Beyond Valuation:
"Options Thinking" in IT Project Management

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Uncertainty is a fact of life for most large IT capital investments. From enterprise applications to infrastructure technologies to IT-enabled strategic initiatives of every flavor, a common element is doubt about the project will achieve its goals. This uncertainty arises from many sources—the immaturity, complexity, and unpredictable evolution of the technologies themselves; the increasing integration of technologies within and across organizations; and the increasing emphasis on using IT to support customer-facing processes and innovative products with hard-to-predict market appeal.

Given the potential for major losses on IT projects, the defensive posture exhibited by many organizations towards these efforts should come as no surprise. One manifestation of this posture is simply downplaying the level of risk. Although major IT initiatives produce disappointing results 50% of the time or more,[1] this uncomfortable fact rarely makes it into the planning processes of many organizations. Another manifestation of a defensive posture is penalizing projects that have large risks but also large potential rewards by employing an excessively high hurdle rate. A third manifestation is applying a veneer of predictability to IT investments by demanding rigidity in project planning and execution. A final manifestation is the tendency to treat setbacks on IT projects as arising first from the inadequacies of the project team, rather than being inherent in the process of undertaking uncertain ventures.

Ironically, these defensive maneuvers are just as likely to increase an organization's exposure to unnecessary risk as to reduce it: downplaying uncertainty discourages vigilance to potential problems; rigid project plans invite corner-cutting; and a blame-the-team-first mentality deters forthright communication about project status. A better approach is to assume a proactive stance that fully acknowledges and seeks to manage uncertainty on these projects.

"Options thinking," an emerging investment management philosophy based on the theory of real options, provides an especially promising foundation for this sort of proactive stance.

A real option refers to the right to acquire some real world asset without the obligation to exercise that right. Whenever an IT project has flexibility about which applications and functions to implement, and when or how to implement them, real options are present. These options can be quite valuable, and much of the academic literature on this topic has focused on developing appropriate tools to assist in quantifying option value. Managers, however, do not need to acquire arcane option quantification skills to put options thinking to work. The bigger win comes from using real options concepts to actively create and extract the value of embedded options that can otherwise be difficult to see.

In this article we describe how practitioners can incorporate options thinking into contemporary IT project evaluation and management.[2] This requires that managers to learn to recognize what kinds of options can be embedded in IT investments; to develop a sound intuition about how options create value; and to understand how to manage projects so that option value that exists in theory is actually realized in practice. It is a certain philosophy of project management—more so than precise quantification—that is the essence of options thinking.

How Flexibility Creates Option Value on Uncertain IT Investments

No other technology supports managerial flexibility quite like IT. One aspect of this flexibility is that modern IT systems are themselves highly malleable. While many kinds of assets (traditional equipment, manufacturing plants, real estate) have a relatively fixed set of potential uses, most forms of IT can be applied to a variety of business processes or products. Further increasing the flexibility of many IT assets—at least those embedded in software—is they can be replicated at low cost, modified if necessary, and then shared or sold. The level of flexibility associated with any given IT system is not pre-ordained. Organizations can enhance flexibility by making systems more generic, multi-purpose, interoperable, and scalable.

A second dimension of flexibility on IT investments concerns the processes by which IT systems are delivered. IT is particularly well suited to the use of simulations, prototypes, pilots, and various forms of staged implementation—all of which generate a wide variety of opportunities for incremental project commitment.[3]

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The two pillars of IT project uncertainty and managerial flexibility make real options especially pervasive on IT investment projects. What exactly are real options, and why does uncertainty together with flexibility enhance their value? Real options are similar to financial-trading options such as calls and puts, and they can be valued similarly using options pricing models (OPMs), such as the Black-Scholes and the Binomial. OPMs were originally developed to assist in the valuation of tangible assets,[4] but have increasingly been applied to more intangible sorts of investments, such as those related to R&D and information technology.[5]

