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Examining Real Options Exercise Decisions in Information Technology Investments

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Abstract:

Researchers have advocated real options thinking (ROT) for evaluating and managing risky IT investments to account for managerial decision flexibility. Effective ROT is a three-step process that requires managers to recognize, value, and exercise options embedded in IT projects. Prior research has illustrated the existence of managerial bias in the recognizing and valuing real options. However, little research has examined real options exercise decisions. Hence, we use prospect theory to examine whether IT managers demonstrate systematic biases while exercising real options in IT projects and portfolios. We also study whether one can control or mitigate such biases. We found evidence of biased (suboptimal) real option exercise decisions in IT projects and in IT portfolios. However, we found differences in biased decision making between a single project and a portfolio scenario. We also found that project scale and real option type influenced vulnerability of a project to biased decision making. In addition, simplifying the presentation of the net effects of real options exercise decisions can help reduce bias, especially for large project portfolios. We discuss the implications of these results on theory and practice.

Keywords: Real Options, Growth Options, Abandonment Options, Information Technology, IT Portfolios.

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1 Introduction

IT projects are high risk-high return endeavors (Benaroch, Jeffery, Kauffman, & Shah, 2007) with high failure rates (Sandish Group, 2014). IT managers often need to make decisions regarding their projects with incomplete or ill-structured information (Tiwana, Wang, Keil, & Ahluwalia, 2007). Research has proposed real options valuation (ROV) as a way to manage uncertainty by considering decision making flexibility in important capital investments. While ROV allows one to more accurately valuate capital investments (Benaroch & Kauffman, 1999; Benaroch, 2002; Tiwana, Keil, & Fichman, 2006), the complexity of the method makes adopting and implementing it challenging. In practice, managers apply real option thinking (ROT) more frequently than ROV (Amram & Kulatilaka, 1999; Fichman, Keil, & Tiwana, 2005; Davis, 2015) because it is relatively simple to use. ROT refers to intuitive decision making of real option exercise decisions after identifying real options embedded in an investment. According to Fichman et al. (2005), ROT complements ROV if used effectively. ROT is a three-step process that requires managers to recognize, value, and exercise options embedded in IT projects for it to me effective. Studies have shown that various systematic biases exist while recognizing and valuing real options (Lankton & Luft, 2008; Tiwana et al., 2006, 2007). For example, IT managers value real options subjectively, and such valuation differs across option types. Specifically, IT managers value growth options and options to defer an investment higher than other options, such as option to scale or to abandon a project (Tiwana et al., 2007). Previous research illustrates that subjective frames impact real option valuation in general and in IT projects in particular (Miller & Shapira, 2004; Tiwana et al., 2007). However, little research has examined how biases affect how managers exercise real options. We need to study real option exercise decisions because real options' value depends on when they are exercised. Real options are valued with the assumption of optimal exercise (Kumar, 2002). Optimally exercising a real option refers to exercising it at a time period (before expiration) when one receives the highest benefit from doing so. Although some researchers have suggested that real options are suboptimally exercised in practice (Copeland & Tufano, 2004, Khan, Khouja, & Kumar, 2013), we lack empirical evidence to support these suggestions and to support the assumption that real options are optimally exercised. Hence, we seek insights into whether managers can fully realize the value of real options by exercising them optimally.

Building on Khan, Kumar, Khouja, and Zhao's (2010) propositions, we use prospect theory (Kahneman & Tversky, 1979) to understand how IT managers may make real option exercise decisions in an IT project setting. Managers make real option exercise decisions under uncertainty associated with the future outcomes (Coff & Laverty, 2007), and these decisions have risk associated with uncertainty. Prospect theory analyzes decision making under risk and explains decision makers' tendencies while evaluating risky alternatives. It shows that, based on the framing of alternatives, people deviate from risk neutrality by overweighting alternatives with certain outcomes and underweighting alternatives with uncertain outcomes (Kahneman & Tversky, 1979). Researchers have extensively applied prospect theory in the psychology, consumer behavior, investment behavior, and financial markets fields. We explore if prospect theory can explain real option exercise decisions. We study real option exercise in the context of a single IT project and in a portfolio setting, where using ROT is more complex due to the presence of multiple concurrent projects. We empirically test our hypotheses through survey data from 310 IT professionals. As prior research has recognized (Fichman, et al., 2005) and as we mention above, using the real options method to manage project risk is a three-step process. We focus on one underresearched stage; namely, exercising the option. We choose to explore option exercise independently as an initial effort. With our results, we plan to investigate this phenomenon further as a complete process that could include all steps. We discuss the limitations and future research directions in detail later in the study.

Our study contributes to the literature in several ways. First, this study is one of the first to focus on real options exercise decisions (i.e., realized value from real options) instead of real options valuation problems (i.e., expected value from real options). Researchers have not studied real option exercise decisions in the IT context thus far due possibly to the topic's infancy and the lack of conceptualization of real option exercise decisions. Hence, our results make an important contribution to an underresearched aspect of the real options literature in MIS. Second, we conceptualize the real option exercise decisions for empirical studies based on financial and economic theories. This conceptualization may help in further studies of real option exercise decisions. Third, we contribute to the literature and practice of IT project and portfolio management by comparing how managers use ROT in both single project and portfolio settings. Fourth, we investigate the vulnerability of real option exercise decisions to decision biases. Our results challenge the fundamental assumption of risk-neutrality in the real option exercise and provide opportunities for exploring similar phenomena in the future. Finally, we extend the literature on behavioral decision making by studying IT real options from the prospect theory perspective. From a managerial perspective, our results help increase awareness about how managerial bias could affect ROT in practice. Managers who are aware of the presence of these biases could use ROT more effectively. We discuss the practical implications later in the study.

This paper proceeds as follows: in Section 2, we review the relevant literature and present our hypotheses. In Section 3, we detail our research design and methodology. In Section 4, we present our results. Finally, in Section 5, we discuss the results and their implications.

2 Literature Review and Hypotheses

2.1 Real Options and IT Investment

Real options in IT investments offer managerial flexibility to change a project's course in response to endogenous or exogenous events (Davis, 2015). Several types of real options may exist in an IT project, including growth options and options to defer, switch, scale, or abandon the project (Benaroch et al., 2007). Each option type provides a different type of flexibility for the project. For example, an option to abandon a failing project mid-way may help to minimize losses. A growth option provides managers an opportunity to increase a project's net value by allowing additional investment in the project. For a detailed taxonomy on real options in the IT context, please refer to Benaroch et al. (2007). Although real options provide a tool for hedging unsystematic risk in IT projects, significant uncertainty persists when exercising them (Coff & Laverty, 2007).

Several studies have focused on using real options for IT investment and project management. They range from conceptualizations of IT investments with real options (Kumar, 1996, 2002), valuation methods for the IT real options (Benaroch, 2002; Benaroch & Kauffman, 1999; Kauffman & Li, 2005; Taudes, Feuerstine, & Mild, 2000), and whether ROT agrees with ROV (Fichman et al., 2005; Tiwana et al., 2007). Some studies show that managerial intuition is typically consistent with the factors that determine normative real options values even without explicit real options methods or training (Bowman & Hurry, 2003; Miller & Arikan, 2004). Another school of thought argues that intuition is not always qualitatively consistent with real options analysis (Busby & Pitts, 1997; Lankton & Luft, 2008; Miller & Shapira, 2004; Tiwana et al., 2006, 2007), and researchers have explored the presence and effects of various biases that could impact ROT at different steps (Table 1).

After recognizing and valuing the embedded options in projects (Fichman et al., 2005), managers commit to the options based on their value (Amram & Kulatilaka, 1999). Option holders commit to an option by determining its value and paying an upfront price for it. In the case of IT projects, IT managers commit to an option through committing to the project that holds the real option. In determining the value of a real option at the commitment stage, we assume that the IT manager will exercise the option optimally. An optimal exercise decision means that the IT manager controls the unsystematic risk in the investment in an unbiased and risk-neutral[1] manner. However, prior literature suggests that, during the commitment stage, "expected real options' value" is susceptible to human decision making biases (Miller & Shapira, 2004). These biases are reflected as different values IT managers ascribe to different real options (Tiwana et al., 2006). Prior studies also show that the consistency between managerial intuition and real option values varies across option types and settings (Benaroch, Lichtenstein, & Robinson, 2006a). Evidence from practice also shows that individuals do not optimally exercise real options (Copeland & Tufano, 2004), which leads to a decrease in their value. Evidence from literature and practice has motivated our investigating the existence of managerial biases on the "realized real option value" in an IT context. We do so by studying the "real option exercise decisions" in varying project contexts based on prospect theory.

We use the term "managerial bias" or "bias" to describe any deviation from the decision that a rational economic agent would make in a similar situation. Given that real options theory and its application in IS uses a risk-neutral framework for valuing options (Benaroch, 2000; Benaroch & Kauffman, 1999), we consider a rational economic agent as a risk-neutral investor. Hence, a rational economic agent would exercise real options optimally, and bias would result in a suboptimal option exercise decision. In this study, we use the terms "rational decision versus optimal decision" and "biased decision versus suboptimal decision" interchangeably.

[1] During a risky decision process, an agent is considered risk-neutral when the agent pursues the highest yield while ignoring the associated risk. In other words, risk-neutral agents are indifferent to identical expected outcomes regardless of the underlying probabilities The Von Neumann–Morgenstern utility theorem further explains risk-neutral behavior (von Neumann & Morgenstern, 1953).

