandonment option)	132 (59.2%)	91 (40.8%)	17.945 (<.001)

The test results were significant for all four projects, showing a significant difference between the rational and biased decisions for each project scenario. This illustrates that framing occurred at the real option exercise time for growth options (project 1 and 3) as well as for the abandonment options (project 2 and 4). Hence, the framing effects at the option exercise decision time for a project can cause the decision maker to take biased decisions according to how it is framed in their minds. Although growth options are found to be valued highly by IT managers (Tiwana et al., 2006), according to our results, they are not exercised optimally due to framing effects. IT managers showed risk-averse behavior at the growth option exercise time and let it expire, instead of realizing the value of the growth options by going for the risky but economically optimal choice. Based on these results, *the framing effects hold for growth options in small as well as large projects*. Hence, hypothesis 1 is supported[7].

For abandonment options, we found most respondents making a rational decision for the *small project with abandonment option* (project 2) and terminating the project. But for larger projects with an abandonment option (project 4), they showed risk-seeking behavior and went for the riskiest and economically suboptimal decision by not terminating the project, instead of going for the small but certain losses as in case of project 2. Based on these results, hypothesis 2 is supported[8], but the project size seemed to play a role. We tested the project size effects next, to see if escalation of commitment set in for large projects.

To test project size effects (hypotheses 4a and 4d), we compared the responses between small and large projects with growth options (project 1 and 3) as well as between small and large projects with abandonment option (project 2 and 4) using the non-parametric Friedman's rank test for k (χ^2)as well as Cochran's Q test for correlated samples. The tests showed significant difference between project 1 and 3 (χ^2 (1) = χ^2_1 =

[7] Hypothesis 1 states: When IT managers exercise a growth option in a single IT project, there will be framing effects.
[8] Hypothesis 2 states: When IT managers exercise an abandonment option in a single IT project, there will be framing effects.

5.556, *p*=.018), as well as between project 2 and 4 ($\chi^2(1) = \chi_1^2 = 31.135$, *p*<.001). Hence, the project size impacted the framing effects for growth options as well as for abandonment options. Combining these results with the frequency analysis of small and large projects in Table 3.12, we found that for growth option scenarios, the percentage of correct responses decreased significantly from 48.9% to 39.9% in large projects. Similarly for option to abandon scenarios, the percentage of correct responses decreased from 80.7% to 59.2% in large projects. These differences were significant as per Friedman's rank test. *Hence, increase in project size increased framing effects in case of growth as well as abandonment options*. Also, the effect was relatively stronger for option to abandon cases (with 21.5% drop in correct responses) than growth option cases (with 10% drop in correct responses). These results are counter intuitive to the prospect theory, where project size should have reduced the narrow framing effects in portfolio 3. Based on these results, both hypotheses 4a and 4b are not supported but hypotheses 4c and 4d are supported[9].

To test for loss aversion (H3), the responses between the *small project with growth option* and *small project with abandonment option* (project 1 and 2) as well as between the *large project with growth option* and *large project with abandonment option* (project 3 and 4) were compared using non-parametric Friedman's rank test for k

[9] Hypothesis 4a states: In IT projects with embedded growth options, framing effects will be stronger in large IT projects than small ones.

Hypothesis 4b states: In IT projects with embedded abandonment options, framing effects will be stronger in large IT projects than small ones.

Hypothesis 4c states: In IT projects with embedded growth options, framing effects will be stronger in small IT projects than large ones.

Hypothesis 4d states: In IT projects with embedded growth options, framing effects will be stronger in small IT projects than large ones.

(χ^2)and Cochran's Q test for correlated samples (χ_1^2). The tests showed significant difference between project 1 and 2 responses (χ^2 (1) = χ_1^2 = 48.835, p<.001), as well as between project 3 and 4 responses (χ^2 (1) = χ_1^2 = 16.963, p=.001).These results show that the real option type impacted the intensity of framing effects in single projects. Combining these results with the frequency analysis (Table 3.12) showed that *the framing effect in small projects was more prominent in the growth option scenario (project 1 with 51.5% suboptimal decisions) than in abandonment options (project 2 with 19.3% suboptimal decisions)*. The trend was similar in large projects (project 3 with 60.1% suboptimal decisions vs. project 4 with 40.8% suboptimal decisions). This trend indicates that IT managers are more prone to making suboptimal decisions for growth options by showing risk-averse behavior, as compared to the option to abandon by showing risk seeking behavior. Based on these results, IT managers did not show significant loss aversion over all in single projects, and hypothesis 3 is not supported[10]. This also implies that overall IT managers are conservative and showed tendencies to "save" rather than "optimize economic returns". These results are contrary to the findings of "escalation of commitment" in IT projects (Keil and Monte, 2000). Given that the projects in the scenarios were halfway complete, more than expected IT managers took a rational decision and exercised the option to abandon, as compared to the growth option scenarios. One reason might be the global economic recession effects, which might have had an impact on IT investment decision makers by making them more conscious on savings than maximizing economic returns.

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[10] Hypothesis 3 states: When IT managers exercise a real option in a single project, framing effects will be greater in an IT project with abandonment option than in an IT project with growth option.

3.5.1.1 Supplementary Analysis

To test the effects of control variables on real option exercise decisions, we conducted seemingly unrelated regression (SUR) analysis (Zellner, 1965; Amemiya, 1985), with the project decision in each project's case as a dependent variable and Gender, Work Experience, Industry Sector, Firm Size, IT Investment Experience, Real Options Experience, and Portfolio Experience as independent variables. We use SUR, because the error terms might be correlated across equations, due to the similarities among the decision scenarios. The equations are as follows:

$$Project\ Decision_i = \beta_0 + \beta_1\ Gender + \beta_2\ Work\ Experience + \beta_3 Industry\ Sector + \beta_4 Firm\ Size + \beta_5\ IT\ Investments\ Experience + \beta_6 Real\ Options\ Experience + \beta_7 Portfolio\ Experience;\ \text{for}\ i = 1,2,3,4$$

The regression unstandardized coefficients and z values, and model fit measures are presented in the Table 3.13. Among all four equations, the model for project 3 ($\chi 2$= 19.69, p<0.01) is significant. This means that there are no differences in single project responses in all the projects based on individual and firm level characteristics, except in the case of *large project with growth option*. For *small project with growth option* (project 1), work experience (*z*= -1.55, *p*=0.05) and experience with real options (*z*= -1.77, *p*=0.07) were significant. IT managers with more work experience as well as experience with real options showed risk-averse behavior and took biased option exercise decisions as compared to the IT managers with lesser work experience. More specifically, with increased work experience, and experience with real options, IT manager's biased decisions increased by 0.134 and 0.156 respectively. We suspect that with more experience, IT managers became more risk-averse for positive outcomes.

They want to make sure positive returns are ensured instead of making optimal decisions. There can be several reasons behind this behavior including budget cuts in organizations, difficulty in generating positive returns in IT support projects like infrastructure etc.

Table 3.13: SUR Results

Explanatory Variables	(1) Project 1	(2) Project 2	(3) Project 3	(4) Project 4
Gender	-0.065 (-0.080)	0.048 (.75)	-.206*** (-2.65)	0.042 (.53)
Work Experience	-0.070* (-1.95)	.035 (1.22)	-.064* (-1.86)	0.021 (.59)
Services Sector	0.018 (.27)	-.031 (-.59)	0.054 (0.83)	-0.039 (-.59)
Firm Size	-0.031 (-1.01)	0.013 (.52)	-0.022 (-.75)	0.020 (.66)
IT Investments Experience	.043 (1.03)	0.010 (.031)	-0.063 (-1.57)	0.015 (0.37)
Real Options Experience	-0.064* (-1.77)	0.008 (.03)	-0.027 (-.78)	-0.045 (-1.28)
Portfolio Experience	0.029 (.73)	0.005 (.18)	0.079** (2.03)	0.052 (1.31)
Constant	0.902*** (4.84)	0.507*** (3.43)	0.948*** (5.32)	0.361** (1.97)
Model Fit				
R^2	0.043	0.024	0.081	0.030
χ^2 statistics	9.94	5.37	19.69***	6.87
No. of obs.	223	223	223	223

*** Significant at 1% significance level
** Significant at 5% significance level
* Significant at 10% significance level

For the *large project with growth option* (project 3), gender (z= -2.65, p<0.01), work experience (z= -1.86, p= 0.06), portfolio experience (z= 2.03, p= 0.04) were significant. Like in the case of the *small project with growth option*, IT managers with more work experience showed risk-averse behavior and took biased option exercise decisions, for the *large project with growth option* as compared to the IT managers with lesser work experience. More specifically, with increased work experience, IT managers are 0.123 times more likely to take biased decisions. We believe this behavior is due to the same reasons as described before.

The results also indicate that *gender becomes significant in the large project with growth option*, where male respondents showed greater risk-averse behavior and made more biased decisions, than female respondents. More specifically, females on average, after controlling for all other variables are 0.174 times more likely to make rational decisions. This shows when stakes are higher in a project with growth potential, male IT managers are more conservative and take biased decisions. Previously, we did find that increasing project size increased the framing effects for growth option significantly. This project size effect on growth option might be due to the gender difference.

We also found that *experience with portfolios facilitated rational decisions* (z= 2.03, p= 0.04). With increased experience with portfolio management, IT managers are 0.204 times less likely to take biased decisions. This result is intuitive where experience with portfolios improves decision making in the *large project with growth option*.

For the *small project with option to abandon* (project 2), and *large project with option to abandon* (project 4), none of the control variables explained the variation in option exercise decisions. This shows that rational decision in the *small project with abandonment option* and biased decisions in the *large project with abandonment option* are irrespective of the individual and firm level characteristics we controlled this experiment for.

3.5.2 Narrow Framing Effects

Hypothesis 5a was tested using non parametric frequency based analysis in SPSS v17, to determine the presence of narrow framing was determined in portfolio scenarios. Hypothesis 5b was tested in two stages. In the first stage, repeated measures ANOVA was conducted in SPSS v17 to examine the effects of changing scenarios from single projects to portfolio, on real option exercise decisions. In the second stage, 3 stage least square (3SLS) was performed in STATA/SE 11.2, to examine the unique contribution of framing of real options in single projects, on the narrow framing in portfolio decision. Our reason for using 3SLS is the endogenous nature of project and portfolio decisions in the experiment, and unknown causality between project and portfolio decisions. Before running the data analyses for hypothesis 5a and 5b, the individual projects' data in each portfolio was coded. We had two responses for each portfolio as a portfolio consists of two projects. First, portfolio data was coded as a combination of correct and incorrect decisions within the portfolio to differentiate the correct portfolio choices from incorrect ones. The portfolio results were then used to run the analyses. The coding key used to code the portfolio choices is given in Table 3.14.

Table 3.14: Coding key to calculate portfolio choices

Growth option response in the portfolio	**Abandonment option response in the portfolio**	**Portfolio outcome**
1 (correct choice)	1(correct choice)	1(correct choice)
1(correct choice)	0(incorrect choice)	0(incorrect choice)
0 (incorrect choice)	1(correct choice)	0(incorrect choice)
0(incorrect choice)	0(incorrect choice)	0(incorrect choice)

After the coding of portfolio choices, frequency analysis was conducted on portfolios 1, 2 and 3. The results are shown in Table 3.15. These results were significant for the portfolio 1 choices with 106 (47.5%) correct portfolio decisions and 117 (52.5%) incorrect decisions (*t-value* (222,223) = 14.182, $p<.001$). They were also significant for portfolio 2 choices with 109 (48.9%) correct portfolio decisions and 114 (51.1%) incorrect decisions (*t-value* (222,223) = 14.569, $p<.001$), and portfolio 3 choices with 56 (25.1%) correct portfolio decisions and 167 (74.9%) incorrect decisions (*t-value* (222,223) = 8.628, $p<.001$). This showed *the presence of narrow framing of decisions at the real option exercise time for all the project portfolios*, and hypothesis 5a[11] is supported.

Table 3.15: Project Portfolio Responses: Portfolios consisting of growth and abandonment options

	No. of rational decisions (percentage)	**No. of biased decisions (percentage)**	**t-statistic (p value)**
Portfolio 1 (small scale independent projects)	106 (47.5%)	117 (52.5%)	14.182 (<.001)
Portfolio 2 (small scale interdependent projects)	109 (48.9%)	114 (51.1%)	14.569 (<.001)
Portfolio 3 (large scale independent projects)	56 (25.1%)	167 (74.9%)	8.628 (<.001)

3.5.2.1 Repeated Measures ANOVA

Small scale growth option and abandonment option scenarios were presented to the respondents three times. They were first presented as single project scenarios, then as a portfolio of independent projects and finally as a portfolio of interdependent

[11] Hypothesis 5a states: When IT managers exercise real options in an IT portfolio, they will engage in narrow framing.

projects. Large scale growth option and abandonment option scenarios were presented to the respondents two times, first presented as single project scenarios, then as a portfolio of interdependent projects.

For the small growth option scenario, a repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean option exercise decisions were statistically different among the three scenarios (F (1.871, 415.45) = 26.287, p <0.000). Post hoc tests using the Bonferroni correction revealed that *changing the decision scenario for small growth options from single project to a portfolio of independent projects elicited a decrease in biased growth option exercise decisions,* which was statistically significant (*p<0.000*). 69% people took rational decision for growth option in portfolio as compared to 49% people in single project scenario. A similar result held for changing the decision scenario from single project to a portfolio of interdependent projects (*p<0.000)*, where again, 69% people took rational decision for growth option in portfolio as compared to 49% people in single project scenario. However, changing the decision scenario to a portfolio of interdependent projects from a portfolio of independent projects was not statistically significantly different (*p=0.999*). We can, therefore, conclude that *a portfolio scenario elicits a statistically significant decrease in biased decisions for growth options, as compared to single projects, irrespective of interdependency among portfolio resources*. However, interdependency among portfolio scenarios does not solely impact biased decisions.

For the small scale abandonment option scenario, a repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean exercise decisions again were significantly different among three scenarios (F (1.964, 436.09) = 7.957, p <

0.001). Post hoc tests using the Bonferroni correction revealed that changing the decision scenario from single project to a portfolio of independent projects as well as to a portfolio of interdependent projects elicited an increase in biased abandonment option exercise decisions, which was statistically significant (*p=0.001 ; p=0.006*). 69% people took rational decision for abandonment option in portfolio as compared to 81% people in single project scenario. However, changing the decision scenario to a portfolio of interdependent projects was not statistically significantly different from a portfolio of independent projects (*p = 0.999*). 70% people took rational decision for abandonment option in portfolio as compared to 81% people in single project scenario. We can, therefore, conclude that *a portfolio scenario elicits a statistically significant increase in biased decisions for abandonment options, as compared to single projects, irrespective of interdependency among portfolio resources*. However, interdependency among portfolio scenarios does not solely impact biased decisions.

For the large scale growth option scenario, a repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean exercise decisions were significantly different among two scenarios (F (1, 222) = 6.489, p= 0.012). Post hoc tests using the Bonferroni correction revealed that changing the decision scenario from single project to a portfolio of independent projects elicited an decrease in biased growth option exercise decisions, which was statistically significant (*p=0.012*). 48% people took rational decision for growth option in portfolio as compared to 40% people in single project scenario. We can, therefore, conclude that *a portfolio scenario elicits a statistically significant decrease in biased decisions for large growth options, as compared to single projects*.

For the large scale abandonment option scenario, a repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean exercise decisions did not differ significantly among two scenarios (F (1, 222) = 1.566, p= 0.212). Post hoc tests using the Bonferroni correction revealed that changing the decision scenario from single project to a portfolio of independent projects did not impact abandonment option exercise decisions. 55% people took rational decision for abandonment option in portfolio as compared to 59% people in single project scenario. We can, therefore, conclude that for the *large project with abandonment option*, *changing scenarios from single project to a portfolio did not affect the exercise decisions.* Framing effects were strong in large project with abandonment option, and the effect stayed in the large portfolio.

3.5.2.2 3SLS Analysis:

For 3SLS the sequential equations used in the analysis are as follows:

Project 1 (growth) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp* (3.1)

Project 2 (abandon) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp* (3.2)

Project 3 (growth) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp* (3.3)

Project 4 (abandon) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp* (3.4)

Portfolio 1 = *Project 1 + Project 2 + Portfolio Exp* (3.5)

Portfolio 2 = *Project 1 + Project 2 + Portfolio Exp* (3.6)

Portfolio 3 = *Project 3 + Project 4 + Portfolio Exp* (3.7)

For 3SLS, project portfolio decisions for all the project portfolios were further coded on a scale of 1 to 4, with 1 being incorrect portfolio choice due to incorrect decisions taken in both the projects in the portfolio, 2 being incorrect portfolio choice due to suboptimal decision for project with growth option, 3 being incorrect portfolio choice due to suboptimal decision for project with option to abandon[12],and 4 being correct portfolio choice due to correct decisions taken in both projects in the portfolio. The coding key used to calculate the portfolio choices is given in Table 3.16. This scale allowed us to capture the variation in portfolio responses explained by individual project responses. With a scaled dependent variable, Maximum Likelihood Estimation (MLE) is recommended (Maddala, 1983). This makes the use of 3SLS appropriate for our case because in 3SLS, equations in 3rd stage are estimated using Generalized Linear Model (GLM), which uses MLE as the estimation technique. The 3SLS model results are given in Table 3.17, with unstandardized coefficients and respective z-values.

Table 3.16: Coding key to calculate portfolio choices

	Project 2 – Exercise Option to Abandon (correct choice)	**Project 2 – Do not Exercise Option to Abandon (incorrect choice)**
Project 1 – Exercise Option to Grow (correct choice)	4	2
Project 1 – Do not Exercise Option to Grow (incorrect choice)	3	1

[12] We chose rank 2 for incorrect portfolio choice due to suboptimal decision for project with growth option, and 3 for incorrect portfolio choice due to suboptimal decision for project with option to abandon, based on the results from hypotheses 1-4. We found that in IT projects, growth options are more sensitive to biased decisions than abandonment options. Therefore, we ranked portfolio suboptimal choice due to growth option lower than abandonment option.

Table 3.17: Three-stage least squares (3SLS) regression results of IT Project Portfolios

Explanatory Variables	(1) Project 1 SSGO	(2) Project 2 SSAO	(3) Project 3 LSGO	(4) Project 4 LSAO	(5) Portfolio 1 SSIND	(6) Portfolio 2 SSINT	(7) Portfolio 3 LSIND
Project 1	-	-	-	-	0.429 (.34)	0.403 (.27)	-
Project 2	-	-	-	-	-0.831 (-.32)	-1.589 (-.52)	-
Project 3	-	-	-	-	-	-	0.498 (.83)
Project 4	-	-	-	-	-	-	2.581* (1.72)
Gender	-0.093 (-1.20)	0.010 (.22)	-.235*** (-3.14)	0.054 (.87)	-	-	-
Work Experience	-.0641* (-1.85)	.0422* (1.83)	-.056* (-1.71)	0.030 (1.14)	-	-	-
Services Sector	-0.005 (-.08)	-.063* (-1.66)	0.021 (.34)	-0.028 (-.60)	-	-	-
Firm Size	-0.026 (-.92)	0.007 (.42)	-0.009 (-.35)	0.016 (.74)	-	-	-
IT Investments Experience	.0635* (1.93)	0.015 (.60)	-0.012 (-.40)	.0461* (1.73)	-	-	-
Real Options Experience	-0.055 (-1.62)	0.014 (.59)	-0.004 (-.14)	-0.037 (-1.23)	-	-	-
Portfolio Experience	-	-	-	-	0.062 (.71)	0.093 (.94)	-0.010 (-.11)
Constant	.884*** (4.84)	.515*** (3.65)	.911*** (5.17)	.348** (2.09)	3.320 (1.38)	3.856 (1.35)	0.822 (1.08)
Model Fit							
R^2	0.040	0.020	0.063	0.021	-0.043	-0.370	-0.715
χ^2 statistics	9.98	7.26	16.96***	5.08	1.90	2.78	8.15**
No. of obs.	223	223	223	223	223	223	223

*** Significant at 1% significance level
** Significant at 5% significance level
* Significant at 10% significance level

SSGO = small scale project with growth option
SSAO = small scale project with abandonment option
LSGO= large scale project with growth option
LSAO= large scale project with abandonment option
SSIND= portfolio of small scale, independent project
SSINT= portfolio of small scale, interdependent project
LSIND= portfolio of large scale, independent project

Among first stage equations, the model for project 3 (χ^2= 16.96, p<0.01) is significant. This means that there are no differences in single project responses in all the projects based on individual and firm level characteristics, except for in the case of the *large project with growth option*. A similar result holds true for third stage equations where there are no differences in portfolio responses in all the portfolios based on single project decisions and portfolio experience, except in case of portfolio 3 (χ^2= 8.15, p<0.05).

For the *small project with growth option* (project 1), work experience (*z*= -1.85, *p*=0.06) and experience with IT investments (*z*= 1.93, *p*=0.05) were significant. For the *small project with growth option*, IT managers with more work experience showed risk-averse behavior and took biased option exercise decisions as compared to the IT managers with lesser work experience. More specifically, with increased work experience, IT managers are 0.122 times more likely to take biased decisions. We believe the reason for this effect is the overall economic recession, where budget cuts for IT investments in organizations have impacted the investment habits, thus changing mind set of IT managers from economic benefit maximization to minimizing losses and keeping IT investments low. In most organizations, IT investment decisions authority is not limited to IT specialists. Such decisions are also entrusted by people with versatile work experience, e.g., finance, general project management etc. We believe this heterogeneity in work experience might have caused the inverse relationship. Although IT managers have more work experience overall, but lack of specialized skills and experience might have led them to take the biased decision. On the contrary, more experience with IT investments lead to more rational decisions. With increased experience with IT investments, IT managers are 0.162 times less likely to take biased decisions. We believe a more focused experience towards IT investments allows managers to evaluate the embedded risks in projects with growth options in a rational manner. Such experience leads them to take rational growth option exercise decisions.

For the *large project with growth option* (project 3), gender (z= -3.14, p<0.01), and work experience (z= -1.71, p= 0.08) were significant. Just like in the case of the *small project with growth option*, IT managers with greater work experience showed risk-averse behavior and made biased option exercise decisions as compared to the IT managers with lesser work experience. More specifically, with increased work experience, IT managers are 0.111 times more likely to take biased decisions. We believe this is due to the same reasons as described earlier. The results also indicate that gender becomes significant in *large project with growth option*, with male respondents exhibiting more risk-averse behavior and making more biased decisions, than female respondents. More specifically, females on average, after controlling for all other variables, are 0.202 times more likely to take rational decisions. This shows when stakes are higher in a project with growth potential, male IT managers are more conservative and take biased decisions. We did find that increasing project size increased the framing effects for the growth option significantly. As seen earlier in the case of single projects, we found that increasing project size increased the framing effects for growth option significantly. We found similar trend here, and the project size effect on growth option might be due to the gender difference.

For the *small project with abandonment option* (project 2), work experience (z= 1.83, p= 0.067) and services sector (z= -1.66, p =0.097) were significant. For the *small project with abandonment option*, IT managers with more work experience showed less risk seeking behavior and took more rational option exercise decisions as compared to the IT managers with lesser work experience. More specifically, with increased work experience, IT managers are 0.102 times less likely to take biased decisions. This result is intuitive and shows an opposite trend from the growth options scenario. It is not surprising, because the options in play are different in nature. This result confirms that, with more work experience, the problem of escalation of commitment can be reduced for small projects. For project 2, respondents belonging to the services sector took more biased decisions. Respondents from the service sector, on average after controlling for all other variables, are 0.079 times more likely to take rational decisions. We believe industry differences are due to the differences in the nature of IT projects managed in services and manufacturing sector. IT investments could be considered more important in the services sector than in the manufacturing sector since this sector is more IT - intensive (Licht and Moch, 1999).

For *large project with abandonment option* (project 4), only experience with IT investments (z= 1.73, p=0.083) was significant. This result indicates that for *large project with abandonment option*, IT managers with more experience in IT investments took more rational decisions and terminated the project by exercising the option; instead of continue to invest in it. More specifically, with increased experience in IT investments, IT managers are 0.118 times less likely to take biased decisions. This result is intuitive. Greater experience led to more rational thinking for large projects. This result along with the similar result for small projects can be used to make an argument that escalation of commitment in large projects can be controlled by letting IT managers with more experience with IT investments manage it.

In a portfolio of small independent projects (portfolio 1) and small interdependent projects (portfolio 2), framing of decisions in single projects (small projects with growth and abandon options) did not contribute towards narrow framing in the portfolio significantly. Also, portfolio experience was not significant either, but for portfolio of large projects (portfolio 3), respective *large project with abandonment option* contributed towards narrow framing significantly (z= 1.72, p=0.086). With an increased number of biased decisions for the *large project with abandonment option*, IT managers' biased decisions for portfolios of large projects increased by 2.93.

These results are supported by the repeated measures analysis, and indicate that *framing of single project options did not contribute towards narrow framing in portfolios, except for the case of large projects with abandonment option*. Based on all these results, hypothesis 5b is partially supported[13]. Trends in framing effects changed significantly in portfolios from single projects, as indicated by repeated measures analysis. Biased decisions for growth options (for both small and large projects) decreased significantly in portfolios whereas biased decisions for abandonment option for small project increased significantly, with no significant change in biased decisions for abandonment option for large project. In small portfolios, the narrow framing occurred due to framing of both growth and abandonment options, but significantly due to the increase in the biased decisions for abandonment options. In large portfolio, the narrow framing occurred due to framing of both growth and abandonment options, but significantly due to no change in the biased decisions for abandonment options.

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[13] Hypothesis 5b states: Framing of real options in single IT projects will lead to narrow framing in IT portfolios.

Hypothesis 6 was tested on suboptimal portfolio decisions[14], by dividing them in two categories. From all the suboptimal portfolio decisions, the suboptimal portfolio responses due suboptimal abandonment option decisions were separated from the suboptimal portfolio responses due suboptimal growth option decisions. If the portfolio decision was suboptimal due to the both suboptimal growth and abandonment option, it was included in both categories. The results are given in Table 3.18.