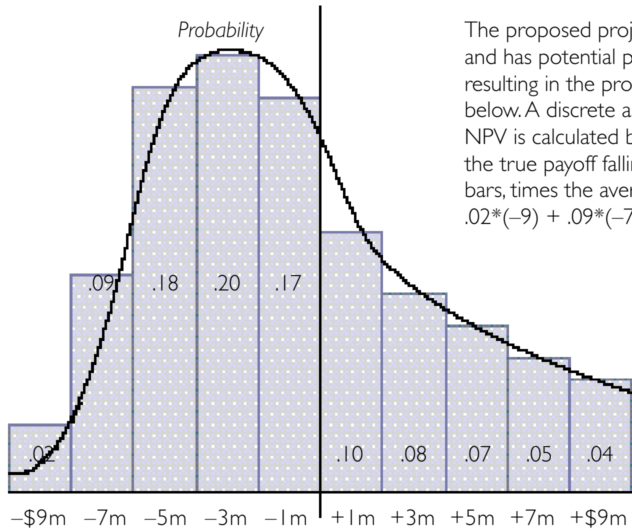
Just as a call (or put) option confers the right but not the obligation to buy (or sell) a given stock at some future date, a real option provides the right but not the obligation to acquire or dispose of some real world asset in the future. In both cases, the value of the option comes from the flexibility to decide whether to exercise the option depending on future conditions. Option holders can participate in the upside of the investment, but limit their losses to the cost of acquiring the option. Since uncertainty about benefits increases the range of the potential upside outcomes but not the downside (which is capped at zero), greater uncertainty increases the value of flexibility and thus the value of the option.

Although most managers can understand why increased uncertainty expands the value of a stock option, the same principle applied to IT investments with embedded options strikes many as counterintuitive, so we offer the following concrete illustration. Suppose a firm is faced with a large project to implement radio frequency ID (RFID) tagging across its supply chain. The firm chooses to begin with a smaller pilot initiative and expects to proceed with full investment only if the pilot goes favorably. The cost of the pilot is akin to the cost of purchasing a call option on the full project—an option that will only be exercised if information gained during the pilot indicates that the payoff for the larger project will likely be positive. These sorts of options can change a project that has a negative expected payoff according to conventional tools (i.e., NPV); to one that has a significant positive value. Figure 1 illustrates the difference in the payoffs for a hypothetical $10 million RFID investment project with no embedded options (e.g., proceeding immediately with full implementation) versus one with an embedded call (e.g., starting with a pilot project that reveals payoffs). Traditional tools do not take into account this sort of managerial flexibility, but rather assume equal exposure to both potential losses and gains (as shown in Figure 1a).

Because options acknowledge managerial flexibility to act in ways that avoid potential losses while preserving potential gains, a project with an embedded option is more valuable than one without (as illustrated in Figure 1b). The extent of this extra value depends on the degree of uncertainty and corresponding variability in potential future gains or losses and on how long the option can be held.[6]

Uncertainty can arise from inherent risks endemic in particular IT projects (technical uncertainty) and from an unknown future (market uncertainty). The

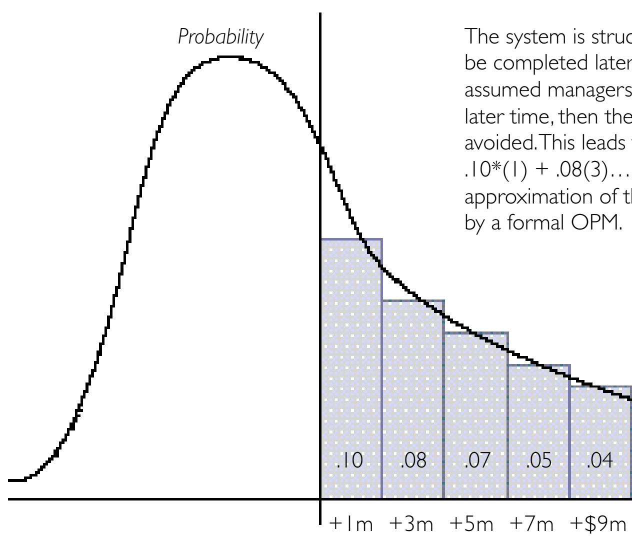
FIGURE 1A. Estimated Value with No Option



The proposed project costs $10m to implement, and has potential payoffs ranging from $0 to 20m, resulting in the probability distribution of net payoffs below. A discrete approximation of the expected NPV is calculated by multiplying the probability of the true payoff falling within one of the 10 probability bars, times the average payoff for the bar, i.e., .02*(–9) + .09*(–7) … .04*(+9)= – $1.1m

Expected NPV = $1.1m

FIGURE 1B. Estimated Value with an Embedded Call



The system is structured as a follow-on project to be completed later (e.g., after a pilot project). If it is assumed managers will know the true payoff at this later time, then the negative net payoff region will be avoided. This leads to a revised estimated payoff of .10*(1) + .08(3)…+ .04(9) = $1.4 m. This is only an approximation of the value that would be estimated by a formal OPM.