Table 1. Literature on Intuitive Valuation of Real Options

Reference	Theory used	Major results	Respondents
Busby & Pitts (1997)	Real options theory	Decision makers in industry evaluate flexibility in capital investments by: • Using periodic reviews or project milestones. • Ensuring greater flexibility to response to business environment for long projects. • Clearly defining exit strategies along with options to delay. • Evaluating all possible negative outcomes.	Senior finance officers
Howell & Jägle (1997)	Human information processing	Managers intuitively value real growth options intermittently and generally optimistically. However, managers' responses to changes in current position of IT asset price (value), volatility, and maturity tended to be in the "correct" direction.	Managers
Miller & Shapira (2004)	Prospect theory and framing effects	Purchasers/sellers of call and put options price them 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 continuation of an IT project with negative feedback.	Managers
	Prospect theory and framing effects	Managers perceive 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 & 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 options.	
Denison (2009)	Escalation of commitment	Participants who explicitly consider real options in a project exhibit less escalation of commitment than do users of net present value analysis alone	Graduate students
Denison, Farrell & Jackson, (2012)	Real options theory	Supervising managers rely less on the real options than the planned path component of project value in long-term projects. The extent to which supervising managers rely on the real options component of value in their funding decisions can be influenced by aggregating or disaggregating the components of project value in a financial summary of subordinates' long-term investment proposals because the report format influences perceptions of the relative accuracy of the planned path and real options components of project value.	Students

We consider two types of real options in this study: growth and abandonment options. From options perspective, one can see an IT investment project as creating a base asset with some expected value (Tiwana et al., 2007). A growth option captures the possibility of building additional assets on top of the base asset (Benaroch, 2002). For example, when implementing an enterprise resource planning (ERP) package is the baseline project, managers can build a data warehouse (i.e., the additional asset) to facilitate the analysis of data captured in the ERP system. Abandonment options refer to flexible actions that managers can make to reduce the potential losses on the base project. It is important to note that, in the case of abandonment options, there is only one asset under evaluation (i.e., the base system), while, in the case of 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). We consider these two types of real options because of their common recurrence in IT projects in practice.

2.2 Prospect Theory and Risky Decisions

Prospect theory suggests that people commonly frame risky choices as either gains or losses. They appear to be risk averse for choices involving gains and risk seeking for choices involving losses (Kahneman & Tversky, 1979). For example, managers could avoid high risk-high return projects because they prefer smaller but relatively certain gains over higher yet probable gains. Their preferences change with situations involve losses, where decision makers strongly favor a probable but higher loss over a certain but smaller loss. Managers' preference for bigger yet probable losses in the future over certain but smaller losses today may lead to difficulty in abandoning a poorly performing IT project.

Prospect theory divides the choice process into two phases. In the first phase (framing and editing), one preliminarily analyzes the decision problem, which frames the possible actions, contingencies, and outcomes. In the second phase (evaluation), one evaluates the framed prospects and selects the prospect of highest value (Tversky & Kahneman, 1981, 1986). In the evaluation phase, individuals makes choices based on the decision problem's framing, and the choices reflect specific risk behaviors.

2.3 Prospect Theory and Real Option Exercise Decisions

The real options literature illustrates that, while valuing real options, managers' perceptions follow prospect theory predictions. According to Miller and Shapira (2004), the buyers and sellers frame real call options[2] as gains and real put options as losses during real option evaluation. Due to this framing of real options, buyers and sellers are likely to show risk-averse behavior for call options and risk-seeking behavior for put options at the options' purchase time. These effects are reflected in the real option price that each party is willing to pay or receive.

In IT projects, growth options are like call options, whereas abandonment options are like put options (Benaroch, 2002). While valuing projects with real options, managers ascribe the greatest importance to projects with growth options and the least importance to the projects with abandonment options (Busby & Pitts, 1997). Similar results hold for IT projects where IT managers perceive a growth option as adding more value to the project than any other type of option. Hence, research has shown IT managers to ascribe the least value to abandonment options (Tiwana et al., 2006). Such perceptual framing of growth and abandonment options suggests the vulnerability of such options to the risk preferences of IT managers at the time of their exercise. For example, while IT managers value projects with growth options higher during the commitment stage, they may not realize the optimal value of a growth option at the exercise stage. Also, with situations involving certain smaller gains and probable larger gains, certainty effects dominate, indicating risk-averse behavior (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992, pp. 297-298). IT managers may deviate from the rational option exercise decision due to their risk aversion for choices that involve gains.

Abandonment options may suffer from suboptimal exercise due to the difficulty in exercising the option. Some reasons identified for the difficulty to exercise include the "sunk cost effect" and "face saving" (Keil, Mann, & Rai, 2000), fear of disruption in ongoing project operations, negative impact on the team's morale and credibility, and the inability of the abandonment option to provide a sense of accomplishment as compared to other real options except curtailing losses (Tiwana et al., 2007). Those challenges could lead to delay or IT managers' failure to exercise.

Perceiving abandonment option as loss may be another reason why IT managers ascribe the least value to abandonment options (Miller & Shapira, 2004). Hence, while exercising them, IT managers might exhibit risk-seeking behavior. For example, usually IT managers tend to wait when projects are not performing well with the hope that the temporary phase might pass and the project will pick up soon (Keil, Depledge, & Rai, 2007). Also, in situations that involve certain smaller loss and probable larger loss, certainty effects dominate, indicating risk-seeking behavior (Kahneman & Tversky, 1979). Given these arguments, we believe that real options may be subject to biased exercise. In Sections 2.4 to 2.8, we build our hypotheses for scenarios where IT managers may be inclined towards biased decision making for growth and abandonment options.

2.4 Real Options Exercise Decisions and IT Project Size

According to Kahneman and Tversky (1979), risk preferences vary according to the stakes involved in the decision. For example, individuals perceive the subjective value difference between a gain of $10 and a

[2] Real call option on an asset gives the option holder a right to further invest in the asset for future expansion (change). Real put option on an asset gives the option holder a right to sell the asset (reduce its scope or sell it) (Amram & Kulatilaka, 1999).

gain of $20 to be greater than the subjective value difference between a gain of $110 and a gain of $120, which leads to greater risk-averse behavior for risky decisions involving smaller amounts. Similar behavior holds true for losses unless the larger loss is intolerable. Hence, the marginal value of both gains and losses generally decreases with their magnitude. IT projects also vary in terms of their scope and investment costs. For example, according to an Aberdeen Group survey (2007), an average total cost of an ERP system ranges from US$0.4 million to US$2.2 million depending on the vendor and the number of system users. Hence, one of the dominant decision variables in a real option exercise decision is the amount at stake. For a project with a growth option, several factors reflect a project's size, such as the project's base value, follow-up costs involved, and the increment in project value after the growth option is exercised. For projects with an abandonment option, the extent of loss incurred and loss saved after the abandonment option is exercised reflect size. In the IS literature, we find evidence that an increase in the project size leads to more biased decisions. Escalation of commitment is more likely in the case of larger projects, which research has explained via the "sunk cost" effect (Keil et al., 2000). Decision makers tend to be more willing to continue a project when the sunk cost level is high. We also find anecdotal evidence of difficulty in terminating large-scale projects. Examples include Denver International Airport's baggage system (Keil & Montealegre, 2000) and London's Taurus stock exchange project (Drummond, 1996). In these cases, research has shown the size of the project along with other factors, such as managers' reputation and the political ramifications of abandoning (Keil et al., 2000), to increase the difficulty in abandoning the project. In larger IT projects with abandonment options, sunk costs are higher compared to smaller projects, which, in turn, might make escalation of commitment more likely. These findings are counter-intuitive to prospect theory predictions for the potential effect of project size on real options exercise decisions.

For a project with a growth option, a larger project usually requires a larger follow-up investment, which increases the project's stakes, as compared to its small counterparts. Factors such as technology market, competitive market position, and importance of IT investment in the organization tend to make organizations cautious about their investments. When organizations are more cautious and when IT managers' reputation depends on a project's performance, they may become more conservative in their investment approach. Keeping in view the evidence from IS literature on escalation of commitment and the strategic bend towards technology spending in the past few years, we believe the prospect theory predictions might not hold. Based on these arguments, we propose:

H1a: IT managers are more likely to make a suboptimal decision for a large IT project with a growth option than for a small IT project with a growth option.

H1b: IT managers are more likely to make a suboptimal decision for a large IT project with an abandonment option than for a small IT project with an abandonment option.

2.5 Single Projects: Real Option Type

While evaluating gains and losses, people tend to be loss averse since they usually prefer avoiding losses than acquiring gains (Kahneman & Tversky, 1979), which means that people are more sensitive to losses than to gains and their displeasure associated with losing a sum of money is generally greater than the pleasure associated with winning the same amount. Researchers have used loss aversion to explain several decision making paradoxes such as people's reluctance to accept fair bets on a toss of a coin (Tversky & Kahneman, 1981) and the discrepancies between the amount of money people are willing to pay for a good and the compensation they demand to give it up (Bishop & Heberlein, 1979; Knetsch & Sinden, 1984; Tversky & Kahneman, 1986). Researchers have also used this phenomenon to explain the endowment effect in which the selling price for consumption goods is much higher than the buying price (often by a factor of two or more). Due to loss aversion, the value of a good to an individual appears to be higher when they view the good as something that they could lose or give up than when they evaluate it as a potential gain (Kahneman, 2003).

