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Information Systems Project Continuation in Escalation Situations: A Real Options Model

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ABSTRACT

Software project escalation has been shown to be a widespread phenomenon. With few exceptions, prior research has portrayed escalation as an irrational decision-making process whereby additional resources are plowed into a failing project. In this article, we examine the possibility that in some cases managers escalate their commitment not because they are acting irrationally, but rather as a rational response to real options that may be embedded in a project. A project embeds real options when managers have the opportunity but not the obligation to adjust the future direction of the project in response to external or internal events. Examples include deferring the project, switching the project to serve a different purpose, changing the scale of the project, implementing it in incremental stages, abandoning the project, or using the project as a platform for future growth opportunities. Although real options can represent a substantial portion of a project's value, they rarely enter into a project's formal justification process in the traditional quantitative discounted cash-flow-based project valuation techniques. Using experimental data collected from managers in 123 firms, we demonstrate that managers recognize and value the presence of real options. We also assess the relative importance that managers ascribe to each type of real option, showing that growth options are more highly valued than operational options. Finally, we demonstrate that the influence of the options on project continuation decisions is largely mediated by the perceived value that they add. Implications for both theory and practice are discussed.

Subject Areas: Decision Making, Escalation, Information Integration, Information Systems, Innovation Management, Investment Decisions, Project Continuation, Project Management, and Real Options.

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INTRODUCTION

An escalation situation exists when there is "decision making in the face of negative feedback about prior resource allocations, uncertainty surrounding the likelihood of goal attainment, and choice about whether to continue" (Brockner, 1992, p. 122). The bulk of prior work on escalation has sought to understand apparently irrational instances of escalation where actors persist in courses of action that they could (or should) have known were destined to fail (Staw, Sandelands, & Dutton, 1981; Brockner, 1992). The main goal has been to isolate nonrational factors (i.e., those leaving the project payoff structure unaffected) that reinforce escalation tendencies. For example, managers are more likely to escalate when they have a greater need for self-justification, when sunk costs are higher, and when they hold asymmetric information about project status (Keil, 1995).

Despite the primary focus on nonrational factors, escalation researchers have acknowledged the possibility of other *rational* factors that promote escalation in the presence of negative feedback. An early literature review by Staw (1981) included two rational factors—probability of future outcomes and value of future outcomes—as determinants of continuation tendencies. Bowen (1987) argued that instances of escalation often involve equivocal information about project status and future prospects and that in such cases the common understanding of escalation as an irrational process of throwing good money after bad would not necessarily hold. In fact, there can be numerous subtleties not readily apparent to external observers that could promote project continuation in spite of negative feedback about project status. In the context of information technology (IT) investment projects, Keil and Flatto (1999) suggested that one of these subtleties is the presence of real options in a given project. In particular, they argued that, in instances that appear to be unwarranted (i.e., irrational), escalation may actually be warranted (i.e., rational) escalation were the value of real options taken into account. In this research, we examine whether real options actually do increase the propensity to engage in what we call *warranted continuation* in escalation situation, that is, a normatively rational continuation of a troubled IT project that has continued uncertainty about goal attainment.

Opportunities to embed real options are pervasive in IT projects (Benaroch, 2002). A project embeds real options when managers have the opportunity (but not the obligation) to adjust the future direction of the project in response to external or internal events. These adjustments can take the form of deferring the project, switching the project to serve a different purpose, changing the scale of the project, implementing it in stages, abandoning the project, or using the project as a platform for future growth opportunities. Yet, real options, which can represent a substantial portion of a project's value (Taudes, Feurstein, & Mild, 2000), rarely enter into a project's formal justification process in practice. Instead, quantitative project valuations are typically based on traditional discounted cash flow techniques such as net present value (NPV) that ignore option value (Busby & Pitts, 1997). Naturally, formal post-mortems are likely to focus on how actual experience comported with expectations on this same NPV basis.

Even though real options are rarely considered explicitly, some studies beyond the IT context indicate that operational managers often implicitly recognize

the value of real options (Busby & Pitts, 1997; Kogut & Kulatilaka, 2004). Therefore, there may be instances in which projects that appear to external reviewers employing an NPV logic to have undergone an irrational escalation actually underwent a warranted continuation owing to implicit recognition by operational managers of real options external to the original justification decision. However, this would only be a pervasive phenomenon if it were true that operational IT managers were likely to place a significant value on real options and were more prone to continue troubled projects when they do.

In this research, we investigate the effects of real options on IT project continuation in escalation situations. Our approach is to use a conjoint study to examine how the presence of one or more different option types affect managers' perceptions of project value and their expressed likelihood of continuing investment in troubled projects. In particular, we study escalation scenarios where there is negative feedback and considerable uncertainty about goal attainment and where managers should be indifferent toward continuation from a traditional NPV perspective (i.e., the NPV is set at zero). Making the base-case indifference toward continuing allows us to better isolate the effects of having one or more real options present.

The key question for us is not whether IT managers might place some positive value on real options. Prior research outside IT (Busby & Pitts, 1997) suggests that they often do, and we see no obvious reason why either the IT project context or the escalation context per se would prevent managers from recognizing option value. Rather, we see the key research issues as being: (i) how *strongly* option value translates into an increased propensity to continue a troubled project and (ii) what *differences* exist in how different types of real options (i.e., to switch use, change scale, stage investments, abandon, or strategically grow a project) are valued in escalation situations. The first issue gives an indication of how pervasive the phenomenon of warranted continuation due to recognition of options might be in practice. The second issue can provide some initial insights into possible biases in how options are valued.

Our results show that the presence of real options does lead to a tendency toward continuing projects (i.e., *warranted* continuation), and this tendency increases with the number of real options that are present. Second, our results show that in escalation situations managers place a much higher value on options that spawn new investment opportunities (strategic options), as compared with options that allow them to reconfigure such elements as the timing, scale, and scope of an investment (operating options). Some options, such as the option to abandon, are given very little comparative value.

Negative feedback about project progress and uncertainty about goal attainment are very common occurrences on IT projects (Wallace, Keil, & Rai, 2004). Decisions about whether to continue or to terminate these troubled IT projects are among the most difficult that IT managers face. To come to a full understanding of these escalation situations and to advise managers appropriately, researchers must endeavor to sort out the rational forces from the nonrational. This study complements the large body of previous work examining nonrational factors that promote unwarranted escalation by considering a pervasive but subtle rational factor—the presence of real options—that could lead to warranted continuation.

The remainder of the article proceeds as follows. In the next few sections, we review the relevant literature on escalation, describe real options analysis (ROA), and use real options theory to develop our hypotheses. Then we describe the methodology and data collection and present our analyses and results. Finally, we discuss the theoretical and normative implications of these results, identify directions for future research, and conclude with a summary of the study's key contributions.

ESCALATION AND REAL OPTIONS

Escalation of Commitment

The concept of escalating commitment refers to the human tendency to adhere to a course of action even in the face of negative information concerning the viability of that course of action (reviews of the escalation literature can be found in Staw & Ross, 1987a; Brockner, 1992). Much of the prior literature characterizes escalation as a phenomenon that arises from flawed decision-making processes. The prevailing view is that these flawed—often irrational—decision-making processes lead to flawed decisions and dysfunctional organizational outcomes. As Brockner et al. (1986, p. 122) observe: "The tendency for decision makers to continue allocating resources to an ineffective course of action can be extremely maladaptive, both for individuals and organizations." A similar perspective is expressed by Staw and Ross (1987a), who tend to view escalation as a dysfunctional response.

In fact, all three dominant theoretical perspectives that have been invoked to explain the phenomenon—self-justification theory, prospect theory, and agency theory—paint escalation behavior as irrational. *Self-justification theory* describes escalation as an attempt by individuals to rationalize their previous behavior against a perceived error in judgment (Staw & Fox, 1977). *Prospect theory* describes escalation behavior as decision makers acting contrary to the invariance criterion of rational choice (Kahneman & Tversky, 1984). Similarly, *agency theory* views escalation behavior as the agent pursuing a course of action that is irrational from the principal's perspective (Harrison & Harrell, 1993). Normative prescriptions in the literature suggest that an escalated project should be terminated because it is irrational to throw good money after bad (Boehm, 1981; Staw & Ross, 1987b).

In a critique of the escalation literature, Bowen (1987) questions whether previous studies provide sufficient evidence to conclude that the decision-making processes that underlie escalation behavior are flawed. He contends that escalation behavior results from decision dilemmas arising from equivocal information concerning a particular course of action. According to Bowen (1987, p. 62), "there are times when decisions to recommit resources are clearly reasonable, times when they are clearly irrational, and times when one simply cannot prejudge the future effectiveness of continuing or discontinuing any particular course of action."