Approximate Option Value = $1.4

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main requirement is that *some* of the uncertainty be resolvable. The mechanisms for resolving uncertainty will differ for technical versus market uncertainty. The former usually requires that managers "do something" to resolve the uncertainty, while the latter can often be resolved by simply waiting (and, of course, staying alert to the market).

There is, of course, no free lunch in the world of traded financial options, because the purchase price of an option at any moment reflects the market's current best estimate of what the option is actually worth. However, in the case of real options, there isn't necessarily a strong correlation between what an option costs to acquire and what the option is actually worth, so quite valuable IT options can often be created relatively inexpensively. Thus, managers that employ options thinking stand to gain a considerable advantage, especially in fast-moving, unpredictable environments where real options tend to be most valuable and plentiful.

From Option Valuation to Options Thinking

Real options concepts not only allow an organization to more accurately *assess* uncertain IT investments, but perhaps more importantly, can guide managers in how to actively *create* and *extract* value. This is the heart of options thinking. The key to understanding how options create actual value lies in the distinction between what an organization *must do* on a project, versus what it *may do*. For those things an organization *must do*, there is (by definition) no flexibility, and so traditional analytic tools (such as NPV and ROI) that place no economic value on flexibility are appropriate. However, for those things a firm *may do*, value is created by actively structuring those elements as an option.

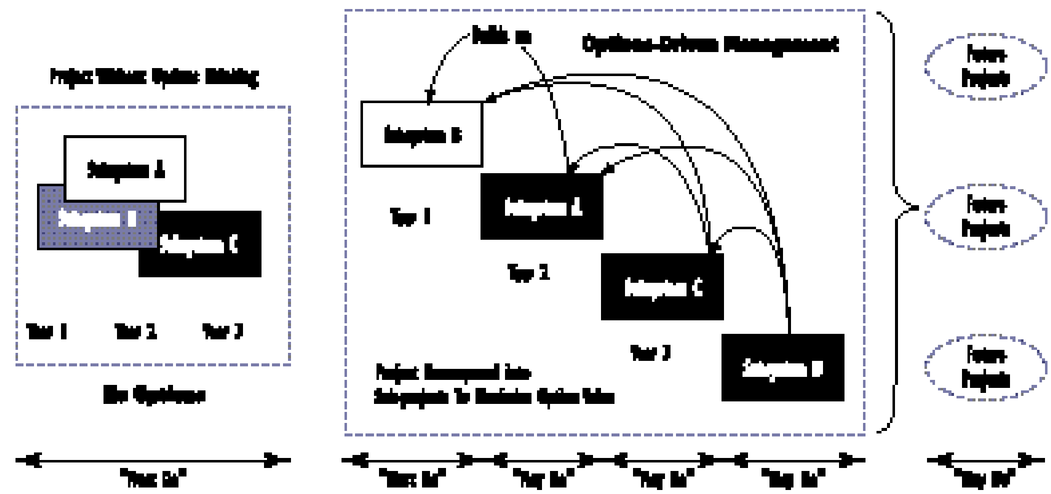
This suggests managers can enhance value creation with two general strategies:

- shifting project elements that are part of the baseline implementation from *must do* to *may do* status; and
- performing a systematic search for opportunities beyond the baseline implementation that represent additional *may do* elements.

In options terms, the first sort are referred to as *operating options*, in that they relate to the operational aspects of a project. The latter sort are referred to as *growth options*, in that they refer to the opportunity to grow the project's scope through follow-on investments beyond what was initially anticipated. Figure 2 illustrates the difference between a traditional project and one driven by options thinking.

Effective options thinking requires that managers do three things well: *recognize* and enhance opportunities to create options with IT; *value* these options (in some way); and *manage* projects to fully extract this value.

FIGURE 2. Traditional Project Management vs. Options Thinking



Six Examples of Real Options in Practice

Embedded IT options can take many forms, including the options to: *stage* investment, *abandon* investment, *defer* initiation of investment, create *growth* opportunities based on an initial investment, change the *scale* of investment, and *switch* assets created by the investment to another use (see Table 1).[7]

Example 1: The Options to Stage and to Abandon— Carlson Hospitality

In practice, most large IT projects are divided into stages for the purpose of resource planning and setting milestones for project tracking. However, the mere existence of stages in a project does not by itself create embedded stage options. To create value using stage options requires an active management approach where execution of each stage is made contingent on a reassessment of the costs and benefits of completing that stage *at the time the stage is reached*. In addition, business requirements or opportunities often change in ways that increase or decrease the importance of what a given stage delivers, and so the team will be better able to recognize and avoid investing in stages that no longer have a worthwhile payoff. In summary, stage options create value by providing the opportunity to alter or terminate a project before each new stage of funding, based on updated information about costs and benefits.