Extending loss aversion to real option exercise decisions in IT investments means that the reaction to losses associated with an abandonment option will tend to be stronger than a reaction to gains associated with a growth option. Hence, suboptimal decision making at the option exercise time for abandonment options is more likely to occur than in the case of growth options.

H1c: IT managers are more likely to make a suboptimal exercise decision for an IT project with an abandonment option than for a similar IT project with a growth option.

2.6 IT Portfolios and Real Option Exercise Decisions

For strategic decisions that involve high stakes for an organization, managers need to make decisions objectively and inclusively by considering all the alternatives and integrating a variety of information (Bukszar & Connolly, 1988). Decisions pertaining to IT portfolios are no different. An IT portfolio is a collection of individual IT projects managed collectively (Bardhan, Bagchi, & Sougstad, 2004; Benaroch, Shah, & Jeffery, 2006b). The overall objective of portfolio management is to maximize the net value of the portfolio by balancing the combined risk and value of individual projects.

Portfolios of IT projects allow IT managers to take advantage of diversification opportunities that real options facilitate. For example, consider two resource-interdependent IT projects in a portfolio. One of the projects embeds an abandonment option, and its status indicates poor performance with a very low chance of recovery. The other project is performing well and has a good chance of reaping additional value contingent on further investment. This project also embeds a growth option. In this scenario, the IT manager can take advantage of real options and maximize the portfolio's economic value by terminating one project by exercising the abandonment option and reallocating resources to the other project. However, if IT managers view these respective decisions as a gain versus a loss, they might be inclined to avoid abandoning the poorly performing project and to let the good performing project take its regular course to avoid further risk. This decision would negatively affect the net portfolio outcome.

Tversky and Kahneman (1981) found a similar phenomenon among individuals who face risky decisions. Naming it "narrow framing", they show that, when making multiple risky decisions simultaneously, individuals tend to consider related problems individually by isolating them from each other. Isolation means decision makers ignore all the relevant current information and/or future implications of their decisions. Hence, narrow framing is the tendency to evaluate risky prospects in isolation rather than associating them with other risks they face (Kahneman & Lovallo, 1993; Tversky & Kahneman, 1981). As Kahneman (2003) puts it: "decisions made in narrow frames depart far more from risk neutrality than decisions that are made in a more inclusive context" (pp. 14). Several studies have focused on finding the causes that lead to narrow framing. The list includes intuitive thinking (Kahneman, 2003), decision makers' risk preferences (Kahneman & Lovallo, 1993), loss aversion (Barberis, Huang, & Thaler, 2006), and regret (Barberis & Huang, 2006). Kahneman (2003) suggests that narrow framing occurs when individuals make decisions intuitively instead of through systematic reasoning and, hence, specify intuitive thinking as a cause of narrow framing. Kahneman and Lovallo (1993) state that: "if a decision maker is risk averse in some situations and risk seeking in others, they end up paying a premium to avoid some risks and a premium to obtain others" (p. 19). This statement suggests that the way individuals intuitively frame decisions leads them to view decisions narrowly. Barberis and Huang (2006) argue that regret[3]-prone individuals are more likely to engage in narrow framing. Similarly, Barberis et al. (2006) identify "aversion to losses" as a cause of narrow framing. Hence, framing a decision narrowly may affect the overall IT portfolio performance. Thaler, Tversky, Kahneman, and Schwartz (1997) suggest that narrow framers evaluate projects one at a time rather than as a part of a portfolio. We explain above that options embedded in individual projects are vulnerable to the risk preferences of IT managers during the options' exercise stage. Combining these arguments with the complexity of the real option exercise decision in portfolios, we hypothesize:

> **H2a:** When IT managers exercise real options in an IT portfolio, they are likely to make suboptimal exercise decisions.

Referring to the above discussion about the causes of narrow framing, individuals may frame the decisions narrowly either due to their respective risk preferences/tolerance, aversion to losses, or aversion to the feeling of regret associated with bad decisions. In the case of an IT portfolio, either or all of the causes might hold depending on the decision makers and how they comprehend the different mixes of option exercise decisions appearing in a portfolio. For example, an IT manager who is risk averse for losses may display this behavior in decisions that involve some extent of losses. Prospect theory suggests that this behavior should be consistent regardless of how the decisions appear. Hence, it would hold for single decisions and in portfolios. In fact, this risk behavior will drive the decision away from rationality and towards isolation. Therefore, how IT managers exercise individual real options in a portfolio should be consistent with how they exercise them in single projects. Once the decisions are isolated from each other in a complex decision scenario, the decision maker perceives them as mutually exclusive decisions, which causes them to ignore the relevance of relationships among these decisions (Kahneman & Lovallo, 1993). Consequently, a risk-

[3] Regret refers to the decision maker's feeling of having made the wrong choice compared to a better alternative (Roese & Olson, 2014).

seeking manager will remain a risk seeker for losses regardless of decisions for a single project or for a portfolio. The same will hold true for a risk-averse manager in the case of gains. Hence, prospect theory preferences will affect the realized option value regardless of the real options' presentation as a single decision or a cumulative decision in a portfolio.

H2b: For an IT project, IT managers' real option exercise decisions will remain the same whether they evaluate the project independently or as a part of a portfolio.

2.7 IT Portfolio and Resource Interdependency

In a portfolio, projects may share various resources, such as financial resources (where a portfolio needs to be maintained out of a budget pool) and human resources (when the same set of people are responsible to develop, implement and maintain the projects involved in the portfolio). The challenge in this case is to maximize portfolio value while efficiently using the scarce resources at hand. Such interdependencies initiate competition for scarce resources (Throp, 1999). Also, such interdependencies act as constraints on the portfolio and affect the portfolio's strategic alignment with the firm's goals (Goldman, 1999). Hence, efficiently managing these scarce resources is vital for project portfolio management. The IS literature highlights the contribution of effective resource management in IS projects by promoting de-escalation of commitment in failing projects (Keil & Robey, 1999). Research has suggested becoming aware of alternative uses of the funds supporting a project as a way to reduce decision making in isolation (Keil & Robey, 1999; Northcraft & Neale, 1986). Research has shown that highlighting the alternative uses of remaining resources leads to decisions that closely reflect the cost/benefit prescriptions (Northcraft & Neale, 1986) instead of subjective decisions based on risk behaviors. Resource interdependency may encourage IT project managers to consider the impact of each option's exercise decision on the portfolio's net outcome and improve the overall portfolio performance.

H3: Recognition of resource interdependency among projects in an IT portfolio will improve the portfolio's rational exercise decision making by IT managers.

2.8 IT Portfolio Size

We hypothesize earlier that an increase in a project's size may intensify biased decision making for growth and abandonment options due to economic recession effects, a shrinking technology market, and greater sunk cost effects in larger projects. We extend the same argument for IT portfolios that comprise growth and abandonment options and propose:

H4: Increasing project sizes in an IT portfolio will reduce the portfolio's rational exercise decision making by IT managers.

3 Research Design and Methodology

While several studies have provided information about valuing real options, we still lack evidence on what real option exercise decisions might look like. In order to simulate the real option exercise decisions in this study, we need to: 1) realistically conceptualizing IT real options and 2) model real options exercise scenarios based on their conceptualization. We discuss both actions in this section and use them to create the survey profiles.

3.1 Conceptualizing IT Real Options

One can conceptualize a real option in an IT project as an American option that one can exercise at any point up until the expiration. For example, one can view a growth option as a compound option, where investment in any time period can result in an option to make a further investment in the next time period (Amram & Kulatilaka, 1999). However, conceptualizing IT real options in this manner makes it hard to value them and, hence, the IS literature has leaned towards a simpler conceptualization (i.e., European options, with a single deterministic expiration and exercise time) (e.g., Su, Akkiraju, Nayak, & Goodwin, 2009). Comparing the two conceptualizations, the general consensus is that an IT real option behaves more like an American type option than a European type option (Benaroch, 2002). A simpler conceptualization of an American option is the one where there are discrete milestones or review points, such as Black's approximation of an American call option (Hull, 2006). For our purposes, this simpler conceptualization is appropriate due to our focus on the option exercise decision.

Consider a fairly general software-implementation scenario such as an ERP system implementation with two modules. Implementing each module could result in benefits such as cost reductions, revenue increases, or both. Such projects are often implemented in phases. Management may not commit to implementing both modules at the start of the project. Implementation of the second module may depend on implementation progress of the first module (Bardhan et al., 2004; Benaroch et al., 2006a). Such a strategy provides managerial implementation flexibility. However, there might be a lead-time involved in procuring resources (contracting for and procuring hardware, software, and personnel) required for the second module. Hence, waiting until completing the first module could delay the implementation of the second module and, thus, delay any benefits (dividends) resulting from implementing the second module. It might be best to make a decision regarding future investment before completing the first module. Management has an option to grow or abandon the project depending on its progress, which one can capture as an expected NPV. In theory, the growth option is an American option, which one can exercise any time during the course of the project. In practice, one may make such decisions at discrete review points. One can find examples of such situations in an IT infrastructure context in Panayi and Trigeorgis (1998) and Taudes et al. (2000).