Table 3.18: Loss Aversion in Portfolio Scenarios

	Total suboptimal decisions[15]	Suboptimal decisions due to option to abandon	Suboptimal decisions due to growth option	Friedman's rank test for k (χ^2) (p-value)
Portfolio 1 (small scale independent projects)	117 (52.5%)	70 (59.8%)	70 (59.8%)	*0.001 (=0.999)*
Portfolio 2 (small scale interdependent projects)	114 (51.1%)	68 (59.6%)	70 (59.8%)	*0.044 (=0.833)*
Portfolio 3 (large scale independent projects)	167 (74.9%)	101 (60.5%)	115 (68.8%)	*1.66 (=0.197)*

The test results were not significant for all three portfolios, showing no significant loss aversion in portfolio suboptimal decisions. This means framing of real abandonment options did not play a significant role in narrow framing of portfolios. This result shows that, *in a portfolio scenario, IT managers are not sensitive to losses as much*. Based on these results hypothesis 6 is not supported.

[14] Hypothesis 6 states: When IT managers exercise real options in an IT portfolio, framing effects will be greater for projects with an abandonment option than for projects with a growth option.
[15] Total suboptimal decisions are the suboptimal portfolio decisions due to the sub optional project decision for either growth option, or abandonment option, or both options.

3.5.3 Reduction in Narrow Framing Effects

Hypotheses 7, 8a,8b and 9 were tested by comparing the results of respective portfolio outcomes using a non-parametric k-related statistical test Friedman statistic and Cochran's Q test. To test the effects of resource interdependency among projects in the IT portfolio on narrow framing (H7), portfolio results of the small independent project portfolio (portfolio 1) were compared with the small interdependent project portfolio (portfolio 2). The tests showed no significant difference between portfolio 1 and 2 ($\chi^2(1) = \chi^2_1 = 0.158$, $p = 0.691$). Hence, *the interdependency among projects in a portfolio did not reduce the narrow framing effects in the IT portfolio*, and therefore hypothesis 7 is not supported. This result is consistent with repeated measures analysis, where resource interdependencies among IT projects in a portfolio did not contribute towards its improved management, and as a result output of the portfolio was not maximized.

To test the effects of project size in the IT portfolio on narrow framing (H8 a,b), portfolio results of the small independent project portfolio (portfolio 1) were compared with the large independent project portfolio (portfolio 3). The tests showed significant difference between portfolio 1 and 3 (χ^2 (1) = $\chi^2_1 = 34.722$, $p < 0.001$). Hence, *the projects' size did impact the narrow framing effects in an IT portfolio*. From the comparative analysis of project portfolios in Table 3.15, we found a different trend than hypothesized. For portfolios 1(small independent projects) and 2 (small interdependent projects), the percentage of correct responses increased from 47.5% to 48.9% in portfolio 2, where the increase was not significant (paired sample t-value = -0.397, p =.692). Similarly for portfolios 1(small independent projects) and 3 (large independent projects), the percentage of correct responses decreased from 47.5% to 25.1% in portfolio 3, where the decrease was significant (paired sample t-value = 6.399, p <0.001). Hence, the project size had an opposite impact on outcomes, where increase in project size increased framing effects in the case of growth as well as abandonment options, instead of reducing them, similar to the single projects case. This result is counter intuitive to the prospect theory, but consistent with escalation of commitment for the abandonment option case. Instead of reducing the narrow framing effects, the increase in project size intensified it. This showed that decision makers handling IT portfolio of larger IT projects are more likely to fall prey to narrow framing, as compared to the IT portfolio of smaller IT projects. We believe the same reasons hold for these results as explained for hypotheses 4a and 4d. Based on these results, hypothesis 8a is not supported, but hypothesis 8b is supported[16].

To test the effects of simplification of portfolio outcomes on narrow framing (H9), portfolio results of small independent project portfolio (portfolio 1) were compared with the results of the decision scenario of a follow up question. The tests showed *significant difference between portfolio 1 and choices made in the simplified decision scenario* (χ^2 (1) = χ^2_1 = 83.769, p <.001). Hence, hypothesis 9 is supported. This result implies two things. One, when portfolio scenarios with real options are simplified to make them less cognitively challenging, decision makers go for rational choices instead of risk sensitive choices due to framing. Secondly, these results showed preference reversal among decision makers, due to framing of real options at exercise time. Given that the decision scenario consisted of the same projects as in small

[16] Hypothesis 8a states: Increasing project sizes in an IT portfolio will reduce the narrow framing effects. Hypothesis 8b states: Increasing project sizes in an IT portfolio will increase the narrow framing effects.

independent project portfolio (portfolio 1), more respondents decided rather rationally in the simplified scenario when the portfolio value became obvious, as compared to the portfolio scenario.

We tested hypotheses H1-H9 using the data collected from international respondents. The results are given in Appendix-B. We found all the hypotheses were supported. However, we did not test H5b and H10, because it is out of the scope of this dissertation.

3.5.4 Individual Risk Behavior

Prior to running the analyses for hypothesis 10, all variables used to measure individual risk were examined for accuracy of data entry, outliers, and missing values. All the values for all variables were within acceptable ranges suggesting that there we no data entry errors. There were some univariate outliers detected (Table 3.19). We re-ran the descriptive statistics with and without outliers and the statistics did not change to merit adjustment. Hence, the observations were retained in the data set. The descriptive statistics of the data is given in Table 3.20.

We checked for multivariate outliers, normality of distribution, and multicollinearity. None of the Mahalanobis distance p-values (based on chi-square distribution) were found to be less than 0.001. Hence, there were no multivariate outliers. In terms of normality of the data distribution, some measures were slightly skewed (Table 3.19) like horse race, poker game, sports bet and gambling. For initial analysis, the data was not transformed to eliminate the skewness. None of the bivariate correlations were very high, i.e., they were less than 0.9 (Table 3.21), so there was not a problem of multicollinearity.

Table 3.19: Univariate Outliers (n=223)

Variable	**Outliers**
Horse Race	26 (>=4)
Mutual Fund	14 (= <1)
Poker Game	29(>=4)
Sports Bet	28 (>=4)
Conservative Stock	12(=<1)
Gambling	84 (>=2)

Table 3.20: Descriptive Statistics

	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Horse Race	1	5	1.56	.932	1.718	.129
Mutual Fund	1	5	3.81	1.024	-1.007	.129
Poker Game	1	5	1.57	.987	1.715	.129
Speculative Stock	1	5	2.67	1.153	.124	.129
Sports Bet	1	5	1.63	.958	1.515	.129
Conservative Stock	1	5	3.81	1.017	-.926	.129
Government Bond	1	5	3.33	1.133	-.422	.129
Gambling	1	5	1.41	.873	2.347	.129

Table3.21: Bivariate Correlations

	H.RACE	M. FUND	P. GAME	S. STOCK	S. BET	C. STOCK	G.BOND	GAMBLE
H.RACE	1							
M. FUND	.095	1						
P.GAME	.592**	.101	1					
S.STOCK	.251**	.286**	.256**	1				
S.BET	.568**	.106*	.551**	.322**	1			
C.STOCK	-.064	.394**	-.114*	.103	-.077	1		
G.BOND	.021	.269**	-.045	.190**	.048	.442**	1	
GAMBLE	.473**	.022	.571**	.177**	.503**	-.078	.047	1

3.5.4.1 Confirmatory Factor Analysis

Before testing the hypothesis, we ran confirmatory factor analysis (CFA) on the risk measures to compare the goodness-of-fit of the empirical data to the hypothesized conceptual model for financial domain specific risk measurement for US respondents. The CFA was run on US data (*n=223*). The conceptual model consists of 8 observed variables and two latent variables, *investment risk* and *gambling risk*, to determine the financial domain specific risk of the respondents. Each latent variable is measured by four items.

We ran one factor model to examine unidimensionality. A one factor model was tested and found not to fit the covariance matrix ($\chi2$ = 447.05, *df* =20, *p*<.0001; RMSEA [90%CI] = 0.286, 0.335; CFI= 0.55; GFI= 0.67). An examination of the standardized residuals indicated a misfit of the data, with standardized residuals as high as 15.9 (POKER_GA), 13.03 (MUTUAL_F), and 13.62 (SPORTS_B).These results suggest that the data is multidimensional (Figure 3.2).

A two factor model, which was based on the original model specification, was tested. Some factor loadings were not statistically significant at the *p* <.01 level: including for government bonds (G.BOND) measuring *investment risk* (*t=-0.39, p>.05*) and item gambling (GAMBLE) measuring *gambling risk* (*t=0.24, p>.05*). The path diagram with standardized estimates is given in (Figure 3.3).

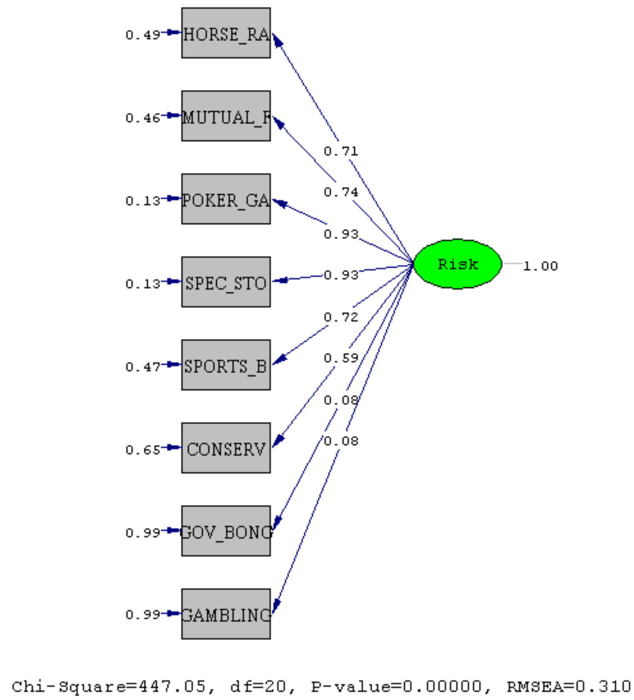

Figure 3.2: One Factor Model

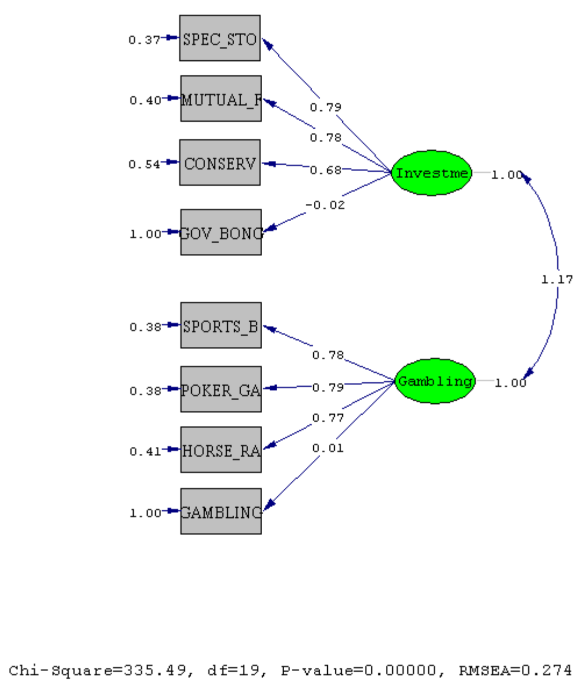

Figure 3.3: Two Factor Model

The overall model fit indices suggested a slight improvement in the fit (χ2 =335.49, df =19, p<.0001; RMSEA [90%CI] = 0.249, .30; CFI=.615; GFI=.726. There was still a significant chi-square and an examination of the residuals suggested a moderate misfit in the model, especially in the Investment risk factor (several standardized residuals were as high as 11.52).

The initial conceptual model was modified by dropping the non-significant measures from the model, i.e., government bonds (GOV_BOND) from investment risk and gambling (GAMBLING) from gambling risk. Also, the conceptual model was modified (based on the modification indices) to allow three error covariance paths between the observed variables. The improvement in the model with all additional error covariance paths is given in the Table 3.22 below, along with the path diagram in Figure 3.4. This resulted in a reasonable fit, χ^2 (5, N=223) = 13.43, p = 0.0197; RMSEA [90%CI] = 0.032, .145; CFI=.994; GFI=.980.

Table 3.22: Model Improvements

Correlation Allowed	**Chi-square**	**RMSEA**
None	χ^2 (8, N=223) = 313.14, p < 0.001	0.415> 0.05
Conservative stock, Sports bet	χ^2 (7, N=223) = 206.86, p < 0.001	0.359> 0.05
Mutual fund, Horse race	χ^2 (6, N=223) = 26.75, p < 0.001	0.125> 0.05
Speculative stock, Poker game	χ^2 (5, N=223) = 13.43, p = 0.0197	0.08> 0.05

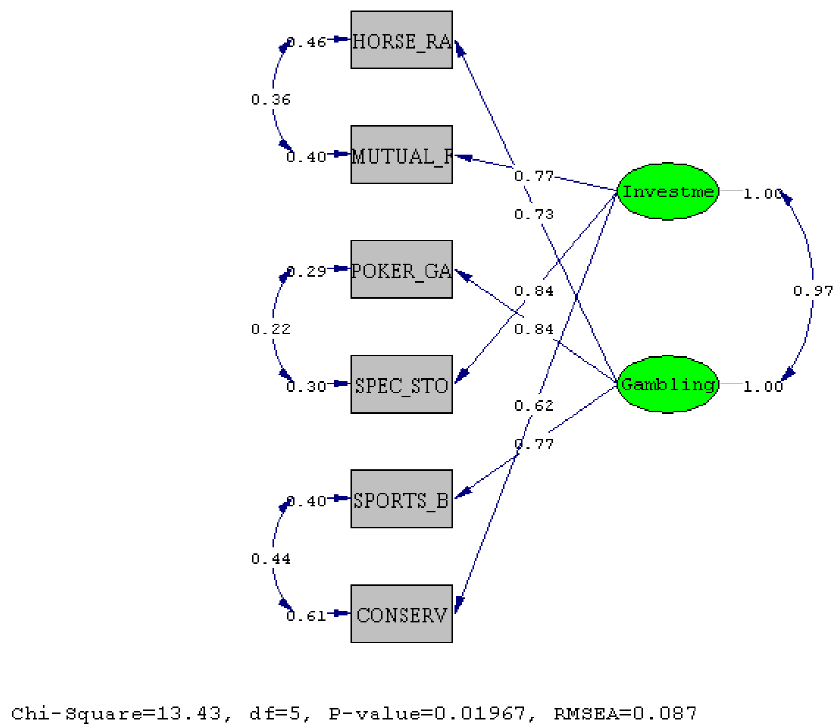

Figure 3.4: Final CFA Model

3.5.4.2 Hypothesis Testing

Based on the CFA results, regression weighted composite values were calculated for *investment risk* and *gambling risk* in SPSS v17. To test the hypothesis, the 3SLS model was used. The sequence of equations used for both data samples is as follows:

Project 1 (growth) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp + Investment risk + Gambling risk* (3.8)

Project 2 (abandon) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp + Investment risk + Gambling risk* (3.9)

Project 3 (growth) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp + Investment risk + Gambling risk* (3.10)

Project 4 (abandon) = *Gender + Work Exp + Firm Size + Industry + IT Exp + RO Exp + Investment risk + Gambling risk* (3.11)

Portfolio 1 = *Project 1 + Project 2 + Portfolio Exp* (3.12)

Portfolio 2 = *Project 1 + Project 2 + Portfolio Exp* (3.13)

Portfolio 3 = *Project 3 + Project 4 + Portfolio Exp* (3.14)

The results for 3SLS model with US data are presented in Table 3.23.

Table 3.23: 3SLS Model Results – With Individual Risk

Explanatory Variables	(1) Project 1 SSGO	(2) Project 2 SSAO	(3) Project 3 LSGO	(4) Project 4 LSAO	(5) Portfolio 1 SSIND	(6) Portfolio 2 SSINT	(7) Portfolio 3 LSIND
Project 1	-	-	-	-	0.646 (1.15)	1.276** (2.19)	-
Project 2	-	-	-	-	-0.648 (-.38)	-0.488 (-.28)	-
Project 3	-	-	-	-	-	-	0.500 (.90)
Project 4	-	-	-	-	-	-	2.239** (2.05)
Gender	-0.078 (-1.06)	0.024 (.44)	-.239*** (-3.13)	0.032 (.50)	-	-	-
Work Experience	-.029 (-0.89)	.039 (1.55)	-.048 (-1.41)	0.031 (1.18)	-	-	-
Services Sector	0.049 (.82)	-.050 (-1.11)	0.030 (.48)	-0.050 (-1.01)	-	-	-
Firm Size	-0.020 (-.77)	0.006 (.31)	-0.010 (-.37)	0.015 (.70)	-	-	-
IT Investments Experience	.034* (1.11)	0.024 (1.01)	-0.016 (-.53)	.053** (2.07)	-	-	-
Real Options Experience	-0.035 (-1.13)	0.001 (.07)	-0.001 (-.03)	-0.042 (-1.54)	-	-	-
Gambling Risk	0.124*** (3.91)	-0.009 (-0.38)	0.035 (1.10)	-0.010 (-0.42)	-	-	-
Investment Risk	0.053* (1.78)	-0.023 (-1.03)	0.012 (.69)	0.046* (1.69)	-	-	-
Portfolio Experience	-	-	-	-	0.060 (.88)	0.073 (1.04)	-0.000 (-.00)
Constant	.716*** (4.04)	.524*** (3.68)	.875*** (4.89)	.363** (2.22)	3.074** (2.13)	2.602* (1.76)	0.990** (1.70)
Model Fit							
R^2	0.105	0.024	0.069	0.031	0.062	0.049	-0.441

χ^2 statistics	26.58***	7.15	18.65**	8.77	4.67	12.50***	9.06**
No. of obs.	223	223	223	223	223	223	223

*** Significant at 1% significance level
** Significant at 5% significance level
* Significant at 10% significance level

SSGO = small scale project with growth option
SSAO = small scale project with abandonment option
LSGO= large scale project with growth option
LSAO= large scale project with abandonment option
SSIND= portfolio of small scale, independent project
SSINT= portfolio of small scale, interdependent project
LSIND= portfolio of large scale, independent project

Among the first stage equations, models for project 1 (χ^2= 26.58, p<0.01) and project 3 (χ^2= 18.65, p =0.02) are significant. Among the third stage equations, the models for portfolio 2 (χ^2= 12.50, p<0.01) and portfolio 3 (χ^2= 9.06, p=0.03) are significant. For the *small project with growth option* (project 1), among all variables, gambling risk (z= 3.91, p< 0.01), and investment risk (z= 1.78, p= 0.076) were significant. These results indicate that for the *small project with growth option*, IT managers who were likely to take risk in their personal life in gambles or personal investments also took risk in project 1 scenario. More specifically, with increased likelihood of taking risk in gambles as well as personal investments, IT managers are 0.249 and 0.106 times less likely to take biased decisions respectively. By preferring to take the risk and exercising the growth option embedded in the project, they took the economically optimal and rational decision for the project instead of going for small but certain gains. The same held true for the managers who were less likely to take risk in their personal lives in gambles or personal investments, which lead them to taking suboptimal decision. Hence, for these managers, *their business decisions were influenced by their personal financial risk behaviors*. These results are counter intuitive to prospect theory that specifies risk behaviors relating to frames are independent of personal risk characteristics. This outcome is a strong indicator that real option exercise decisions are complex decisions, and these decisions are likely to be affected by the personal financial risk behavior of the decision maker. IT managers are shown to become personally vested in the project they are managing (Keil et al., 1995), which cause them to escalate their commitment to a failing project. We believe that IT managers have a tendency of getting personally vested in any project they are managing, due to which their personal risk behavior starts to influence their business decisions.

For the *large project with growth option*, only gender (z= -3.13, p<0.01) was significant, where male respondents showed risk-averse behavior and took more biased option exercise decisions than female respondents. More specifically, females on average, after controlling for all other variables, are 0.206 times more likely to take rational decisions. These results establish two main insights. First, for the growth option embedded in the large project, gender plays a significant role in decision making. Second, for growth options embedded in the large project, male IT managers are more prone to showing risk-averse behavior at option exercise time and taking biased decisions than female IT managers.

For the *small project with abandonment option* (project 2), none of the instrumental variables were significant. This showed that none of the individual level, firm level and country level characteristics impacted the decision in the *small project with abandonment option*. Hypothesis 3 results showed that most of the respondents took a rational decision (80.3%) and terminated the project. 3SLS results indicate that the decision was not influenced by any exogenous variable.

For the *large project with abandonment option*, experience with IT investments (z= 2.07, p=0.039) and investment risk (z= 1.69, p=0.091) were significant. This result indicates that for the *large project with abandonment option*, IT managers with more experience in IT investments took more rational decision and terminated the project by exercising the option. More specifically, with increased experience in IT investments, IT managers are 0.139 times less likely to take biased decisions. This result is intuitive where more experience leads to more rational thinking, hence, facilitating options thinking in large projects (similar to 3SLS results for H5). Finding significant investment risk effects indicates that for the *large project with abandonment option*, *IT managers who were likely to take risk in their personal investments took a rational decision for the project with an abandonment option and exercised the option optimally, instead of continuing to invest in the project*. The same holds true for managers who are less likely to take risk in their personal investments, which lead them to taking suboptimal decision. More specifically, with increased likelihood of taking risk in personal investments, IT managers are 0.093 times less likely to take biased decisions. Hence, for these managers, their business decisions were influenced by their personal investment risk behavior. This result is counter intuitive to prospect theory that specifies risk behaviors relating to frames are independent of personal risk characteristics.

In a portfolio of small independent projects (portfolio 1), none of the decisions in the *small project with growth option* (project 1) and an *abandonment option* (project 2) contributed towards narrow framing significantly. But for the portfolio of small scale interdependent projects (portfolio 2), the *small project with growth option* (project 1) contributed towards narrow framing significantly (z= 2.19, p =0.028). With increased biased decisions for the *small project with growth option*, IT managers' biased decisions for portfolio of small interdependent projects increased by 0.603. In the first stage equations, gambling and investment risks were significant for project 1. It is likely that the individual risks explained narrow framing via framing of project 1. Hence, these results indicate that *framing of growth options in small single project is carried forwarded in project portfolios of interdependent projects, and personal risk behavior for investments and gambling affects these decisions*.

In a portfolio of large independent projects (portfolio 3), the *large project with abandonment option* (project 4) contributed towards narrow framing significantly (z= 2.05, p =0.041). With an increased number of biased decisions for the *large project with abandonment option*, IT managers' biased decisions for portfolio of large projects increased by 2.54. In the first stage equations, investment risk was significant for project 4. It is likely that the individual risk explained narrow framing in portfolio 3 via framing of project 4. Hence, these results indicate that *framing of abandonment options in large single project is carried forwarded in project portfolios, and personal risk behavior for investments affects these decisions.*

In summary, individual risk behavior did contribute significantly towards narrow framing in project portfolios via framing effects in single projects. It played a significant role in case of portfolio of small interdependent projects, via growth option and in case of portfolio of large projects via abandonment option. Based on these results, hypothesis 10 is not supported and personal risk preferences did impact IT projects and portfolios decisions with real options. The summary of all the hypothesis results is given in Table 3.24.

Table 3.24: Summary of Hypotheses Results and Support

Hypothesis		Test	Test Parameters	Supported by Results
H1	Framing of growth options	t-stat (p- value)	Project 1, Project 3	Yes
H2	Framing of abandonment options	t-stat (p- value)	Project 2, Project 4	Yes
H3	Loss aversion in single projects	Friedman's rank test for k (χ^2)	Project 1vs.2 Project 3 vs.4	No
H4a	Framing reduced by size – growth option	Friedman's rank test for k (χ^2)	Project 1vs.3	No
H4b	Framing reduced by size – abandonment option	Friedman's rank test for k (χ^2)	Project 2vs.4	No
H4c	Framing increased by size – growth option	Friedman's rank test for k (χ^2)	Project 1vs.3	Yes
H4d	Framing increased by size – abandonment option	Friedman's rank test for k (χ^2)	Project 2vs.4	Yes
H5a	Framing of options in a portfolio leads to narrow framing	t-stat (p- value)	Portfolio 1, Portfolio 2, Portfolio 3	Yes
H5b	Framing of options in single projects leads to narrow framing in a portfolio	Repeated Measures	Portfolio 1, Portfolio 2, Portfolio 3	Partially (for large abandonment options only)
		3SLS	All projects and portfolios	
H6	Loss aversion in a portfolio	Friedman's rank test for k (χ^2)	Portfolio 1, Portfolio 2, Portfolio 3	No
H7	Interdependency reduces narrow framing	Friedman's rank test for k (χ^2)	Portfolio 1 vs. Portfolio 2	No
H8a	Project size reduces narrow framing	Friedman's rank test for k (χ^2)	Portfolio 1 vs. Portfolio 3	No
H8b	Project size increases narrow framing	Friedman's rank test for k (χ^2)	Portfolio 1 vs. Portfolio 3	Yes
H9	Simplification reduced narrow framing	Friedman's rank test for k (χ^2)	Portfolio 1 vs. Simplified decision	Yes
H10	Individual risk does not impact narrow framing	3SLS	All projects and portfolios	No

3.6 Discussion and Implications

3.6.1 Framing Effects

We found significant framing effects for growth option scenarios (both small and large projects), as well as for the abandonment option scenario (only for large project). IT managers displayed risk-averse behavior for growth option while exercising them, irrespective of project size, and risk seeking behavior for option to abandon only in large projects while exercising them. Framing of real options induces respective risk behaviors at option exercise time that may lead to suboptimal exercise decisions, hence, impacting its realized economic value. Projects with growth options are valued the most by IT managers because they seem to add more value than any operational option (Tiwana et al., 2006), and drive their commitment to it. Our results indicate that growth options have a potential to prevent IT managers from optimally exercising them by making them risk-averse, irrespective of the amount at stake. However, for options to abandon, only large project suffered significant framing effects. Although projects with option to abandon are valued the least by IT managers because they seem to add the least value due to difficulty in exercising them (Tiwana et al., 2006; Busby and Pitts, 1997), yet, IT managers exercise them optimally. The preference for option exercise was significantly different for large projects, where IT managers took suboptimal exercise decisions. These findings for abandonment option are consistent with escalation of commitment behavior in IT projects, where inability to terminate a project midway is attributed to its size, along with other factors, like disruption in ongoing project operations, negative impact on the team's morale and credibility, and the ability of the option to give no accomplishment as compared to other real options, except curtailing losses (Tiwana et al., 2006). We also found the size of the project intensifying framing effects in growth options. For growth options, IT managers became even more conservative for large projects. We believe there could be several reasons for this. Several risk factors has been identified affecting large projects like ERP systems, including, organizational fit, skill mix, management structure and strategy, system design, user involvement and training and technology planning and integration (Sumner, 2000). Most of these risk factors are unsystematic, where managers have no control in mitigating them. Our project scenarios did not specify the strategic importance of projects to the organizations, nor any other information that could relate to the kind of risk involved, i.e., either systematic or unsystematic. Hence, due to the sheer size of the project and stakes involved in it, respondents might have decided for the safest choice. Also, economic recession effects might have come into play by impacting the IT investment decision makers, where departmental cost cuts (Botello, 2009) and a shrinking technology market (Ante, 2008) made them more conscious on savings than maximizing returns.