In an extension consistent with Bowen (1987), Keil and Flatto (1999) posited that there are two different types of escalation: warranted and unwarranted. *Warranted escalation* (what we call *warranted continuation*) refers to situations in which the decision to continue a project is reasonable because, even though negative

events have transpired since the project was initiated, the expected future benefits of continuing outweigh the costs. (We adopt the label *warranted continuation* rather than Keil and Flatto's label *warranted escalation* in deference to the widespread connotation of escalation as being *necessarily* irrational, even though this assumption is not actually made among escalation researchers.)

Conversely, *unwarranted escalation* refers to situations in which the decision to continue a project can be seen as irrational because expected benefits have been sufficiently lowered, or remaining costs have sufficiently increased, such that the project is no longer economically justified. Using real options theory, Keil and Flatto (1999) presented a conceptual argument that many cases that would be labeled as escalation and assumed to be irrational under the traditional NPV rule actually represent warranted continuation if one considers the value of real options. In other words, on projects where real options are present but which are justified according to an NPV logic, there will effectively be slack in the true valuation of the project that can serve to buffer the effects of negative events that may have transpired since project initiation. Should these options still exist despite the negative events, then continuation could be considered rational even if it would be irrational to continue from the original NPV perspective. This raises the question of whether managers do, at least implicitly, place a value on options when making escalation decisions.

Real Options and Software Project Value

The economic rationale for continuing to invest in a technology-development project is typically determined based on cost/benefit analysis to establish whether the net benefits of the project exceed its cost. Such assessments have traditionally relied on discounted cash-flow techniques such as the project's NPV and cost/benefit analyses (Bharadwaj, Bharadwaj, & Konsynski, 1999; Sullivan, Chalasani, Jha, & Sazawal, 1999). NPV computations use the estimated cash flows discounted to their present value at a discount rate that reflects the market price of the risk involved in continuing the project (Bowman & Moskowitz, 2001). When the cost of bringing a project to completion exceeds the benefits a firm expects from incurring that remaining cost, a project is said to have escalated. However, if NPV underestimates the true value of a project, it may be economically rational to continue the project.

Because NPV estimates do not consider the value of the opportunity for managers to intervene across the project's trajectory, they represent the lower bound of an ongoing project's actual value to the firm (Taudes, Feurstein, & Mild, 2000). The traditional NPV assessment may lead to systematic undervaluation and a corresponding bias against continuing software projects because it ignores the value of managerial flexibility to divert the project's course based on new information. Software development projects are often subject to considerable uncertainty, due to the difficulty of accurately estimating future development time and costs, business needs that may drift over the course of development, and the difficulty of ensuring that the system's functionality maps to evolving project requirements (Ropponen & Lyytinen, 2000). However, as new information emerges over the course of development, managers can actively intervene and redirect the project.

The limitations of NPV approaches have motivated IT scholars to find newer valuation methods that appropriately value managerial flexibility. In particular, IT scholars have begun to advocate applying a real options framework for assessing the value of information systems (IS) investments (Taudes, 1998; Benaroch & Kauffman, 1999; Keil & Flatto, 1999; Taudes et al., 2000; Benaroch, 2002). Real options extend the use of financial options pricing models (OPMs; e.g., Black-Scholes) to value nonfinancial assets. Real options value goes beyond NPV to include the values of the options that are created when a series of repeated decisions can be made sequentially concerning an ongoing capital-investment stream. Thus, a real options approach allows more accurate valuation of capital investments.

A software project possesses a real option when it offers management the opportunity, but not the obligation, to take some action in the future in response to endogenous (within the firm) or exogenous (in the business environment) events (Benaroch & Kauffman, 1999). Software development involves decision making under uncertainty and incomplete knowledge (Sullivan et al., 1999), which makes managerial flexibility to respond to contingencies especially valuable. Flexibility therefore buffers risk while retaining entrée to upside opportunities over the trajectory of a project. Recognizing and promoting such flexibility is the equivalent of acquiring an option, and exploiting it is the equivalent of exercising an option.

Real options often exist in bundles; that is, a project can involve multiple distinct options (McGrath, 1999; Benaroch, 2002). The goal of ROA is to determine the *active* NPV of project, which is equal to the traditional or *passive* NPV plus the value of managerial flexibility—the latter being a fuction of the value of the bundle of options embedded in the project (Benaroch 2002). Thus,

$$NPV_{Active} = NPV_{Passive} + f(\text{value of the bundle of real options embedded in the project}). \quad (1)$$

The true value of a project with zero NPV therefore equals the total value of the various real options embedded in the project. Such a project, to which managers should be indifferent toward continuing from an NPV standpoint, can still be worthwhile when the additional value from options is considered.

Despite the growing interest in using ROA to evaluate uncertain IT investments, it is worth pausing for a moment to consider some challenges that have been raised (Fink, 2001; Teach, 2003). First, there are concerns about the lack of transparency, especially in the frequently used Black-Scholes OPM. The Black-Scholes model is based on a complex, five-parameter formula and requires a solid grasp of calculus to interpret. (However, the binomial model OPM is a bit easier to understand, as are decision trees, which can give a rough approximation of option value.) Other complaints have been raised about the absence of a traded market for IT assets, which can lead to difficulty in estimating options parameters—especially the volatility parameter—and a corresponding risk that analysts may back into values for OPM parameters to get the desired outcome. (However, analysts can identify traded securities that are perceived to have a similar risk profile and use the beta values for these securities to estimate volatility of project value. They can also

do a sensitivity analysis to determine whether a project is justified under different sets of assumed levels of volatility.) As one more challenge, even though options formulas place a higher value on longer times to expiry, in reality the value of an IT initiative may erode with time due to loss of potential competitive advantage. (However, when such erosion is an issue, analysts can estimate the expected value of a project separately for multiple-candidate expiration dates.). For more details on ROA challenges and potential remedies, see Benaroch and Kauffman (1999) and Copeland and Tufano (2004).

Prior research has developed a taxonomy of real options based on the type of flexibility that is associated with each option (Trigeorgis, 1993). These options are: (i) to defer investment, (ii) to switch use, (iii) to change the scale of investment, (iv) to stage investments, (v) to abandon, and (vi) to grow investments. Benaroch (2002) draws an important distinction between the first five option types, which he calls *operational options*, and the sixth option type, *growth options*.

From an options perspective, an IT investment project is seen as creating a base asset with some expected value; for example, the baseline implementation of an enterprise resource planning (ERP) package. *Operational options* pertain to discretionary actions that managers can make to reduce the potential for losses (usually) or increase the potential for gains (occasionally*) on that base project*. *Growth options*, in contrast, capture the possibility of building additional assets on top of the base asset if the initial project were to be completed; for example, building a data warehouse to facilitate the analysis of data captured in the ERP system. In the case of operational options, the focus is on the potential for modification of the nature of the asset created by the base investment (e.g., ERP), while for strategic growth options, the focus is on assets enabled by the base investment (e.g., data warehousing).

Definitions for the different types of options included in our study are summarized in Table 1. The option to defer investment is not applicable to ongoing projects and was thus excluded from our study. The other types of options were all included because they could potentially contribute to the active NPV of a project in an escalation situation.

Even though it may be difficult to precisely calculate the value of real options, it is plausible that managers motivated by the prospect of producing a positive economic return would ascribe a higher value to a project with one or more embedded options than they would to the same project without any embedded options. In an exploratory survey of managerial practice surrounding real options, Busby and Pitts (1997, p. 169) found that "[v]ery few decision makers seemed to be aware of real options research but, mostly, their intuitions agreed with the qualitative prescriptions of such work." Kogut and Kulatilaka (2004) indicate that interviews with managers have shown that real options valuation is rarely used, but, even if this is the case, managers may still be engaging in real options thinking. McGrath, Ferrier, and Mendelow (2004) point out that firms often persist with underperforming investments longer than would be expected under the traditional NPV rule. This behavior pattern, they suggest, may reflect an underlying real options reasoning. Fichman, Keil, and Tiwana (2005) present several case examples in which IT managers took actions and/or gave rationales consistent with options thinking, even though real options were not a formal part of the project assessment.

Table 1: Summary of real option types.

Option	Definition/Example
Switch	The option to switch use refers to the option to put an asset to a different purpose from that for which it was originally intended (Trigeorgis, 1993). For example, a firm might develop an information system for internal use, but then decide to sell it to a third party.
Change Scale	The option-to-change scale allows the resources allocated to a project to be contracted or expanded in order to change the scope of the application (Pindyck, 1988). For example, the team may have discretion over what features are included in the initial implementation or about which sets of users will initially receive the system.
Stage	The option to stage investments exists when a project is structured as a series of incremental outlays that allows the project to be terminated if business conditions become unfavorable. The pursuit of each stage is contingent on a reassessment of costs and benefits at the time the preceding stage is completed.
Abandon	An abandonment option is associated with a project if managers can, without major negative consequences, discontinue the project prior to completion and redeploy remaining project resources (Hubbard, 1994). While any project can be terminated in principle, an abandon option refers to a situation where termination and redeployment can be carried out relatively easily.
Strategic Growth	A growth option is embedded in a project when an initial baseline investment opens the door to pursue a variety of potential follow-on investments, not all of which can necessarily be foreseen (Trigeorgis, 1993). For example, Taudes et al. (2000) present the case of a European automaker that justified a baseline investment to implement an ERP system because this would enable subsequent investments in Electronic Data Interchange-based purchasing and invoicing, workflow applications for sales, engineering document handling, and Web-based e-commerce.