3.2 Modeling a Real Option Exercise Decision

Exercising an option is a decision that involves considering risk. Research has conceptualized decision making under risk as choices between prospects or gambles (Kahneman & Tversky, 1979). The closest approximation of capturing such decisions in organizations is to treat them like a gamble (Kahneman & Lovallo, 1993), which is characterized by uncertainty and the dependency of payoffs on a decision. We used Tversky and Kahneman's (1981) design for testing the "framing of act". Their experiment captured "risky choice framing" (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981, 1986) with implications for prospect theory in terms of certainty effects, loss aversion, and narrow framing of decisions. The gambling design is a popular design to capture risk preferences in various disciplines including business, economics (Levin, Schneider, & Gaeth, 1998), and real option valuation (Miller & Shapira, 2004). In IT project management, top management uses the expected value method (EVM) to quantitatively analyze the best course of action in situations where future outcomes are uncertain (Wu, Ong, & Hsu, 2008). EVM is close to the gambling design; hence, the gambling design appears to be the simplest yet most realistic way to represent a real option exercise decision.

We conducted a survey among IT professionals, and Table 2 summarizes our survey characteristics based on Kuhberger's (1998) taxonomy for risky choice design. We gave each survey participant eight decision scenario profiles that varied in terms of option type, project size, and decision scenario presentation. Appendices A and B provide additional details for decision scenario profiles, independent and dependent variables, and survey[4].

Table 2. Decision Scenarios' Characteristics

Risk characteristics		
Characteristics	**In our study, we used**	**Explanation**
Risk manipulation	Reference point	We based risk manipulation for project scenarios on NPV of the projects as reference points (Fichman et al., 2005). We presented the positive and negative outcomes with respect to zero NPV to the respondents.
Quality of risk	Riskless/risky option	Each real option decision comprised a risky and a riskless decision so we could map real options to risk averse and risk-seeking behavior based on prospect theory.
Number of risky events	Single/multiple risk event	Each project decision scenario had only one risky decision against a riskless one. For a portfolio scenario, there were two risk events.
Task characteristics		
Characteristics	**In our study, we used**	**Explanation**
Framing manipulation	Task-responsive	We induced the gain/loss perception by risk manipulation. We did not label outcomes as gains or losses.

[4] Complete survey and additional details for decision scenario profiles and independent and dependent variables is available in the supplementary material.

Table 2. Decision Scenarios' Characteristics

Response mode	Choice	Each respondent had to make a choice for each real option scenario. Choice responses dominate framing research (Kuhberger, 1998).
Comparison	Within subjects	We analyzed data within subjects.
Unit of analysis	Individual	We used individual responses to test the hypotheses.
Problem domain	Economic	Real options decisions in it investments are an economic decision problem.
Participant characteristics		
Characteristic	**In our study, we used**	**Explanation**
Sample	Target sample	We conducted our survey among the target sample of IT professionals involved with project and portfolio decisions.

3.3 Sample and Data

We pilot tested the decision scenarios among MBA students at a large U.S. university. We obtained a total of 37 usable responses to test the quality of the questions and the clarity of the project and portfolio scenarios. We made minor modifications based on the feedback. We further tested the decision scenarios using Dun & Bradstreet's 2010 executives list (Tiwana et al., 2006, 2007) that comprised top and mid-level management in U.S. organizations involved in IT management. We obtained a total of 43 usable responses to pre-test the decision scenarios among professionals. Based on the results, we determined that we did not need to make any modifications. We sent the finalized questionnaire to 1821 IT management professionals in the US and abroad using Project Management Institute (PMI) U.S. chapters and communities of practice. The target sample comprised IT professionals from different industries. We received 331 responses (for an 18.18% response rate). Of these responses, 310 were complete. Further, 180 responses were from U.S. respondents and 130 from international respondents.

All values for all variables were within acceptable ranges, which suggested that there were no data entry errors. We detected some univariate outliers for the variable "real options experience". As such, we computed the descriptive statistics with and without outliers, but they stayed the same. Hence, we retained the observations in the data set. We checked for multicollinearity and normality of distribution for the control variables. We dropped the variable "age" from the analysis based on VIF (2.94 with work experience) and bivariate correlation (0.8 with work experience). In terms of normality of data distribution, some variables were slightly skewed but not enough to merit data transformation. Tables 3 and 4 provide the respondents' demographic information.

Table 3. Descriptive Statistics (N = 310)

		Frequency	Percent	Cumulative percent
Gender	Female	60	19.4	19.4
	Male	250	80.6	100
Sector	Manufacturing	176	56.8	56.8
	Services	134	43.2	100
Firm size	Less than 1 million	62	20	20
	1 Million - 500 Million	122	39.4	59.4
	500 Million - 1 Billion	37	11.9	71.3
	More than 1 Billion	89	28.7	100
Age	Less than 20	51	16.5	16.5
	20-29	49	15.8	32.3
	30-39	55	17.7	50
	40-50	59	19	69
	Above 50	96	31	100

Table 3. Descriptive Statistics (N = 310)

Work experience	Less than 4 years	2	0.6	0.6
	5-9 years	38	12.3	12.9
	10-14 years	55	17.7	30.6
	15-20 years	44	14.2	44.8
	Above 20 years	171	55.2	100

Table 4. Descriptive Statistics: Experience (N = 310)

Variables	Minimum	Maximum	Mean	Std. Deviation
Experience: it investment	1	5	3.22	1.164
Experience: real options	1	5	3.29	1.138
Experience: portfolio management	1	5	2.93	1.188

When comparing answers between early and late respondents (Armstrong & Overton, 1977), we did not find any significant non-response bias. To check for non-response bias, we compared our test sample with the pilot test respondents on six demographic dimensions. We selected this sample because of the similarities between these two groups. The survey was sent out in two phases. We used Pearson's correlation to calculate the effect size because it is one of the most common effect size measures (Rosenthal & DiMatteo, 2001). We found no significant difference between early (phase 1) and late (phase 2) respondents on any scale (Table 5). The effect sizes were negligible. By inference, we conclude that responders and non-responders did not differ and that we did not have a nonresponse bias on our surveys.

Table 5. Comparison of Early and Late Responders on Six Demographic Scales

	Phase 1 and 2	N	Mean	SD	Difference	Effect size*
Age	Early respondents	43	4.39	0.903		
	Late respondents	310	3.32	1.47	1.07	0.106
Firm size	Early respondents	43	2.83	0.92		
	Late respondents	310	2.49	1.11	0.34	0.084
Work experience	Early respondents	43	4.79	0.56		
	Late respondents	310	4.11	1.13	0.68	0.073
IT investment experience	Early respondents	43	4.63	0.59		
	Late respondents	310	3.22	1.16	1.41	0.193
Real options experience	Early respondents	43	4.14	1.06		
	Late respondents	310	3.29	1.13	0.85	0.159
Portfolio management experience	Early respondents	43	3.98	1.1		
	Late respondents	310	2.93	1.18	1.05	0.113
* We calculated effect size using Pearson's correlation.						

4 Results and Analysis

4.1 Real Option Exercise Decisions in Single Projects

We coded the data as binary where 1 represented the rational response (optimal exercise decision) and 0 represented the biased response (suboptimal exercise decision). Further, we coded the portfolio data as Table 6 shows. Rational responses were the economically dominant ones, and we considered any other responses as biased. For each real option, the economic dominant choices were the ones with the higher net value after accounting for uncertainty. Appendix A provides additional details for decision scenario profiles and the respective choice mapping[5].

Table 6. Coding key to calculate portfolio choices

Possible portfolio outcomes	Growth option response in the portfolio	Abandonment option response in the portfolio	Portfolio outcome
Scenario 1	1 (correct choice)	1 (correct choice)	1 (correct choice)
Scenario 2	1 (correct choice)	0 (incorrect choice)	0 (incorrect choice)
Scenario 3	0 (incorrect choice)	1 (correct choice)	0 (incorrect choice)
Scenario 4	0 (incorrect choice)	0 (incorrect choice)	0 (incorrect choice)

We used non-parametric frequency analysis to evaluate the responses for each decision scenario followed by a Chi-square test (Table 7). According to the results, respondents took a significant proportion of biased decisions for the growth options (project 1 and 3), abandonment options (project 2 and 4), and portfolios. Specifically, project 3 and all three portfolios had more biased decisions than rational ones. Furthermore, we used a Chi-square test to test whether IT managers were significantly more likely to make rational exercise decisions compared to biased decisions. The difference was statistically significant for project 1 (χ_1^2= 46.22, p < .05), project 2 (χ_1^2 = 46.22, p < .001), project 4(χ_1^2 = 46.22, p < .05), and portfolio 3 (χ_1^2 = 46.22, p < .001), which Table 7 shows. These results show that, for projects 1, 2, and 4, IT managers were significantly more likely to prefer rational decisions over biased decisions. However, for portfolio 3, IT managers were significantly more likely to prefer biased decisions over rational decisions. For project 3, portfolio 1, and portfolio 2, the differences between rational and biased decisions were statistically insignificant.