We, however, did not find significant loss aversion effects in single projects. These results held for both small and large projects. In the case of IT investments, IT managers are more risk-averse than loss averse. Same held true in portfolios. Hence, the option type does influence biased decisions, where growth options are more susceptible to being exercised suboptimally than options to abandon.

3.6.2 Narrow Framing Effects

Narrow framing effects were significant in all the portfolios. Narrow framing in all the portfolios was caused by suboptimal decisions for growth options as well as abandonment options. Even though most respondents took rational decisions for small scale single project with abandonment option, their preferences for option exercise decision changed in the portfolio setting where some of them took biased decisions and showed risk seeking behavior. This change was indicated by the repeated measures result, where biased decisions increased for abandonment option in small scale portfolios. Similarly, most respondents took biased decisions for large scale single project with abandonment option. But their preferences for option exercise decision did not change significantly in the portfolio setting (as indicated by repeated measures analysis). In both small and large portfolios' case, increase in the number of biased decisions for abandonment option was not significant enough to indicate loss aversion. For small and large single projects with growth options, managers showed significant risk-averse behavior. The number of biased decisions for growth option was decreased in portfolio scenarios, but they were still greater than the number of biased decisions for abandonment option. Therefore, narrow framing in small portfolios was caused by increased biased decisions for *small abandonment options*, in the presence of significant number of biased decisions *small growth option.* In large portfolio, narrow framing was caused by the presence of biased decisions for *large abandonment option*, and *large growth option.*

Similar to the results found in the case of single projects, narrow framing effects were significantly higher in the case of large project portfolio compared to the small project portfolios. This outcome was possibly due to significant suboptimal decisions in both growth and abandonment option exercise, and due to no change in biased decisions for abandonment option decisions as compared to single project scenarios. Hence, the combined impact of risk-averse behavior in the *large project with growth option,* risk seeking behavior in the *large project with abandonment option*, and with reference point impact in portfolios resulted in intensifying narrow framing effects in large project portfolios. The option to abandon a project seems to be unlikely to be exercised, and hence, not very valuable, when the project involves higher stakes (in terms of size) and the project is a part of a portfolio where other projects have a potential for positive returns.

Interdependency among project resources in a portfolio had no significant impact on the narrow framing outcome. Although awareness of alternative uses of the funds supporting a project has been shown to force the decision makers out of decision making in isolation (Keil and Robey, 1999; McCain, 1986; Northcraft and Neale, 1986), it did not hold in our case. In the presence of framing effects on real options, resource interdependencies did not initiate competition for scarce resources (Throp, 1999), nor did they act as constraints on the portfolio, specified as a key in portfolio alignment (Goldman, 1999). Hence, it is likely that framing effects dominated the resource interdependencies among IT projects in a portfolio, and in turn negatively affected the efficient management of the IT project portfolio.

When portfolio scenarios were simplified, narrow framing effects were eliminated. This result confirmed that uncertainty at option exercise time in a portfolio causes biased decision making. When the portfolio choice(s) are simplified and reframed such that economic dominance of the combined choice is obvious, most of the IT managers' preferences for portfolio decision changed from risk-driven to economically optimal rational decisions.

Framing of single project options did not contribute towards narrow framing in portfolios, except for the case of large projects with abandonment option. Portfolio scenarios decreased biased decisions in small and large growth options, and increased biased decisions in small abandonment option significantly, with significant biased decisions in large abandonment option. This outcome indicates that in portfolios, decision makers were willing to take risk for both growth and abandonment options, where taking risk for growth option was necessary to realize its optimal value but taking risk for abandonment option was not. Combining the projects with growth and abandonment options in a portfolio facilitated risk taking among managers. The overall goal of portfolio management is to maximize the portfolio returns. Also, high returns are attributed to taking high risks. The risk behavior change in portfolios can be attributed to the general conception of taking higher risk to maximize returns. Reference point shift among IT managers in the portfolios may also be a cause of this outcome. With a growth option in the same portfolio as an abandonment option, and with certain and probable gains possible, the reference point for the managers to evaluate the real options' outcomes was not neutral anymore. The narrow framing effects in portfolio decisions indicate that IT managers evaluated each project in isolation, relative to the status quo of the project with positive outcome, i.e., growth option, as a reference point, instead of a neutral reference point of zero NPV. We believe this reference point shift lead to the decreasing risk aversion for growth options. Managers valued the project with growth option more as compared to the one with abandonment option, which facilitated their willingness to invest in it further. Managers value growth option more than abandonment option (Tiwana et al., 2006).

The change in reference point also made risk seeking behavior significant in portfolio decisions. Managers' focus in this case changed from loss minimization for projects with abandonment option, to taking a chance to breakeven the project. We believe managers did not value abandonment options with growth option in the same portfolio, which lead them to decide not to terminate the project and incur loss. Reference point shifts happen due to the availability of multiple candidate reference points where the new reference point is a function of past information, also known as *adaption* (Baucells et al., 2011). Also, recently experienced gains and losses can impact managers' risky behavior by making them risk takers after a gain (Sullivan and Kida, 1995). In our case, both effects came into play in a portfolio scenario, where *adaption* consisted of information from the growth option scenario, with possible higher gains realized for growth option scenarios possibly leading to risk taking behavior for the option to abandon in the same portfolio. This result indicates that risky decision making in a portfolio setting is more complex than explained by prospect theory (Sullivan and Kida, 1995).

When the decision makers' individual risk preferences were taken into account in equations (3.8) to (3.11), decisions in the *small project with growth option* also significantly contributed towards narrow framing in small interdependent project portfolio (portfolio 2). Also, decisions in the *large project with abandonment option* contributed significantly towards narrow framing in the portfolio of large projects. This set of results illustrate a significant role played by individual risk behavior towards framing of option decisions in single projects and in turn narrow framing of option exercise decisions in portfolios. Based on these results, framing of decisions in single projects did lead to narrow framing in portfolios.

3.6.3 Predicting Framing and Narrow Framing Effects

Growth option decisions were explained by control variables but option to abandon decisions were not. This result indicates that growth option decisions can be predicted via individual or firm level characteristics, but option to abandon decisions hold irrespective of them. Growth option decisions for the small project were explained by work experience and real options experience. This indicates that respondents with more work experience as well as experience with real options took biased decisions. We suspect that with more experience, IT managers tend to get risk-averse. Hence, they see a project with high uncertainty in terms of downside risk instead of upside potential. They tend to minimize risk to make sure positive returns are ensured. There can be several reasons behind this behavior including budget cuts in organizations, difficulty in generating positive returns in IT support projects like infrastructure projects. However, for the large project with a growth option, gender, portfolio experience, and work experience became significant in explaining the growth option decisions. The work experience relationship is similar here to that observed in the case of the *small project with growth option*, and we believe the same reasons hold here as well. Portfolio experience on the other hand decreased the tendency of framing in large projects. We believe that with greater portfolio management experience, IT managers take more objective decisions. Our results indicate that managers work experience is significant only for large projects. This could be due to the fact that managers evaluate portfolios with large projects more carefully due to the higher stakes involved

Our results also indicate that for *large project with a growth option*, women are 0.174 times less likely to take biased decisions than men. This result is contrary to findings of gender differences in investment risk behaviors, where men are found to be greater risk seekers than women (Fellner and Maciejovsky, 2007). We believe that in the case of growth options, gender differences are based on preferences for final outcomes, and women focused on maximizing returns whereas men focused on ensuring positive returns, hence, the risk-averse behavior.

When control variables were run in a 3SLS model, along with the portfolio decisions, some similarities and differences were noticed (Table 3.25).

Table 3.25: Significant Variables-Single Projects

Explanatory Variables	(1) Project 1 SSGO	(2) Project 2 SSAO	(3) Project 3 LSGO	(4) Project 4 LSAO
Gender	-	-	-.235*** (-3.14)	-
Work Experience	-.0641* (-1.85)	.0422* (1.83)	-.056* (-1.71)	-
Services Sector	-	-.063* (-1.66)	-	-
IT Investments Experience	.0635* (1.93)	-	-	.0461* (1.73)

*** Significant at 1% significance level
** Significant at 5% significance level
* Significant at 10% significance level

SSGO = small scale project with growth option
SSAO = small scale project with abandonment option
LSGO= large scale project with growth option
LSAO= large scale project with abandonment option

Gender was still significant for the *large project with growth option*. ***Work experience*** was significant for all projects except for the *large project with abandonment option*. Work experience became significant for *small project with* *abandonment option*, and the direction of the impact was positive. IT managers with greater work experience showed less risk-seeking behavior and made rational option exercise decisions when compared to the IT managers with lesser work experience. This result is intuitive because with increasing work experience, IT managers are able to see the value of loss minimization provided by abandonment option. Also, experienced IT managers have a strong managerial reputation which allows them to look beyond making bad performing projects successful by taking high risks. This result also shows an opposite trend from the growth option scenarios, where with increasing work experience, IT managers became more conservative in their investments. It is not surprising, because the options in play are different in nature. This result confirms that, with more work experience, the problem of escalation of commitment can be controlled for small projects only. However, with greater work experience, risk-averse behavior for growth opportunities intensifies.

Industry sector was significant for the *small project with abandonment option.* Respondents belonging to the services sector made more biased decisions. This may be due to the differences in the nature of IT projects managed in the services and manufacturing sectors. IT investments may be considered more important in the services sector than in manufacturing sector, since the service sector is more IT intensive (Licht and Moch, 1999). ***IT investment experience*** was also significant for the *small project with growth option* and the *large project with abandonment option*. These results indicate that for *small project with growth option* as well as for *large project with abandonment option*, IT managers with greater experience in IT investments made more rational decisions and exercised the respective options, instead of showing respective risk behaviors based on frames. Greater experience with IT investments enabled IT managers to see the potential for value maximization due to growth option, and potential for loss minimization due to abandonment option. Hence, greater experience lead to more rational thinking for *small project with growth option* as well as for *large project with abandonment option*, and facilitated options thinking in these projects. ***IT Investment experience*** affected large portfolio decisions through *large project with abandonment option*. The relationship was positive implying that greater experience with IT investments lead respondents to make rational decisions, which in turn affected the portfolio decisions through more rational decisions.

When individual risk factors were introduced, only ***Gambling*** and ***Investment risks*** were significant for the *small project with growth option* (Table 3.26).

Table 3.26: Significant Variables – Single Projects and Individual Risk

Control Variables	(1) Project 1 SSGO	(2) Project 2 SSAO	(3) Project 3 LSGO	(4) Project 4 LSAO
Gender	-0.078 (-1.06)	0.024 (.44)	-.239*** (-3.13)	0.032 (.50)
IT Investments Experience	.034* (1.11)	0.024 (1.01)	-0.016 (-.53)	.053** (2.07)
Gambling Risk	0.124*** (3.91)	-0.009 (-0.38)	0.035 (1.10)	-0.010 (-0.42)
Investment Risk	0.053* (1.78)	-0.023 (-1.03)	0.012 (.69)	0.046* (1.69)

*** Significant at 1% significance level
** Significant at 5% significance level
* Significant at 10% significance level

SSGO = small scale project with growth option
SSAO = small scale project with abandonment option
LSGO= large scale project with growth option
LSAO= large scale project with abandonment option

Work experience, IT investment experience and real options experience were not significant anymore. These results indicate that personal risk behavior explained the growth option exercise decision better than any other individual and firm level characteristic in this project scenario. For the *small project with growth option*, IT managers who were likely to take risk in their personal life in gambles or personal investments also took risk for the *small project with growth option*. By preferring to take the risk and by exercising the growth option embedded in the project, they took the economically optimal and rational decision for the project instead of going for small but certain gains. Similarly managers who were less likely to take risk in their personal lives in gambles or personal investments made suboptimal (risk-averse) decisions. Hence, for these managers, their business decisions were influenced by their personal risk behaviors. These results are counter to prospect theory which specifies risk behaviors relating to frames to be independent of personal risk characteristics.

Along with ***IT investment experience, investment risk*** became significant for the *large project with abandonment option*. The relationship was positive showing IT managers with greater experience in IT investments made more rational decisions and exercised the respective options, instead of showing respective risk seeking behavior based on frames. These results are intuitive and greater experience leads to more rational thinking for large projects (optimal option exercise), with possible negative outcomes. Significant ***investment risk*** indicates that personal investment risk behavior explained the abandonment option exercise decision. For *large project with abandonment option*, IT managers who were likely to take risk in their personal life in personal investments exercised the abandon option embedded in the project. They made the economically optimal and rational decision for the project instead of going for probable large uncertain losses. This result is counter to prospect theory, which specifies that risk behaviors relating to frames are independent of personal risk characteristics.

Framing effects in small project with growth option significantly contributed towards narrow framing in small interdependent projects portfolio (portfolio 2) (Table 3.27)**.** This result was not true for the 3SLS model without risk preferences. The relationship was positive, implying that personal risk preferences (both gambling and investment risk) contributed positively towards the framing of growth option in small project, which in turn affected the portfolio decision through more irrational decisions.

Table 3.27: Significant Variables - Portfolio Outcomes

Dependent Variables	Project 1 SSGO	Project 4 LSAO	IT Investments Experience	Gambling Risk	Investment Risk
Project 1 SSGO	n/a	n/a	.034* (1.11)	0.124*** (3.91)	0.053* (1.78)
Project 4 LSAO	n/a	n/a	.053** (2.07)	-	0.046* (1.69)
Portfolio 2 SSINT	1.276** (2.19)	n/a	n/a	n/a	n/a
Portfolio 3 LSIND	n/a	2.239** (2.05)	n/a	n/a	n/a

*** Significant at 1% significance level
** Significant at 5% significance level
* Significant at 10% significance level

SSGO = small scale project with growth option
LSAO= large scale project with abandonment option
SSINT= portfolio of small scale, interdependent project
LSIND= portfolio of large scale, independent project

IT investment experience and ***investment risk*** affected project portfolio decisions of large projects by affecting the *large project with an abandonment option*.

Both relationships were positive, implying that a) greater experience with IT investments lead respondents to take rational decisions, which in turn affected the portfolio decision through more rational decisions, and b) increased likelihood in taking risk in personal investments lead respondents to make rational decisions.

3.6.3 Theoretical Implications

We contribute to the understanding of IS literature on real options as well as IT portfolio management. Earlier literature has recognized the differences among real option values in general (Busby and Pitts, 1996; Miller and Shapira, 2004), as well as at the project selection stage based on the real option type embedded in the project (Tiwana et al., 2006). By using the framing and narrow framing literature as a theoretical lens, we provide a nuanced understanding of IT real option exercise decisions associated with project and portfolio characteristics. We illustrate different behaviors based on type of the option embedded in the project and size, which impacts the realized value from the real option. The framing of real options is carried forwarded from the project selection stage to the decision making stage (exercising of real option) which leads to different risk behaviors among the decision makers because growth options and abandonment options are subject to different types of risk behaviors. The difference in risk behaviors associated with real option types deviate IT managers from making a rational real option exercise decision.

Our findings about the existence of framing and narrow framing effects in IT project and portfolios provide insights for the consequences of the intuitive framing of the real options and their effects on real option exercise decisions. They also challenge the general perception of real options as adding to the portfolio value due to decision making flexibility. The selection of portfolios based on embedded real options is not productive if the real options embedded in them are not exercised optimally.

Factors that can help reduce the framing and narrow framing effects, such as project size, and simplification of portfolio decisions extend the understanding of decision theory in the context of IT. Narrow framing theory suggests that decision makers tend to make concurrent decisions in isolation, but the literature on IT portfolio management suggests that recognizing resource interdependency among IT projects improves its performance by enabling better management of resources (Keil and Robey, 1999; McCain, 1986; Northcraft and Neale, 1986). Our results indicate that the framing effects dominate concurrent evaluation of projects in portfolios, leading to the decision making in isolation.

Our findings about the increased framing effects in large projects and project portfolios enrich the IT project management literature. They illustrate the differences due to biases between the management of projects and portfolios of different sizes. Contrary to the Prospect Theory, we found intensified risk behaviors for larger projects and portfolios, where framing effects are milder closer to reference point (i.e. in small project and portfolio case) of decision making (Kahneman and Tversky, 1981).

The results on the role played by individual risk preferences of the decision maker in framing of projects and portfolios add to the understanding of decision theory. These results highlight the correlation of individual risk behavior of decision makers and their decisions for long term investments in IT. It also adds to the Prospect Theory by identifying an exception to the underlying assumption of independence between framing of decisions and individual risk behavior. Organizational behavior studies have established that Prospect Theory does not hold in completely in organizational decision making under uncertainty (Sullivan and Kida, 1995). Our results indicate the same, but in the context of investment decisions for IT.

3.6.4 Practical Implications

Real options are advocated as an effective way of exploiting the embedded flexibility in IT projects during their life cycle. Their value is realized only when they are exercised optimally (Kumar, 2002). Findings reflecting the reasons with the potential to hinder the realization of their value are important in order to exploit the benefits of this methodology. Our results improve the understanding of the biases that can affect the real options' realized value. The IT managers valuing the real options subjectively at the project selection stage pose a risk at the options' realized value, because subjective valuation may induce certain risk behaviors at the option exercise time, with the direct impact on option exercise decisions.

Our results add to the explanation for the determinants of over valuation of projects with growth options. Framing of growth options as gains, as well as the consequence of framing in the form of risk-averse behavior can cause the decision maker to take minimal risk by playing it safe, instead of valuing the option rationally in its face value. Similarly, for the option to abandon in large projects, framing of an option to abandon as a loss, as well as the consequence of framing in the form of risk seeking behavior causes the decision maker to take extreme risk by playing the odds, instead of valuing the option in its face value, rationally. Further, framing of real options in IT portfolios affects the IT portfolio management, by impacting portfolio outcomes directly due to isolation effect.

To overcome the framing and narrow framing effects, changes in organizational culture and procedures can help. Real options should be explicitly recognized and valued for projects from the start, their value should be tracked during the project life cycle, and commitment to exercising them when appropriate should be understood. Training in real option recognition and effects of framing is warned. Implementation of quantitative measures to track the implications of decision flexibilities is a must for large projects with real options and project portfolios. Understanding of the factors that can reduce narrow framing effects in IT portfolios like, project size and simplification of real options exercise decisions accounting for cumulative risk and return of the portfolio, instead on individual projects in the portfolio, can play a role in controlling these effects. Explicitly accounting for the interdependency among IT projects in a portfolio have shown to improve portfolio outcome (Keil and Robey, 1999; McCain, 1986; Northcraft and Neale, 1986). However, our results indicate that this trait does not reduce narrow framing effects in portfolios. Also, if the simplification of portfolio decisions does impact the narrow framing, then IT portfolio management practices aimed at implementing procedures to facilitate these decisions will be of great help. Last, but not the least, finding a connection between risky decisions and individual risk behavior of the decision makers highlights the importance of practitioners using caution while using the real options method for IT investment management. Managers' awareness about their risk behavior, the impact of individual risk behaviors on real options exercising decisions, and their experience with IT investments, may also help in controlling for the framing and narrow framing effect biases. However, there is a need for additional research to explore this relationship

3.6.5 Limitations to the Study and Next Steps

In this study, we studied only two types of real options that exist in IT investment scenarios, i.e., the real growth and real abandonment options. Several other real options exist in IT projects, including options to defer, switch use, scale and lease (Benaroch et al., 2002). Studying the framing and narrow framing effects for these real options is a valid extension to this study.

The outcomes for each real option used in our experiment were presented as either a pure gain (for growth option scenarios) or a pure loss (for abandonment option). The abandonment option scenarios we used are closer to the reality. However, IT growth options may not always represent a pure gain scenario. If the projects embed a growth option, there is always an uncertain cost element along with the uncertain benefits in these investments at the onset of the project commitment that cannot be ignored. Examples include infrastructure investments, ERP systems implementation, etc. Also, we created simple project portfolios to test for narrow framing. More complex portfolios exist in reality with varying degrees of interdependency among them. Studying the impact of varying interdependencies among projects on narrow faming is another reasonable extension to this study.

IT projects are usually sequential in nature and completion of one project is necessary to start new projects. We did find reference point shifts in portfolio scenarios, where project with growth option was presented before the project with abandonment option. It can be argued that one factor contributing to the reference point shifts was the order of project presentations. As we did not check for the effects of sequential interdependencies among projects in a portfolio, but this argument qualifies for another extension to this study. Finally, we did not take into account the dynamics of loss aversion explicitly. This evidence suggests that the degree of loss aversion depends on prior gains and losses: A loss that comes after prior gains is less painful than usual, because it is cushioned by those earlier gains. On the other hand, a loss that comes after other losses is more painful than usual. After being burned by the first loss, people become more sensitive to additional setbacks. This can explain the extent of risk seeking behavior in IT managers responsible for IT projects with embedded abandonment

CHAPTER 4: STUDY 2 – EFFECTS OF TIME-INCONSISTENT PREFERENCES ON INFORMATION TECHNOLOGY INFRASTRUCTURE INVESTMENTS WITH GROWTH OPTIONS

4.1 Introduction

Information technology (IT) investments are a collection of technological components and human skills that serve the needs of an organization. It provides a platform to facilitate large-scale connectivity, effective interoperation of an organization's IT applications and strategic alignment of IT (Colin and Dhaliwal, 2011; Kumar, 2004). They are complex endeavors which include decisions about large scale enterprise systems, networks, and databases (Gal et al., 2008). IT infrastructure investments have been under a spotlight due to their increasing importance. According to CIO magazine (2010), IT infrastructure spending was expected to grow 9.2% in 2010, which is above the 6.6% average of other IT products and services.

Investment in IT infrastructure may enable other projects and their completion along with the infrastructure itself may yield significant value (Dos Santos, 1991; Bardhan et al., 2004). For example, investment in software platforms such as operating systems, database systems, workflow/workgroup systems and application packages such as SAP R/3 or ORACLE, enable firms to realize value from their application systems (Taudes et al., 2000). Investment in a data architecture or telecommunications network may provide a firm with an opportunity to implement a new product differentiation strategy that employs these infrastructures (Kambil et al., 1993). Investment in web technologies provides the firm with numerous e-business opportunities and process automation (Bardhan et al., 2004). Investment in electronic banking services allows firms to deploy point-of-sale debit services (Benaroch and Kauffman, 1999, 2000). These examples illustrate how IT infrastructure projects have embedded “growth” options, where firms have a “right” but not an obligation to initiate future projects (Kambil et al., 1993; Taudes et al., 2000).

IT infrastructure investments contain options whose exercise brings forth further opportunities for investment as well as generating cash flows (Panayi and Trigeogis, 1998). Hence growth options enabled by IT infrastructure projects play a significant role in their economic justification. These investments are categorized as high risk due to their capital intensive nature, irreversibility and valuation difficulty[17] (Dos Santos, 1991; Kambil et al., 1993). Traditional financial metrics (Discounted Cash Flows, Net Present Value, Internal Rate of Return, and Return on Investment) have been shown to undervalue IT infrastructure projects because they ignore the value of the opportunity for managers to intervene during the project’s course (Taudes et al., 2000). Hence real options analysis is advocated because it takes into account the uncertainty involved in IT investments while considering managerial flexibility in decision making (Benaroch and Kauffman, 1999; Benaroch, 2002; Kumar, 2002; Tiwana et al. 2006).

The value of real options depends on the time of their exercise (Dos Santos, 1991; Kumar, 1999). IT literature assumes managers as rational economic agents who would exercise these options on time. This rationality assumption has several

[17] These characteristics are more prominent for IT infrastructures that are built and maintained in-house by the organizations than IT infrastructures that are outsourced, like IT-as-a-service for applications management and cloud computing for data management. In-house IT infrastructures provide firms with an opportunity to expand the use of these platforms via investing in new IT assets. In this study, our focus is the in-house IT infrastructures because they provide the firm with growth options.

implications. Economic agents maximize utility by eliminating any state of the world that yields the same outcome regardless of one's choice (cancellation), adhering to transitivity of preferences (transitivity), selecting the dominant option when one option is better than another in one state and at least as good in all other states (dominance), by showing same preferences in the face of different representations of the same choice problem (invariance), and by showing same preferences about the future plan at different points in time (time-consistent preferences) (Tversky and Kahneman, 1986). However, some IS literature provides evidence that managers may not possess all the above characteristics (Tiwana et al., 2006), and so does the literature on time-inconsistent preferences (Frederick et al., 2002). We therefore examine the implications of IT managers being bounded rational agents with time-inconsistent preferences, applying real options thinking in managing growth options.