In one of the few laboratory experiments to date on real options valuation, Howell and Jagle (1997, p. 922) found that "the naïve NPV rule is a poor description of how managers empirically value growth options" when presented with decisions on a series of investment case studies. While they found that in the majority of the cases presented to subjects the mean valuation was higher than the NPV estimate, the high level of noise in the empirical valuations led them to conclude that "there is only a weak and approximate correspondence between management's intuition and real growth option theory" (p. 932). They did not explore any operating options that would affect the timing, scale, or scope of a project. Thus, little is known about how managers value operating options or the relative value they ascribe to different types of real options that may be embedded in software development projects. Nor has there been any attempt to examine empirically how real options affect IT project continuation decisions.

In this research, we propose and test a model of project continuation behavior in escalation situations that incorporates the perceived value associated with both growth and operating options that may be embedded in an IT project.

RESEARCH MODEL AND HYPOTHESES

We hypothesize that the perceived value added associated with continuing a project will be a function of the $NPV_{Passive}$ going forward plus the value of real options, as indicated in Equation (2):

$$\begin{aligned} Value\ added = NPV_{Passive} \\ + \{\beta_0 + \beta_{switch} \times Switch + \beta_{scale} \times Scale \\ + \beta_{stage} \times Stage + \beta_{abandon} \times Abandon \\ + \beta_{grow} \times Grow\} + \varepsilon_1. \end{aligned} \tag{2}$$

When $NPV_{Passive} = 0$, the value added is equal to the total value of the real options. We expect that managers' willingness to continue a troubled project is based primarily on the total perceived value that it adds to the firm, which in turn is a function of the options embedded in the project. In other words, we believe that the effect of real options on willingness to continue will be largely or fully mediated by the perceived value added they represent. Despite the expected strong relationship between perceived value and willingness to continue, the variables are by no means interchangeable. In fact, the bulk of the escalation literature investigates how variables other than normatively rational ones (such as perceived option value) might affect the decision to continue a course of action.

We remain open, however, to the possibility of direct effects between the real options embedded in a project and willingness to continue. Therefore, we specify Equation (3) as follows:

$$\begin{aligned} Willingness\ to\ continue = \beta_1 + (\beta_{value-added} \times Value - added) \\ + (\beta_{d-grow} \times Grow) + (\beta_{d-switch} \times Switch) \\ + (\beta_{d-scale} \times Scale) + (\beta_{d-stage} \times Stage) \\ + (\beta_{d-abandon} \times Abandon) + \varepsilon_2. \end{aligned} \tag{3}$$

The specific rationales linking each kind of option to perceived value are presented in the next five subsections. Then we address our second research question pertaining to the relative value managers ascribe to different types of real options. In particular, we develop a rationale for why managers should ascribe a higher value to growth options than operating options.

Option to Switch Use

The *option to switch use* refers to the option to put a project to a different application than that for which it was originally intended (Trigeorgis, 1993). Managers are likely to value projects with an embedded switch use option more highly for two reasons: (i) Firms inherently exhibit a preference to invest in nondepreciating projects over depreciating ones (Hubbard, 1994) and (ii) an embedded *switch use*

option's presence facilitates recouping some of the sunk costs if the project were to fail. In the presence of a switch use option, a project is less likely to depreciate in value due to a change in business needs. When a project's goals can be repositioned or the project repurposed, it carries higher value because it can be adapted to meet changing business needs. Furthermore, because irreversibility of investments is a fundamental attribute of many technology projects (Fichman, 2004), the option to switch use creates valuable opportunities to recoup some of the sunk costs by repurposing the project. Therefore, the presence of an embedded switch use option increases the perceived value of a project and thus increases the likelihood that managers will rationally escalate commitment to it even when such continuation might not otherwise be warranted. This leads to our first hypothesis.

H_{1a}: A real option to switch use increases the likelihood of warranted continuation.

Option to Change Scale

The *option to change scale* allows the resources allocated to a project to be contracted or expanded (Pindyck, 1988). The key resources in IT projects are the allocated budgets, personnel, hardware, and software. The option to change scale is valuable when the new information that becomes available during the project warrants expanding or contracting the allocated resources. If the prevailing conditions warrant, this option allows managers the flexibility to increase the resources allocated to a project or to free them up for other purposes. Examples of some ways in which the option to change scale is manifested in projects include: additional (fewer) personnel can be assigned to work on the project, the allocated budget can be increased (decreased) to accommodate revised cost estimates (reflect a curtailed scope), and/or new development tools and hardware can be allocated to the project. We expect that managers will, therefore, perceive higher value in projects with an option to change scale, because it allows them the discretion to allocate additional resources or to free allocated resources in response to emerging conditions. This will, in turn, increase their willingness to recommit to a troubled project.

H_{1b}: A real option to change scale increases the likelihood of warranted continuation.

Option to Stage Investments

The *option to stage investments* exists when a project is structured as a series of incremental outlays that allows the project to be terminated after any particular increment if business conditions become unfavorable (Majd & Pindyck, 1987). When a project is decomposable into a series of incremental development stages, each stage can be viewed as an option on the value of the subsequent stages and valued as a compound option (Benaroch, 2002). An investment in the earlier stages of the project gives the right to proceed with the subsequent stages if the outcomes of the preceding stages are favorable (Panayi & Trigeorgis, 1998). For example, in software development projects, a development plan that provides funding for

coding only after requirements analysis has been completed, and installation only after testing has been completed, has this option embedded in it.

Projects with a staging option are more valuable to firms for two reasons. First, staging provides managers the flexibility to abandon a project earlier if emergent conditions warrant (Myers & Majd, 1990). If conditions become unfavorable to continuing to the next stage, a firm can decide not to invest in the subsequent stage, and the loss is limited to the cost incurred in the preceding stages. Second, it helps forestall commitment to an infeasible project concept, idea, or design (Sullivan et al., 1999). Such flexibility to adapt based on new information allows managers to limit a project's exposure to risk. Managers are, therefore, more likely to perceive higher value in a project with an embedded staging real option and are thus more likely to continue such a project.

H_{1c}: A real option to stage investments increases the likelihood of warranted continuation.

Option to Abandon

An *abandonment option* is associated with a project if managers have the discretion to discontinue it prior to completion and redeploy remaining project resources (Hubbard, 1994). While in principle any project can be terminated, not every project has an abandon option of nontrivial value. For example, if there is no useful way to reallocate the project's resources, or a contract does not include a termination clause and so the developer must be paid in full anyway, or if the company will go out of business or be subject to severe regulatory sanctions if the project is not completed, then there would not be an abandon option. Even when potentially valuable abandonment options do exist, they are often difficult to exercise for two reasons: (i) ambiguity about timing and (ii) reputational consequences.

First, unlike strike dates in financial options, there is typically no specific point in time where managers must confront the abandonment option (Zardkoohi, 2004). Second, managers' desire not to appear wasteful, the political implications of cancellation, and the possible detrimental effect of abandonment on staff morale and reputation can keep even a deeply troubled project alive (Keil, Mann, & Rai, 2000). Denver's International Airport baggage system (Keil & Montealegre, 2000) and London's Taurus stock exchange project (Drummond, 1996) are among the better known cases of large-scale project failures where the abandonment option was difficult to exercise. In both cases, abandonment was difficult because of the public nature of the expended resources (taxpayer funding) and the political ramifications of reneging on stakeholder expectations. In theory, however, an embedded abandonment option should increase the perceived value of a project because it provides managers the flexibility to contain further losses, which increases the likelihood of warranted continuation.

H_{1d}: A real option to abandon increases the likelihood of warranted continuation.

Option to Grow

A *growth option* is embedded in a project if it unlocks future opportunities for follow-on investments, not all of which can be foreseen (Trigeorgis, 1993). This option can increase the value of a project in two ways. First, a project with an embedded growth option can serve as a link in a chain of directly interrelated future projects. For example, investments in an ERP system might provide a necessary foundation for workflow or supply chain management systems in the future. Second, a growth option can be associated with projects that provide the firm with new technical knowledge and capabilities that make it easier to assimilate and exploit future technologies (Kogut & Kulatilaka, 1994). Such knowledge relates to both future generations of the technologies used in the project as well as the technology management skills that accrue. For example, early investments by firms in C-language-based projects, client-server applications, and graphical user interfaces provided them the knowledge to later exploit object-oriented programming innovations (Fichman & Kemerer, 1997). We therefore expect that managers will view even troubled projects with embedded growth options as being more valuable, which increases the likelihood of warranted continuation.

H_{1e}: An embedded growth option increases the likelihood of warranted continuation.