In practice, stage options often overlap with other options, such as abandon, change scale, and strategic growth. In cases where completion of each stage does not produce a useable system, but is merely a necessary condition to proceed to the next stage, this is a form of the abandon option (stage-abandon).[8] Stage-abandon options can be created by developing "throw away" prototypes

TABLE 1. Six Types of Real Options

Option	Definition	How Value is Created	Pitfalls
Stage	A project can be divided into distinct stages where pursuit of each stage is contingent on a reassessment of costs and benefits at the time the preceding stage is completed.	As each stage is completed the ambiguities about the net payoffs from subsequent stages are resolved; only stages with positive payoffs are pursued.	Managers may prefer all-at-once funding to obtain maximum control over a project's fate or to generate full *a priori* commitment to the project.
Abandon	A project can be terminated midstream and remaining project resources relatively easily redeployed.	As a project unfolds actual costs and benefits become more clear, and losses can be curtailed by terminating the project.	Projects tend to take on a life of their own and are difficult to terminate. Abandoning projects can carry intangible costs related to credibility and morale. Resources can't always be productively redeployed.
Defer	A decision on whether to invest can be deferred for some period without imperiling the potential benefits.	The firm avoids investing in what is destined to be a losing proposition. Chances are increased of making the right choice on a crucial project decision.	Strategic benefits often erode with time. Direct experience with a technology is often required to resolve uncertainty.
Strategic Growth	An initial baseline investment opens the door to pursue a variety of potential follow-on opportunities.	Over time, the relative value of follow-on investments becomes more apparent and only investments with positive pay offs are pursued.	Growth options can be difficult to value due to higher ambiguity and the longer time frames often involved.
Change Scale	Resources allocated to a project can be contracted or expanded, or the operational system enabled by a project can be scaled up or down more easily.	The organization can increase the scale of a project/system (and thus the range of potential benefits) if circumstances are favorable; or can reduce the scale (and thus potential losses) if circumstances are unfavorable.	Building in the option to scale up or down can add to project costs. As with the abandon option, scaling down a project can carry intangible costs related to credibility and morale.
Switch	An IT asset developed for one purpose can be redeployed to serve another purpose (switch use). A key foundation technology supporting a project can be swapped out for another (switch inputs).	Over time, the relative value of alternative uses becomes more apparent and only uses with positive payoffs are pursued. If a chosen foundation technology proves less robust than a rival technology, the organization can switch to the rival technology.	If licensed technologies are involved there may be legal restrictions on the ability to switch use. Creating this option usually involves making the system more generic, typically at added expense.

or following the traditional waterfall SDLC (i.e., analysis, design, construction, implementation) but with a formal go/no-go decision for each phase, such as in the spiral model of development.[9] Conversely, when early stages produce a useable, but smaller-scale system that can subsequently be scaled up, or to which additional functions can be added, the overlap is with the option to change scale (stage-scale) and growth options (stage-growth). The latter sort of staging options are naturally preferable, as they produce a useable asset at the end of each stage.

Carlson Hospitality Worldwide's recent implementation of a new Customer Reservation System (CRS)[10] illustrates how a project can be reconceptualized to create embedded *stage-growth* and *stage-abandon* options. The project was initially pitched as a $15 million all-at-once investment. When that proposal was soundly rejected, the IS team reconceptualized the project as a set of nine separately implementable "chunks," each of which had to produce a direct business benefit. Though no formal OPM was used, it was clear that management understood how staging can create value through increased flexibility: "[the IS team] managed to get funding for the first chunk, and soon they started rolling out the new CRS…along the way, they would insert one chunk and ditch another as needed to get the biggest payback, while staying open to suggestions." Furthermore, IT managers structured each stage to be implemented gradually, so that at any point the roll-out of a given stage could be reversed, thus creating additional stage-abandon options.

This example illustrates a key tactic for increasing the value produced by embedded stage options, which is to ensure that each stage actually produces an identifiable benefit beyond simply enabling subsequent stages. Otherwise it is difficult to develop an estimate of net benefits of performing that stage in isolation. This suggests that a project be divided into incremental units of functionality, each of which can be implemented separately even if no further increments are implemented.[11] A second useful tactic is to schedule stages with the most uncertainty as late as possible in the overall project lifecycle, since the value of an option increases the longer the option can be held. This tactic will be even more valuable if project managers segregate functions with the most uncertainty from functions with the least uncertainty. This can be done by combining the most uncertain functions together into the same stages or, even better, by isolating uncertain functions into their own stages.