This paper examines the relationship between managerial bias and time of option exercise. We focus on a growth option whose value depends on the option exercise time (Dos Santos, 1991; Kumar, 1996, 2002) and realization of option value depends on its optimal exercise. The economic literature suggests that people could have a bias for the present (Thaler, 1981; Loewenstein and Prelec, 1992), which in turn, could affect real options thinking. We explore the effects of time-inconsistent preferences on IT growth option exercise time and its realized value. Using a two time periods binomial model for option valuation, and utility model for inter-temporal preferences, we derive a closed-form expression for the critical value of the present-bias self-control parameter below which a manager will exercise the option too early. We provide insights on how present-bias interacts with option parameters and extend the analysis to more than two periods' option in a numerical experiment. The results indicate that present-bias impacts growth option value via sub optimal exercise timing. A manager with time-inconsistent preferences may fail to foresee that he will evaluate the payoffs differently in the future than today leading to suboptimal exercise time. Furthermore, a present-biased manager is more likely to exercise a growth option early when the project is performing well. Organizations aware of the present bias preferences of the managers can develop incentives geared towards minimizing the risks from early growth option exercise. Findings of this study may apply to other investments embedding real growth options such as manufacturing infrastructure and R&D.

The following section summarizes the relevant literature on real options in IT investments along with the literature on time-inconsistent preferences. Subsequently, a model of time-inconsistent preferences for growth options with two exercise periods is presented along with a numerical example and sensitivity analysis. A numerical experiment examining the problem with more than two exercise periods is then conducted. Finally, discussion and implications are presented.

4.2 Incentivizing IT Growth Options

There is extensive IS literature on IT infrastructure investments embedding growth options. Dos Santos (1991) justified investment in IT infrastructure projects by conceptualizing them as having embedded growth options. He used Margrabe's financial options framework (Margrabe, 1978) to justify the value of initial investment with optional future projects. Panayi and Trigeorgis (1998) valued IT investment projects in telecommunication infrastructure utilizing a growth options framework.

Taudes (1998) developed a general valuation model for IT software growth options in the context of embedded information systems (IS) functions in an IT platform. Benaroch and Kauffman (1999, 2000) used a traditional call option to evaluate the deployment of IT point-of-sale debit services as a growth opportunity. Hillhorst et al., (2008) proposed a method to select a preferred IT infrastructure from competing alternatives using Dempster-Shafer theory along with real options theory.

Although real options use is justified and advocated in IS literature, formal real options models are rarely used by managers in practice due to the complexity and difficulty in calculating the value of real options (Tiwana et al., 2007). Research has shown that even if managers are not aware of the method, or are not formally using it, their intuitions and decisions agree with the qualitative prescriptions of the framework most of the times. This phenomenon is referred to as real options thinking (Busby and Pitts, 1997) and is considered as an alternative to formal real options analysis (Fichman et al., 2005). Some studies have claimed that in the absence of explicit real options methods or training, managerial intuition typically responds in the correct direction to the factors that determine normative real options values (McDonald, 2000; McGrath, 1997; 1999; Miller and Shapira, 2004). According to this view, formal or heuristic real options analysis adds logical support and quantitative precision to managerial intuition but does not differ qualitatively from it. In case of IT investments, studies indicate that managerial intuition may not always conform to real options theories, due to managerial bias (Lankton and Luft, 2008; Tiwana et al., 2007). Incentives may be appropriate in order to foster real options thinking.

4.2.1 Real Options and Managerial Biases

While several models have been introduced for real options analysis of IT projects (Dos Santos, 1991; Kumar, 1999, 2002; Benaroch, 2002; Swartz and Zozaya-Gorostiza, 2003), firms continue to use intuition instead of the formal analyses to manage flexibility in the projects (Fichman et al., 2005; Lankton and Luft, 2008). Hence, investment decision making in IT projects remains a mix of formal real options analysis, and qualitative real options thinking, with conventional financial methods.

A stream of MIS literature exploring causes of managerial risk in investment decisions from a behavioral perspective has been growing. Table 4.1 highlights the major findings of some of these studies that view the divergence between real options thinking and real options analysis as a major cause of risk in IT project management.

Effective options thinking requires managers to recognize and enhance opportunities to create options within IT projects, value these options, and manage projects to fully extract this value (Fichman et al., 2005). The largest value of an option is realized when it is exercised at the optimal time (Kumar, 2002). Hence, exercising real options sub optimally (when it is worth waiting or when the optimal exercise time has passed) reduces their value. This behavior is most likely to occur when managers apply real options thinking. Prior research has examined factors consisting of personal characteristics of managers including preferences based on their attitude towards risk (Tiwana et al., 2006, 2007; Lankton and Luft, 2008) that result in real options thinking being different from real options analysis. For example, an option to abandon is less preferred by managers compared to an option to grow, switch and/ or scale (Tiwana et al., 2007). External factors such as market competition also affect managers' risk preferences (Lankton and Luft, 2008). Adding to this list, we build a case for present-biased managers, who may fail to realize the optimal value of the growth option by exercising it too early.

Table 4.1: Research Identifying Various Managerial Biases Affecting Real Options Thinking

Study	Findings	Explanation
Lankton and Luft (2008)	• As uncertainty increases, individuals judge deferral options as more valuable than growth options. • Competitor's presence decreases deferral option value while increasing growth option value.	Option-specific decisions are based on expected utility payoffs and anticipated regret, consistent with behavioral economic theories.
Tiwana et al., (2007)	• IT managers show bounded rationality bias in real option valuation for growth, scaling, switching and abandonment options. • For option to scale, managers value the flexibility to change scale irrespective of project NPV, unlike in the case of staging and deferral options.	Managers only search for more information to support the project when project's NPV is low. With high NPV they do not assess real options.
Tiwana et al., (2006)	• Managers correctly recognize and value real options in troubled IT projects. • Managers intuitively value growth options more than operational options (stage, scale, switch, defer and abandon).	Possible reasons for differences across option types include signaling effects, exercise difficulty, framing effects, and anti-failure bias.
Benaroch et al., (2006a)	• Managers follow options-based risk management mostly based on intuition. • Intuitive decisions lead to suboptimal or counterproductive practices.	Managers intuitively think of forms of flexibility (options thinking) as the level of risk rises.

4.3 Time-Inconsistent Preferences

Time-inconsistent preference refers to the preference for immediate utility over delayed utility (Fredrick et al., 2002). Experimental studies suggest that people have time-inconsistent preferences (Loewenstein and Prelec, 1992; Thaler, 1981). It means when two rewards are far away in time, people act relatively patiently (e.g., they prefer two apples in 101 days, rather than one apple in 100 days). However, when both rewards are brought forward in time, they act more impatiently (e.g., they prefer one apple today, rather than two apples tomorrow). Hence these individuals give greater weight to earlier reward as it gets closer. These time-inconsistent preferences are also known as “present-biased" preferences (O'Donoghue and Rabin, 1999a). We will use this term from here on.

From a theoretical perspective, Phelps and Pollak’s (1968) study is the first to analyze the dynamically inconsistent time-preferences. Later O’Donoghue and Rabin (1999a) proposed a utility model for a person’s inter-temporal preferences at time *t*, which captures the salience of the present over the future. These “present-biased” preferences are represented by a simple model referred to as “quasi-hyperbolic” or (β, δ)- preferences.

$$U^{\mathrm{t}}\,(u_t, u_{t+1}, \dots, u_T) \equiv \delta^t\; u_t + \;\beta \sum_{\tau=t+1}^{T} \delta^{\tau}\, u_{\tau}$$

With u_t as the instantaneous utility an individual receives at period *t*, the utility function U^{t} represents his intertemporal preferences at time *t*. In this model, parameter δ is a simple discount rate for future utilities, and β= (0,1] is a self control parameter, that represents a time-inconsistent preference for immediate gratification. For β=1, these preferences are time-consistent; but for β< 1 the individual has a bias for now over the future. In other words, as β decreases, people are more present-biased.

To better understand how these preferences address self-control problems, consider the following example similar to the one given by O’ Donoghue and Rabin

(2001). Suppose an IT manager can choose to invest in two technologies, *ipad2* in period *2* or *Samsung galaxy 10.1* in period *3*, but can't invest in both, due to scarcity of resources. If *Samsung galaxy 10.1*gives higher utility as a productivity tool (in terms of connectivity, backward integration with existing systems, etc.) than *ipad2*, these options yield the following instantaneous utilities (u_t):

ipad2 in period 2: $u_1 = 0$, $u_2 = 4$, and $u_3 = 0$.

Samsung galaxy 10.1 in period 3: $u_1 = 0$, $u_2 = 0$, and $u_3 = 6$.

The instantiations future utilities (u_2 and u_3) are lump-sum utilities for the respective time period (*t=2,3)* adjusted for time value of money that takes into account utilities from all future periods as well. An IT manager's utility, with self-control parameter β=1/2 (assuming δ=1) in period-1, will be $U_1 = max[\frac{1}{2}u_2, \frac{1}{2}u_3]$. Hence, the manager prefers to invest in *Samsung galaxy 10.1*, because it yields intertemporal utility of *(1/2)6 = 3* whereas investing in *ipad2* would yield intertemporal utility of *(1/2)4=2*. When period 2 arrives, the manager's preferences change to $U_2 = max[u_2, \frac{1}{2}u_3]$ and he now prefers to invest in *ipad2*, because doing so yields intertemporal utility of *4* whereas waiting to *Samsung galaxy 10.1* would yield intertemporal utility of *3*. Such impatience towards technological investments has been observed in organizations (CIO, 2011).

Several studies have utilized time-inconsistent preferences to study problems in different areas (Fredrick and Loewenstein 2002). Also, the use of quasi-hyperbolic discounting to conceptualize "present-biased" preferences of managers is seen in different fields as shown in Table 4.2. We integrated this basic model with real option model to evaluate the effect(s) of present-bias on growth option exercise decision.

The key to understanding present-bias preferences is to consider a person at each decision time period as a separate agent who maximizes utility with regards to his current preferences while his “future selves” will determine future behavior according to the preferences that prevail at that time (O’Donoghue and Rabin, 1999a). Therefore, a person’s belief about his future selves’ preferences becomes important, because evaluating future preferences differently does not mean that person has a bias for present. It is the self-awareness of the time-inconsistent preferences that plays a role, since an individual who is aware of his time inconsistency will anticipate their future choices and choose consequently (Caillaud and Jullien, 2000), as compared to the individuals who lack such awareness. There are four types of assumptions about individuals’ self-awareness, based on their actual self-control parameter β, and their perceptions about future self-control parameter $\hat{\beta}$ (O’Donahugh and Rabin, 2001). If the person believes that in the future he will encounter self-control problem, i.e. $\hat{\beta} < 1$, he will choose his current behavior to maximize his current preferences (determined by his true self-control parameter β). With this formulation, people with standard time-consistent (TC) preferences (do not have a bias for present and are fully aware of it) have $\hat{\beta} = \beta = 1$, sophisticates (have a bias for present and are aware of it) have $\hat{\beta} = \beta < 1$, naïves (have a bias for present but believe otherwise) have $\beta < \hat{\beta} = 1$, and partial naïves (have a bias for present and are partially aware of it) have $\beta < \hat{\beta} < 1$.

Table 4.2 : Literature on "Present-Biased" Preferences

Reference	Area	Problem Studied	Major Findings
O'Donoghue and Rabin (1999a)	Economics	How principals should design incentives to induce time-inconsistent agents to complete tasks efficiently	• Salient rewards can potentially be efficiency-enhancing as compared to punishment for delaying a task. Simple deadlines are better than simple rewards for completing a task early.
O'Donoghue and Rabin (1999b)	Economics	How timing of costs and rewards and agents sophistication affect present biasness	• Naïve people delay immediate cost activities and rush in immediate reward activities. • Sophistication mitigates putting off tasks, but aggravate rush behavior. • For immediate cost activities, a small present-bias can severely affect naïve decision makers. For immediate rewards activities, a small present-bias can severely affect only sophisticated people.
Laibson (1997)	Marketing	Decisions of a hyperbolic consumer who has access to an illiquid asset whose sale must be initiated one period before the sale proceeds are received	• Financial innovation may have caused the ongoing decline in US savings rates. • Financial market innovation may reduce welfare by providing "too much" liquidity.
Caillaud and Jullien (2000)	Economics	Implications of time-inconsistent preferences for individual behavior	• Time-inconsistency is characterized by a positive value of commitment. • A fundamental approach to the formalization of time-inconsistent preferences is to use an axiomatic approach based solely on revealed preferences.
Della Vinga and Malmendier (2004)	Economics	How do rational firms respond to consumer biases via contract design?	• Firms price investment goods below marginal cost and leisure goods above marginal cost. • For all goods firms introduce switching costs and charge back-loaded fees. • Contractual design targets consumer misperception of future consumption and underestimation of the renewal probability. • Time-inconsistency has adverse effects on naïve consumers' welfare.
Gilpatric (2008)	Management	Occurrence of shrinkage in contracts	• Present-biased preferences of employees, their naïveté about it, and employers' inability to penalize shrinkage, leads to shrinkage in contractual agreements. • Shrinkage can be reduced if employers allow some opportunity for employees to work less hard than they anticipate.
Gilpatric (2009)	Marketing	Occurrence of slippage in mail-in rebate programs	• Present-biased preferences of consumers and their naïveté lead to slippage in rebates. • Rebates are profitable once designed to exploit these preferences.
Brocas and Carrillo (2001)	Management	How the individual's time-inconsistent preferences affect their decision to invest in projects yielding either current costs and future benefits or current benefits and future costs?	• Competition between agents for the same project mitigates the tendency to procrastinate. Complementarity of projects aggravates the tendency to rush and to procrastinate and can decrease the expected welfare of each individual.
O'Donoghue and Rabin (2008)	Management	How time-inconsistent preferences impact projects with multiple stages?	• Naïve people might undertake costly effort to begin projects but never finish. • Procrastination is more likely when the costs of completing different stages are more unequal, and when later stages are more costly that people start but do not finish projects. • If the cost structure is endogenous, people are prone to choose cost structures that lead them to start but not finish projects.

We consider two cases of self-awareness of managers in making IT infrastructure investments, i.e. TC and naïve. We examine the effects of the actual self-control parameter β of the manager on the growth option exercise decision. TC with their actual self-control parameter β and their perceptions about future self-control parameter $\hat{\beta}$ both equal to 1 will provide one extreme case with no bias for present and as a benchmark for comparison. Naïves with their actual self-control parameter β less than 1 (showing bias for present) but their perceptions about future self-control parameter $\hat{\beta}$ equal to 1 showing their complete unawareness about their actual biased preferences will provide the other extreme case to capture the effects of present bias on growth option exercise decision. We do not consider sophisticates and partial naïves to keep the analysis simple, but they are a valid extension to this study. If the sophisticates and partial naïves are considered, then for those types, $\hat{\beta}$ is less than 1 and the analysis should reflect it. Also, TC and naïve cases are the most discussed ones in the literature (Fredrick and Loewenstein 2002).

As discussed before, in the IT real options framework, it is assumed that managers exercise real options on time. However, this may not be true in practice. Suppose a manger initially plans to exercise a growth option at a specific future time based on pre-determined criteria. Theoretically, the option exercise decision will be made at the pre-determined time if the criteria are met. However, there could be several cases where such options are exercised either too early or are allowed to expire (Coff and Laverty, 2007), resulting in compromised payoffs. Evidence of early commitment to premature technologies (Koghut and Kulatilaka, 1994) and early market entry with new technology (Kalish and Lilien, 1986) has been reported. Such actions of IT managers can possibly be attributed to present-bias.

It can be argued that incentives may dominate biases like effects of time-inconsistent preferences on growth option exercise decisions. This argument is situation specific. Situations can be found where incentives might not dominate time-preferences of IT managers. Time-inconsistent preferences have shown to affect entrepreneurial decisions (Brocas and Carrillo, 2001), contract designs (Gilpatric, 2008), and long term projects (O'Donohugh and Rabin, 1999b).

4.4 Time-Inconsistent Preference And Real Options On IT Assets

A standard option has two stages, commitment stage and option exercise stage (Hull, 2008). At the commitment stage, value of the asset underlying the option is evaluated based on future payoffs from the exercise decision, and costs involved in exercising the option. For example, investment in ERP systems or DSS systems has an option for competitive expansion by utilizing it to integrate the supply chain (Collins et al., 2010). In this scenario, the growth option is the opportunity for competitive expansion. Similarly, investment in secure network infrastructure has an option for office automation by mobilizing employees via cloud computing and equipping them with mobile devices, or for flexible decision support in dynamic inter-organizational networks (Collins et al., 2010). Hence to value these options, cost of implementing the ERP/ DSS system or communication network are the commitment costs for the projects and the growth options they provide, and costs involved in competitive expansion, office automation or strategic flexibility are the exercise prices of these options. The benefits from competitive expansion, office automation or strategic flexibility are the payoffs from exercising these options. To realize the value of these growth options, managers must decide whether to go for competitive expansion/office automation/strategic flexibility or not, when the necessary infrastructure is in place. This is known as exercise stage. The growth option exercise decision is made based on the current project progress and potential future payoffs (e.g. if ERP/DSS system implementation was successful, and supply chain members have the compatible technology enabling integration), and before the expiration of the option. Hence the option exercise stage is contingent to commitment stage (Dos Santos, 1991; Kumar, 1996, 2002), and realized option value depends on the exercise time.

In IS literature, real option analysis assumes managers are rational when making decisions. However, the economics literature argues that people could have a bias for the present (Thaler, 1981; Loewenstein and Prelec, 1992), and their lack of awareness about this bias leads to suboptimal choices. This, in our case, translates into the potential for IT managers exercising a growth option pre-maturely.

4.4.1 The Utility Function for Real Options

We assume an IT infrastructure project with significant startup cost, where benefits can only be realized once all the costs are incurred. Typically the project without growth options will be valued using the discounted cash flow (DCF) method as

$$\textit{Project value}^{\,DCF} = \pi - c \quad \text{with} \quad \pi = PV(\pi_i) = \sum_{i=1}^{T} \frac{\pi_i}{(1+r)^i} \qquad (4.1)$$

Where

i = a period index,

π= all the certain payoffs from the project,

c = all the costs incurred to execute the project,

r= risk free discount rate, and
T= life of project.

If $\pi > c$, the project is profitable. For IT infrastructure projects, most of the future payoffs/ benefits are uncertain, which makes it difficult to determine the true economic value of the project upfront, hence leading to difficulty in their economic justification. For such cases, if a project embeds a growth option, it will have additional value from the flexibility of future decision making (Benaroch, 2002, Trigeogris, 1993).

$$\text{Project value}^{RO} = \pi - c + \text{real growth option value}$$

Where *Project value* ^{RO} is the net strategic value of the project, which is equal to the difference between certain payoffs from the project and costs involved to execute the project ($\pi - c$), and the value of decision making flexibility.

To value growth options, we use a binomial option valuation method (Cox et al., 1979) due to its simplicity, its requirements for estimating fewer parameters, easy application to a single real option case, and its previous successful implementation in IT investments (Kambil et al., 1993; Benaroch, 2002; Dai et al., 2007). This method assumes that the underlying asset value (present value of future payoffs) follows a binomial multiplicative diffusion process. Starting at time $t_1 = 1$, the future payoffs value from the project may rise by factor u with probability p or fall by factor d with probability $1-p$, by the exercise decision time $t_2 = t_1 + \Delta t$. Hence, at the option exercise decision time in t_2, the expected value of the option payoffs will have only two possible variations. The IT manager will take into account these movements of the future payoffs from the growth option to evaluate the project's full value. The value of the real option, V, is calculated via backward induction by[18]:

$$V = \frac{p\max([0\ ,ub-f] + (1-p)\max[0,db-f]}{r} \quad \text{for} \quad n=1 \tag{4.2}$$

where

$u=e^{\sigma\sqrt{\Delta t}}$(expected upward movement in future benefits),

$d=1/u$ (expected downward movement in future benefits), $d < r < u$

r= risk free rate,

T = project life (option expiration time),

σ = uncertainty around future payoffs,

$p=\frac{(r-d)}{(u-d)}$; subjective probability of the event,

f= one time follow-up investment (to exercise the growth option), and

b= benefits realized after exercising the real option.

For a growth option with *n* periods until maturity, option value depends on the same parameters and becomes complex. As long as option value is greater than zero, *Project value*^{RO} will be greater than *Project value*^{DCF}. Also, since real option value is proportional to the underlying uncertainty around future benefits, value of a project with uncertainty will be higher once the embedded real option is taken into account. Hence, *Project value* ^{RO} > *Project value*^{DCF}, when $\sigma > 0$, which is in-line with findings in IS literature (Dos Santos, 1991, Kumar, 1996, Benaroch, 2002). We also assume $\Delta t = T/n = 1$ which is commonly done in the literature.

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[18] The Max function of payoffs in option value function has minimum value of zero, because the initial investment c is a part of the "Project Value" function consisting of certain benefits b, initial investment c and the real option value.

4.4.2 Time-inconsistent preferences and utility

The IT manager commits to the project and obtains the embedded growth option with it at time *t=1* with the expansion of the project in mind, i.e. by exercising the growth option if the condition $ub - f > 0$ holds at time $t = 2$. At time $t=2$, he will choose to exercise the option if $ub - f > 0$. At the commitment stage ($t=1$), β will be equal to 1 for TC managers[19] as well as for naïve managers[20] (naïves). Although naïves have a tendency of choosing present utility over future utility (with $\beta < 1$), they are unaware of their bias and think they will act in a time-consistent manner. Present-bias comes into play only when the rewards come near in the future (O'Donoghue and Rabin, 1999a, Caillaud and Jullien, 2000, Della Vinga and Malmendier, 2004). Hence both types of managers will evaluate and value the project equally. This correct evaluation for the project at the commitment stage by naïves also holds if the growth option has more than one exercise time period.

Proposition 1: *An IT manager with time-consistent (TC) preferences and an IT manager with time-inconsistent preferences (naïve) will value an IT project with embedded growth option more than an IT project without a growth option.*

Once committed to the project, the manager will decide about option exercise in the next period based on the evaluation of future payoffs at that time against the exercise price of the option. For a growth option with one time period to expire i.e. $n=1$ at $t=T=2$, the manager has to decide at $t=2$ whether to exercise the option or let it expire. He will exercise the option if $\beta ub > f$ else the option will not be exercised. At

[19] These managers awareness about their self-control ($\hat{\beta}$) and their actual self control (β) is equal to 1. Hence they do not have a bias for present.

[20] These managers awareness about their self-control ($\hat{\beta}$) mismatches their actual self control (β) such that $\beta < \hat{\beta} = 1$. Hence they have a bias for present but they believe that they don't.

t=2, β will still be equal to 1 for TC managers as well as the naïves because the payoff is immediate.

Proposition 2: *IT managers (both TC and naïve) will exercise a growth option with one time period to expiration optimally.*

Typically there is more than one opportunity to exercise an option. We depict this real option exercise decision for two points in time in Figure 4.1, where IT manager decides after evaluating his/her utility at each stage. Figure 4.1 describes the necessary parameters that determine the utility from exercising a growth option.

1

Real option commitment decision where utility is a function of real option value $U^t (V)$, which is a function of initial costs, future payoffs, follow-up investments, uncertainty around payoffs, risk free rate and optimal time to option expiration.
$V = g\,(c, b, f, t^*, \sigma, r)$

2

Real option exercise decision at *t=2*, where utility is equal to the intrinsic value of the option, and is a function of future payoffs, follow-up investments, uncertainty around payoffs, risk free rate and time to option expiration.
$U^2 = g(\,b, f, t_1, \sigma, r)$

3

Real option exercise decision at *t=3*, where utility is equal to the optimal value of the option, and is a function of future payoffs, follow-up investments, uncertainty around payoffs, risk free rate and time to option expiration.
$U^3 = g(\,b, f, t_2, \sigma, r)$

Figure 4.1: Timeline for real growth option with two time periods until expiration

Let $V_{i,j}$ be the value of the option determined in period i if it is exercised in period j. For example, $V_{1,2}$ is the value a manager has for the option in period 1 if the option is exercised in period 2. At the commitment stage, *t=1*, both TC and naïve will commit to the project as per Proposition 1 as long as project value is positive. Once committed to the project with growth option, the exercise decision will be based on how the project performs overtime. For a growth option with expiration time of two periods

(*T=3*), the manager has to decide at *t=2* whether to exercise the option today or wait until maturity *t=T=3*.

4.4.3 Two periods Growth Option

Real growth options are typically modeled as European options, especially in the IT context (Kumar, 1996, 2002; Benaroch et al., 2006a), which can only be exercised at expiration. However, real options often do not have a fixed exercise time (Benaroch, 2002) and can be exercised any time before expiration. For example, decisions such as an infrastructure investment in a software platform can usually be made any time until a cutoff date. Therefore, viewing a growth option as an American call option helps in capturing the option exercise flexibility.

A key property of an American call option on a non-dividend paying asset[21] is that it is never optimal to exercise it before expiration (Cox et al., 1979, Hull, 2008). We utilize this property and assume that a growth option is an American style call option on a non-dividend paying asset. This makes it optimal to exercise the option at the expiration date i.e. *t*=3* for a two period growth option. The real option value at the project commitment stage to be exercised at *t=3* is

$$V_{1,3}=\frac{(1-p)^2\text{Max}\left[0,d^2b-f\right]+2p(1-p)\text{Max}[0,(udb-f)]p^2\text{Max}\left[0,\left(u^2b-f\right)\right]}{r2} \tag{4.3}$$

As long as r is positive, $V_{i,j}$ will always be greater than zero. Practically there is no situation in IT investments where the discount rate is non-positive, hence we will not consider that case. We further make the following assumptions:

---

[21] A growth option in an IT infrastructure investment can be viewed as a call option on a non-dividend paying stock, because benefits from such investments are realized later in the future, over the period of time. This is consistent with the current IS literature (Benaroch, 2002; 2006b)

- Benefits from exercising the option (*b*) exceed the exercise cost (*f*), i.e. $b>f$.
- u is greater than risk free rate r and d is less than risk free rate r, i.e. $d<r<u$.
- Risk free rate, future payoffs, option exercise cost, and uncertainty around future payoffs are constant.