Table 7. Individual Project Scenario and Portfolio Responses (N = 310)

	No. of rational decisions (percentage)	No. of biased decisions (percentage)	Chi-square (p-value)
Project 1 (small project-growth option)	173 (55.8%)	137 (44.2%)	4.181 (<0.05)
Project 2 (small project-abandonment option)	243 (78.4%)	67 (21.6%)	99.92 (<.001)
Project 3 (large project-growth option)	146 (47.1%)	164 (52.9%)	1.05 (0.307)
Project 4 (large project--abandonment option)	174 (56.1%)	136 (43.9%)	4.66 (<0.05)
Portfolio 1 (small-scale independent projects)	144 (46.5%)	166 (53.5%)	1.56 (0.21)
Portfolio 2 (small-scale interdependent projects)	152 (49.0%)	158 (51.0%)	0.116 (0.733)
Portfolio 3 (large-scale independent projects)	86 (27.7%)	224 (72.3%)	61.43 (<.001)

4.1.1 Single Projects: Effect of Project Size

To test project size effects (H1a and H1b), we compared the responses between small and large projects with the same option type using the non-parametric Cochran's Q test (Cochran, 1950). The tests showed significant differences between projects 1 and 3 (χ_1^2 = 8.01, p < .01) and between projects 2 and 4 (χ_1^2 = 46.22, p < .001), which indicates that project size intensified the biased decisions for growth options and for abandonment options. Combining these results with the frequency analysis in Table 7, we found that, for growth option scenarios, the percentage of rational responses decreased significantly from 55.8 percent in small projects to 47.1 percent in large projects. Similarly, for abandonment option scenarios, the percentage of rational responses decreased from 78.4 percent in small projects to 56.1 percent in large projects. Thus,

[5] Complete survey and additional details for decision scenario profiles and independent and dependent variables are available in the supplementary material.

biased decisions were more prevalent in large projects with real options than in small projects, which supports H1a and H1b. Also, the effect was relatively stronger for the abandonment option (with 22.3% drop in rational responses) than for the growth option (with 8.7% drop in rational responses).

4.1.2 Single Projects: Real Option Type

To test for loss-aversion (H1c), we compared the responses between the growth and abandonment options for projects of similar size using the non-parametric Cochran's Q test for correlated samples. The tests showed significant differences between project 1 and 2 responses (χ^2_1 = 35.00, p < .001) and between project 3 and 4 responses (χ^2_1 = 5.6, p = .018), which indicates that the real option type affected the intensity of biased decisions in single projects. Furthermore, the proportion of biased decisions was greater for the growth option regardless of project size, which suggests that IT managers did not show significant loss aversion. Thus, IT managers were more prone to making biased decisions for growth options by exhibiting risk-averse behavior as compared to the abandonment option. Hence, our results reject H1c.

4.2 Real Option Exercise Decisions in IT Portfolios

To test the decision making trend in the portfolios (H2a), we used non-parametric frequency analysis. Further, we used repeated measures ANOVA to examine the isolation effect due to changing scenarios from single projects to portfolio on real option exercise decisions (H2b). The frequency analysis (Table 7) showed a significantly higher proportion of biased decisions taken for portfolio 1 (53.5%), portfolio 2 (51%), and portfolio 3 (72.3%). These results illustrate the presence of biased portfolio decisions for all of the project portfolios. We used the Chi-square test to test whether the proportions of rational decisions and biased ones differed significantly. The difference was statistically significant for portfolio 3 (χ^2_1= 46.22, p < .001). Thus, we found partial support for H2a.

We used repeated measures ANOVA to test the trend of real options' decisions between single projects and portfolios. We presented small projects with the growth option and the abandonment option to the respondents three times. We first presented them as a single project scenario, then as a portfolio of independent projects, and finally as a portfolio of interdependent projects. However, we presented large projects with the growth option and the abandonment option to the respondents twice: first as a single project and then as a portfolio of independent projects. For the small growth option scenario, repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean option exercise decisions were statistically different among the three scenarios (F (1.87, 576.61) = 22.21, p < .001). Post hoc tests using the Bonferroni correction revealed that changing the decision scenario for small growth options from a single project to a portfolio of independent projects elicited a decrease in biased growth option exercise decisions that was statistically significant (p < .001): 71.6 percent of respondents made a rational decision for the growth option in the independent portfolio as compared to 55.8 percent of respondents in the single project scenario. A similar result held when we changed the decision scenario from a single project to a portfolio of interdependent projects (p < .001) with 71 percent of respondents making a rational decision. Thus, a portfolio elicited a statistically significant decrease in biased decisions for growth options as compared to a single project regardless of interdependency among portfolio resources. We found similar results for the large growth option with significantly different exercise decisions between the two scenarios (F (1, 309) = 9.382, p < .01). Post hoc tests using the Bonferroni correction revealed that, for a large project, changing the decision scenario from a single project to a portfolio of independent projects elicited a statistically significant decrease in biased decisions (p < .01): 55.5 percent of respondents made rational decisions for the growth option in a portfolio as compared to 47.1 percent of respondents in a single project scenario.

For the small abandonment option scenario, mean exercise decisions were significantly different among the three scenarios (F (1.96, 606.37) = 9.979, p < .001). Changing the decision scenario from a single project to a portfolio of independent projects or to a portfolio of interdependent projects elicited an increase in biased abandonment option exercise decisions that was statistically significant (p < .001; p < .01): 66.5 percent of respondents made rational decisions for the abandonment option in a portfolio as compared to 78.4 percent of respondents in a single project scenario. Hence, portfolios elicited a statistically significant increase in biased decisions for abandonment options as compared to single projects.

The results were different for large abandonment options where the mean exercise decisions did not differ significantly between the two scenarios (F (1, 309) = 1.33, p = 0.25). This result shows that changing the decision scenario from a single project to a portfolio of independent projects did not impact abandonment option exercise decisions: 52.6 percent of respondents made a rational decision for the abandonment option in the portfolio as compared to 56.1 percent of respondents in the single project scenario. Hence, for the large project with an abandonment option, changing scenarios from a single project to a portfolio did not affect the exercise decisions. The proportion of biased decisions in the large project with an abandonment option was large, and the trend stayed the same in the large portfolio. In summary, the risk behavior changed significantly as the real option exercise decision changed from a single decision to a portfolio decision, which rejects H2b. This result indicates some other underlying reason for narrow framing, and we provide possible explanation in Section 5.

To confirm narrow framing in the portfolio setting, we compared the results of the small independent project portfolio[6] with the results of the simplified question[7]. The test showed a significant difference between choices made in the portfolio and the simplified decision scenario (χ^2_1 = 114.6, p < .001). This result shows that, when we removed uncertainty from the portfolio outcome, most of the respondents changed their preferred decision and went for the optimal portfolio outcome, which confirms the existence of narrow framing bias in portfolios.

4.2.1 IT Portfolios: Resource Interdependency and the Effect of Project Size

We tested Hypotheses 3 and 4 by comparing the results of respective portfolios using Cochran's Q test. To test the effects of resource interdependency among projects in the IT portfolio, we compared the portfolio results of the small independent portfolio (portfolio 1) with the small interdependent portfolio (portfolio 2). The tests showed no significant difference (χ^2_1 = 0.889, p = 0.346). Hence, the interdependency among projects in a portfolio did not facilitate decision quality in the IT portfolio, which does not support H3. We further confirmed the result with a repeated measures analysis.

To test the size effects in portfolios (H4), we compared the results of the small independent portfolio with those of the large independent portfolio. The tests showed significant differences (χ^2_1 =34.327, p < .001). Hence, the projects' size did impact the narrow framing effects in an IT portfolio. From the comparative analysis of portfolios in Table 7, we found that the percentage of rational responses decreased from 46.5 percent in portfolio 1 to 27.7 percent in portfolio 3, where the decrease was significant. Hence, increase in project size increased narrow framing effects instead of reducing them, which supports H4. This result is counter-intuitive to the prospect theory but consistent with prior IS literature and shows that decision makers who handle large IT portfolios are more likely to fall prey to narrow framing as compared to those who handle small IT portfolios. Table 8 summarizes the results.

Table 8. Summary of Hypotheses Support

Hypothesis	Support
H1a: IT managers are more likely to make a suboptimal decision for a large IT project with a growth option than for a small IT project with a growth option.	Supported
H1b: IT managers are more likely to make a suboptimal decision for a large IT project with an abandonment option than for a small IT project with an abandonment option.	Supported
H1c: IT managers are more likely to make a suboptimal exercise decision for an IT project with an abandonment option than for a similar IT project with a growth option.	Not supported
H2a: When IT managers exercise real options in an IT portfolio, they are likely to make suboptimal exercise decisions.	Partially supported
H2b: For an IT project, IT managers' real option exercise decisions will remain the same whether the project is evaluated independently or as a part of a portfolio.	Not supported
H3: Recognition of resource interdependency among projects in an IT portfolio will improve the portfolio's rational exercise decision making by IT managers.	Not supported
H4: Increasing project sizes in an IT portfolio will reduce the portfolio's rational exercise decision making by IT managers.	Supported

5 Discussion and Conclusion

Our results indicate that managers consistently made suboptimal real options' exercise decisions in both single IT projects and project portfolios. In single projects, regardless of their size, IT managers were risk averse while exercising growth options and risk seeking while exercising abandonment options. Though IT

[6] See portfolio question in the sample survey provided in the supplementary material.
[7] See the last question in sample survey provided in the supplementary material.

managers value projects with growth options the most (Tiwana et al., 2006), we found that they did not exercise options in a risk-neutral manner. We observed IT managers' risk aversion at option exercise time. Instead of realizing the optimal value of the growth option, they played it safe. However, for abandonment options, we found most respondents making a risk-neutral decision when the project involved was small. Although IT managers value the projects with option to abandon less (Tiwana et al., 2006), we found that they optimally exercised this option. Real options suffered from biased decision making in portfolios as well. These findings indicate a potential vulnerability of project management based on ROT.