Potential Pitfalls of Stage-Growth and Stage-Abandon Options

Not all projects can be divided up to create embedded stage options. Sometimes a firm must make a binding commitment to a project as a whole, such as when external funds must be raised or when co-investment from other parties is required. The payoffs from investment may depend on whether a self-reinforcing adoption process reaches critical mass, meaning that a potential investor must, in essence, play to win or not play at all.[12] In such all-or-nothing investment situations, valuable options may still exist in the form of the option to defer.

Even when a project could be staged in principle, managers may find it hard to craft stages that conform to the above criteria. Another pitfall is that stakeholders may prefer all-at-once funding to obtain maximum control over a project's fate and to have more time to get a troubled project back on track before facing the next round of justification. In practice, it can be difficult to distinguish the ordinary setbacks that occur on most implementations[13] from those that indicate embedded options should not be exercised—thus raising the possibility of premature cancellation of valuable *"may do"* project elements. A final pitfall of stage-growth options is they may require temporary interfaces and reworking previously implemented functions. Some organizations may resist the idea of incurring these certain expenses to enable uncertain benefits later.

The main pitfall associated with abandonment, a second kind of option on the Carlson CRS project, is that many projects take on a life of their own and can be difficult to terminate, as illustrated in the large literature on escalation of commitment.[14] In fact, some observers see this as perhaps the central challenge associated with options thinking.[15] People involved in a project can become personally vested in seeing the project succeed, thus terminating projects can carry intangible costs related to morale. Also, those involved may suffer a loss of credibility, owing to ambiguity about whether project failure was due to project team deficiencies or factors beyond their control.

Example 2: The Option to Defer Investment—Yankee 24

An option to *defer* exists when a decision on whether or how to invest can be delayed for some period without imperiling the potential benefits. When uncertainty is high but can be resolved over time, deferral options can be surprisingly valuable. A good example of an embedded deferral option was Yankee 24's implementation of a network infrastructure to support point of sale (POS) debit cards for New England merchants.[16]

Yankee first began considering the POS network investment in 1987 when considerable uncertainty existed in four key areas:

How fast would retailers adopt POS debit cards as a payment option?

Would Massachusetts, which represented 50% of the New England market, revise banking regulations that currently discouraged POS debit adoption among smaller businesses?

Would consumers in New England take up POS debit cards at the same rate as other markets?

Would a competing network signal an intent to enter the POS debit arena?

Yankee understood, correctly, that by simply waiting, much of the uncertainty about payoffs could be resolved. For example, they could observe debit card adoption rates in other more mature markets and lobby the Massachusetts government for favorable legislation. Meanwhile, the upside opportunity was not in serious peril for at least three years, because this was how long Yankee thought the most likely competitor would need to establish the necessary infrastructure.

Yankee, by contrast, could move much more quickly because it had most of the necessary infrastructure already in place.

A retrospective options-based analysis of the Yankee case by two IT researchers determined that the optimal time for Yankee to defer investment was three years. This three-year deferral option was estimated (using the Black Scholes OPM) to be worth approximately $150,000. This compares with an estimated NPV for initiating the project immediately in 1987 of minus $80,000. Interestingly, Yankee did, in fact, defer entry for three years, which gives an example of managing an investment in ways that were consistent with options thinking without adopting a formal OPM.

Possible Pitfalls of Deferral Options

There are two main pitfalls associated with this option. The first is the potential for erosion of project benefits with time. This may occur when first mover advantages exist and there is a danger of preemption by another firm or when it can be expected that other firms will quickly follow. In fact, the possibility of value eroding with time runs counter to the standard OPM assumption that longer deferral periods increase the value of options. The second pitfall stems from the fact that a firm must often gain direct experience with an innovative technology in order to be in a position to resolve uncertainty about its potential uses and benefits. Organizations that make a habit of deferring investments may therefore suffer a general loss of innovative capabilities and may lose the ability to appreciate new technologies, and thus they may find themselves "locked out" of not only the current opportunity, but future opportunities as well.[17]

Example 3: Options that Provide Growth Opportunities— A European Automaker

An embedded *growth* option exists when an initial baseline investment opens the opportunity to pursue a variety of potential add-on projects. Unlike the other options described so far, which produce value mainly by limiting the extent of potential losses, growth options add value by increasing potential gains.