Bias for present comes into play when the rewards come near in the future (O'Donoghue and Rabin, 1999a, Caillaud and Jullien, 2000, Della Vinga and Malmendier, 2004) and per Proposition 1 both types of managers will value this project and growth option equally.

Proposition 3: *IT managers (both TC and naïve) will place the same value on an IT project with growth option with two time periods to expiration.*

At the first decision point $t=2$ the manager can exercise the option and realize immediate payoffs or wait until $t=3$. At $t=2$, a naïve manager will exhibit present-bias for immediate payoffs and may exercise the option. This will give the real option value evaluated in period 2 and to be exercised in period 3 as:

$$V_{2,3}=\frac{(1-p)^2\text{Max}[0,\beta d^2b-f]+2p(1-p)\text{Max}[0,(\beta udb-f)]p^2\text{Max}[0,(\beta u^2b-f)]}{r} \tag{4.4}$$

Since the benefits are immediate if the option is exercised at period 2, β in Equation (4.4) is less than 1 for naïve managers since those benefits are realized in $t=3$. For some value of β, the Max function(s) in Equation (4.4) will result in zero. As β will impact only the payoffs in next period, a naïve manager may see $V_{2,3} < V_{2,2}$ and will choose to exercise the option early, i.e. $t=2$. The utility from such decision at $t=2$ is

$$U_2 = \text{Max}(V_{2,2},\ V_{2,3}) \tag{4.5}$$

Hence the utility is the maximum value from exercising the growth option today or in the next period. If $V_{2,3} < V_{2,2}$, a naïve manager will choose to exercise the option early at *t=2*. Proposition 4 establishes the value of β for which a naïve manager will exercise the option suboptimally in period 2 instead of period 3. We refer to this value as the critical self-control parameter level and denote it by $\bar{\beta}$.

Proposition 4: *There is a* $\bar{\beta} = \frac{f(p+r-2)-bru}{bu(2d(p-1)-pu)}$ *, such that for IT projects with a growth option with two exercise periods:*

- *If* $\beta \leq \bar{\beta}$ *the manager will exercise the options suboptimally in period 2 instead of period 3.*
- *If* $\beta > \bar{\beta}$ *the manager will exercise the option optimally in period 3.*

As the expression in Proposition 4 shows, $\bar{\beta}$ is a function of *b, f, r,* and *σ*. A naïve IT manager with a self-control parameter less than or equal to $\bar{\beta}$ will exercise the growth option at *t=2* and realize the payoffs sooner than waiting until *t=3* to exercise the option and realize its optimal value.

Proof. See Appendix-C

4.5 Numerical Example and Sensitivity Analysis

To illustrate the effect of present-bias we use an example with the parameters shown in Table 4.3.

Table 4.3: Parameter values for growth option, Kambil et al., (1993)

Parameters	Values	$\bar{\beta}$	$V_{1,2}$	$V_{1,3}$ (for $\beta = 1$)
b	\$375,000	0.94	\$ 90,174	\$ 110,003
f	\$320,000			
σ	0.3			
r	1.05			

Without present-bias, $V_{1,3}$ is greater than $V_{1,2}$, and the optimal value for this growth option will be realized when it is exercised at maturity, i.e. *t=3*. For naïve IT manager, with β less than or equal to 0.94, he will exercise the option at *t=2* instead of at maturity as shown in Figure 4.2. The lost value due to early exercise is \$ 19,829. We conducted some numerical sensitivity analysis using the example to explore the relationship between $\bar{\beta}$ and the option parameters.

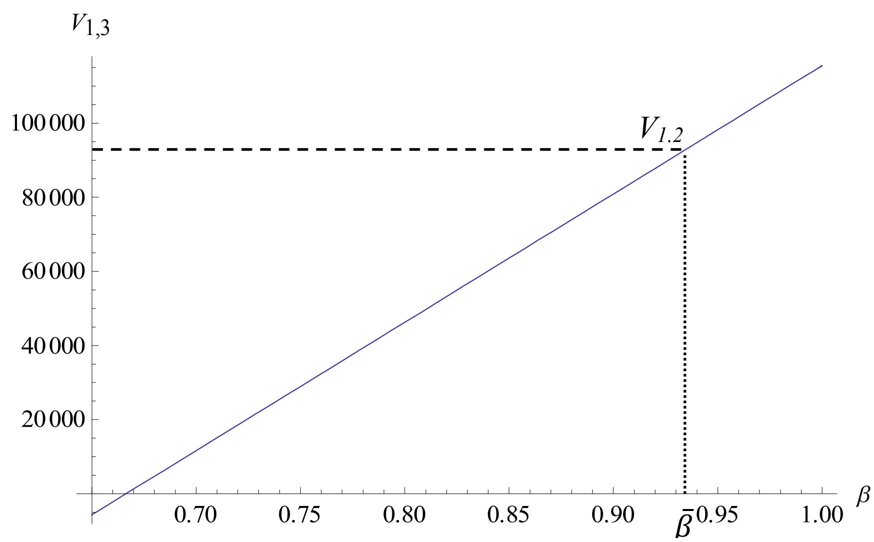

Figure 4.2: Sensitivity of Growth Option Value to β

For growth options, the overall risk is determined by the volatility of the investment σ. As shown in Figure 4.3, increase in volatility first has little effect on the option value until σ reaches 0.1. Above σ of 0.1, increase in volatility tends to increase option value, also known as the volatility smile (Hull, 2008). Figure 3 also shows $\bar{\beta}$ as a function of σ. As the figure shows, in the range of σ where volatility has little effect on option value, i.e. $0 < \sigma < 0.1$, $\bar{\beta}$ is small. For values of σ above 0.1, $\bar{\beta}$ is increasing in

σ. This relationship between $\bar{\beta}$ and σ is similar to the volatility smile. For $0 < \sigma < 0.1$, option value is relatively certain, and $\bar{\beta}$ is smaller. When IT managers know that the additional value they can realize by waiting is certain, they are more likely to wait. Hence under low volatility, a present-biased IT manager is less likely to exercise the option early. For $\sigma > 0.1$, the option value starts increasing at a fast rate but it is more uncertain, and, hence, present-biased IT managers are less likely to wait because of the uncertainty. This result is different than some of findings of empirical studies on growth options (Howell and Jagle, 1997; Lankton and Luft, 2008).

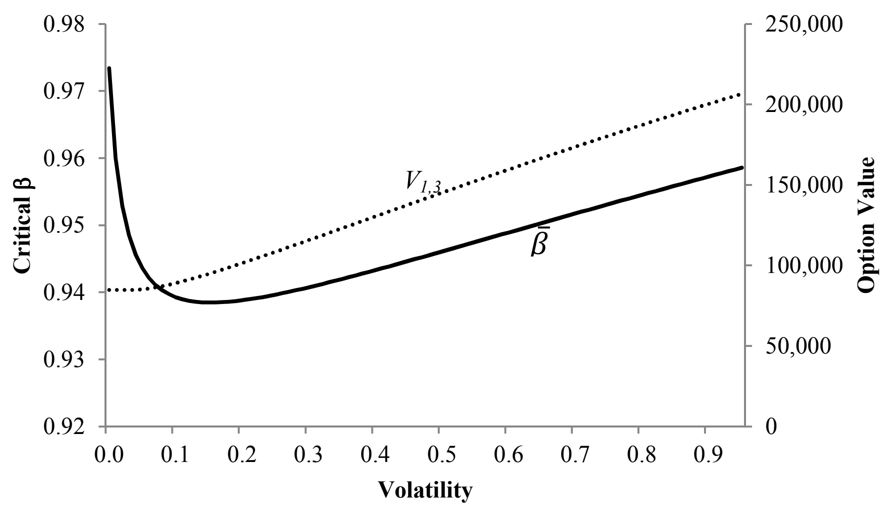

Figure 4.3: Sensitivity of Critical β and Option Value to the Volatility

We explore the sensitivity of $\bar{\beta}$ to the risk free rate in Figure 4.4 which shows that $\bar{\beta}$ is decreasing in the risk free rate *r*. Increase in the risk free rate increases the probability of an increase in the option value (i.e. due to the increase in $p=\frac{r-d}{u-d}$). This provides a higher incentive to wait to exercise the option. Therefore, IT managers will not exercise the option today and realize a lower value than they could realize if they wait until maturity. Hence, $\bar{\beta}$ decreases as the risk free rate increases.

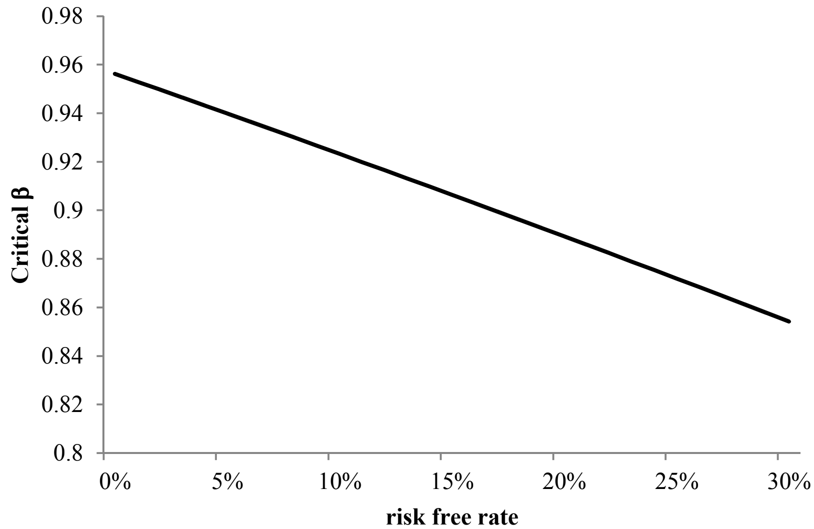

Figure 4.4: Sensitivity of Critical β to the risk-free discount rate

Real option value has an inverse relationship with the follow-up costs *f*. The sensitivity of $\bar{\beta}$ to *f* is shown in Figure 4.5. The figure shows that $\bar{\beta}$ increases with *f* which implies that for higher values of growth option exercise price, present-bias is more likely to cause early exercise. As follow-up cost increases, growth option value will decrease, which makes it more attractive to exercise early since waiting is of little additional value which is offset by present biasness.

Higher future payoffs increase the option value. We explore the sensitivity of $\bar{\beta}$ to values of future payoffs *b* in Figure 4.6 which shows that $\bar{\beta}$ is decreasing in *b*. For higher values of *payoffs* from exercising a growth option, it is less likely that managers will exercise it early. As future payoffs increase, the growth option value will increase and it is more attractive to wait for the high payoffs.

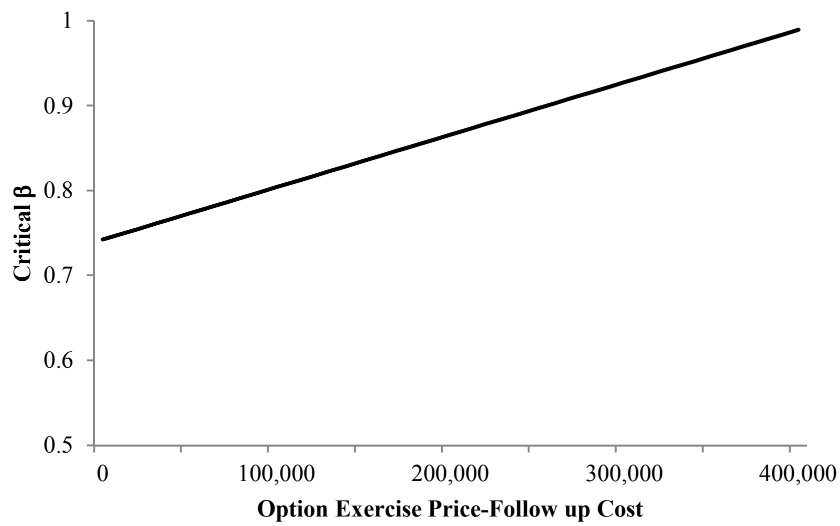

Figure 4.5: Sensitivity of Critical β to the follow-up cost

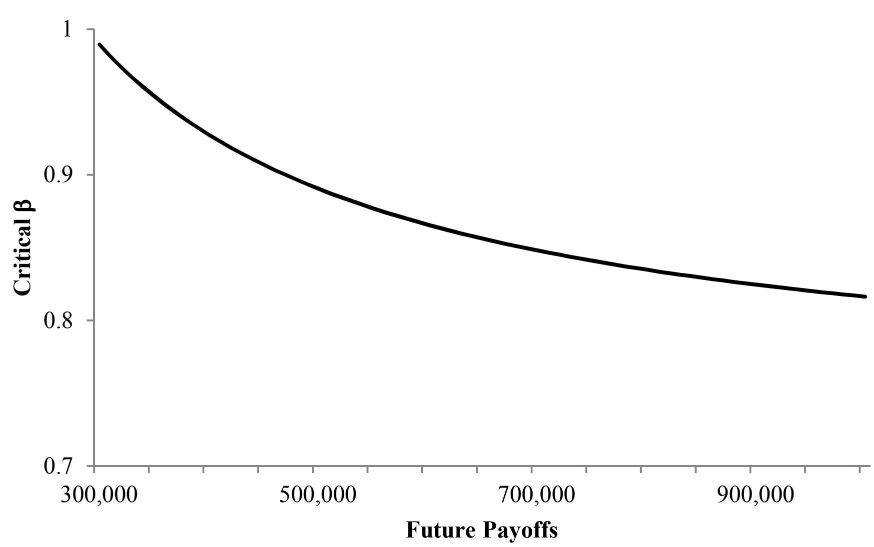

Figure 4.6: Sensitivity of Critical β to the future payoffs

The results of the sensitivity analysis above can be confirmed for zero risk free rate, i.e. $r = 1$, for which the following expressions can be obtained:

$$\frac{\partial\bar{\beta}}{\partial\sigma} = \frac{e^{\sigma}(b-f)}{b(e^{\sigma}+2)^2}; \qquad \frac{\partial\bar{\beta}}{\partial f} = \frac{1}{be^{\sigma}+2b}; \qquad \frac{\partial\bar{\beta}}{\partial b} = -\frac{f}{b^2(e^{\sigma}+2)}$$

These expressions support our numerical sensitivity analysis. The directions and the forms of the relationships hold for each case. $\bar{\beta}$ increases with increases in volatility and future payoffs and decreases with an increase in follow-up costs. Also, $\bar{\beta}$ has a non-linear relationship with volatility and future payoffs whereas it has a linear relationship with follow-up costs.

We further analyze the effects of present-bias on growth options with more than two exercise periods. We kept all the parameters same except for *f = $345,000,* and five time periods, *n=5*, to exercise the option and obtained the values of $\bar{\beta}$. At each option exercise time *t=2,3,4,5 (t=1* is the project commitment stage), the manager evaluates his utility from exercising the option at *t,* or waiting until the optimal exercise time *t= 6*. Using the binomial option valuation method, we solved $V_{t,t} = V_{t,6}$, *t=2,3,4,5* for β. This allowed us to obtain $\bar{\beta}_t$ for *t=2,3,4,5* which is the value of present-bias parameter below which a manager will exercise the option in period *t<6* instead of *6.* Table 4.4 gives the $\bar{\beta}_t$ values, along with cost of early exercise for each period. For a manager with $\beta \leq$ 0.816, he will opt for exercising at *t=2*, given the project perform well over this period (an upward movement in payoffs). If the project did not perform well, he will not exercise the option since the realized value is negative. For a manager with 0.816≤ β ≤0.885, he will wait for one period and exercise the option at *t=3,* given the project keeps performing well (i.e. two upward movements). In case the project does not perform well in $t=3$ (a downward movement in payoffs), he will wait to exercise. This is shown by a value of $\beta = 0.517$ which is smaller than $\beta = 0.816$ and the manager would have exercised the option at $t=2$ already. Similar results hold for $t=4$. For a manager with $0.885 \leq \beta \leq 0.909$, he will exercise the option at $t=4$, given the project keeps performing well (i.e. three upward movements). Figure 4.7 shows the relationship between $\bar{\beta}_t$ for $t=2,3,4$ and cost of early exercise when project is performing well throughout (only upward movements). In case the project does not perform well in $t=4$, the manager will wait to exercise. At $t=5$, a naïve manager will not exercise the growth option at this point and will wait until maturity.

Table 4.4: Critical β for each time period on the growth option horizon of n=5, along with cost of early exercise

Exercise time	Project Progress[22]	$\bar{\beta}_t$	Exercise Decision	Cost of early exercise
$t=2$	upward	0.816	If $\beta \leq 0.816$	\$71,453.50
$t=3$	$(\text{upward})^2$	0.885	If $0.816 \leq \beta \leq 0.885$	\$56,717.50
	(upward)(downward)	0.517	At maturity	None
$t=4$	$(\text{upward})^3$	0.909	If $0.885 \leq \beta \leq 0.909$	\$31,076
	$(\text{upward})^2(\text{downward})$	0.504	At maturity	None
	$(\text{upward})(\text{downward})^2$	0.504	At maturity	None
$t=5$	All	>1	At maturity	None

[22] "upward" means single upward movement in the value of asset i.e. potential payoffs from the project, and "downward" means single downward movement in the value of asset i.e. potential payoffs from the project.

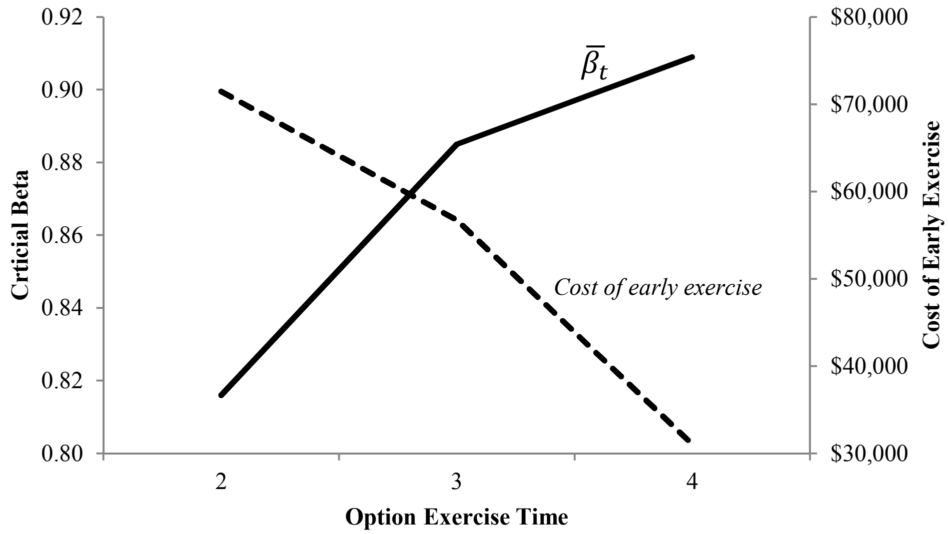

Figure 4.7: Critical β and Cost of Early Exercise with Upward Project Progress

We further analyzed the effects of σ, r and b, on $\bar{\beta}_t$. A 3x3x3 experiment was run with $\sigma = \{0.3, 0.6, 0.9\}$, $r = \{5\%, 10\%, 15\%\}$ and $b = \{165{,}000, 180{,}000, 195{,}000\}$ for an option with five time periods to exercise, $n=5$. We kept f = \$150,000 since it is realistic to assume the option will not be exercised if the project did not perform well in $t=2$ (the first movement is downward). The range of b values was selected to ensure equal chance of negative feedback during the course of the project along with positive feedback. We then averaged the $\bar{\beta}_t$ values across each parameter as shown in Table 4.5. As shown, the direction of the relationship between $\bar{\beta}_2$ and σ (decreasing then increasing), $\bar{\beta}_2$ and r (decreasing), $\bar{\beta}_2$ and b (increasing) observed for the two-period option also hold here. The values of $\bar{\beta}_t$ for any period with a down movement (not shown) were smaller than values of $\bar{\beta}_t$ in prior periods where the project performed well. Therefore, there is small likelihood that the option will be exercised in periods with down movement (when project did not perform well). This can be explained by the fact that a downward movement decreases the present value of the option and makes even present-biased managers less likely to exercise it in that period. Also, Table 4.5 shows that the threshold for $\bar{\beta}_t$ is largest (i.e. strong present-bias is needed for early exercise) for options in which payoff is high, volatility is high, and the discount rate is low. For these options, a present-biased manager is encouraged to be patient due to the large reward. Potential reward may even get larger because of the high volatility, and the low eroding power small discount rate has on future payoffs.

Table 4.5: Average critical β needed to exercise the option in the first three periods with three upward movements

σ	$\bar{\beta}_2$ needed to exercise in *t=2*	$\bar{\beta}_3$ needed to exercise in *t=3*	$\bar{\beta}_4$ needed to exercise in *t=4*
0.3	0.810	0.914	0.925
0.6	0.805	0.903	0.871
0.9	0.817	0.898	0.852
r			
0.05	0.815	0.850	0.704
0.10	0.809	0.899	0.944
0.15	0.808	0.966	1.000
b - f			
$15,000	0.789	0.911	0.922
$30,000	0.818	0.901	0.884
$45,000	0.825	0.904	0.842

4.6 Discussion

Growth options help in IT infrastructure investments' economic justification. They also facilitate the realization of IT infrastructure investments' strategic value by providing a platform to manage IT tools that impact firms' productivity. For the best utilization of these investments, it is important to make optimal exercise decisions for growth options embedded in them. There is a chance of suboptimal exercise decisions motivated by a manager's desire to realize the benefits sooner. This suboptimal exercise time may even lead to the whole project having a negative value. Such occurrences are related to some previous findings in the literature. For example, it has been shown that the existence of complementarity among projects aggravates the tendency to rush (Brocas and Carrilo, 2001). Growth options can be considered complimentary projects to infrastructure investments. This complementarity could accentuate present-bias of IT managers in exercising growth options.

We examined two distinct cases of self-awareness among IT managers about their time-preferences, TC and naïve. Our results indicate that at the commitment stage, IT project with growth option is valued equally irrespective of time-preferences of the manager. This result is consistent with the real options analysis literature (Tiwana et al., 2006).

Present-bias preferences affect the growth option exercise decisions when the real option allows the IT manager multiple exercise decision time periods during project's life. Having multiple exercise decision time periods is likely in IT infrastructure projects (Kumar, 2004). Also, infrastructure components are sequentially dependent on each other and need to be carefully coordinated. For example, implementation of new system integrators, upgrading software platforms, expanding network platforms etc., are the decisions that can be taken within a specific time period. IT managers with present-bias preferences may exercise these growth options early due to preferring immediate payoffs and their unawareness of such preferences. Business environment may impact the IT manager's time-preferences as well. In situations like economic recession or market competition, where preference for immediate utility from IT utilization may lead IT managers to make decisions and waiting to invest does not seem feasible (even if it is so). Also if the strategic importance of a technology is high to the firm, it might impact IT managers' decisions about investment by affecting their time-preferences due to stake holder's pressure and to keep the firm competitive.

We found that higher values of *payoffs* from exercising growth option decrease the likelihood that the manager will exercise the option early. Also, for higher values of growth option exercise price, present-bias was found to more likely cause early exercise of the option. These findings are counter-intuitive. Naïves are supposed to delay immediate cost activities and rush into immediate reward, where for immediate cost activities; a small present-bias can severely affect naïve decision makers (O'Donoghue and Rabin, 1999b). Higher payoffs increase option value and higher exercise costs decrease the option value. Accordingly, IT managers should be tempted to realize the value sooner than later when payoffs are high and should not rush the exercise decisions when costs involved are high. Our results point in the opposite direction. Large net payoffs (high payoffs and low follow-up costs) decrease $\bar{\beta}$ and require the manager to have more present-bias to exercise the option early. One may view this as higher net payoffs tempt the manager to wait while lower net payoffs provide the manager with little incremental value from waiting which are easily discounted by his/her present-bias. This is particularly true when the discount rate is high.

Our experiment demonstrates the importance of project's progress on its vulnerability to early exercise. Projects progressing well overtime are most vulnerable to early exercise by naïve managers. Such projects could have large immediate payoffs and therefore be vulnerable to present-biasness which penalizes future payoffs. This, in turn, results in unrealized project value due to premature exercise.

4.6.1 Managerial Implications

Managers with present-bias may exercise growth options early. Hence, it is not enough for managers to recognize growth options in a project and intuitively evaluate their value (options thinking). They need to conduct formal option analysis; to be aware of their time-preferences over time; to reevaluate payoffs, costs, and parameters compared with previous period's estimates. Furthermore, the organization should have incentives in place to mitigate the effects of present-bias. Understanding the effects of time inconsistent preferences may help in designing better incentives. For example, consider two scenarios. One with no managerial incentives and the other with incentives for periods $t=2,3$. The incentive amount depends on when the growth option is exercised i.e. either at $t=2$ or at maturity. Let U_t be the instantaneous utility a manager gets in period t from incentives given in that period. For the scenario with no incentives, the manager will have zero utility from incentives. For the incentives scenario, the utility of the manager from incentives in period 2 is

$$U_2\ (u_2, u_3) \equiv\ Max\ [u_2, \beta u_3]$$

Suppose the incentive amount is a certain fraction "v" of the payoff from exercising the growth option "b_t" at time t. Hence the utility from an incentive at time t, u_t will be $u_t = vb_t$; whereas future incentives are discounted by β.

With the above equation, for a two time period option, the incentives evaluated in period 2 are $u_2 = vb_2$; $u_3 = \beta \frac{vb_3}{1+r}$. This incentive will motivate the manager to wait until $t=3$ to exercise the growth option if $vb_2 \leq \beta \frac{vb_3}{1+r}$ or $b_3 \geq \frac{(1+r)b_2}{\beta}$. If this condition does not hold, then offering an incentive scheme in which the manager receives a fraction of v_2 from payoffs if the option is exercised in period 2 or a fraction of v_3 from payoffs if the option is exercised in period 3 can be used. As long as $\frac{v_3}{v_2} > \frac{b_2(1+r)}{\beta\, b_3}$, it is utility maximizing for the manager to wait until period 3. This result is in agreement with the convexity of managerial incentives to overcome risk-averse behavior of decision makers (Coles et al., 2006).