Growth Options Versus Operating Options

While *operating options* give managers the flexibility to change the features of a base project by modifying its timing, scale, or scope, strategic growth options refer to the opportunity to create one or more additional but related assets beyond the asset produced by the base project (Benaroch, 2002). In the case of operating options, there is only one asset under evaluation (i.e., the base system), while in the case of strategic growth options, there are multiple assets to consider (the base system, plus one or more future investment in assets that build on the base system). The rationale for why managers may tend to place a relatively higher value on growth options than operating options has two underlying reasons.

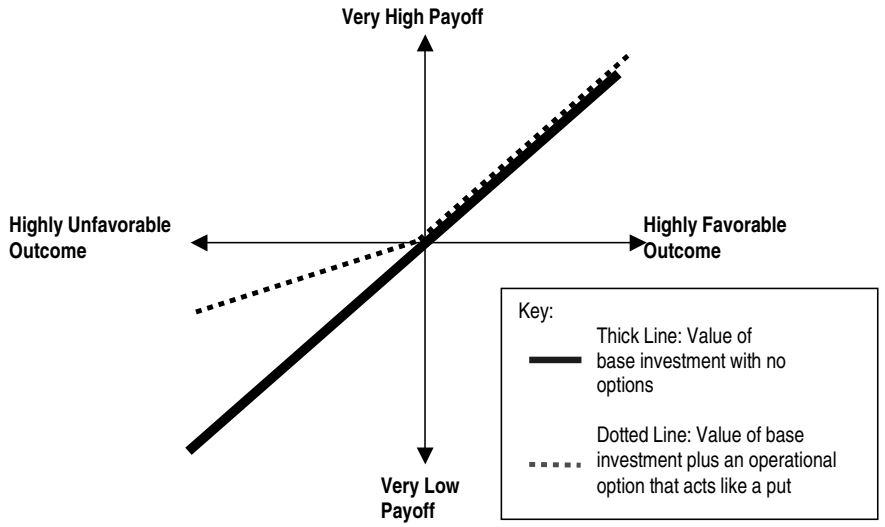
First, we believe that managers will tend to view an option that generates the opportunity to create one or more additional assets as more valuable than one that adjusts the payoffs for a single asset. There is, of course, no guarantee that a growth option will be more valuable than an operating option, because the adjustment to a base project's value from the operating option could be large, and the scope and corresponding net value of the add-on projects constituting the growth option could be small. However, in the absence of any information on the relative sizes of the base project and the add-on projects, it would be reasonable for managers to conclude that all of the net value associated with one or more assets would be greater than an adjustment to the net value associated with one asset.

Second, we believe that managers will tend to place a higher value on strategic growth options because they behave like a call option on a new but related asset, whereas operating options behave more like a put option on an exposed position in an existing asset (Benaroch, 2002). Figures 1 and 2 provide a stylized illustration of the differential effects of operational and strategic growth options on overall

investment payoffs. Figures 1 and 2 were inspired by figures used by Benaroch (2002) to explain the general effects of adding different option types to a base investment. We depart from Benaroch by dropping two simplifying assumptions: (i) that a put-like option eliminates *all* losses on a project and (ii) that a call-like option would be exercised only on a project with a nonnegative payoff on the base project. These assumptions would hold in the case of financial options and are useful for illustrating the general effect of adding options to a base investment. However, they simplify away an important element of realism in the context of our particular study of IT investment.

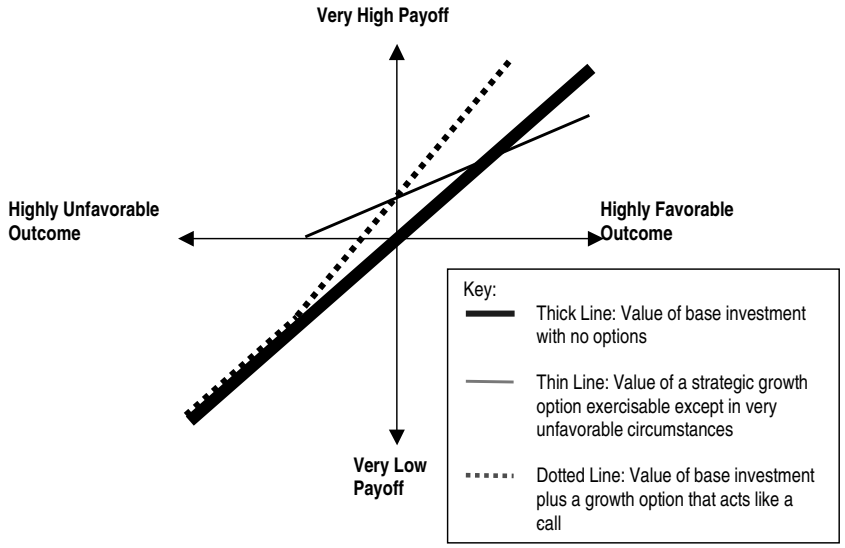
As Scenario A in Figure 1 illustrates, an operational option moderates the extent of the maximum loss but does not decrease the probability of some loss. In contrast, the net effect of adding a strategic growth option, as depicted in Figure 2, is to increase the chance of at least breaking even overall, because moderate losses

Figure 1: The effect of operational options on IT investment payoffs.



Scenario A: In the figure above, the horizontal axis represents the range of *possible outcomes* on an uncertain IT investment project, ranging from highly favorable to highly unfavorable. The vertical axis represents the payoff produced by the investment *given any particular outcome*, ranging from very low (highly negative) to very high (highly positive). The thick line shows the payoff function for a base investment in a new IT system that has no options. Unfavorable outcomes lead to negative payoffs, and favorable outcomes lead to positive payoffs. The dotted line shows the payoff function for the same project with the addition of an operational option (e.g., to abandon). Such options act like a financial put option on a stock that is held long. If the project goes badly, the operational option is exercised and the losses are moderated. The magnitude of losses in the event of unfavorable outcomes has been reduced, but the probability of loss has not been reduced. If the project goes well, the option is not exercised and the upside potential payoffs are unchanged.

Figure 2: The effect of strategic options on IT investment payoffs.



Scenario B: In the figure above, the horizontal axis represents the range of *possible outcomes* on an uncertain IT investment project, ranging from highly favorable to highly unfavorable. The vertical axis represents the payoff produced by the investment *given any particular outcome*, ranging from very low (highly negative) to very high (highly positive). The thick line shows the payoff function for a base investment in a new IT system that has no options. Unfavorable outcomes lead to negative payoffs, and favorable outcomes lead to positive payoffs.

The thin line represents a strategic growth option enabled by the base investment, such as a new system that builds on the base IT investment. We assume this will be exercisable as long as outcomes are no worse than moderately unfavorable. If the project goes very badly, the call won't be exercisable and losses will not be moderated. Otherwise, the call will be exercised, and its value will increase with increasingly favorable overall outcomes and will be added to the payoff of the base project. This option acts like a financial call option on a stock that is different from but related to a stock that is held long.

The dotted line shows the combined payoff function for the base project with the addition of the strategic growth option. Although the extent of the most severe potential losses has not been reduced, the probability of an overall loss has been reduced, and the magnitude of the potential upside gain has been increased.

on the base project can be offset by gains related to the add-on project enabled by the strategic growth option.

Prior research on framing and its effect on decision making under uncertainty suggests that decision makers are risk-seeking when it comes to decisions framed as a choice between losses (Kahneman & Tversky, 1979). In particular, decision makers will strongly prefer scenarios that have at least the chance of breaking even over scenarios that have a certain but smaller maximum loss, even when the expected value of both scenarios is identical. Because adding a put option to a base investment tends to curtail the maximum loss rather than decreasing the chance of any loss, prior research on framing suggests that managers would tend to view such options as less attractive than call options on related assets, which have the opposite effect.

H_2: Managers perceive strategic growth options embedded in a project as adding more value to the firm than operating options.

METHODOLOGY

A field experiment using a conjoint research design was administered to IT managers in 123 firms to test the hypotheses. The strength of this research design is that it combines the control of a laboratory experiment with the external validity of a survey. We first describe this methodology, the reasons guiding its selection, and its operationalization.

Research Design

An overview of the conjoint experiment approach

Conjoint analysis is a multi-attribute judgment analysis technique based on Anderson's (1981) Information Integration Theory that involves a posteriori decomposition of the respondent's decision process, here project continuation (Louviere, 1988). There are three central elements in a conjoint research design: attributes, conjoint profiles, and part-worth and overall utilities. An *attribute* refers to a decision criterion (presence of various options) that respondents might use to evaluate the dependent variable (willingness to recommit). The overall value assigned to the dependent variable is referred to as its *overall utility*. Willingness to recommit can therefore be viewed as a multi-attribute decision-making problem in which managers integrate their knowledge of various attributes to arrive at an overall assesment about their willingness to recommit. The contribution of each attribute toward the formation of the overall utility of a project is called its *part-worth utility*. Different combinations of attribute levels are called treatments or *conjoint profiles*.