A case study of an ERP implementation project by a European auto maker provides a well-developed example of how to value IT growth options in practice.[18] The base project, which involved upgrading from SAP's R/2 system to R/3, was expected to cost $1.85 million and to produce about $1.45 million in operational savings, leading to a negative NPV of about $400,000. The base implementation by itself was not cost justified, but managers realized that the greater robustness and flexibility of the R/3 system would enable several potential follow-on projects that would otherwise have been infeasible, including introduction of EDI-based purchasing and invoicing, workflow applications for sales, engineering document handling, and web-based e-commerce. The NPV of these additional applications was estimated to be $150,000—still not enough.

Thus, had the project team simply expanded the bounds of the initial *must do* project to include these elements, the project would have remained unjustified, with a negative NPV of $250,000. However, the project team recognized that the add-on projects should be treated as *may do* elements that would only be pursued in favorable circumstances, and to value them accordingly using an OPM. The resulting Black-Scholes estimate for the add-on projects was $650,000—enough to make the overall project worth undertaking—and based on this expanded estimate of value managers did proceed with the implementation.

In this case, the value of having the flexibility to say "no" to one or all of the add-on projects if the base implementation went poorly or other unfavorable events transpired (e.g., an adverse change in business environment) was over $500,000. (To put this amount in perspective, the add-on projects were expected to cost $2.2 million to implement and maintain.)

IT platform implementations, by their very nature, will tend to have a variety of embedded growth opportunities. Managers will gain the most by attempting to identify and value these opportunities as embedded options when: the base project has an unclear payoff taken alone; the NPV of the add-on projects is not enough to give the project an overall positive payoff; and there is much uncertainty regarding the net payoffs of the add-on projects.

Potential Pitfalls of Growth Options

Growth options are most likely to be present on more-innovative projects and on those that implement a platform for future applications.[19] The main challenge here is the difficulty of estimating option values (due to ambiguity about potential future cash flows) and uncertainty about the appropriate value for option model parameters. These challenges are compounded to the extent that longer time horizons are involved, as is often the case with growth options.

Example 4: The Option to Change Scale—Cypress Communications Authority

An embedded option to *change scale* exists when the resources allocated to a project can be contracted or expanded in response to future conditions, or when the production system enabled by a project can be scaled up or down with comparative ease. If unexpected technical barriers are encountered—or a change in business conditions reduces the value of the intended system—a project with an embedded scale-down option can be reduced in scope, and some project resources can be reassigned. Thus the scale-down option may be viewed as a milder form of an abandon option. Conversely, a project structured to increase the scope of the resulting system in the event of favorable future conditions has a scale-up option that is similar to a growth option.

An initiative by the Cypress Communications Authority (CYTA) to enable a major network expansion provides a case of an IT investment that created a valuable scale-up option.[20] In 1992, CYTA anticipated that Cypress's eventual entry into the European Union would warrant a significant expansion of its telecommunication network. Yet, they determined that this expansion would only be feasible if a complementary investment was made in upgrading the information system used to support the daily operations of the authority. The upgrade would produce some immediate benefits (e.g., improved network utilization, productivity improvement, and overtime reduction) even if the future network expansion was not pursued, but the expected value of these immediate benefits was negative £1.7 million. However, the value of the option to expand the telecommunication network in the future, should conditions warrant, was estimated to be £2.55 million, resulting in an overall valuation for the IS development of £0.85 million, enough to justify proceeding with the project.

Possible Pitfalls of Scale Options

The pitfalls associated with scale options depend on whether the option is to scale up or down. The option to scale up can add to project costs, and some organizations may resist adding such costs in return for an uncertain future payoff. Conversely, in the case of scale-down options, there may be resistance—albeit less severe—to exercising the option in practice similar to that for the abandon option.

Example 5: The Option to Switch Use—TWA

An embedded option to *switch use* exists when an IT asset developed for one purpose can be redeployed to serve another purpose. Software is more malleable than physical assets and has a very low cost of reproduction. This means that software applications can be more easily repurposed without necessarily having to discontinue use of the system from its original application.

Trans World Airlines' (TWA) development of a computer-aided software engineering (CASE) "template" for their Frequent Flyer Benefits (FFB) shows how to create a switch-use option.[21] A CASE template is a detailed design model that automatically generates part or all the program code required to implement the target system.