Changes to IT governance may help mitigate the effects of present-bias. IT governance procedures will benefit from requiring formal analytical methods to valuate investment decisions. This analysis must rely on inputs from multiple managers and must have a post-project evaluation of performance to identify any existing biases. Incorporating healthy competition with IT governance can hence help control the effects of these biases as well (Brocas and Carrilo, 2001).

Another important implication for IT governance and for managing IT projects is the choice of methods and procedures for controlling risks, especially in IT infrastructure investments. Since there is a risk that a present-biased manager will exercise an option early, especially if the project is performing well, using a systematic and objective method to update estimates needed for option evaluation is important to reduce risk. A possible way for achieving that is to conduct a “net change” evaluation at each option exercise period. This implies that the evaluation begins with the estimates of option parameters, costs, and payoffs used in the previous period and changes are only made when justifications are provided based on new information. Following such approach would limit the creep of present biasness.

4.6.2 Limitations and Future Steps

We have focused on growth options. Growth options are call-like options that are strategic in nature. Our analysis might apply to other operational call-like options such as options to defer investment, scale and switch use, but understanding the exact effects of present bias warrants further investigation. Time-inconsistent preferences may also impact put-like real options such as abandonment option. For abandonment options, the effects of present bias on exercise timing might be different from growth options because abandonment options are geared towards loss minimization in the project instead of profit maximization. Also, the effects may vary depending on the salvage value of the project, ability to put the project to another use and timing of payoffs from this switch in use.

Analyzing the effects of present-bias on these options will give useful insights. It also might explain problems like escalation of commitment in IT projects. Also, we used a discrete time valuation model. Comparison among different real option valuation methods can provide better understanding of the effects of present-bias on option exercise time and realized value.

We have focused on one project with one embedded growth option. Real options may appear in compound form in IT infrastructure projects (Bradhan et al., 2004; Benaroch et al., 2006b), where exercise decision of one real option may lead to enabling further real options in the project. For example, exercising a growth option on an internet platform by a utility firm may enable electronic application and billing for customers. Analytical exploration of the impact of present-bias in such compound options where sequential interdependency exists will give insights into the long term impacts of such decisions, in terms of timing and realized value. Also, we focused on in-house IT infrastructures. Future studies can analytically explore the impact of present-bias effects on options underlying outsourced IT infrastructures with embedded real option.

CHAPTER 5: STUDY 3 – EFFECTS OF TIME-INCONSISTENT PREFERENCES ON INFORMATION TECHNOLOGY INVESTMENTS WITH ABANDONMENT OPTIONS

5.1 Introduction

Escalation of commitment to a failing course of action is studied in great detail in IS literature (Keil et al., 1995; Keil and Monte, 2000). In this stream of research, IS managers are shown to get vested in the bad performing projects while keeping on investing resources into them instead of terminating them. Several factors have been identified that lead to escalation of commitment such as, sunk cost effect, project completion effect, presence and absence of alternate courses of action etc. (Keil et al., 1995). If we look at the phenomenon of escalation of commitment in failing projects from the real option's perspective, it may be failing to exercise the option to abandon in an IS project that may or may not have been identified before committing to the project. Along with escalation of commitment, real option to abandon has also been studied as a management practice in IS project management, with the factors leading up to abandonment (Ewusi-Mensah and Przasnuski, 1991), and the perceived repercussions of this practice.

One school of thought explains that the presence of flexibility in abandonment option exercise time in projects leads to delay in their exercise (Adner and Levinthal, 2004), hence leading to escalation of commitment. Another school of thought argues that the flexibility in exercise time increases the abandonment option value. In the presence of option to abandon in a project with less flexibility in exercising time, managers may use it as an excuse to decide on terminating a project earlier than it should be, and using the real option in justifying their action (Zardkoohi, 2004). The value of a real option is time sensitive, where it's realized value depends on the time of its exercise (Dos Santos, 1991; Kumar, 1999). These schools of thought are implying that the realized value of an option to abandon is affected by its exercise time. Also, these findings cannot be generalized as IT projects are heterogeneous in terms of scale, size, strategic importance etc., and the impact of flexibility might vary among these factors. We focus on the abandonment options with flexibility in exercise time and see how time inconsistent preferences impact their exercise time and realized value.

As described in Chapter 4, we find evidence in IS literature that managers may not be rational in their decision making (Tiwana et al., 2006).We examine the implications of IT managers being bounded rational agents with time-inconsistent preferences, who apply real options thinking in managing options to abandon. We examine the relationship between managerial bias and time of abandoning IT projects. We focus on option to abandon whose value depends on the option exercise time (Dos Santos, 1991; Kumar, 1996, 2002) and the realization of option value depends on its optimal exercise. Based on the economic literature which suggests that people could have a bias for the present (Thaler, 1981; Loewenstein and Prelec, 1992), we argue that this, in turn, could affect IT projects' abandonment decisions. We explore the effects of time-inconsistent preferences on IT option to abandon exercise time and its realized value.

The following section motivates this study. Subsequently, a model of time-inconsistent preferences for option to abandon projects with two exercise periods is presented along with a numerical example and sensitivity analysis. We also present a model of time-inconsistent preferences for option to abandon projects with decreasing salvage value over time. Finally, we discuss the similarities and differences between the impacts of time-inconsistent preferences on real options of different type.

5.2 Incentivizing Real Abandonment Option in IT

An IS project can have an embedded option to abandon, where it can be terminated before its completion. For example, IT application that have lost its value for the organization (Weil and Vitale, 1999), lease contracts that have lost value, technological changes making the current project outdated etc. Abandonment option value comes from its ability to minimize losses by preventing further investment in a nonproductive project, once exercised. Option to abandon is like a financial put option[23], where the goal is to minimize losses instead of maximizing payoffs. It works like insurance on the project for downside protection. An option to abandon a project is like an American put option that can be exercised anytime during the life of the project before its completion in exchange for the salvage value of the project or value in its best alternative use. Also, it may be optimal to exercise an option to abandon early, if the option is sufficiently deep in the money and continuing the project would incur further losses or alternate use of resources would generate profits etc.

Technically every project has an option to abandon. Based on project reviews, if conditions are unfavorable, the project can be terminated before completion. In practice,

---

[23] A put option gives its buyer a right to sell the underlying asset at a pre-determined price. Hence it covers the underlying asset position against unfavorable fluctuations in its value (Benaroch, 2002).

it is not feasible to abandon every project, due to several reasons. For example, contractual agreements not allowing terminating projects, political implications, temporary economic conditions, strategic importance of the project, maximum upfront resource allocation, etc. Under these circumstances, it is hard to argue a case for abandoning a project mid-way, solely based on performance.

In IS literature, abandonment option is sometimes associated with a switch-use option (Benaroch, 2002; Tiwana et al., 2006, 2007), where abandonment options become more valuable if the resources from the abandoned project can be salvaged by putting to another use e.g., using website for internal organizational communication when it was originally intended for e-commerce. Such an action is also known as substantial abandonment (Ewusi-Mensah and Przasnyski, 1991), where a project is made radically different from the original specification before its implementation and the value is generated by minimizing losses on the overall investment through reducing resource waste and redirecting resources to generate some benefit. This is possible for projects when, most of the costs are not incurred upfront, project is not bound by contracts (and can be terminated before completion), the resources are usable somewhere else (also known as high interaction effects), and when competitors' reactions are strong to the project (Kim and Sandars 2002). In either complete abandonment or switch use case, the objective is to control the damages, by exercising the option on time.

Similar to a standard option, an option to abandon has two stages, i.e. commitment stage and option exercise stage (Hull, 2008). At the commitment stage, value of the asset underlying the option is evaluated based on the payoffs from the exercise decision, and costs involved in exercising the option. For example, investment in a new and risky software project has an option of terminating it if the project loses its value before completion. In this case, the option to abandon is the opportunity for minimizing losses by not investing in the project further, and putting the project to another use to generate alternate stream of income or selling the partially complete project for some amount. In valuing an option to abandon, the costs at the commitment stage include the cost of starting up the project, adjusted for the hedge option to abandon the project provides. At the option exercise stage, the costs involved in terminating the project before completion is the exercise price, e.g., given up payoffs from continuing the project. The benefits from terminating the project prematurely resulting into savings, alternate stream of income via putting project resources to another use or selling the partially complete project for some amount, are the payoffs from exercising the option. We refer to them as the project's salvage value.

For real assets like a manufacturing plant, it is relatively easy to exercise the option to abandon if the project is deep in the money because the salvage value of the asset is deterministic. In case of IS, exercising option to abandon is not as simple. One of the reasons is that IS projects seldom have substantial positive salvage value (Ewusi-Mensah and Przasnuski, 1991), especially when project has not progressed much. Under these circumstances, the value of the option to abandon increases if there is a possibility of switching use of the resources (Keil et al., 1995).

To realize the value of an option to abandon, managers must decide whether to go for terminating the project prematurely or not, given the project's progress. This is known as exercising decision. The exercise decision of an option to abandon a project is made based on the current project progress, potential future payoffs if project is not terminated, salvage value of the project if the project is terminated before the expiration of the option. Hence the option exercise stage is contingent to the commitment stage (Dos Santos, 1991; Kumar, 1996, 2002), and realized option value depends on the exercise decision and time of exercise.

Empirical evidence shows that option to abandon is least valued by the managers in terms of valuation as well as exercising (Ewusi-Mensah and Przasnuski, 1991; Tiwana et al., 2006), hence leading them either not to commit to projects with such options or not exercising the option even when it is appropriate to do so (Busby and Pitts, 1997; Miller and Shapira, 2004; Tiwana et al., 2006). Several reasons for this behavior have been identified, including political implications of cancellation of the project, personal reputation of managers, negative impact on staff morale, etc. (Ewusi-Mensah and Przasnuski, 1991; Keil et al., 2000).

As discussed before, in the IT real options framework, it is assumed that managers exercise real options on time. However, this may not be true in practice. Suppose a manger initially plans to exercise an option to abandon project at a specific future time based on pre-determined criteria. Theoretically, the option exercise decision will be made at the pre-determined time if the criteria are met. However, cases of IS projects where exercising the option to abandon was difficult have been reported in the literature. It included Denver's International Airport baggage system (Keil and Montealegre, 2000) and London's Taurus stock exchange project (Drummond, 1996). In these cases, the size and scale of the project have been shown to play a major role in the difficulty in exercising option to abandon along with other factors like managers' reputation, the political ramifications of abandoning, and the possible effect of abandonment on staff morale (Keil, Mann, and Rai, 2000). We argue that such actions of IT managers can possibly be attributed to their time inconsistent preferences.

5.3 Valuing Option to Abandon

For this study, we assume a simple IT project scenario, with some startup cost, and periodic operational costs over time. The benefits from the project can only be realized once all the initial estimated costs are incurred. To value option to abandon, we use a binomial option valuation method (Cox et al., 1979) due to its simplicity, its requirements for estimating fewer parameters, easy application to a single real option case, and its previous successful implementation in IT investments (Kambil et al., 1993; Benaroch, 2002; Dai et al., 2007). Although MIS literature focuses more on call options with its successful implementation in IT investments (Kambil et al., 1993; Benaroch, 2002; Dai et al., 2007), we extend the same reasoning for the use of this approach for valuing option to abandon, while making some necessary modifications.

The binomial option valuation method assumes that the underlying asset value follows a binomial multiplicative diffusion process. For a project with one period to exercise the option, starting at time $t_1 = 1$, the future payoffs value from the project may rise by factor u with probability p or fall by factor d with probability $1-p$, by the exercise decision time $t_2 = t_1 + \Delta t$. Hence, at the option exercise decision time in t_2, the expected value of the option payoffs will have only two possible variations. The IT manager will take into account these movements of the future payoffs from the project to evaluate the project's full value. The value of the real option, V, is calculated via backward induction by:

$$V = \frac{p\max([0\ ,s-ub]+(1-p)\max[0,s-db]}{r} \text{ for } n=1 \quad (5.1)$$

where

u=$e^{\sigma\sqrt{\Delta t}}$(expected upward movement in future benefits),

$d=1/u$ (expected downward movement in future benefits), $d < r < u$

r= risk free rate,

T = project life (option expiration time),

σ = uncertainty around future payoffs,

p=$\frac{(r-d)}{(u-d)}$; subjective probability of the event,

b= present value of the future benefits from the ongoing project, and

s= salvage value of the project (may include present value of the implementation/ operating costs of the project, benefits from switching use of the invested resources, benefits from the partial implementation of the project, and selling price of the project equipment).

For an abandonment option with n periods until maturity, option value depends on the same parameters and is more complex. As long as option value is greater than zero, the project value with an option to abandon will be greater than the project value without an option to abandon. Also, since real option value is proportional to the underlying uncertainty around future benefits, value of a project with uncertainty will be higher once the embedded real option is taken into account. Hence, the project value with an option to abandon will be greater than the project value without an option to abandon, when σ> 0, which is in-line with the findings in IS literature (Dos Santos, 1991, Kumar, 1996, Benaroch, 2002). We also assume$\Delta t = T/n = 1$.

5.3.1 Salvage Value

In IT projects, salvage value varies in terms of amount, certainty and time of realization. Some projects have tangible salvage value like network infrastructure projects, where salvage value can be realized after they are sold. But some projects do not have substantial and certain salvage value e.g. customized online billing system. Salvage value may also be a function of time, where it may increase (for example projects for which additional features can added in the future, hence increasing its value), decrease (for example hardware value depreciates over time due to rapid technological changes), or stay constant as a project progresses. In any case, the salvage value of the project as well as the uncertainty around the salvage value play an important role in determining the value at the option exercise time. The source of salvage value in an IT project may be from value generated by switching the use of resources, partial implementation of the project, savings on future operating costs, or present value of selling price of resources. Hence, salvage value from these sources can either be stochastic or deterministic. Some examples are given in Table 5.1. For each case, in Table 5.1, the salvage value or "exercise price" of option to abandon, will differ which will affect the abandonment option value at the exercise time. Under these circumstances, the option exercise decision for a naïve manager will be different, due to the value certainty of the salvage value of the project. To account for the dependency of salvage value on time, we assume salvage value *"s"* as a function of time and certainty:

$$s_t = \alpha + \varphi(t - 1) + \varepsilon \tag{5.2}$$

where

s_t = salvage value of the project in period t.

α = base/initial salvage value of the project.

φ = rate of change in salvage value. For φ=0, salvage value of the project is constant over time. For φ< 0, salvage value of the project decreases over time. For φ> 0, salvage value of the project increases over time.

t = time period at which salvage value is calculated. We consider *t=1* as the commitment stage, and option cannot be exercised at the commitment stage. Hence salvage value at *t=1* is not applicable and first salvage value is calculated at *t=2.*

ε = a random variable with expected value of zero and known distribution, to account for salvage value certainty.

Table 5.1: Value Orientation of Salvage Value sources in an IT Project

	Value Certainty	**Example Salvage Value Source**
1	Deterministic	Savings on future operating costs, selling price of project/resources, Payoffs from partial implementation of project, switch use of resources
2	Stochastic	Selling price of project/ resources, , Payoffs from partial implementation of project, Switch use of resources

For simplicity and we consider an IT project with *deterministic* salvage value, i.e., $\varepsilon = 0$. Further we first analyze constant salvage value case ($\varphi = 0$), and then analyze decreasing salvage value case over time ($\varphi < 0$). We consider these two cases because they are more common in IT projects. It is unlikely that an IT project's salvage value will be increasing over time. We further make the following assumptions:

- Salvage value (s) from exercising the option exceed the exercise cost (db), i.e. $s > db$ at *t=2*. This assumption will ensure that the option is deep in the money at *t=2*, and $udb > s > d^2b$ at *t=3*.
- *u* is greater than the risk free rate *r* and *d* is less than risk free rate *r,* i.e. $d<r<u$.
- Risk free rate, future payoffs, option exercise cost, and uncertainty around future payoffs are given and constant.

5.3.2 Example of Option to Abandon

As a high risk[24] project progresses and the uncertainty does not resolves in favor of its continuation, IT managers may have an option to abandon the project before its completion for downside protection. If the future payoffs seem to suffer a sustainable decline, management can forego the future payoffs *"b"* in exchange for the project's salvage value "*s*" in the form of selling off the hardware, putting the resources' in best alternative use (utilizing capital and human resources for other productive purpose), or saving costs by not investing in the project any further. For the option with maturity T=3, the decision problem of the IT manager at *t*=1 is shown in Figure 5.1.

Let $V_{i,j}$ be the value of the option determined in period i if it is exercised in period j. For example, $V_{1,2}$ is the value a manager has for the option in period 1 if the option is exercised in period 2. At *t*=1, with parameters *s*= \$320,000, *b*= \$375,000, *r*=5%, σ = 30%, and *n* = 2, the abandonment option is valued at[25]

$V_{1,3} = \frac{(1-p)^2 \text{Max}[0, s-bd^2] + 2(1-p)p\text{Max}[0, s-bdu] + p^2 \text{Max}[0, -b+su^2]}{r^2}$ = \$25,108. Hence the option to abandon has a positive value. If at *t=2*, the project progresses well with *ub*=\$506,197, there is no reason to abandon the project as its prospects look promising (*Max (0, s-ub)* = 0). However, if at *t*=2, the project does not progress well with *db*= \$277,807, the project performance is lower than what can be salvaged *s*=\$320,000 (*Max (0,s-db) = Max (0,\$320,000-\$277,807)= \$42,193*). At *t=2*, the IT managers' decision problem is to decide between savings of *\$42,193,* or waiting to abandon the project at

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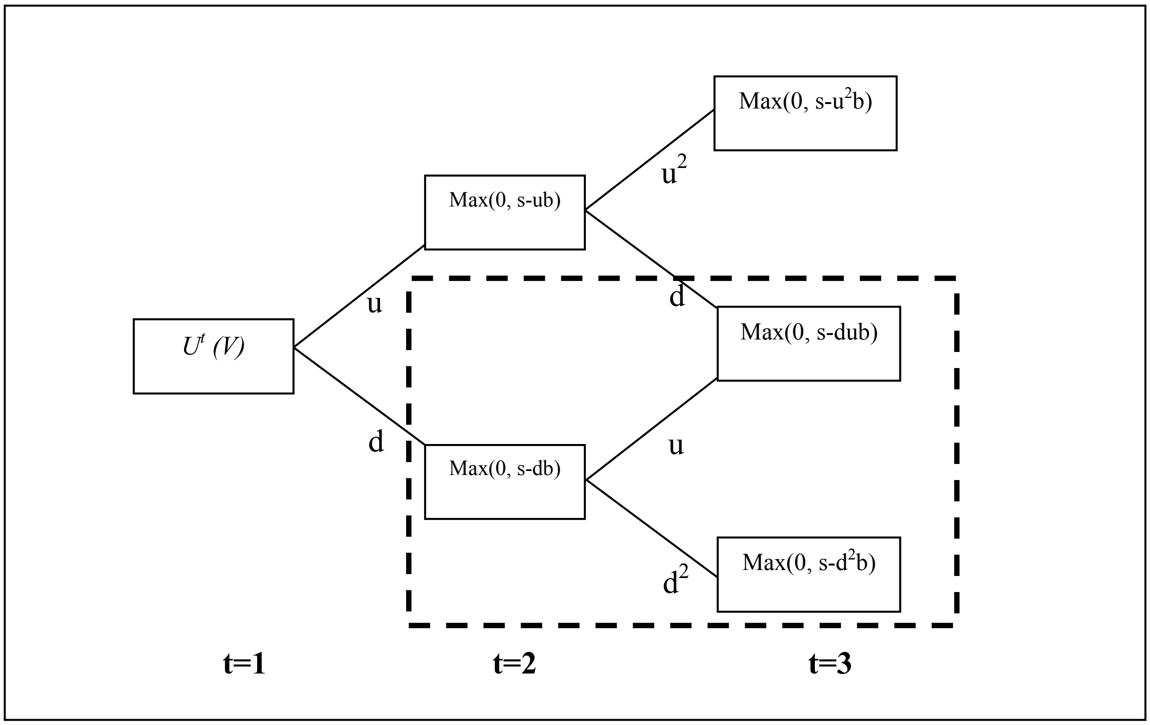
[24] We refer to the uncertain outcomes from the project as high risk

[25] $V_{1,3} = \frac{(1-p)^2 \text{Max}[0, s-bd^2] + 2(1-p)p\text{Max}[0, s-bdu] + p^2 \text{Max}[0, -b+su^2]}{r^2} = \frac{(0.49)^2 \text{Max}[0, 320000-205804] + 2(0.49)(0.51)\text{Max}[0, 320000-375000] + (0.51)^2 \text{Max}[0, 320000-683000]}{1.05^2}$ = \$25,108

t= 3 with[26] $V_{2,3} = \frac{(1-p)^2 \text{Max}[0,s-bd^2]+p(1-p)\text{Max}[0,s-dub]}{r}$= \$13,271.2, if the project does not recover. Therefore, with the poor performance of project at *t=2,* and *s-db>0,* it is better to terminate the project now than later to minimize the losses.

Figure 5.1: Abandonment Option Decision Problem



5.4 Time Preferences and Option to Abandon Project

Literature on time-preferences makes a distinction of cases studied for time preferences, based on the time orientation of costs (c) and benefits (π) involved, while conceptualizing intertemporal utility of the decision makers (O'Donoghue and Rabin, 1999b, Brocas and Carrillo, 2001). The two main cases studied the most are:

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[26] $V_{2,3} = \frac{(1-p)^2 \text{Max}[0,s-bd^2]+p(1-p)\text{Max}[0,s-dub]}{r} = \frac{(0.49)^2 \text{Max}[0,320000-205804]+(0.49)(0.51)\text{Max}[0,320000-375000]}{1.05}$
= \$13,271.20

a) *Immediate cost, future rewards* case, with intertemporal utility of $\beta\pi - c$.

b) *Immediate rewards, future cost* case, with intertemporal utility of $\pi - \beta c$.

The case of option to abandon can be classified as both, based on the characteristics of the salvage value. At a given exercise decision time *t*, an IT manager has to evaluate the decision based on the benefits from exercising the option i.e. the salvage value of the project "*s"*, and the cost involved in realizing the benefits i.e. given up future benefits from continuing the project "*b"*. We assume the constant salvage value case with φ=0 is an immediate reward and future cost case, whereas decreasing salvage value case with φ<0 is an immediate cost and future reward case. In the constant salvage value case, we assume the salvage value is realized immediately by selling the project or its resources, in return for giving up the project and its future payoffs. Hence the salvage value of the project is the immediate reward and the project's future payoffs are the future costs. In the decreasing salvage value case, the source of the salvage value of the project is assumed to be the payoffs from switching the project's use, in return for giving up the current project and its future payoffs. Switching the project's use involves time and costs before it starts to payoff. Therefore, the salvage value of the project is the future reward and the project's future payoffs are the immediate costs. We will use this decision to build our decision problems and solving them.

Irrespective of the nature of salvage value of the project. An IT manager commits to a risky project and obtains the embedded option to abandon at time *t=1* with the possible termination of the project in mind, i.e. by exercising the option to abandon if the condition *s-db*>0 holds at time *t = 2* (as demonstrated in the example above). At time *t=2*, he will choose to exercise the option if *s-db>0*. At the commitment stage (*t=1)*, β will be equal to 1 for TC managers[27] as well as for naïve managers[28] (naïves). Although naïves have a tendency of choosing present utility over future utility (with $\beta <$ 1), they are unaware of their bias and think they will act in a time-consistent manner. Present-bias comes into play only when the rewards come near in the future (O'Donoghue and Rabin, 1999a, Caillaud and Jullien, 2000, Della Vinga and Malmendier, 2004). Hence both types of managers will value the project equally. This correct evaluation for the project at the commitment stage by naïves also holds if the option to abandon has more than one exercise time period.

Proposition 1: *An IT manager with time-consistent (TC) preferences and an IT manager with time-inconsistent preferences (naïve) will value an IT project with embedded option to abandon equally and more than an IT project without an option to abandon.*

Once committed to the project, the manager will decide about option exercise in the next period based on the evaluation of future payoffs at that time against the exercise price of the option. For an option to abandon with one time period to expire i.e. *n=1* at *t=T=2*, the manager has to decide at *t=2* whether to exercise the option or let it expire. At *t=2*, β will be equal to 1 for TC managers as well as the naïfs because the payoff is immediate.

Proposition 2: *IT managers (both TC and naïf) will exercise the option to abandon with one time period to expiration optimally.*

[27] These managers awareness about their self-control ($\hat{\beta}$) and their actual self control (β) is equal to 1. Hence they do not have a bias for present.
[28] These managers awareness about their self-control ($\hat{\beta}$) mismatches their actual self-control (β) such that $\beta < \hat{\beta}$ =1. Hence they have a bias for present but they believe that they don't.

5.4.1 Two Time Period Model

Typically there is more than one opportunity to exercise an option. We depict this real option exercise decision for two points in time in Figure 5.2, where IT manager decides after evaluating his/her utility at each stage. Figure 5.2 describes the necessary parameters that determine the utility from exercising an option to abandon.

1

Real option commitment decision where utility is a function of real option value $U^t(V)$, which is a function of initial costs, future payoffs, salvage value of the project, uncertainty around payoffs, risk free rate and optimal time to option expiration.

$U^1 = V = g(c, b, s_t, t^*, \sigma, r)$

2

Real option exercise decision at $t=2$, where utility is equal to the intrinsic value of the option, and is a function of future payoffs, salvage value of the project, uncertainty around payoffs, risk free rate and time to option expiration.

$U^2 = g(b, s_t, t_1, \sigma, r)$

3

Real option exercise decision at $t=3$, where utility is equal to the optimal value of the option, and is a function of future payoffs, salvage value of the project, uncertainty around payoffs, risk free rate and time to option expiration.