The conjoint technique requires respondents to make a series of judgments about a dependent variable based on a set of attributes from which the underlying structure of their cognitive system can be statistically inferred. A series of conjoint project profiles with different combinations of attribute levels were presented to each respondent, and the respondent provided an assessment of the dependent variables for each project profile. The five embedded real options were the attributes, and perceived option value and willingness to recommit were the dependent variables.

Based on the options included and excluded in each project profile, each respondent provided an assessment for the two dependent variables. (Details of the precise steps in the data collection process are described later in the data collection section.) The underlying structure of the respondents' cognitive models regarding the influence of various options on the respondents willingness to recommit can be statistically inferred from these judgments by analyzing the responses at the individual and aggregate levels using multiple regression (Louviere, 1988).

The analyses are roughly comparable to repeated measures experimental design and explicitly account for the nonindependence among the assessments of multiple project profiles by a single respondent. To identify attributes that are statistically significant at the aggregate level, the regression coefficient for each

attribute is averaged across individuals and the sign of this coefficient indicates the direction of the relationship between the attribute and the dependent variable (Vancouver & Morrison, 1995). A Z-statistic aggregates the T statistics derived from the individual-level analysis for each attribute to assess the statistical significance of the attribute in predicting the dependent variable. Such analysis at both the individual respondent level and aggregate level increases the predictive ability of the model (Moore, 1980). These significance tests are supplemented with Hays' (1973) ω^2, which measures the variance explained by each attribute and is used to assess the relative importance of each attribute (Louviere, 1988). Thus, beta values indicate the directionality and ω^2 indicates the *relative importance* of each option.

Factors guiding the choice of the conjoint research design

Our choice of the conjoint design over a traditional survey-based approach was motivated by three considerations.

First, previous research on real options analysis of technology projects has considered only one option at a time, although multiple options might be embedded in such projects (Benaroch, 2002). The conjoint method has been developed primarily to decompose respondents' utilities for multiattribute decision making. The design therefore allows us to decompose the contributions of multiple project attributes—here, the five embedded real options—in arriving at a holistic project continuation decision (Louviere, 1988). A conjoint design thus allowed us to examine how real-world managers concurrently consider all five options in evaluating each project.

Second, the study examined behavior in escalation situations, about which managers are likely to be sensitive and defensive. Using a traditional survey-based approach would have required us to have managers retrospectively recall a recent troubled project to assess the extent to which various real options might have been embedded in it. This would have introduced the likelihood of invoking some form of social desirability bias. Because the conjoint project profiles are hypothetical and do not require the respondents to recall their previous project assessments, the design is immune to the threats of social desirability bias and retrospection bias.

Third, the study is grounded in real options theory and pursues a theory-testing goal. Conjoint-based research designs are especially suitable for such theory-testing endeavors (Graham & Cable, 2001).

Measures and conjoint profile development

Each conjoint profile represented a different project with varying combinations of real options embedded in the project. The first phase of the study involved developing descriptions for the five types of options in the conjoint project profiles for the subsequent experiment. The operationalization of each real option was based on existing descriptions of real options in software projects (Dos Santos, 1991; Taudes, 1998; Keil & Flatto, 1999; Sullivan et al., 1999; Benaroch, 2002; Fichman, 2004). Specifically, the option to switch use tapped into whether the project could be put to another use. The option to change scale tapped into whether the allocated project resources such as personnel, hardware and software, and the budget could be expanded or contracted. The option to stage investments referred to

whether the project could be incrementally funded in stages. The option to abandon referred to whether the project could be abandoned prior to completion. Finally, the option to grow was operationalized by indicating whether the project represented a necessary foundation for developing future firm-level technology capabilities. The dependent variable, willingness to continue the project, was measured using a nine-point semantic differential scale (see Appendix). The mediating variable, perceived option value, assessed managers' perceptions of the likelihood that a given project would contribute positively to the value of their firm. An alternative to fractional factorial conjoint analysis is Experimental Choice Analysis (ECA) (Louviere & Batsell, 1991; Louviere, Hensher, & Swait, 2000). Both techniques belong to the same family of techniques, although the latter relies on discrete choices between two alternatives by the respondent, such as a binary representation of project continuation/discontinuation decisions. While conjoint analysis is a stated preference model, ECA is a stated choice model (Louviere et al., 2000). In this study, use of the conjoint technique is advantageous over ECA because it allows for finer grained analysis of managers' willingness to continue a troubled project. Becauase our objective was to assess the degree to which the respondent is likely to lean toward continuing, use of ECA would have resulted in excessively coarse data, making it impossible to assess the extent to which the respondent is likely to recommit. Furthermore, once the scaling data obtained through the conjoint approach are dichotomized, the results are closely comparable to ECA (Moore, Gray-Lee, & Louviere, 1998).

Consistent with the semantic differential measurement technique deployed for these scales, only the endpoints of the scale had text anchors. These anchors were bipolar opposites, as is common practice with the semantic differential measurement approach. Because the traditional NPV was set to zero for all projects in the experiment, the respondents' perception of value added by the project was attributed to the presence of embedded real options. Materials were extensively pretested with a convenience sample of three mid-level IT executives and five academic experts in financial options theory and IT project management to ensure that the instrument was unambiguous and possessed face validity and that the project scenarios were realistic. Feedback from this panel also was used to refine the instrument so that the attribute definitions were clearly worded and interpretable without cognitive difficulty.

Because escalation situations involve negative feedback about a previously chosen course of action, all projects were framed as having spent 100% of their allocated budget but as being only 50% complete. The respondents were informed that—notwithstanding the considerable uncertainty that surrounded each project—the estimated NPV for each project from this point forward was zero (i.e., the expected returns from each project exactly equaled the expected expenditures from this point forward, adjusting for the time value of money). Thus, respondents should be indifferent toward continuing a project with zero NPV, all other things being equal. Each embedded real option attribute had a binary value; that is, it was either present or absent in each project. The conjoint algorithm implemented in SPSS® 11.5 was used to generate the fewest number of conjoint project profiles to be presented to each respondent that most efficiently generated the maximum information (Kuhfeld, Tobias, & Garratt, 1994).

Table 2: Means and standard deviations for each conjoint project profile.

Conjoint Project Profile	Real Options Embedded in the Project					Value Added		Continuation	
	Stage	Scale	Abandon	Switch Use	Growth	Mean	*SD*	Mean	*SD*
1	Yes	No	No	Yes	Yes	6.82	1.61	7.17	1.68
2	No	No	No	No	No	2.34	1.79	2.08	1.77
3	Yes	Yes	No	No	Yes	6.38	1.56	6.43	1.71
4	Yes	No	Yes	Yes	No	5.13	1.80	4.81	1.98
5	No	Yes	No	Yes	No	4.79	1.56	4.67	1.76
6	No	Yes	Yes	Yes	Yes	7.41	1.36	7.32	1.47
7	No	No	Yes	No	Yes	5.57	1.90	5.47	2.00
8	Yes	Yes	Yes	No	No	3.36	1.84	3.38	2.11

The advantage of using a fractional factorial design is that it is informationally efficient and protects against sources of variation that are not estimated. This design safeguards perimeter estimates against bias from theoretically important factors that are not included in the model (Louviere, 1988). It also reduces the number of attribute combinations into a manageable set of profiles that each participant must assess (Green, Helsen, & Shandler, 1988). Recent comparisons suggest that the predictive ability of a fractional design is highly comparable to a full profile design (Molin, Oppewal, & Timmermans, 2000). The number of treatments for each respondent increases greatly as the number of attributes considered increases; the most feasible conjoint designs therefore rely on a fractional factorial design (Louviere, 1988; Priem, 1992). In this case, the lowest number of required conjoint profiles was eight, which means that each manager was presented with the same set of eight project profiles (real options combinations).

The levels of all five options were described in each project profile. Therefore, there was full consistency in the information conveyed by each profile. In contrast, if we had only informed the respondents about which options were present in each profile, we might have introduced the risk that the respondents might have differentially inferred the presence of options that were absent in a given scenario.

Table 2 summarizes the eight conjoint project profiles along with the means and standard deviations for the respondents' assessments for willingness to continue.

Survey Sample and Data Collection

Dun and Bradstreet's Million Dollar database (Dun & Bradstreet, 2002)—a directory of executives—was used to identify a random sample of management information systems (MIS) directors in 750 firms. This directory provides contact information for executives in various positions in the majority of private and public firms in the United States. We specifically chose to target executives with the job title "MIS director" for our sampling frame. MIS directors are senior IT executives who report to the corporate chief information officer (CIO) and are responsible for the operational and developmental aspects of their firms' information technology portfolios. We constructed a random sample and contacted each executive through the mail, providing a link to a Web-based version of the survey instrument.