The FFB system was originally developed for TWA's own use, however, the CASE template facilitated subsequent sale of the system to Canadian Air. While any software system can, in principle, be sold to another firm, the likelihood of another firm being interested and what they will pay—and thus the value of the embedded switch-use option—depends on how easy the system is to understand and modify. In this case, the use of a template allowed Canadian Air to produce a customized system in eight months, as compared to the 18 months needed for a from-scratch development. The rapid modifications were possible because of: the explicit depiction of business rules in the CASE template (rather than having this buried in program code); the ease of generating operational prototypes, and the ease of modifying a design model and regenerating program code compared to modifying the program code itself.

Potential Pitfalls of Switch-Use Options

The main potential pitfall of this option is that it can add extra time and expense to the initial development project. Some researchers have estimated that making program modules generically reusable—which may be seen as the ultimate in creating switch-use options—can cost several times as much as creating single-use modules.[22] In some cases, the cost of creating a switch-use option could exceed the value it produces.

Example 6: Stage, Growth, and Switch-Use Options—Starbucks Coffee Company

Starbucks' recent introduction of their pre-paid card was a project that had embedded stage, growth, and switch-use options.[23] Though a formal options valuation methodology wasn't used, the approach to managing the project provides an excellent example of options thinking in practice.

The original intent for the Starbucks card was simply to speed checkout in a business where cash transactions dominate. Managers were unsure about demand for such a card, and so they consciously chose a bare-bones approach to the initial implementation rather than a more ambitious rollout. The card used a simple, stand-alone magnetic stripe design, which meant the only infrastructure upgrade needed was some reprogramming of cash registers to read the cards. Later, after demand for the card was clear, Starbucks went the additional step of providing online registration of the cards, which allowed users to replace lost cards, reload cards with more money, and view transaction histories. This second stage could easily have been anticipated and included from the start. However, by segregating this functionality into a separate stage, managers created an embedded stage option. If the card had flopped, the expense of this extra functionality would have been avoided.

After the second stage was completed Starbucks managers realized that the card could do much more than simply speed check out, so a third stage, the card was enhanced to support loyalty points redeemable at Starbucks based on purchase volume, entry in occasional sweepstakes, and e-mail notification of in-store promotions and new products. Since this add-on project created a new asset (e.g., a loyalty program) rather than changing the value of an existing asset (as with online registration for the initial pre-paid card), it represented a growth option rather than a scale-up option.

Most recently, Starbucks has taken a fourth step that illustrates an embedded switch-use option similar to the TWA FFB case. They have collaborated with Visa USA and Bank One to introduce a co-branded card that combines the functionality of the enhanced Starbucks prepaid/loyalty card with standard Visa credit card functionality. Since all of the prior functionality of the pre-paid card (programming of cash registers, online registration) could be reused to support the new dual use card, this can be seen as a switch-use option.

It is worth emphasizing that there is no evidence that Starbucks managers had planned from the start to consider all of these potential enhancements or to place a value on them using an OPM; rather, their intent was simply to "keep their options open" by using an incremental commitment approach. However, this sort of alert incrementalism is a central principle of options thinking. As it happened, Starbucks managers were confident that at least the initial step was worth pursuing and so putting a value on options was not necessary. However, if things had been different, then estimating the option value of potential enhancements could have been crucial in justifying the initial project, as was the case in the ERP and network expansion examples described earlier. Thus, it is important that managers interested in real options be acquainted with approaches to estimating option value.

Valuing Real Options

As prior examples show, the quantified value of a real option is not always intuitively obvious and can change a decision on a worthwhile project from a no-go to a go. Also, estimating option value can help with more tactical decisions, for example, whether to incorporate flexibility to support either of two standards that are currently battling it out in the market place, rather than placing a bet on only one standard.

The most commonly used tools for valuing real options are the Black-Scholes and the Binomial OPMs. The Binomial model[24] has less stringent assumptions than the Black-Scholes and is likely to receive increasing attention from options researchers. Copeland and Tufano note that"[the Binomial model] captures the contingencies of real options and addresses nearly all of the more commonly voiced criticisms of using option theory to manage those contingencies."[25] In addition, some newer OPM variants have been developed that are even more flexible than the Binomial model.[26]

The use of OPMs on IT investments is subject to several challenges, starting with concerns about "transparency."[27] However, counterarguments and remedies exist (see Sidebar 1: "Options Valuation Challenges") that make the use of OPMs, while not perfect, still generally superior to traditional NPV approaches, which place no quantified value on flexibility at all.[28] Nevertheless, adopting formal OPMs today will require that senior management be open to considering leading-edge valuation techniques; and, even then, a considerable education effort will be required. However, these hurdles should be lowered as more managers get exposed to the use of OPMs in business schools and at leading firms such as Merck, Hewlett-Packard, and Intel.[29]