$U^3 = g(b, s_t, t_2, \sigma, r)$

Figure 5.2: Timeline for real abandonment option with two time periods until expiration

At the commitment stage, $t=1$, both TC and naïve will commit to the project as per Proposition 1 as long as project value is positive. Once committed to the project with option to abandon, the exercise decision will be based on how the project performs overtime. For an option to abandon project with expiration time of two periods ($T=3$), the manager has to decide at $t=2$ whether to exercise the option today or wait until maturity $t=T=3$.

Real abandonment options often do not have a fixed exercise time, and can be exercised any time before expiration. For example, decisions such as terminating a poorly performing project can and must be made any time until a cutoff date. Therefore, viewing an option to abandon as an American put option helps in capturing the option exercise flexibility. A key property of an American put option is that, for an option with *n* periods, it might be optimal to exercise it any time before expiration, as long as the option is sufficiently deep in the money (Cox et al., 1979, Hull, 2008). For example, for a project performing poorer than the targeted performance at *t=2,* it might be better to terminate it and realize the salvage value. We utilize this property and assume that an option to abandon is an American style put option, that is sufficiently deep in the money at *t=2*, with salvage value greater than future payoffs if the project performed bad. This makes it optimal to exercise the option before the expiration date i.e. *t*=2* for a two period growth option (i.e. *n=2)*.The real option value at the project commitment stage to be exercised at *t=2* is:

$$V_{1,2}=\frac{(1-p)\text{Max}[0,s-bd]+p\text{Max}[0,s-bu]}{r} \tag{5.3}$$

And the real option value at the project commitment stage to be exercised at *t=3* is:

$$V_{1,3}=\frac{(1-p)^2\text{Max}\left[0,s-d^2b\right]+2p(1-p)\text{Max}[0,(s-\beta udb)]p^2\text{Max}\left[0,\left(s-u^2b\right)\right]}{r2} \tag{5.4}$$

As long as r is positive, $V_{i,j}$ will always be positive for any *t,* if $s > d^2b$. Practically there is no situation in IT investments where the discount rate is non-positive, hence we will not consider that case.

Bias for present comes into play when the rewards come near in the future (O'Donoghue and Rabin, 1999a, Caillaud and Jullien, 2000, Della Vinga and Malmendier, 2004) and per Proposition 1, both types of managers will value this risky project and abandonment option equally.

Proposition 3: *IT managers (both TC and naïve) will place the same value on an IT project with option to abandon with two time periods to expiration.*

Proposition 3 will hold if the option to abandon has more than one exercise time period.

5.4.2 Case 1: Deterministic Constant Salvage Value in Time

With $\varphi = 0$, salvage value "s_t" of the project at any time would be a constant "α" according to equation (5.2). This assumption implies that the salvage value of the project will not change overtime, and it can be realized as soon as the project is terminated. As $s_t = \alpha$, we dropped the subscript from s_t. At the first decision point *t=2*, when the project does not perform well, the manager can exercise the option and realize salvage value by giving up future benefits from the project, or wait until *t=3*. The decision problem at *t=2* for a manager will be:

$$Max(V_{2,2}, V_{2,3}) \qquad (5.5)$$

where:

$$V_{2,2} = \big((1-p)(s-db)\big) \qquad (5.6)$$

and

$$V_{2,3} = \frac{(1-p)^2 \text{Max}\left[0, \beta(s-d^2b)\right] + p(1-p)\text{Max}[0, (\beta(s-udb))]}{r} \qquad (5.7)$$

In equation (5.7), the term $\beta(s-udb)$ will be negative, because $udb = b$ and $s < b$. This condition implies that if the project recovers in *t=3*, it is worth continuing it. With the salvage value of the project at *t=2* less than or equal to its average performance i.e.,

$s < udb$, the term $Max[0, \beta(s - udb)]$ will be zero for all values of β. This will reduce equation (5.7) to:

$$V_{2,3} = \frac{(1-p)^2 \mathrm{Max}[0, \beta(s - d^2 b)]}{r} \qquad (5.8)$$

An IT manager's decision problem at *t=2* is based on the output of the decision function $Max[V_{2,2}, V_{2,3}]$. If the project is deep in the money at *t=2*, this will render $V_{2,3}$ to equation (5.8). We can show that:

$$\big((1-p)(s-db)\big) > \frac{(1-p)^2 Max[0, \beta(s - d^2 b)]}{r}\text{; or}$$

$$\big((s-db)\big) > \frac{(1-p)\mathrm{Max}[0, \beta(s - d^2 b)]}{r} \qquad (5.9)$$

Thus, $V_{2,2} > V_{2,3}$ will hold for any value of β. This outcome indicates that if the IT project is deep in the money at *t=2*, managers will always exercise the abandonment option immediately to realize the salvage value. In this case, the present biased preferences of the managers do not impact their decision.

Proposition 4: *If the salvage value of a project is immediate and non-increasing, the IT manager will exercise the abandonment option at t=2, irrespective of their time preferences.*

With immediate salvage value, the manager will only wait until *t=3* to exercise the option to abandon if the salvage value is increasing overtime, or if $\varphi > 0$. This will result in $s_{2,2} < s_{2,3}$. Some value of φ will result in $V_{2,2} < V_{2,3}$ indicating that higher option value can be realized if the abandonment option is exercised in *t=3*.The increasing salvage value which will cause the IT manager to wait until *t=3*:

$$\big((s_2-db)\big) < \frac{(1-p)\mathrm{Max}[0, \beta(s_3 - d^2 b)]}{r}\text{; or}$$

$$((\alpha + \varphi) - db) < \frac{(1-p)\text{Max}[0, \beta((\alpha + 2\varphi) - d^2 b))]}{r} \qquad (5.10)$$

Given the condition in equation (5.10), a TC manager with $\beta = 1$, will always wait to terminate the project. Interestingly, in this case, the naïve manager might terminate the project prematurely, because on one hand, increase in φ will result in $V_{2,2} < V_{2,3}$. And at the same time, a lower β of a naïve manager would discount the net salvage value for *t=3*. Under these circumstances, there will be a critical beta ($\bar{\beta}$), which will discount the net salvage value enough such that $V_{2,2} = V_{2,3}$. However, in the case of IT projects, the salvage value seldom increases overtime. Therefore we did not solve for $\bar{\beta}$ in this case.

5.4.3 Case 2: Deterministic and Decreasing Salvage Value in Time

As an IT project progresses, it becomes more customized. With increasing customization, the project's ability to be put to another use decreases and switching costs increase as well. We account for this property in equation (3) with $\varphi < 0$, which will result in $s_t > s_{t+1}$. This will change our original assumption as follows:

- Salvage value "s_t" is decreasing over time due to $\varphi < 0$ in $s_t = \alpha + \varphi t$. This will result in $s_2 > s_3$.
- Salvage value (*s*) from exercising the option at *t=2* exceed the exercise cost (*db*), i.e. $s_2 > db$. This assumption will ensure that the option at *t=2* is deep in the money, and at *t=3*, $s_3 > d^2 b$.
- Salvage value $s_3 \leq dub$. This implies that if the project performed on average at *t=3,* after recovering for a bad performance in *t=2,* it is better to continue it instead of terminating it. We use this assumption because due to high uncertainty and qualitative goals in terms of project payoffs for most IT projects,

it is more realistic to continue an average performing project after investing in it than terminating it.

At the first decision point *t=2,* when the project does not perform well, the manager can exercise the option and realize salvage value s_2 by giving up future benefits from the project, or wait until *t=3* to realize s_3 by abandoning the project. As described before, switch-use case is an immediate cost and future payoff case. With switching use of project as a source of a salvage value, it usually takes at least one period to materialize it, hence making the orientation of the salvage value towards future and making s_t subject to discounting. The decision problem at *t=2* for a naïve manager will be similar to equation (5.5) : $Max(V_{2,2}, V_{2,3})$

where:

$$V_{2,2} = \big((1-p)(\beta s_2 - db)\big) = \big((1-p)(\beta(\alpha + \varphi) - db)\big) \qquad (5.11)$$

and

$$V_{2,3} = \frac{p(1-p)Max[0,\beta(s_3 - dub)] + (1-p)^2 Max\big[0,\beta(s_3 - d^2 b)\big]}{r}$$

$$= \frac{p(1-p)Max[0,\beta((\alpha + 2\varphi) - dub)] + (1-p)^2 \mathrm{Max}\big[0,\beta((\alpha + 2\varphi) - d^2 b)\big]}{r} \qquad (5.12)$$

In equation (5.11), the value from switching the project's use, if exercised at *t=2,* will be discounted due to its future orientation. In equation (5.12), the value from switching the project's use, if exercised at *t=3,* will be discounted for the same reason, along with payoffs from continuing the project.

In equation (5.11), with the assumption s_2>*db*, the term $(\beta s_2 - db)$ will be either positive or negative, depending on the value of β. For $\beta \approx 1$, the condition $\beta s_2 > db$ will hold on the discounted salvage value. For $\beta \approx 0$, the term $(\beta s_2 - db)$ will become negative. So for some value of β, the term $(\beta s_2 - db)$ will become negative, hence making $V_{2,2}$ negative.

In equation (5.12), with the assumption $dub \geq s_3 > d^2 b$, the term $Max[0, \beta(s_3 - dub)]$ will be zero for 0≤ $\beta \leq 1$. So we take it out of the equation (5.12), making it look like as follows:

$$V_{2,3} = \frac{(1-p)^2 Max[0, \beta(s_3 - d^2 b)]}{r} = \frac{(1-p)^2 \text{Max}[0, \beta((\alpha + 2\varphi) - d^2 b)]}{r} \tag{5.13}$$

In equation (5.13), the term $Max[0, \beta(s_3 - d^2 b)]$ will be positive for any value of β. This will make $V_{2,3}$ positive for any value of β.

A TC manager with β = 1, will evaluate the decision function *Max* ($V_{2,2}$, $V_{2,3}$), and will decide based on the output. The assumptions discussed above will result in:

- Positive $V_{2,2}$, because the condition $\beta s_2 > db$ will hold on the discounted salvage value in equation (5.11).
- Positive $V_{2,3}$, because the term $Max[0, \beta(s_3 - d^2 b)]$ in will be positive for any value of β in equation (5.12)
- $V_{2,2} > V_{2,3}$, because of s_2>*db*, $\varphi < 0$, and $d<r<u$.

The difference between $V_{2,2}$ and $V_{2,3}$ will be the cost of waiting and will be:

$$V_{2,3} - V_{2,2} = -\frac{e^{\sigma}(e^{\sigma} - r)(b - be^{\sigma} r - r(s + \varphi) + e^{\sigma} r(s + 2\varphi) + e^{2\sigma}((-1 + r)s + (-2 + r)\varphi))}{(-1 + e^{2\sigma})^2 r} \tag{5.14}$$

Based on equation (5.14), the decision of a TC manager would be to terminate the project at *t=2*.

A naïve manager with β< 1, will exhibit present-bias for project future payoffs, and salvage values at different time periods. As for some value of $\beta < 1$, the term $(\beta s_2 - db)$ in equation (5.11) will become negative, it will make $V_{2,2}$ negative as a result. A negative $V_{2,2}$ implies that it will seem less attractive to IT manager to terminate the project at *t=2*. As $V_{2,3}$ is positive for any value of β, a naïve manager will see $V_{2,2}=V_{2,3}$ for a specific value of β leading him to delay the termination decision. We call this value of β, critical β $(\bar{\beta})$.

Proposition 5: *There is a* $\bar{\beta} = \frac{b(-1+e^{2\sigma})r}{-br+e^{2\sigma}r(s+2\varphi)+e^{3\sigma}((-1+r)s+(-2+r)\varphi)+e^{\sigma}(b-r(s+\varphi))}$, *such that for IT projects with abandonment option with two exercise periods and decreasing salvage value:*

- *If* $\beta \leq \bar{\beta}$ *the manager will not exercise the option optimally in period 2.*
- *If* $\beta > \bar{\beta}$ *the manager will exercise the option optimally in period 2.*

As Proposition 5 shows, $\bar{\beta}$ is a function of *b, s, r,* φ, and σ. A naïve IT manager with a self-control parameter less than or equal to $\bar{\beta}$ will delay exercising the abandonment option at *t=3* and realize the salvage value later than not waiting until *t=3* to exercise the option and realize its optimal value.

To illustrate the effect of present-bias we use an example with the parameters shown in Table 5.2.

Table 5.2: Parameter values for option to abandon

Parameters	Values	$\bar{\beta}$	$V_{2,2}$	$V_{2,3}$ (for $\beta = 1$)
b	\$375,000	0.91	\$ 72,277	\$ 60,537.90
s	\$350,000			
σ	0.7			
r	1.05			
φ	- \$50,000			

In this case, $V_{2,2}$ is greater than $V_{2,3}$, at the first decision point t=2. For naïve IT manager, with $\bar{\beta}$ less than or equal to 0.91, he will not exercise the option at $t=2$, and instead will wait. The lost value due to waiting to exercise is \$ 11,739.10. We conducted some numerical sensitivity analysis using the example to explore the relationship between $\bar{\beta}$ and the option parameters.

The sensitivity of $V_{2,2}$ and $V_{2,3}$ to volatility σ is given in Figure 5.3. For a given set of parameter values, increase in volatility first has little effect on the option value until σ reaches 0.1. Above σ of 0.1, increase in volatility tends to increase option value, also known as the volatility smile (Hull, 2008). This holds for both values of option to abandon i.e. $V_{2,2}$ as well as $V_{2,3}$. For very low values of volatility, $V_{2,2}$ is positive, but $V_{2,3}$ is negative. This means if the project is deep in the money and its future is certain, then it is better to terminate it immediately. As volatility increases both the option values increase, and for high values of volatility $V_{2,2}$ is greater than $V_{2,3}$. This trend implies that as uncertainty increases about the project, abandonment option's value increases, and if the option is deep in the money at the beginning of the project, it is better to terminate it instead of waiting for one more period.

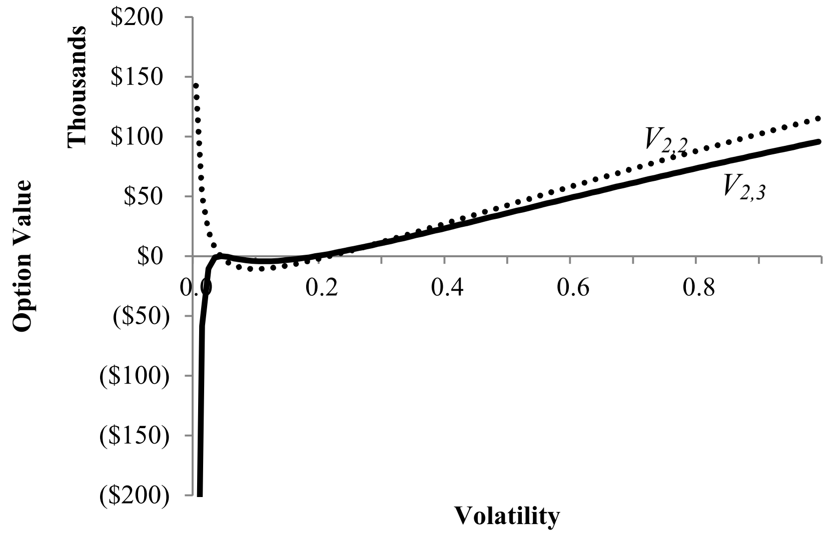

Figure 5.3: Sensitivity of Option Values to the Volatility

The sensitivity trend of option value and critical beta to volatility σ is given in Figure 5.4. β in this case is impacting $V_{2,2}$ along with $V_{2,3}$, hence in this case, multiple parameters are impacted by time preferences. Figure 5.4 shows $\bar{\beta}$ as a function of σ, where $\bar{\beta}$ is a decreasing function of σ. For very low volatility, $\bar{\beta}$ is very high, and as the volatility increases, $\bar{\beta}$ decreases. The rate of decline in $\bar{\beta}$ is higher for low values of volatility, as compared to the higher values of volatility. There exists a range of volatility $0 \leq \sigma \leq 0.28$, where $\bar{\beta}$ is greater than 1. In the same volatility range, $V_{2,2}$ and $V_{2,3}$ are negative, indicating that option does not have a positive value at *t=2*. As value for $\bar{\beta}$ cannot exceed 1, we believe the reason for this outcome is the negative option value for very low uncertainty for our selection of parameters. When there is no abandonment option to exercise, IT managers will not take any action.

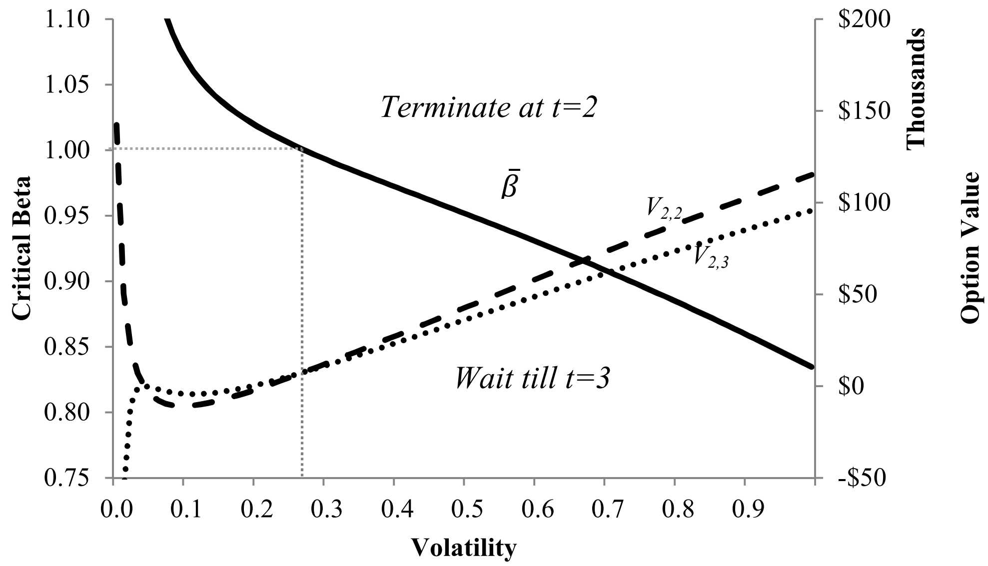

Figure 5.4: Sensitivity of Critical β and Option Values to the Volatility

For σ> 0.28, $V_{2,2}$ becomes greater than $V_{2,3}$ indicating the project being deep in the money at *t=2.* With increasing volatility, difference between $V_{2,2}$ and $V_{2,3}$ also increases. For the same volatility values, $\bar{\beta}$ is decreasing, indicating that managers are less likely to delay exercising the option because of the uncertainty. With increasing volatility, option value increases, and managers will likely to exercise it at *t=2,* to realize the option value. Higher uncertainty also decreases their confidence in project recovering in the future, leading them not delaying the termination of the project. The first derivative of $\bar{\beta}$ with respect to volatility (by setting *r=1* for simplified form) shows the same trend: $\frac{\partial\bar{\beta}}{\partial\sigma} = \frac{be^{\sigma}(b-s+2e^{\sigma}\varphi(1+\mathrm{Sinh}[\sigma]))}{(b+e^{\sigma}(s+\varphi-e^{\sigma}\varphi))^2}$; indicating the inverse relationship, and similar to case 1. The numerator in this case is negative due to high negative value of φ, resulting into the declining trend.

The sensitivity trend was similar for risk free rate *r* is shown in Figure 5.5. We believe the same explanation hold true here as in the first case. Again, for a given set of parameter values, the $\bar{\beta}$ in salvage value through switch-use case is lower than constant salvage value case. It is due to the impact of β on multiple parameters thus impacting $V_{2,2}$ along with $V_{2,3}$. The derivative of $\bar{\beta}$ with respect to risk free rate is $\frac{\partial\bar{\beta}}{\partial r} = -\frac{be^{\sigma}(-1+e^{2\sigma})(-b+e^{2\sigma}(s+2\varphi))}{(-br+e^{2\sigma}r(s+2\varphi)+e^{3\sigma}((-1+r)s+(-2+r)\varphi)+e^{\sigma}(b-r(s+\varphi)))^2}$, showing the relationships similar to case 1.

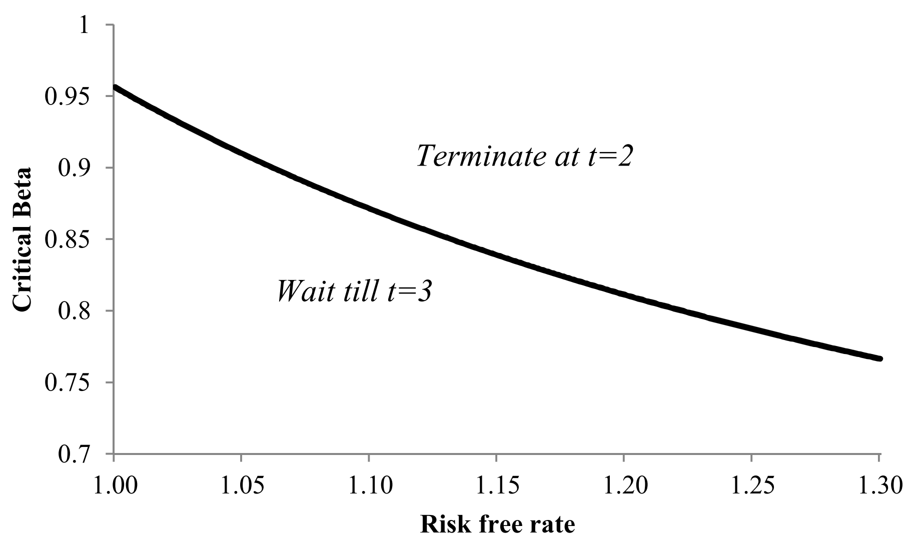

Figure 5.5: Sensitivity of Critical β to the Risk free discount rate

We explore the sensitivity of $\bar{\beta}$ to values of future payoffs *b* in Figure 5.6 which shows that $\bar{\beta}$ is increasing in *b*. For higher values of *payoffs* from not exercising the abandonment option, IT managers are less likely to exercise it early. As future payoffs increase, the option to abandon value will decrease and it is more attractive to wait for the high payoffs. Hence for extremely high payoffs, option to abandon loses its value significantly and therefore $\bar{\beta}$ keeps increasing for those values. The derivative of $\bar{\beta}$ with respect to b (by setting *r=1* for simplified form) is $\frac{\partial\bar{\beta}}{\partial b} = \frac{e^{\sigma}(1+e^{\sigma})(s+\varphi-e^{\sigma}\varphi)}{(b+e^{\sigma}(s+\varphi-e^{\sigma}\varphi))^2}$, showing a non-linear positive relationship for b.

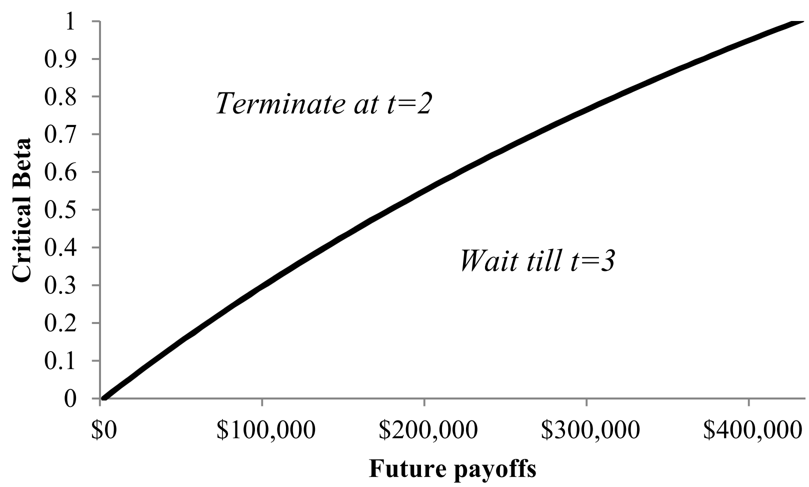

Figure 5.6: Sensitivity of Critical β to the Payoffs

Increase in salvage value of the project increases the option to abandon value, ceteris paribus. The relationship of real abandonment option value, in this case, is no different. The sensitivity of $\bar{\beta}$ to base salvage value "*s*" is shown in Figure 5.7. The figure shows that $\bar{\beta}$ decreases with increasing value of s. Relationship of $\bar{\beta}$ with s implies that for higher values of base salvage value through switching use of project, present-bias is less likely to cause early exercise. As salvage value increases, option to abandon value will increase, which makes it more attractive to terminate the project early once it has performed badly, since waiting is of little additional value. The derivative of $\bar{\beta}$ with respect to s (by setting *r=1* for simplified form) is $\frac{\partial\bar{\beta}}{\partial s} = -\frac{be^{\sigma}(1+e^{\sigma})}{(b+e^{\sigma}(s+\phi-e^{\sigma}\phi))^2}$, showing a non-linear positive relationship for s.

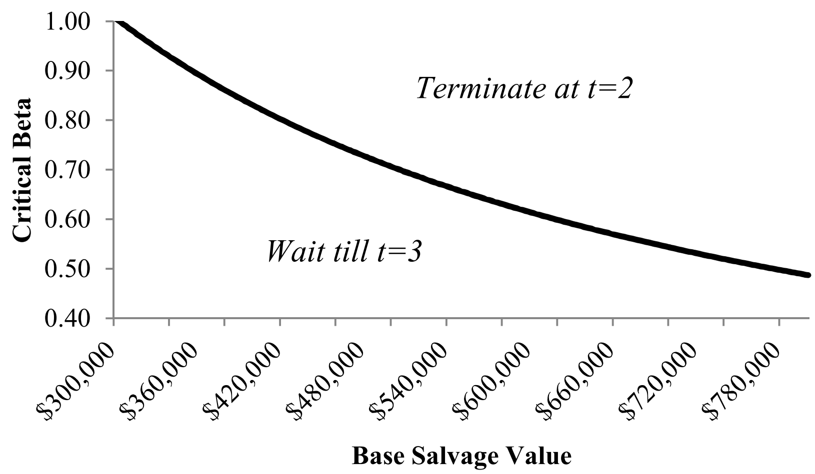

Figure 5.7: Sensitivity of Critical β to the Base Salvage Value *s*

The difference in this relationship comes from the varying value of "φ". As shown in Figure 5.8, $\bar{\beta}$ increases with the decrease in φ, indicating as the difference between the payoffs from switching use of the project resources increases, the likelihood of delaying the decision of switching use decreases. This is indicated by increasing value of $\bar{\beta}$ with decreasing φ. Hence, IT managers are less likely to delay the decision of switching use of project, if the payoffs from switching use decline at an increasing rate over the period of time. The derivative of $\bar{\beta}$ with respect to φ (by setting *r=1* for simplified form) is $\frac{\partial\bar{\beta}}{\partial\varphi} = \frac{be^{\sigma}(-1+e^{2\sigma})}{(b+e^{\sigma}(s+\varphi-e^{\sigma}\varphi))^2}$, showing a non-liner positive relationship for φ.