Following the instructions, the respondents were sequentially presented with eight project profiles—each with different combinations of options—to evaluate by rating the dependent variables for each profile. The profiles were presented to all respondents in the same sequence, following the exemplar of prior studies that have used this methodology with managers in field settings. A sample conjoint project profile is shown in the Appendix. Finally, respondents completed a postexperiment questionnaire in which they answered demographic questions and provided self-assessments of their confidence about the evaluations they had just completed. Seventy-nine mailings were returned as undelivered and four additional executives declined to respond because of company policy. We received 123 completed sets of responses from managers in 123 firms. This represents a response rate of 18.4%, which is comparable to other surveys of this length. These responses provided data on overall project risk assessments for eight conjoint project profiles from each of 123 managers (984 total observations) in 123 organizations. The sample size is therefore 123, for which there are 984 nonindependent observations.

Respondent Demographics and Descriptive Statistics

On average, the respondents had 15.2 ($SD = 8$) years of IT experience and had previously been involved in making continuation decisions for 26 ($SD = 32$) projects. This suggests that our respondents were experienced managers who were knowledgeable about IT projects and had previously been involved in a decision-making role regarding project continuation. The mean response for perceived option value variable was 5.23 ($SD = 2.26$) and for warranted continuation was 5.16 ($SD = 2.43$). On average, the firms in our sample had annual revenues of \$42.7 ($SD =$ \$59.2) million. The conjoint research design precluded generation of a correlation matrix among the five real options (the conjoint attributes). The sample represented a diverse spectrum of firms engaged in both manufacturing and services.

ANALYSIS AND RESULTS

Hypotheses Testing Strategy

Following the recommended procedures native to conjoint analysis (Green et al., 1988; Louviere, 1988), both individual and aggregate level analyses were conducted to test the hypotheses. A hierarchical mediated regression model was used to test the hypotheses following the procedures outlined by Baron and Kenney (1986). Hypotheses 1a through 1e are mediation hypotheses, proposing that each type of option increases the likelihood that a project will be continued and that such continuation is rational *because* the option increases the perceived option value of the project although the NPV is zero. Each hypothesis was, therefore, tested by assessing mediation of the relationship between the embeddedness of the option and managerial willingness to recommit by perceived option value. This involved three sets of regression tests: (i) the mediator (perceived option value) predicting the dependent variable (willingness to recommit), (ii) the independent variables (the presence of the five embedded real options) predicting the mediator, and (iii) Sobel mediation tests to assess the direct effects of the independent variables on the dependent variable. In the first step, three control variables

were included to account for rival explanations for willingness to recommit: (i) the level of confidence that the respondent had in his or her assessments in the experiment, (ii) the number of projects for which the respondent had been directly involved in making continuation decisions, and (iii) prior IT experience of the respondent. Confidence was measured as a single item assessment of the degree to which the respondent was confident in his or her overall assessment of the eight project profiles. This variable controls for individual-level differences in the degree of self-assurance among the respondents in their project continuation assessments.

Hypothesis 2, which proposed that strategic options have a larger influence than operating options on managerial willingness to recommit, was tested by creating two conjoint superattributes for operating options and strategic options. *Superattributes* are composed of multiple attributes in a conjoint design and capture higher-order factors that are implied from a theoretical perspective in the conjoint profiles (Hair, Anderson, Tathan, & Black, 1995). Following the procedure outlined by Hair, Anderson, Tathan, and Black (1998, p. 576), we computed a composite additive score of the switch, scale, stage, and abandon options to create the operating options superattribute. The single growth option represented the strategic options superattribute. These two superattributes were used to test Hypothesis 2.

To ascertain the stability of the results, we also tested the hypothesized paths using multinomial logistic regression and found the results to be consistent with those obtained using hierarchical regression. We computed the incremental variance explained by each embedded option in order to assess what proportion of the variance in active NPV is explained by the variance in each embedded option. The values for each option were 30.4% (growth), 11.7% (switch use), 1.3% (change scale), 1% (stage investments), and 0.4% (abandon).

Hypotheses-Testing Results

Hypotheses 1a–e

The results of the hypothesis tests for H1a through H1e are summarized in Table 3. This table summarizes the aggregated regression coefficient for each risk factor, the corresponding Z statistic, its ω^2 explained variance value, and the significance of the change in explained variance across hierarchical regression steps. Step 1, in which the relationship between the mediator and willingness to recommit was tested, shows a positive and significant relationship between the perceived option value of an uncompleted project with zero NPV and managers' willingness to recommit ($\beta = .757, Z$ statistic $= 36.2, p < .001$). In this step, the control variables explained 3% of the variance in managers' continuation tendency, perceived option value 72.2%, and the direct effects an additional 1.5%. In step 2, the relationship between all five types of options and the mediator (perceived option value) was tested. The options are listed in the order of their relative importance, as suggested by our analysis. At the aggregate level of analysis, the Z statistics were statistically significant for each of the five embedded real options predictors and the signs (indicated by the β coefficients) are in the hypothesized directions. The path coefficients and

Table 3: The effects of each option on value added and willingness to continue.

	Step 1 Mediator (Value Added)→Continuation			Step 2 Options→Mediator (Value Added)	Step 3 Options→Willingness to Continue	
	Step 1.1 Enter Controls β(Z statistic)	Step 1.2 Enter Mediator β(Z statistic)	Step 1.3 Enter Real Options β(Z statistic)	β(Z statistic)	Sobel Mediation Test for Direct Effects (Z statistic)	Hypothesis
Constant	(11.645)	(1.899)	(4.344)	(97.486)		
Confidence	**.078**(2.43)**	−.001(−.059)	.009(.584)			
No of Projects	−.015(−.439)	**−.032*(−1.809)**	**−.029*(−1.745)**			
IT Experience (years)	−.003(−.086)	−.006(−.374)	−.006(−.359)			
Value Added		**.868***(54.36)**	**.757***(36.29)**			2
Growth			**.144***(7.478)**	**.551***(23.149)**	**7.11*****	1e
Switch Use			**.070***(4.109)**	**.341***(14.34)**	**3.94*****	1a
Scale			**.027*(1.755)**	**.112***(4.692)**	1.64	1b
Stage			**.046**(2.992)**	**.100***(4.188)**	**2.43****	1c
Abandon			−.013(−.814)	**.061**(2.55)**	.775	1d
Model R^2 (Model F)	**.003*(1.98)**	**.752***(744.8)**	**.767***(360.39)**	**.443***(157.5)**		
ΔR^2 (F-Change)	—	(2955.4)***	(13.82)***	—		

$^{*}p < 5\%$, $^{**}p < 1\%$, $^{***}p < .1\%$; significant paths in bold.

Z statistics corresponding to each of the five types of embedded real options are shown in the Step 2 column of Table 3.

All five real options had statistically significant effects on perceived value (the mediator): growth option ($\beta_{\text{grow}} = .551$, Z statistic $= 23.1$, $p < .001$; Hypothesis 1e), switch use option ($\beta_{\text{switch}} = .341$, Z statistic $= 14.34$, $p < .001$; Hypothesis 1a), scale option ($\beta_{\text{scale}} = .112$, Z statistic $= 4.69$, $p < .001$; Hypothesis 1b), stage option ($\beta_{\text{stage}} = .10$, Z statistic $= 4.18$, $p < .001$; Hypothesis 1c), abandon option ($\beta_{\text{abandon}} = .061$, Z statistic $= 2.55$, $p < .01$; Hypothesis 1d). The wide range of weights (from .5 to .06) ascribed to various options provides some assurance that the respondents did not base their assessments on a simple count of the number of options present in each project scenario. The options explained 44.3% of the variance in perceived value. These results are consistent with our nomological network, which posits that the portfolio of real options embedded in a project increases perceived option value, which, in turn, increases willingness to recommit. The next step was to assess the mediating effect of perceived value on the relationships between the five embedded options and willingness to recommit. We followed the Sobel mediation testing procedure outlined by Baron and Kenny (1986), as described earlier in this section. The Sobel mediation test statistics (step 3) for the statistical significance of the direct effects of the options on willingness to recommit were significant for growth, switch, and stage options. This suggests that perceived value partially mediates the effects of three of the five embedded options (growth, switch, and stage options) and fully mediates the effects of scale and abandon options. However, the addition of the direct effects to the model explained a trivial 1.5% additional variance in willingness to recommit and the magnitude of the path coefficients of the direct effects was very small. Thus, while these direct effects are significant from a statistical standpoint, they appear to be trivial from a theoretical standpoint because they contribute little additional explanatory power to the model. The implication of these results is that, although the presence of options in a project also directly increases managers' willingness to continue, most of their effect is due to the increase in managers' perception of value that is caused by such embedded options. Embedded real options, therefore, increased managers' perceived option value, which in turn increased their willingness to continue a project even though its NPV was zero. Thus, the presence of various forms of embedded real options in an unfinished project with zero NPV looking forward increases managers' willingness to continue the project, supporting Hypotheses 1a through 1e.