We found some exceptions to prospect theory as well. For the effect of project size, our results contradict prospect theory. In both single projects and portfolios, the proportion of biased decisions increased significantly for large projects. For growth options, some IT managers became more conservative while exercising the option for large projects. One can explain this phenomenon in several ways. Several risk factors affect large IS projects: organizational fit, skill mix, management structure and strategy, system design, user involvement and training, and technology planning and integration (Sumner, 2000). Hence, as the project becomes capital intensive, the associated risks increase as well. Most of these risk factors are systematic, and managers have less control over their mitigation. In turn, this lack of control may cause managers to avoid risk to save the project as agency theory for managerial decision making explains (Wiseman & Gomez-Mejia, 1998) and, thus, lead to more conservative investment strategies. The IS literature suggests that, under high uncertainty, managers value deferral options more than growth options (Lankton & Luft, 2008). We find evidence from theory (Benaroch et al., 2006a) and from practice (Leslie & Michaels, 1997) that IT managers are reluctant to use growth options with high uncertainty, which may also explain our results.

The type of project embedding a growth opinion significantly determines the option's value. For example, managers value growth options embedded in strategic projects more than those in transactional projects (Dimakopoulou, Pramatari, & Doukidis, 2012). The IS literature suggests that IT platforms benefit more from growth options (Dai, Kauffman, & March 2007; Fichman, 2004; Taudes, Feurstein, & Mild, 2000) because they have a strategic orientation. Similarly, lack of competition may also lead one to not exercise growth options (Zhu & Weyant, 2003). Our project scenarios did not specify the strategic importance of projects to the organizations or any other information that could relate to the kind of risks involved and the orientation of the investment scenario. Hence, the respondents might have decided to make safe choices due to the stakes involved in the decision. Also, economic recession effects might have come into play by impacting the IT investment decision makers. Factors such as departmental cost cuts (Botello, 2009) and a shrinking technology market (Ante, 2008) could have motivated participants towards conservative investment rather than profit maximization.

For larger projects with abandonment options, IT managers exhibited risk-seeking behavior and selected the riskier and economically suboptimal decision as compared to small projects with the same option. These findings are consistent with escalation of commitment behavior in IT projects and contrary to prospect theory predictions. The IS literature suggests that reluctance to terminate a project midway comes from its size and other factors (Tiwana et al., 2007). One might also explain these results through the sunk cost effect. Empirical evidence suggests that decision makers find it hard to ignore the sunk cost while making an abandonment decision, which contributes towards escalation of commitment to a failing project (Keil et al., 2000). Higher sunk costs increase the probability of escalation behavior. On a positive note, our results do demonstrate that smaller projects are easier to kill than larger projects—even mid-way through. As such, IT managers may not undervalue abandonment options as much as the literature demonstrates, and these options may not always be difficult to exercise (Tiwana et al., 2006).

Our results do not illustrate loss aversion that prospect theory predicts. IT managers were more conservative in their decisions and exhibited a tendency to "save" as their choice to abandon poorly performing projects demonstrates. They may have been more conservative because losses in IT project decisions are organizational losses (as opposed to individual decisions). Hence, managers may be less emotionally impacted by losses compared to decisions that result in significant individual losses.

In portfolio scenarios, we found inconsistency in risk behavior among the decision makers. Narrow framing did occur as the significant number of suboptimal decisions evidences. However, the risk behavior also changed between portfolios and the single projects. Specifically, the proportion of biased decisions for the growth option decreased in portfolio scenarios; it was opposite for the case of small abandonment options. Even though most respondents made rational decisions for the small single project with an abandonment option, a significant number made biased decisions and exhibited risk-seeking behavior in the portfolio setting for the same option. Interestingly, while most respondents made biased decisions for the large single project with an abandonment option, their preferences did not change significantly in the portfolio setting. Overall, managers took more risk in portfolios that favored only the growth option but not the abandonment option. One might ask if this change of risk behavior depicts an "isolation effect". Our conclusion is that isolation effect did occur but not due to consistency in risk preferences among decision makers. The underlying phenomenon could be the avoidance of regret of facing a loss in a portfolio. While taking risk in growth options with higher payoffs, the managers might also be trying to avoid regret (Barberis & Huang, 2006) of facing a certain loss in parallel. Loss aversion also supports the abandonment option decisions (Barberis et al., 2006) because we saw a significant increase in biased decisions for abandonment options in portfolios as compared to single projects. Given the mix of growth and abandonment options, decision makers leaned towards loss aversion in portfolios, which caused narrow framing. One may explain the risk-taking tendency in portfolios could be the disposition effect that caused the managers' risk perception to change in the portfolios. The disposition effect is reference-dependent behavior and is a special case of narrow framing (Kahneman, 2011) that explains investors' behavior in a portfolio. Due to the disposition effect, people tend to realize gains from selling/disposing winners (i.e., getting the gain out of the opportunity) too soon and keep the losers for too long by being reluctant to realize the losses from disposing them. In our case, contrary to their single project decisions, a majority of the managers invested in the project with the growth option and chose not to abandon the poorly performing project. Hence, they took the opportunity to get the benefit from the growth option, or selling winners, which was beneficial for the portfolio, but they also chose to keep investing in the poorly performing project, similar to riding the losses.

Another reason for risk behavior change in portfolios might be due to a reference point shift among IT managers. 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, Webber, & Welfens, 2011). Also, recently experienced gains and losses can impact managers' risk behavior by making them risk takers after a gain (Sullivan & Kida, 1995). In our case, both effects might have come into play in the portfolio scenario. Adaption comprised information from the single project growth and abandonment options and availability of similar options in the portfolio. With recent experience of a certain gain and a loss in single projects (as per our results), managers might have considered these outcomes while making portfolio decisions. This information might have affected their reference point of project evaluation and led them to take more risk in the portfolio. Hence, managers' focus changed from loss minimization for projects with an abandonment option to taking a chance to breakeven the project with the presence of a growth option. These results indicate that risky decision making in a portfolio setting is more complex than prospect theory explains (Sullivan & Kida, 1995). We also found that, when we simplified portfolio scenarios, we almost eliminated narrow framing. When we simplified portfolio scenarios with real options to remove uncertainty and they became less cognitively challenging, decision makers went for the optimal choice. This phenomenon is known as preference reversal[8]. The simplified decision scenario comprised the same projects as in the first portfolio but without any mention of real options and related decision variables. When we simplified and reframed the portfolio choice(s) such that economic dominance of the combined choice was obvious, most of the IT managers' preferences for portfolio decision changed from risk-driven to risk-neutral and economically optimal decisions.

Interdependency among project resources in a portfolio had no significant impact on the narrow framing. Although research has shown awareness of alternative uses of the funds that support a project to improve decision making (Keil & Robey, 1999; Northcraft & Neale, 1986), it did not hold in our case. In other words, resource interdependencies did not initiate competition for scarce resources (Throp, 1999), nor did they act as constraints on the portfolio, which previous research has specified as important for portfolio alignment (Goldman, 1999). Hence, prospect theory preferences dominated the resource interdependency among IT projects in a portfolio and negatively affected the efficient management of the IT portfolio.

5.1 Theoretical Implications

We contribute to the IS literature by improving the understanding of real options and IT portfolio management. Through this study, we document the evidence of biased real option exercise decisions for growth and abandonment options. We also identify some reasons that might inhibit IT managers from realizing the real options' value while exercising them. Such reasons include the type of real option, size of involved project, and orientation of decision scenarios (single vs. portfolio). Growth options, although valued higher by IT managers, tend to be vulnerable to biased decision making, whereas abandonment options seem to be less vulnerable to biased decision making. Our results indicate that single project decision scenarios facilitated optimal abandonment option exercise decisions, whereas portfolio scenarios facilitated

[8] Preference reversal in prospect theory occurs when people's preferences change for similar choices when they are presented differently (Kahneman & Lovallo, 1993).

optimal growth option exercise decisions. These results indicate the possibility of managing biased real option exercise decision making by carefully examining their type and their presentation in a project. Also, as the size of a project increases, biased decision making tends to increase. Hence, by knowing about the possibility of biased decision making and their potential effects on real options' value, IT managers could improve their decision making either with the help of decision tools and group decision making or by being conscious of their potential biases.

Prior literature has recognized the differences in values among different types of real options (Busby & Pitts, 1997; Miller & Shapira, 2004). Prior research has also recognized such real option value differences at the project-selection stage (Tiwana et al., 2007). However, research has not studied the valuation of different types of real options at the option exercise stage. One reason for why might be the difficulty in conceptualizing real option exercise decisions. Using prospect theory, we provide a nuance understanding of IT real option exercise decisions associated with project and portfolio characteristics. We illustrate different behaviors based on option types embedded in the project since growth options and abandonment options are subject to different types of risk behaviors.

Our findings provide insights into the consequences of ROT and their effects on real options exercise decisions. Our results challenge the general perception of real options as adding to the portfolio value due to decision making flexibility because managerial biases can negatively affect the realized value from real option exercise decisions. Our findings also identify factors that can help reduce managerial biases, such as project size and simplification of portfolio decisions. To improve real options decision making in large IT projects and portfolios, we recommend relying less on intuitive decision making and using decision making tools. Also, in IT portfolios with real options, we recommend identifying the net effect of combined decisions upfront and using available quantitative tools.

We also extend the understanding of behavioral economics by applying it to the context of IT. Narrow framing 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 the portfolio's performance by enabling better resource management (Keil & Robey, 1999; Northcraft & Neale, 1986). Our results indicate that decisions' framing dominates how IT managers concurrently evaluate projects in portfolios. Also, we found that IT managers' risk behaviors change in the portfolios, which lead to inclusive yet still suboptimal decision making.

Our findings about increased biased decisions in large projects and portfolios enrich the IT project management literature by demonstrating the dominance of the IT scale effects on managers' thinking over the relative gain/loss that prospect theory predicts. Our findings illustrate the differences in biases between the management of projects and portfolios of different sizes. Contrary to prospect theory, we found intensified risk behaviors for larger projects and portfolios compared to smaller projects and portfolios.