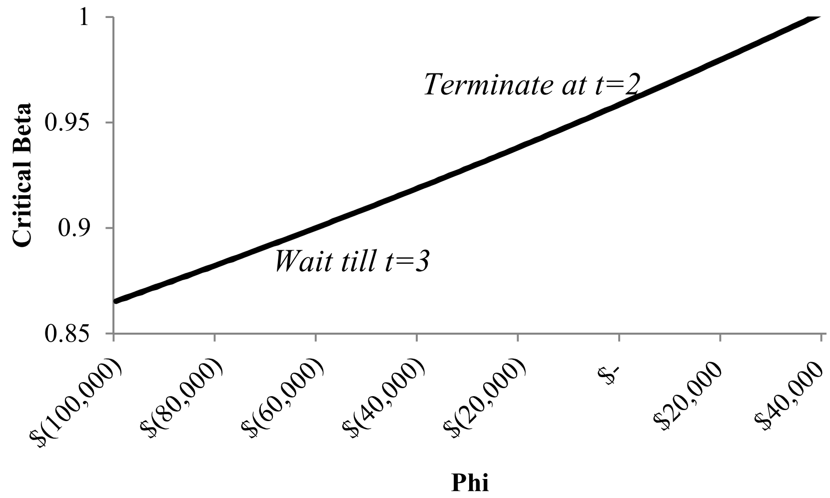

Figure 5.8: Sensitivity of Critical β to the Decrease in Salvage Value φ

We changed the $s_3 \leq dub$ assumption on salvage value to $s_3 > dub$, indicating the chances of salvage value *t=3* be greater than the average performance of the project. In this case, the solutions held for $\beta \approx 1$ and $\beta \approx 0$ cases. However, the critical beta with same set of parameters was lower for this case: $\bar{\beta} = 0.75$. This is because with the assumption $s_3 > dub$, the term $Max[0, \beta(s_3 - dub)]$ in equation (5.9), will not be zero for $\beta \approx 1$ as well as $\beta \approx 0$. So the term stayed in the equation (5.9). Due to this change, closed form solution for critical beta changed to $\bar{\beta} = \frac{br}{br + e^{\sigma}((-1+r)s + (-2+r)\varphi)}$. We had a higher threshold beta for the case with $s_3 \leq dub$, i.e. $\bar{\beta} = 0.91$. Comparing the two cases for critical beta, the case of higher threshold beta will hold because higher threshold beta means more sensitivity of exercise decision to the time inconsistent preferences.

5.5 Discussion

Option to abandon facilitates the justification and management of risky projects because they provide downside protection in case the project does not perform well. To better manage such projects, it is important to make optimal exercise decisions for option to abandon embedded in them. By optimally exercising the option to abandon, the project value can be salvaged in the form of savings on the project or by putting the resources to another use. There is a chance of suboptimal exercise decisions motivated by a manager's desire to delay realizing the costs associated with project abandonment. This suboptimal exercise may even lead to the whole project being unsuccessful, over time and over budget. We find these occurrences in the literature. For example, Denver's International Airport baggage system (Keil and Montealegre, 2000) and London's Taurus stock exchange project (Drummond, 1996). In these cases, the size and scale of the project, managers' reputation, the political ramifications of abandoning, and the possible effect of abandonment on staff morale (Keil, Mann, &Rai, 2000), could accentuate present-bias of IT managers in terminating these projects.

We examined two distinct cases of self-awareness among IT managers about their time-preferences, TC and naïve. Our results indicate that at the commitment stage, IT project with option to abandon is valued equally irrespective of time-preferences of the manager. Present-bias preferences affect the option to abandon exercise decisions when the real option allows the IT manager multiple exercise decision time periods during project's life. Having multiple exercise decision time periods is likely in IT projects, especially in large scale projects, with considerable risk involved. Also, high risk projects are typically managed in stages, especially when switch use option is present. For example, while developing a new system, it might be put to another use in the organization, after initial stage, if it does not work for its initially intended use.

IT managers with present-bias preferences may exercise these options to abandon late due to avoiding immediate costs or realizing immediate salvage value, and their unawareness of such preferences. Business environment may impact the IT manager's time-preferences as well. In situations like when managers' reputation is at stake, the political ramifications of abandoning, and the possible effect of abandonment on staff morale (Keil, Mann, &Rai, 2000), it may prevent IT managers from terminating the project, with a hope of project recovery. Unfortunately, the projects seldom recover and end up as a failed endeavor.

We found that when the salvage value of the project is immediate and constant over time, managers' time preferences will have no impact on their decision to terminate the deep in the money project. In case if the salvage value of the project is decreasing overtime, time preferences of the managers will come into play. For higher values of salvage value of the project, present-bias was found to less likely to cause delay in the exercise of the option. With increasing rate of decline in salvage value of the project, present-bias was found to less likely to cause delay in the exercise of the option. We also found that higher values of payoffs from not exercising the option to abandon project in this case decrease the likelihood that the manager will exercise the option early. These findings are partially consistent with the literature. Naïves are supposed to delay immediate cost activities and rush into immediate reward, where for immediate cost activities; a small present-bias can severely affect naïve decision makers (O'Donoghue and Rabin, 1999b). Higher payoffs from continuing the project decrease option value and higher salvage value increase the option value. Accordingly, IT managers should be tempted to realize the value when either project payoffs are high, or salvage value is high. Also, they should not delay the exercise decisions when salvage value decreases at increasing rate overtime. Our results point in the same direction, when the salvage value is decreasing overtime. Large salvage value, payoffs from continuing the project and rate of decrease in salvage value decrease $\bar{\beta}$and require the manager to have more present-bias to delay exercising the option. But in the case of immediate and constant salvage value, managers will instead take the rational decision and terminate the project, if it is performing below expectation.

5.5.1 Managerial Implications

Managers with present-bias may delay exercising option to abandon. Hence, it is not enough for managers to recognize option to abandon in a project and intuitively evaluate their value (options thinking). They need to conduct formal option analysis; to be aware of their time-preferences over time; to reevaluate payoffs, costs, and parameters compared with previous period's estimates. Furthermore, the organization should have incentives in place to mitigate the effects of present-bias.

Changes to IT governance may help mitigate the effects of present-bias. IT governance procedures will benefit from requiring formal analytical methods to valuate investment decisions. This analysis must rely on inputs from multiple managers and must have a post-project evaluation of performance to identify any existing biases. Incorporating healthy competition with IT governance can hence help control the effects of these biases as well (Brocas and Carrilo, 2001).

Another important implication for IT governance and for managing IT projects is the choice of methods and procedures for controlling risks, especially in IT infrastructure investments. Since there is a risk that a present-biased manager will delay exercising an option, especially if the project has political ramifications, using a systematic and objective method to update estimates needed for option evaluation is important to reduce risk. A possible way for achieving that is to conduct a "net change" evaluation at each option exercise period. This implies that the evaluation begins with the estimates of option parameters, costs, and payoffs used in the previous period and changes are only made when justifications are provided based on new information. Following such approach would limit the creep of present biasness.

Present-bias preferences can impact option exercise decisions for growth options as well as option to abandon project. But their impact is significantly different in each case. For naïve IT managers, present bias preferences may rush them to exercise the growth option. However, the same preferences may prevent them from terminating a poorly performing project. Both options are impacted by these preferences when there are multiple decision instances for the manager.

5.5.2 Limitations and Future Research

In this study, we concentrate on two simple cases of abandonment option i.e. constant salvage value overtime and decreasing salvage value overtime. In both cases we assumed salvage value to be deterministic. A valid extension would be to explore the effects of time inconsistent preferences on IT projects with stochastic salvage value. We also studied only a two-time period model. Another extension to this research would be to expand the model for multiple time periods and analyses the sensitivity and impact of time inconsistent preferences with respect to project performance.

CHAPTER 6: CONCLUSIONS

Prior studies have found inconsistencies between managerial intuition and real option values across different real option types and settings (Benaroch et al., 2006; Busby & Pitts, 1997; Lankton & Luft, 2008; Tiwana et al., 2006; Tiwana et al. 2007). Recent IS literature is inclined towards the idea due to the increasing popularity and advocacy of the real option theory in justifying and managing IT investments. In this dissertation we approached the problem by studying it from more realistic angle i.e. vulnerabilities of real options exercise decisions to managerial intuition.

The first part of the dissertation focuses on testing the effects of framing on real options exercise decisions in individual IT projects, narrow framing in IT portfolios and role of individual risk behavior of the decision maker. By concentrating on two types of real options commonly found in IT investments i.e. growth and abandonment, we tried to study if the perceptual framing associated with growth and abandonment option values result in different risk behaviors at exercise decision time, leading to sub optimal exercise decisions respectively. We found that real option exercise decisions are vulnerable to framing and narrow framing effects and individual risk behavior play a significant role in managing IT investments by influencing these decisions.

We also tried to test for factors that can potentially decrease these effects hence improving the decision making under flexibility. We found that simplification of decision scenarios and reducing the scale of the projects can limit these effects.

The second and third studies theoretically explain the impact of time-inconsistent preferences on real option exercise decisions. We conducted numerical tests to get a deeper understanding of how time inconsistent preferences impact the decision of IT managers under uncertainty, for growth option and abandonment option scenarios. We found that present-bias preferences may play a role in biased decision making for option exercise decisions for growth options as well as option to abandon project. The impact of present bias preferences of IT managers is significantly different, depending on the type of the real option. For naïve IT managers, present bias preferences may rush them to exercise the growth option. However, the same preferences may or may not prevent them from terminating a poorly performing project.

Findings of this thesis will hopefully change the way real options are perceived in IS. Although managerial instincts have been shown to be in alignment with the real options logic, they are vulnerable to the managerial biases. We add knowledge to the use of real options in IT investment decisions by exploring three of the biases found to be primitive to human cognition: framing, narrow framing and time-inconsistent preferences. We are confident that our findings may apply to other areas where ROT is used as a risk management methodology. Further investigation is required though to confirm their generalizability.

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APPENDIX A: SURVEY

General Instructions

1. You will be evaluating **four individual IT projects** and **three IT portfolios** in order to determine their future direction.
2. Each IT portfolio consists of **two IT projects** that may or may not be related.
3. Each project (individual and in portfolios) that you will be evaluating in this survey, will have either an option to invest further in it for its future expansion (**Option to Grow**) or an option to kill it before it is completed (**Option to Abandon**).
4. You will be given information regarding expected future payoffs from the project and the uncertainty around these payoffs.

Evaluation of Individual Projects

- All the projects are approximately **mid-way** in their life cycle i.e. they have spent **50%** of their allocated budget and are only **50%** complete.
- The estimated net present value (NPV) for each project depends on your decision. ***NPV of a project is the net future cash inflows of the project, adjusted for the time value of money.***
- Based on the information given, **please make a decision in terms of exercising the option (described below).**

IT Project Profile 1 of 4

This project has the option to Grow (Further investment in this IT project may enhance future revenues). Your choices are as follows.	
Invest (Exercise the option)	**Do not Invest (Do not exercise the option)**
25% chance of NPV being $1,800,000 75% chance of NPV being $0	100% chance of NPV being $250,000

What would you choose to do for Project 1?

- [x] Invest (Exercise the option)
- [ ] Do not Invest (Do not exercise the option)

IT Project Profile 2 of 4

This project has the option to Abandon (Further investment in this IT project may reduce future revenues). Your choices are as follows.	
Abandon (Exercise the option) 100% chance of NPV being $ -250,000	**Do not Abandon (Do not exercise the option)** 25% chance of NPV being $0 75% chance of NPV being $ -600,000

What would you choose to do for Project 2?

☐ **Abandon** (Exercise the option)

☐ **Do not Abandon** (Do not exercise the option)

IT Project Profile 3 of 4

This project has the option to Grow (Further investment in this IT project may enhance future revenues). Your choices are as follows.	
Invest (Exercise the option) 25% chance of NPV being $4,800,000 75% chance of NPV being $ 0	**Do not Invest (Do not exercise the option)** 100% chance of NPV being $1,000,000

What would you choose to do for Project 3?

☐ **Invest** (Exercise the option)

☐ **Do not Invest** (Do not exercise the option)

IT Project Profile 4 of 4

This project has the option to Abandon (Further investment in this IT project may reduce future revenues). Your choices are as follows.	
Abandon (Exercise the option) 100% chance of NPV being $ -1,000,000	**Do not Abandon (Do not exercise the option)** 25% chance of NPV being $0 75% chance of NPV being $ -1, 600,000

What would you choose to do for Project 4?

☐ **Abandon** (Exercise the option)

☐ **Do not Abandon** (Do not exercise the option)

IT Portfolios Evaluation

Evaluation of IT Project Portfolios

- Next you will be evaluating **three** IT project portfolios. Each project portfolio consists of **two** IT projects, and some information on resources allocated to them.
- Each project within these project portfolios gives you a decision flexibility of either investing in it further for its growth (**Option to Grow**) or killing the project (**Option to Abandon**).
- All the projects in the portfolios are approximately **mid-way** in their life cycle, i.e. they have spent **50%** of their allocated budget and are only **50%** complete.
- Based on the information given, **please make a decision in terms of exercising the option (described below) for each project within the portfolio.**

IT Project Portfolio Profile 1 of 3

Both projects in this portfolio are **independent of each other in terms of resources**. This means each project in the portfolio has its ***own pool of financial and human resources.***

PROJECT 1 This project has the option to Grow (Further investment in this IT project may enhance future revenues). Your choices are as follows.	
Invest (Exercise the option) 25% chance of NPV being $1,800,000 75% chance of NPV being $ 0	Do not Invest (Do not exercise the option) 100% chance of NPV being $250,000

PROJECT 2 This project has the option to Abandon (Further investment in this IT project may reduce future revenues). Your choices are as follows.	
Abandon (Exercise the option) 100% chance of NPV being $ -250,000	Do not Abandon (Do not exercise the option) 25% chance of NPV being $ 0 75% chance of NPV being $ -600,000

What would you choose to do for each project in Portfolio 1?

	Exercise the Option	**Do Not Exercise** the Option
Project 1 (Growth Option)	☐	☐
Project 2(Abandonment Option)	☐	☐

IT Project Portfolio Profile 2 of 3

Both projects in this portfolio have **resource dependency**. This means each project in the portfolio **share the same pool of *financial* and *human resources***. This sharing of resources among the projects within this portfolio means that **resources from one project can be utilized in another project.**

PROJECT 1 This project has the option to Grow (Further investment in this IT project may enhance future revenues). Your choices are as follows.	
Invest (Exercise the option) 25% chance of NPV being $1,800,000 75% chance of NPV being $ 0	Do not Invest (Do not exercise the option) 100% chance of NPV being $250,000

PROJECT 2 This project has the option to Abandon (Further investment in this IT project may reduce future revenues). Your choices are as follows.	
Abandon (Exercise the option) 100% chance of NPV being $ -250,000	Do not Abandon (Do not exercise the option) 25% chance of NPV being $ 0 75% chance of NPV being $ -600,000

What would you choose to do for each project in Portfolio 2?

	Exercise the Option	**Do Not Exercise** the Option
Project 1 (Growth Option)	☐	☐
Project 2(Abandonment Option)	☐	☐

IT Project Portfolio Profile 3 of 3

Both projects in this portfolio are **independent of each other in terms of resources**. This means each project in the portfolio has its ***own pool of financial and human resources.***

PROJECT 1 This project has the option to Grow (Further investment in this IT project may enhance future revenues). Your choices are as follows.	
Invest **(Exercise the option)** 25% chance of NPV being $4,800,000 75% chance of NPV being $ 0	**Do not Invest** **(Do not exercise the option)** 100% chance of NPV being $1,000,000
PROJECT 2 **This project has the option to Abandon** **(Further investment in this IT project may reduce future revenues).** **Your choices are as follows.**	
Abandon **(Exercise the option)** 100% chance of NPV being $ -1,000,000	**Do not Abandon** **(Do not exercise the option)** 25% chance of NPV being $ 0 75% chance of NPV being $ -1,600,000

What would you choose to do for each project in Portfolio 3?

	Exercise the Option	**Do Not Exercise** the Option
Project 1 (Growth Option)	☐	☐
Project 2(Abandonment Option)	☐	☐

Suppose you are managing a portfolio of two projects. Project 1 has the option to grow and project 2 has the option to abandon. Which of the following choices will be your decision for this portfolio?

☐ Realize Net Present Value of $450,000 for project 1 and Net Present Value of $ -450,000 for project 2.

☐ Realize Net Present Value of $450,000 for project 1 and Net Present Value of $ -250,000 for project 2.

☐ Realize Net Present Value of $250,000 for project 1 and Net Present Value of $ -450,000 for project 2.

☐ Realize Net Present Value of $250,000 for project 1 and Net Present Value of $ -250,000 for project 2.

Individual Risk Preferences

For each of the following statements, please **indicate the *likelihood*** of engaging in each activity or behavior. Please provide a rating from "Very Unlikely" to "Very Likely".

1. Would you consider betting a day's income at the horse races?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

2. Would you consider investing 10% of your annual income in a moderate growth mutual fund?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

3. Would you consider betting a day's income at a high stake poker game?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

4. Would you consider investing 5% of your annual income in a very speculative stock?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

5. Would you consider betting a day's income on the outcome of a sporting event (e.g. baseball, soccer, or football)?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

6. Would you consider investing 5% of your annual income in a conservative stock?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

7. Would you consider investing 10% of your annual income in government bonds (treasury bills)?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

8. Would you consider gambling a week's income at a casino?

1 Very Unlikely	2 Unlikely	3 Not Sure	4 Likely	5 Very Likely

Please answer the following questions to the best of your knowledge.

1. Your gender Choose an item.

2. Your Age (in years)

3. Your work experience (in years)

4. Industry sector that your organization belongs to? Choose an item.

5. Size of your firm in terms of annual revenue? Choose an item.

6. On a scale of 1 to 11, please indicate your experience with IT investment decisions?

I have no experience at all	2	3	4	I am highly experienced

7. On a scale of 1 to 11, please indicate your experience with decisions involving real options?

I have no experience at all	2	3	4	I am highly experienced

8. On a scale of 1 to 11, please indicate your experience with IT project portfolio decisions, similar to this survey?

I have no experience at all	2	3	4	I am highly experienced

APPENDIX B: ADDITIONAL RESULTS

Hypotheses results for international data with sample size n=132.

Hypothesis	**Test**	**Test Parameters**	**Values**	**Hypothesis Support**	**Consistent with US data**
H1	t-stat (p- value)	Project 1	15.392, $p<.001$	Supported	Yes
		Project 3	11.798, $p<.001$		
H2	t-stat (p- value)	Project 2	22.571, $p<.001$	Supported	Yes
		Project 4	11.978, $p<.001$		
H3	Friedman's rank test for k (χ2)	Project 1,2	χ^2 (1) 8, $p<.01$	Not Supported	Yes
		Project 3,4	χ^2 (1) = 0.019, $p=.891$		
H4a-d	Friedman's rank test for k (χ^2)	Project 1,3	χ^2 (1) = 8.26, $p=.004$	H4a,b not supported. H4c,d supported	Yes
		Project 2,4	χ^2(1) = 29.45, $p<.001$		
[29]H5a	t-stat (p- value)	Portfolio 1	10.61, <.001	Supported	Yes
		Portfolio 2	10.94, <.001		
		Portfolio 3	7.41, <.001		
H6	Friedman's rank test for k (χ^2)	Portfolio 1	χ^2 (1) = 2.97, $p=.0.085$	Not Supported	Yes
		Portfolio 2	χ^2 (1) = 3.27, $p=.071$		
		Portfolio 3	χ^2 (1) = 4.63, $p=.031$		
H7	Friedman's rank test for k (χ^2)	Portfolio 1 and 2	χ^2(1) = 0.125, p =0.724	Not Supported	Yes
H8a,b	Friedman's rank test for k (χ^2)	Portfolio 1 and 3	χ^2 (1) = 10.52, p=0.001	H8a not supported. H8b supported	Yes
H9	Friedman's rank test for k (χ^2)	Portfolio 1 and Simple Decision	χ^2 (1) = 45.56, p <.001	Supported	Yes

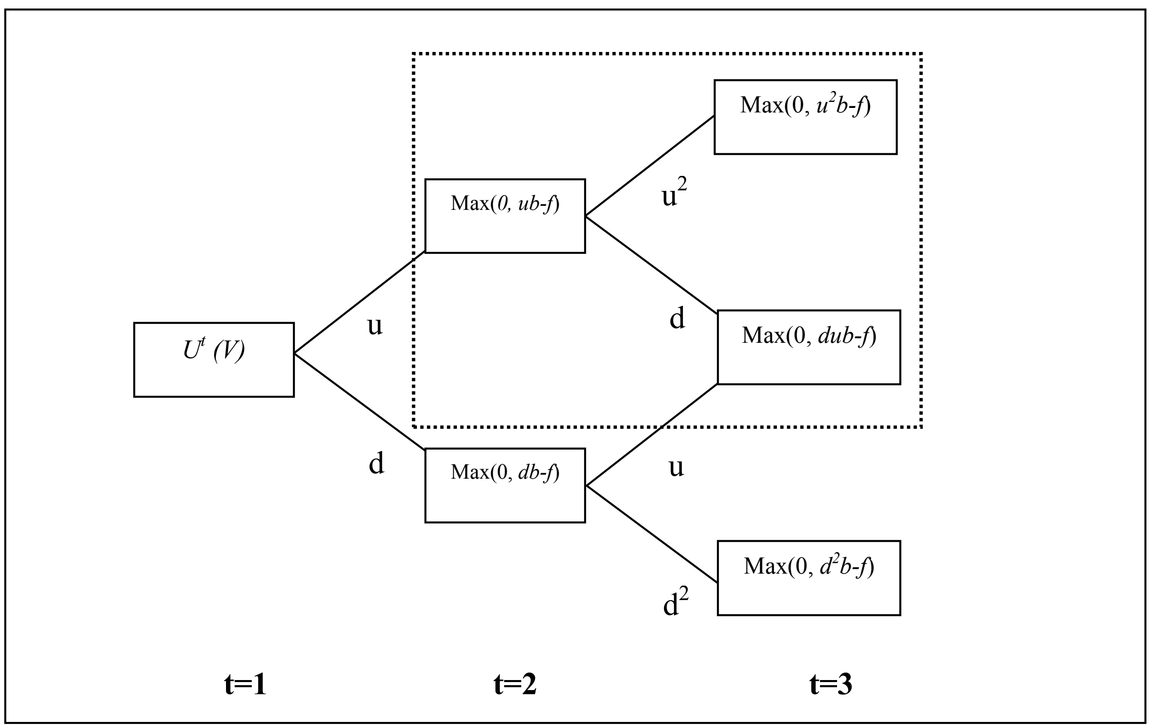
[29] H5 on international sample was only tested for the presence of narrow framing in portfolios. Testing the impact of scenario change and control variables is not the scope of this dissertation.

APPENDIX C: PROOF OF PROPOSITION 4.

An IT manager will exercise the option in*t=2* instead of *t=3*if $V_{2,2} \geq V_{2,3}$.Therefore to find$\bar{\beta}$, we solve $V_{2,2} = V_{2,3}$for $\bar{\beta}$. As shown in Figure 4.8, at *t=2*, the manager may only exercise the option today if uncertainty has resolved in projects favor and payoffs looks relatively certain. This will reduce equation (4.2) for $V_{2,2}$to:

$$V_{2,2} = p(ub - f) \qquad \text{(a-1)}$$

Figure 4.8: Decision problem of naïve IT manager at *t=2*



In equation (a-1), Max terms are eliminated because by *t=2*, uncertainty is resolved and the option is only feasible to be exercised today if payoffs moved upward. Hence the downward lattice in Figure 4.8 will be eliminated. Also *r=1* because of the present nature of the exercise decision.

Similarly, at *t=2*, equation (4) for $V_{2,3}$will be:

$$V_{2,3} = \frac{2(1-p)p(bdu\beta-f)+p^2(bu^2\beta-f)}{r} \qquad \text{(a-2)}$$

Again, Max terms are eliminated because by *t=2*, some uncertainty is resolved if option is exercised in the next period. As the payoffs have already moved upward by *u* at this point, eliminating the downward lattice of the tree at *t=2* indicates the adjusted option value for the decline in future payoffs at that time. For the value of option at *t=3*, the possible movement of future payoffs further by *u* and *d* will stay in the valuation because there is still uncertainty around payoffs value at *t=3*. The possibility of future payoffs recovering from downward movement in *t=3* is kept in the $V_{2,3}$. Future payoffs value moving down by *d* in *t=3* after moving up by *u* in *t=2* is equal to future payoffs value moving up by *u* in *t=3* after moving down by *d* in *t=2*. As the Max function will possibly not give a zero outcome for Max (0, *dub-f*) due to our conditions $d<r<u$ and $ub - f > b - f > 0 > db - f$, it was kept in the equation. Also discount rate *r* will apply for only one time period because when the IT manager at *t=2*, the payoffs in period *t=3* are only one time period away.

Solving (a-1) and (a-2) for $\bar{\beta}$ gives $\bar{\beta} = \frac{f(p+r-2)-bru}{bu(2d(p-1)-pu)}$