The magnitude of the ω^2 values for each option indicates its relative importance in shaping managerial perceptions of option value, which in turn increases their willingness to continue a project. The results indicate that, on average, the presence of a growth option is the most important predictor of continuation ($\omega^2 = 30.4\%$). The second most important predictor is the presence of a switch use option ($\omega^2 = 11.6\%$). The third most important predictor is the presence of a change scale option ($\omega^2 = 1.2\%$). Stage ($\omega^2 = 1.0\%$) and abandonment options ($\omega^2 = .4\%$) are next, in that order.

Hypothesis 2

Hypothesis 2 predicted that strategic growth real options embedded in a troubled project weigh more heavily in managerial continuation decisions than operational

Table 4: Superattribute analysis for strategic versus operational real options.

Options Superattribute	Beta	*Z* statistic	*p* value	ω^2
Strategic Options	.551	22.231	$p < .001$	.303
Operational Options	.307	12.374	$p < .001$	.093

real options. This hypothesis is amply supported by the observation that the ω^2 value for strategic growth is more than double the value of any other option. To further examine this hypothesis, we conducted superattribute analyses. *Superattributes* are attributes composed of multiple attributes in a conjoint design. Following the approach recommended by Hair et al. (1998), we created two superattributes by computing separate composite variable scores for the strategic growth ($\text{STRATEGIC}_{\text{superattribute}}$) and operational ($\text{OPERATIONAL}_{\text{superattribute}}$) real options at the project level. We repeated the analyses by regressing the two superattributes on perceived option value, the results of which are summarized in Table 4. A comparison of the ω^2 values associated with the strategic growth versus operational option superattributes suggests that embedded strategic options weigh more heavily than all operational options combined in shaping perceived option value of a troubled project with zero NPV, further strongly supporting Hypothesis 2.

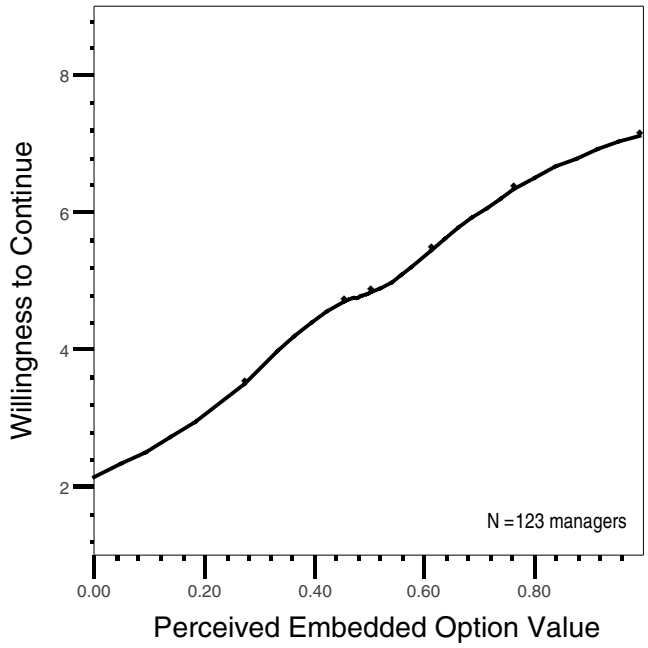
DISCUSSION

Real Options and Escalation Rationality

A key finding of this study is that the presence of options increases managers' willingness to continue a troubled project. The central mediation role of perceived option value further suggests that managers recognize and implicitly value the embedded real options, and are, therefore, acting rationally in their decision-making process of whether to continue it. A large and statistically significant path coefficient of .757 ($p < .001$) between perceived option value and managerial willingness to recommit as well as the large variance explained by it (76%) suggests strong support for our idea that embedded real options will engender *warranted* continuation in troubled projects.

Continuation of a project with zero NPV should be largely explained by the value of the real options that it carries. The relationship between the total value of options (computed as a weighted sum of the options in each project, with weights derived from the regression model) and managers' willingness to continue a troubled project is illustrated in Figure 3. The figure illustrates that managers are closer to the termination end of the scale and remain below the neutral point (i.e., 5) until the option bundle exceeds the standardized .5 level. The .5 level for perceived option value is equivalent to the value the average respondent placed on configurations with an average bundle of options present (two to three). Thus, managers appear to err on the side of being too conservative and risk averse when few real options are embedded. Our conjoint design included a conjoint profile in which there were no embedded options and the NPV was set to zero (profile 2 in Table 2). Other things being equal, subjects should be expected to be neutral toward

Figure 3: The relationship between willingness to continue and the total perceived option value.



continuing a zero NPV project with no embedded options. However, the mean willingness to continue score of 2.08 for this conjoint profile was well below the midpoint of 5, indicating neutrality. In terms of the frequency distribution, 84.3% of the respondents leaned against continuation of the project when no options were embedded. This suggests that there was considerable uncertainty in managers' minds when they assessed the project's future.

Relative Importance of Various Real Options

A second important insight from the results is the relative importance that managers ascribe to each type of real option (beta weights in Table 3). Consistent with Hypothesis 2, managers ascribed more weight to strategic than to operational options. An embedded growth option had the highest ascribed importance in managers' perceptions of a project's option value. This result is consistent with both of the rationales presented earlier and with survey results reported by Busby and Pitts (1997). On one hand, it could be that managers ascribe more value to growth options because such options capture the complete value of one or more additional assets, rather than modifying the value of a single asset as with operational options. Or it could be that the framing explanation holds sway, that is, managers prefer options that decrease the probability of any loss over those that decrease the severity of potential losses should a loss occur.

Among the remaining options, managers ascribed the most value to the option to switch use. This option was much more highly valued than changing scale,

staging investments, or abandonment. One possible explanation may be that some managers viewed the option to switch use as affecting payoffs similarly to a growth option, rather than as a tool to contain downside losses as with the other operating options. While the switch use option is traditionally conceived as an option that is exercised only when the original use has proved infeasible, software assets have two unique properties compared to other assets such as furnaces, manufacturing plants, or industrial machines in which real options analyses were originally conceptualized. The malleability of software suggests that it can be more easily modified than physical assets and, therefore, IT applications should be more easily repurposed compared to other kinds of assets. Moreover, due to the low cost of reproduction, a software-based system need not be discontinued from its original application before it can be repurposed. For example, a system originally developed for internal use can be sold to another firm even while the developing firm continues to use it. That is, due to their high malleability and low cost of duplication, software assets can be used simultaneously for their original purpose and for different purposes. These potential new purposes may be seen as a call option on separate but related assets. Viewed in this light, a switch use option can be interpreted as providing value in a way that is similar to growth options, which increases the chances of at least breaking even rather than decreasing the extent of the most severe losses.

Managers perceived the abandonment option as less valuable than the other options, which is consistent with prior survey results (Busby & Pitts, 1997). Because the abandonment option is likely to be exercised only on the least successful projects, the low value placed on this option is consistent with the framing argument presented earlier, where managers are less appreciative of options that only serve to curtail severe losses. Another possible explanation for the low value placed on abandonment is the difficulty of exercising this option in practice. Exercising this option is particularly disruptive and may cause morale and credibility problems among team members and other stakeholders, because they may have become personally invested in seeing the project completed. In contrast, exercising the growth and switch use options may even boost morale and evoke a sense of accomplishment among project stakeholders. Using similar logic, neither reducing the scale of a project nor staging investments is likely to be viewed as negatively as exercising the option to abandon. Changing scale implies that the project may still be implemented, though on a smaller scale than originally anticipated. The option to stage implies that it has been acknowledged all along that continued funding is contingent upon achieving interim milestones. In both cases, the degree of perceived failure may be less than that associated with the abandonment option.

To develop this line of reasoning further, it is possible that the signaling effects associated with exercising different options will lead managers to view some as being more valuable than others. Managers are likely to ascribe more weight to options that increase the opportunity to create a positive impression regarding project status. Abandonment is not likely to be exercised unless the manager believes that the project cannot be brought back on track, and even in these instances, the manager may be inclined to avoid abandonment in order to save face. In contrast, the option to switch use carries a positive connotation because it signals that the investment can be profitably salvaged by channeling the project in a new direction. This may explain why the option to switch use has the highest perceived

value after the growth option. Exercising the option to change scale in response to a troubled project situation would signal that, although the project is troubled, the scope of the problem is still containable. Just higher than the abandonment option is the option to stage investments. Exercising this option signals that some, but not all, of the project can be salvaged and that managers had been taking a prudent approach to funding the project to that point. Overall, the pattern of results obtained suggests that managers' ascribe more value to options that allow for positive signaling upon exercise.

Limitations

Before proceeding to the implications of these results, six limitations of the study must be noted. First, caution should be observed in generalizing our findings beyond our homogenous sample of MIS managers because other project stakeholders may weigh options differently. Second, the five options were represented as either being present or absent in each project. Future studies should extend such coarse binary valuation to more granular continua.