5.2 Practical Implications

Our results indicate that real option exercise decisions are not easy and that the biased decision making depends on the option type (growth vs. abandonment), project size, and decision scenario (single project vs. portfolio). Hence, understanding these factors can help managers in their decision making and help them choose where intuitive decision making works and where they need to formalize their decisions. Our results also help explain the determinants of overevaluating projects with growth options. Risk-averse behavior while exercising growth option 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, risk-seeking behavior while exercising the option could preclude optimal results. Further, suboptimal real options' exercise decisions in IT portfolios affect IT portfolio management by impacting portfolio outcomes.

To overcome the managerial bias resulting in risk-seeking and risk-avoiding behaviors, training programs that increase managerial awareness of such behaviors could be useful. Focused culture change programs such as those that consulting companies[9] offer may help. Additionally, supplementing ROT with specific valuation and decision evaluation criteria tailored to project or organizational need may be helpful. As Copeland and Tufano (2004) discuss, for better real options' management, using simpler models such as the binomial model

[9] Some consulting companies that specialize in organizational culture management include Deloitte (http://www2.deloitte.com), Culture Consultancy (http://www.cultureconsultancy.com), Gotham Culture (http://www.gothamculture.com).

may be helpful. However, one needs to choose the right valuation model that fits the project's needs and does not become overwhelming. Furthermore, one may need to modify budgeting and planning systems.

Explicitly identifying the real option exercise decision points during their lifecycle and specifying the optimal exercise boundaries (rules governing the option exercise decision) may allow managers to stay on track. These decision points may come in the form of ranges to guide the managers about making option exercise decisions. For example, one may plan an exercise decision around a certain event (e.g., competitors' announcement regarding product release) or the project's progress. McCarthy and Monkhouse (2002) give a good example of guiding principles to facilitate the real option exercise decisions.

Formally designating the real option exercise responsibility to the IT managers and ensuring their motivation may also be helpful. In some instances, optimally exercised real options add value to the projects; however, their effects are not convincing. For example, exercising an option to abandon a project may have significant economic value. However, cancelling the project may also have political implications, a negative impact on managers' personal reputation, negative impact on staff morale, and so on (Ewusi-Mensah & Przasnuski, 1991; Keil et al., 2000). In such cases, managers with designated responsibility must be rewarded based on the optimal decisions.

Organizations that can take up the challenge should explicitly recognize and value real options for projects from the start, should track their value during the project life cycle, should understand when to commit to exercising them, and should train staff in ROV. Our findings can facilitate this training. Implementing quantitative measures to track when and whether individuals exercise real options is important for large projects with real options and project portfolios. Understanding the variables that can potentially facilitate decision making in IT portfolios such as project size and simplification of real options exercise decisions can help to control these effects. Research has shown that explicitly accounting for the interdependency among IT projects in a portfolio improves the portfolio outcome (Keil & Robey, 1999; Northcraft & Neale, 1986). However, our results indicate that doing so does not help to control bias.

5.3 Limitations and Future Directions

We studied only two types of real options that exist in IT investment scenarios (i.e., growth and abandonment options). Several other real options exist in IT projects, including options to defer, switch use, scale, and lease (Benaroch, 2002). Studying them from the prospect theory's perspective would usefully extend this study. We focused on the exercise decision. Future research could examine different steps in ROT (i.e., from identification to commitment and then to exercise decision to understand the relationships between biases in these steps). Future research could consider a longitudinal design to address this issue. Research has previously studied the effects of factors such as gender, work experience, and risk attitudes (Khan, Kumar, Zhao, & Stylianou, 2013; Khan, Zhao, Kumar, & Stylianou, 2015). However, exploring how such factors may influence the real option exercise decisions would also be helpful.

In order to test the carry-forwarded effects of decisions in single scenarios into portfolios, we presented survey questions/decision scenarios to participants first with single projects and then portfolios. Hence, the order of scenarios mattered, and we kept it constant for all respondents. Not changing the order of survey questions might lead to inter-scenario contamination. Hence, one could test the real option exercise decisions using random scenario allocation design in a future study. We used a single population design in this study. In the future, one could use an independent sample design to test the effect of framing of real options on their exercise decision.

We presented the outcomes for each real option used in our survey as either a pure gain (for growth options) or a pure loss (for abandonment options). The abandonment option scenarios we used are closer to reality. However, IT growth options may not always represent a pure gain scenario. Projects that embed a growth option always contain an uncertain cost element along with the uncertain benefit in these investments that one cannot ignore. Examples include infrastructure investments, ERP systems implementation costs, and so on. Also, we created simple project portfolios, but complex portfolios exist in reality with varying degrees of interdependency among the projects. Studying the impact of varying interdependencies among projects on narrow faming would reasonably extend our study. In our portfolio scenarios, we presented the project with the growth option before the project with the abandonment option. Such an order might affect loss aversion because the degree of loss aversion depends on prior gains and losses. A loss that comes after prior gains is less painful than usual because earlier gains moderate it (Barberis, Huang, & Santos, 2001). By contrast, 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. We also did not check for the effects of sequential interdependencies among projects in a portfolio, which could be another extension.

IT projects vary in nature. As a result, their progress monitoring and control mechanisms vary as well. One may evaluate projects multiples times as they progress. However, mid-way evaluations are quite common. As such, we set the project progress at 50 percent. In addition, setting the project progress at 50 percent allowed for simplicity in calculating the earned value of the project in our decision scenarios while keeping them realistic. One could extend our study by evaluating a real option exercise at varying project progress stages, which might explain whether project progress is a contributing factor in real option exercise decisions.

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Appendix A: Decision Profiles and Variables Description

Single Project Profiles

The survey comprised four single IT project profiles. For each project, we presented information about the embedded option, size of the project, and risk and return associated with real option exercise decisions. Each project profile comprised either a growth option or an abandonment option with two outcomes (i.e., a risky outcome due to uncertainty and a riskless outcome). The project profiles also varied in size, represented by the investment costs and payoffs. Table A1 summarizes the project profiles. For the growth option, the risky outcome was to exercise the option by investing further, with probable higher returns. We incorporated uncertainty by presenting the outcome with a probability. The corresponding riskless decision was set as letting the option expire, leading to a certain but lower outcome. We assumed gains for either outcome since growth options are valued higher (Miller & Shapira, 2004; Tiwana et al., 2007) due to the potential for larger future benefits. However, the future realized benefits are uncertain when exercising the option (Coff & Laverty, 2007). One can argue that deferring the investment can reduce the outcome uncertainty. We sought to capture the investment behavior in the absence of such flexibility and to examine the risk behavior of IT managers under such situations. In reality, the flexibility to delay the investment is usually not used by firms operating in a competitive market, where growth is vital for their survival (Lankton & Luft, 2008). Hence, we controlled the survey for absence of deferring the decision. For simplicity, we did not account for time value of money. Hence, we did not provide any discount rates in decision scenarios.

Table A1. Single IT Project Profiles Breakdown

Project profile	Embedded real options	Size of the project
1	Growth	Small
2	Abandonment	Small
3	Growth	Large
4	Abandonment	Large

For the abandonment option, the risky outcome was to continue to invest in a poor-performing project with a slight possibility to breakeven. For poor-performing projects, the outcome uncertainty contributes towards the risk (Keil et al., 2007). We set the respective riskless outcome for these projects as exercising the option to abandon with certain partial loss. Often, in reality, for a project with the option to abandon, the decision has to be made between a smaller but sure loss and a 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 preventing this option from being exercised. Such restrictions include contractual agreements and regulatory ramifications associated with incomplete projects. We assume none of these restrictions for the project.

Further, testing of risky decisions under prospect theory requires the tool to be built around a reference point (Kahneman, 2003). For IT managers, the common criterion used to evaluate projects is their NPV (Fichman et al., 2005; Keil et al., 2007). Hence, we used project's NPV as a reference point, which also serves as a boundary that distinguishes gains from losses (Tversky & Kahneman, 1992). Based on the reference point, we presented the growth options in both project profiles as prospects with the possibility of minimum zero NPV and the abandonment options as prospects with the possibility of maximum zero NPV.

Project Portfolio Profiles

To test for the narrow framing in the IT project portfolios, the survey comprised three IT portfolios. Combining the two single project profiles described above created each portfolio. The portfolios varied in terms of the interdependency among the projects win the portfolio and the size of the projects. Portfolio 1 was the control. Table A2 gives a breakdown on the portfolios' set up. We evaluated the presence of narrow framing in portfolios through the decisions of the respondents in the portfolios and evaluating it against the economically optimal choices for those portfolios. In this case, portfolio's performance might suffer from either suboptimal decision for either or both the option exercise decisions. Further portfolio scenarios helped us in testing the consistency in risk behaviors among decision makers throughout the survey.

Table A2. IT Project Portfolios Breakdown

Portfolio	Number of projects	Embedded options	Interdependency among projects	Size of projects
1	Two	Growth and abandon each	No	Small
2			Yes	Small
3			No	Large

The last decision scenario tested the effects of simplifying portfolio decisions with real options. Based on prospect theory (Tversky & Kahneman, 1981), the optimal alternative is more likely to be recognized if choices presented in a portfolio can be further simplified. Hence, in this question, each choice was an aggregate outcome of option exercise decisions presented in the control portfolio (i.e., the net NPV adjusted for uncertainty in each project). Uncertain decisions are further simplified and represented as single expected values. Meanwhile, certain decisions were unchanged. Out of the four choices, three choices were theoretically consistent with prospect theory's predictions, with the remaining one as the optimal choice.

Independent Variables

Option type: we focused on growth and abandonment options.

Uncertainty and payoffs: consistent with reality, we modeled the real option exercise decision as a simple "exercise" versus "do not exercise" decision. Growth option exercise decisions are usually high risk-high return decisions where risk is contributed by the uncertainty around future outcome. This uncertainty is similar to "volatility in asset price" in real option valuation. For example, exercising a growth option means investing in an ongoing project further with an aim for higher returns. However, for abandonment option, exercise decisions are riskless with a relatively small but certain loss.

In our survey, each real option decision scenario had a certain outcome and an uncertain outcome. For the growth option, the risky decision was the "exercise" decision, which captured the uncertainty associated with further investment in the project. For the abandonment option, the risky decision was the "do not exercise" decision, which captured the uncertainty associated with not abandoning a project with negative feedback. The return from the growth option exercise decision was much higher but with a relatively low probability. Also, the probability of projects with the abandonment option to become valuable again was low. Prospect theory shows that the threshold for risk behavior change is approximately at 50 percent. Risk-seeking behavior in gains and risk-averse behavior in losses are observed for better outcomes with probability less than 50 percent (Tversky & Kahneman, 1992). Therefore, we chose 25 percent as the probability that the better probable outcome would happen in a manner similar to "framing of acts" experiments (Tversky & Kahneman, 1981). We kept the same uncertainty in all scenarios for simplicity and consistency. We used these probability figures as an approximation of volatility in asset price (future project payoffs), covered under a real option. We used payoffs data based on real ERP systems cost figures to make them realistic. ERP systems are a good example of IT projects and project portfolios due to their wide implementation. Also, these investments are considered important due to the variety of applications that are enabled by the ERP systems. The average costs we found for ERP systems ranged from approximately US$0.4 Million to US$2.3 Million (Aberdeen, 2007). We kept payoffs in all the profiles close to these figures. The payoffs varied only for each real option scenario based on project size. We give the details on the project sizes below.

Project size: to control for the projects' size, we chose US$0.5 million for small projects and US$2.0 million for large projects. We positioned all the projects as completed mid-way, where the project progress and resource investment was set at 50 percent. So the earned value for small projects became US$0.25 million and US$1.0 million for the large projects. Earned value enabled us to create a suitable decision point in terms of planned value of the projects. Respondents had to decide the future of the projects purely based on the embedded real option. Table A3 breakdowns the payoffs values and respective probabilities. Consistent with prospect theory, we kept the net payoff difference between risky and riskless options the same in small and large projects (equal to US$200,000) to capture the size effects.

Resource interdependency: we created resource interdependency in one of the portfolios by explicitly mentioning the flexibility in resources (funds and human) use between the projects.

Dependent Variable: Option Exercise Decision

Control variables: we controlled the survey for gender based on risk behavior differences (Fellner & Maciejovsky, 2007) age, work experience (Liu, Wang, & Zhao, 2010), industry sector, and country. For industry sectors, we used distinction of manufacturing and services.

Table A3. Uncertainty and Payoffs used in Decision Scenarios

<table>
<tr><th rowspan="4">Small Projects</th><th colspan="4">Growth</th><th colspan="4">Abandon</th></tr>
<tr><th colspan="2">Exercise</th><th colspan="2">Expire</th><th colspan="2">Exercise</th><th colspan="2">Expire</th></tr>
<tr><th>Pr.</th><th>Payoff</th><th>Pr.</th><th>Payoff</th><th>Pr.</th><th>Payoff</th><th>Pr.</th><th>Payoff</th></tr>
<tr><td>25%</td><td>$1,800,000</td><td>100%</td><td>$250,000</td><td>100%</td><td>$(250,000)</td><td>75%</td><td>$(600,000)</td></tr>
<tr><th>Expected Value</th><td colspan="2">$450,000</td><td colspan="2">$250,000</td><td colspan="2">$(250,000)</td><td colspan="2">$(450,000)</td></tr>
<tr><th>Difference</th><td colspan="4">$200,000</td><td colspan="4">$(200,000)</td></tr>
<tr><th rowspan="4">Large Projects</th><th colspan="4">Growth</th><th colspan="4">Abandon</th></tr>
<tr><th colspan="2">Exercise</th><th colspan="2">Expire</th><th colspan="2">Exercise</th><th colspan="2">Expire</th></tr>
<tr><th>Pr.</th><th>Payoff</th><th>Pr.</th><th>Payoff</th><th>Pr.</th><th>Payoff</th><th>Pr.</th><th>Payoff</th></tr>
<tr><td>25%</td><td>$4,800,000</td><td>100%</td><td>$1,000,000</td><td>100%</td><td>$(1,000,000)</td><td>75%</td><td>$(1,600,000)</td></tr>
<tr><th>Expected Value</th><td colspan="2">$1,200,000</td><td colspan="2">$1,000,000</td><td colspan="2">$(1,000,000)</td><td colspan="2">$(1,200,000)</td></tr>
<tr><th>Difference</th><td colspan="4">$200,000</td><td colspan="4">$(200,000)</td></tr>
</table>

Appendix B: Complete Survey

General Instructions

You will be evaluating four individual IT projects and three IT portfolios in order to determine their future direction.

- Each IT portfolio consists of two IT projects that may or may not be related.
- 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).
- 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 Portfolio 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) 25% chance of NPV being $1,800,000 75% chance of NPV being $0	Invest (exercise the option) 25% chance of NPV being $1,800,000 75% chance of NPV being $0

What would you choose to do for Project 1?
- Invest (exercise the option)
- Do not invest (do not exercise the option)

IT Project Portfolio 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 Portfolio 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 Portfolio 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)

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 for each project within the portfolio.**

IT 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.

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
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 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 the resources from one project can be utilized in another project.

<table>
<tr><td colspan="2">This project has the option to grow (further investment in this IT project may enhance future revenues). Your choices are as follows.</td></tr>
<tr><td>Invest (exercise the option)

25% chance of NPV being $1,800,000
75% chance of NPV being $0</td><td>Do not invest (do not exercise the option)

100% chance of NPV being $250,000</td></tr>
<tr><td colspan="2">This project has the option to abandon (further investment in this IT project may reduce future revenues). Your choices are as follows.</td></tr>
<tr><td>Abandon (exercise the option)

100% chance of NPV being - $250,000</td><td>Do not abandon (do not exercise the option)

25% chance of NPV being $0
75% chance of NPV being - $600,000</td></tr>
</table>

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 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.

<table>
<tr><td colspan="2">This project has the option to grow (further investment in this IT project may enhance future revenues). Your choices are as follows.</td></tr>
<tr><td>Invest (exercise the option)

25% chance of NPV being $4,800,000
75% chance of NPV being $0</td><td>Do not invest (do not exercise the option)

100% chance of NPV being $1,000,000</td></tr>
<tr><td colspan="2">This project has the option to abandon (further investment in this IT project may reduce future revenues). Your choices are as follows.</td></tr>
<tr><td>Abandon (exercise the option)

100% chance of NPV being - $1,000,000</td><td>Do not abandon (do not exercise the option)

25% chance of NPV being $0
75% chance of NPV being - $1,600,000</td></tr>
</table>

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)	○	○

Based on your own experience and knowledge please choose between the following sets of decisions. 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 $250,000 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 $450,000 for project 1 and Net Present Value of $ -250,000 for project 2.
- Realize Net Present Value of $450,000 for project 1 and Net Present Value of $ -450,000 for project 2.

About the Authors

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Ram L. Kumar is Professor of Management Information Systems & Data Science and Business Analytics in the Belk College of Business at the University of North Carolina at Charlotte. He received his PhD from the University of Maryland where he was the recipient of the Frank T. Paine award for academic merit. He worked for major multinational corporations, such as Fujitsu, before entering the academia. His research has been funded by organizations such as the U.S. Department of Commerce, National Institute of Standards and Technology and firms in the financial services and energy industries. His current research interests include Managing Portfolios of Technology Investments, Service Science, Business Analytics and Open Source/Innovation. His research has been published in *Communications of the ACM, Computers and Operations Research, Decision Sciences, Decision Support Systems, International Journal of Electronic Commerce, International Journal of Production Research, Journal of Management Information Systems*, and others. He has advised organizations on the evaluation of R&D projects and IT portfolios and related issues. His international teaching experience includes Hong Kong, France, Mexico, and Taiwan.

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Antonis C. Stylianou joined the Belk College of Business at the University of North Carolina at Charlotte in 1990. Currently, he is the BISOM Department Chair and professor of Management Information Systems and Data Science and Business Analytics. In addition to consulting with several Fortune 1000 companies and non-profits organizations, his industry experience includes an appointment in the Information Management department at Duke Energy. Dr. Stylianou has published numerous research articles in *Management Science*, *European Journal of Information Systems*, *Journal of the AIS*, *Decision Sciences, Decision Support Systems, Information & Management, International Journal of Electronic Commerce, Communications of the ACM*, and other journals. He has received funding for his research from the National Science Foundation, the US Department of Education, the National Institute of Standards and Technology, and other sources. In addition to UNC Charlotte, he has taught courses and delivered seminars at Kent State University, Villanova University, Mannheim University (Germany), Cologne University (Germany), and EGADE (Technologico de Monterrey, Mexico). He currently serves as a senior editor for the *Database for Advances in Information Systems* journal.