Third, the conjoint design set the traditional NPV for all projects to zero and attributed perceptions of value added to the presence of embedded real options. However, there might be other intangible costs and benefits associated with the projects that were not accounted for. For example, our operationalization of the abandonment option captured managerial flexibility to terminate the project but did not specify whether the project had any salvage value. This was a deliberate simplification to avoid introducing a double-barreled option operationalization in the conjoint profiles.

Fourth, we operationalized a troubled project as one that was halfway completed but had expended its entire budget. Alternative means of signaling development-stage trouble, such as technical implementation hurdles, stakeholder disagreement, and poor functionality, should be explored in future work.

Fifth, concerns about common method bias arise in any study in which independent and dependent variables are captured from the same respondents in the same survey. However, we believe that common method bias is not a significant concern affecting our most important results. Common method bias is of greatest concern when hypothesis guessing or social desirability bias might be present. It seems unlikely either of these would be relevant in the relative value that respondents ascribed to the five real options. The respondents would have no reason to expect that some options should be valued more than others or that the researchers would be hoping for some particular pattern of results. A more likely concern is that they could guess that the presence of options should increase the value added, which might lead to some magnification of the variance explained for value added.

Finally, interaction effects among various options are possible, even likely. However, assessing interactions was outside the scope of this study. Instead, our primary objectives were to assess the main effects of the five options and how managers make trade-offs in evaluating these main effects/option types. While one could argue that in the ideal case each conjoint attribute would be mutually exclusive, there is a large body of precedent-setting work in marketing, MIS, and strategy where the conjoint design has been used to similarly assess the main effects

of the predictors. Even where there are interactions among attributes, the conjoint approach has proven to be a robust technique in studies with a similar objective of assessing the strengths and relative importance of the main effects (e.g., Shepperd, 1999; Tyler & Steensma, 1995; Bharadwaj & Tiwana, 2005). As a practical matter, the interactions among different option types are not likely to be large in relation to their main effects. Furthermore, one would need additional contextual information beyond that included in the profiles to infer if any particular interactions effects were present.

IMPLICATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The primary contribution of this study is the solid empirical evidence it provides that the presence of real options influences decision makers to rationally exhibit continuation tendencies. The key implication of the study is that instances of continuation that may seem to be irrational escalation based on traditional methods of evaluating projects may in fact be quite rational when the value of options is considered. These results have important implications for both research and practice.

Implications for Research

The key finding of the study—that project continuation in escalation situations is not necessarily the result of flawed or irrational managerial decision making—sheds new light on the phenomenon of escalation. Using real options theory, we demonstrate that the presence of one or more real options in a troubled project with zero NPV can increase its perceived value and in turn engender managerial willingness to recommit.

The application of real options theory provides a mechanism for distinguishing warranted continuation from unwarranted escalation, which is something that traditional escalation theories do not address. Traditional theories provide no explanation for situations in which escalation behavior is economically prudent. While we do not mean to suggest that all cases of continuation in escalation situations are warranted, we do believe that real options theory offers a new theoretical perspective on this issue.

The theory of real options should be regarded as complementing, rather than replacing, previous theories that have been offered to explain escalation behavior. In the case of warranted continuation, options theory provides a rational, economic reason why continuation is a sensible course of action. In the case of unwarranted escalation, though, real options theory offers no explanation for this behavior, and we must invoke one or more of the traditional theories to explain the phenomenon.

In addition, the results of the study provide original insights into the relative value that managers ascribe to different types of real options that can be embedded in a project. Notably, managers appear to assign greater weight to strategic options that provide future growth opportunities than operational options that provide the flexibility to contain losses.

Implications for Practice

While our research shows that managers are quite open to placing a value on real options when they are made salient in an experimental setting, this will be of little

practical consequence unless mechanisms are put in place to make real options salient in practice—and then used appropriately. These mechanisms include augmenting project planning to include an active search for opportunities to embed real options, employing techniques that realistically value real options, implementing project management practices to continuously track the evolving value of options, and committing to actually exercising options when appropriate.

Second, our results suggest that managers may have systematic biases to overcome in correctly valuing different types of real options. In particular, managers may be prone to undervalue real options that tend to be exercisable in just the most unfavorable circumstances, such as the abandonment and staging options. These biases may arise from a manager's own misperception of the value-generating potential of such options or from recognition of organizational constraints on the exercise of such options. The latter may be viewed as an example of what McGrath (1999) labels the antifailure bias in organizations, wherein project termination is interpreted as a sign of failure rather than as a natural gamble in initiating uncertain projects.

Overcoming perceptual biases can be accomplished by developing a more thorough understanding of when and how abandon and stage options add value. To overcome organizational biases, managers must take steps to change the elements of organizational culture and procedures that reinforce the antifailure bias (Fichman et al., 2005). This includes countering the tendency to label any project that is not brought to completion, and the people associated with such projects, as failures. Projects for which abandon and stage options have been explicitly recognized and valued from the start can be portrayed—and rightfully so—as "appropriate terminations," rather than as failures. Nevertheless, there will be organizations in which the antifailure bias is so strongly embedded that changing this culture is not a realistic aspiration for IT managers. In such cases, our results suggest that managers might give relatively more attention to creating and valuing options that are more easily exercised, such as switch use and growth options.

Directions for Future Research

Future research using a real options perspective can extend our understanding of project continuation in escalation situations, and there are four avenues that may be fruitful.

First, future work should examine how different sources of uncertainty differentially influence the relative importance of various options. A useful dichotomy is to contrast endogenous (project-related) and exogenous (market and environmental) sources of uncertainty. Of most interest are endogenous uncertainties, because they are often project-specific and are not replicable, as they are in the case of financial options. Two key types of endogenous uncertainty in software projects arise from requirements risk (inability to meet requirements) and technical risk (inability to implement the desired system). This area is also ripe for laboratory studies in which uncertainty levels can be manipulated and the option values can be made explicit.

Second, a longitudinal study that tracks options throughout the project life cycle in a real-world setting can provide insights into how the values of dif-

ferent real options rise or fall as a project progresses through various stages. To accurately assess their values, each embedded real option must be analyzed several times over the course of a project (Bowman & Moskowitz, 2001). The interactions between project duration and option values should also be empirically assessed because longer projects imply a longer option expiration period.

Third, in terms of technology projects, different types of projects might carry differential option value. For example, it is possible that growth-oriented options might be more valuable in radical innovation-seeking projects as opposed to incremental improvement projects. In contrast, such options might carry lower value in one-off application projects than in infrastructural or technology-positioning projects involving emerging technologies (Fichman, 2004).

Fourth, different project stakeholders might value each type of option differently. Future research should directly examine these differences. Without the facility to reconcile divergent, subjective stakeholder viewpoints, firms might miss the opportunity to invest in creating options whose value is less obvious to a relatively homogenous group of IT executives.

CONCLUSIONS

This study makes two important theoretical contributions to the literature on escalation and project management. The first contribution lies in theoretically and empirically linking real options to project continuation in escalation situations. We showed that situations that appear to be irrational escalation from the traditional NPV perspective might be completely rational when viewed through a real options lens. To our knowledge, this is the first study to empirically test the predictions of real options theory in an escalation context. The second contribution of the article is that of assessing the relative importance that managers ascribe to each type of real option. We showed that managers ascribe more value to strategic real options than to operational ones. While this study represents an important first step in demonstrating how real options can affect managerial decision making in escalation situations, we believe that it offers a complement rather than a substitute to the rich body of work on this complex phenomenon.[Received: September 2005. Accepted: June 2006.]

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APPENDIX: SURVEY INSTRUMENT

Instructions

Assume that you have been asked to review your company's portfolio of 8 IT projects and to furnish a recommendation to continue or abandon them. Assume further that you personally were responsible for having approved or initiated all 8 projects. You will be presented with a series of 8 project scenarios (in the form of tables). As a decision maker involved in IT project assessment, please evaluate each scenario by answering the two questions that appear with the scenario. In the scenarios that follow:

1. Consider that all projects have spent 100% of their allocated budget but are only 50% complete.
2. Though considerable uncertainty exists, the estimated net present value (NPV) for each project from this point forward (i.e., ignoring expenditures that have already been made) is ZERO—that is, the expected returns from each project exactly equal the expected expenditures from this point forward, adjusting for the time value of money.
3. Project resources refers to personnel, hardware and software, and budget.

IT Project Profile #1 of 8

Option to...	Operationalization of Option in Conjoint Scenario	Presence
Stage investments	Investments in this project can be incrementally funded in stages	Yes
Change scale	Project resources can be expanded or contracted	No
Abandon	This project can be abandoned prior to completion	No
Switch use	This project can be put to another use	Yes
Grow	This project is a necessary foundation for developing future IT capabilities	Yes

Use the information provided in the table and your own experience and knowledge to answer the two questions below.

I think this project will fail to add value to my firm	1	2	3	4	5	6	7	8	9	I think this project will succeed in adding value to my firm
Lean toward terminating this project	1	2	3	4	5	6	7	8	9	Lean toward continuing this project

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