Alternatives to Formal OPMs

If it is expected that senior managers will (for whatever reason) resist the use of formal OPMs, then decision trees or even qualitative option-valuation approaches provide viable alternatives. Decision trees, unlike OPMs, are highly transparent. In the ERP example above, the framing of proposed investments in the form of a decision tree is what ultimately convinced management, rather than the OPM estimates *per se*. The main limitations of decision trees are: first, that the complexity of a tree can increase rapidly as more alternative scenarios are incorporated; and second, that there is no straightforward way to determine what the correct risk adjusted discount rate for the whole tree should be.[30] Yet,

SIDEBAR 1. Real Options Valuation Challenges

Challenge	Counter Argument/Remedy
Absence of a traded market for IT assets makes it difficult to estimate the expected value of a project (one key option model parameter).	Managers must estimate the future expected cash flows of a project even under the NPV approach, and options valuation is no more sensitive than NPV valuation to mis-estimates of project cash flows.
Absence of a traded market for IT assets makes it difficult to estimate the volatility (uncertainty) of the value of a project (another key option model parameter) and may raise concerns that analysts might "fudge" this parameter.	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. Analysts can do a sensitivity analysis to determine whether a project is justified under different sets of assumed levels of volatility. Analysts can use conservative values for uncertainty until they have gained more experience.
Absence of a fixed time by which options must be exercised makes it less likely that projects will be appropriately terminated.	Escalation of commitment is a common problem even on projects not conceived as options; in fact, options, by explicitly recognizing things might not go as planned, can support a more disciplined approach to the problem of terminating troubled projects. Managers can adopt new project management guidelines (such as explicit exit points) that counter the natural resistance to project termination.
Lack of "transparency" associated with OPMs, especially the Black-Scholes.	When transparency is important, analysts can use the binomial OPM or even more transparent approaches, such as a decision trees.
The value of an IT initiative may erode with time due to loss of potential for competitive advantage, but options formulas place a higher value on longer times to expiry.	When erosion of competitive advantage is an issue, analysts can estimate the expected value of a project separately for multiple candidate expiration dates.

decision trees come closer to correctly valuing a project than conventional approaches that place the value of flexibility at exactly zero.

Managers can gain considerable benefit from using structured but qualitative approaches that help them to think about option value more intuitively.[31]

However, if managers are to rely on intuition, they must be on guard against systematic biases. In a separate research study, we found some interesting indications of bias in how managers viewed different kinds of options (see Sidebar 2: "Is Options Thinking Real?").

The following attributes increase the importance of using real options concepts when estimating a project's value:

Embedded options clearly exist due to high uncertainty in combination with flexibility in the systems delivery process and/or in the delivered system itself.

The project is going to be evaluated quantitatively "by the numbers." Given that managers are going through the effort of estimating cash flows, the incremental effort of employing OPMs is, surprisingly, not that great.

Traditional quantitative analysis produces a result that leaves the value of the project with a negative NPV—but not so negative that the potential value of options is overshadowed. It is when options value might well change the decision on whether to proceed with a project that using an OPM will be most important.

Managing Real Options

While putting a number on the option value of projects is not a mandatory part of options thinking, it is essential that projects at least be managed in such a way that the potential value that has been created by building in options actually gets extracted. To put this another way, projects must be managed so that options contracts are honored.[32]

When managers seek to create value by embedding options, they are in effect writing an options contract. What this contract says is that at some specific future time they will compare the revised estimated value of proceeding with further investments against the revised estimated cost, and they will proceed if, and only if, this value exceeds the cost—just as the holders of financial options only choose to exercise options that are "in the money" at expiration. Thus, an options contract is a commitment to employ certain principles in deciding whether the element will be done, rather than binding commitment to actually do a project element.

An organization that fails to honor such contracts will not only systematically over-value options, but will also lose credibility and thus the discretion to write such contracts in the future. Thus, firms that use real options as part of the project justification process must put managerial guidelines in place that allow sound options contracts to be created and honored in practice. We offer ten such guidelines in Sidebar 3: "Guidelines for Bringing Options Thinking into Project Management."

SIDEBAR 2. Is Options Thinking Real?

To investigate whether any biases might exist in the intuitive valuation of real options, we recently undertook a field study to examine how the presence or absence of different kinds of options affected managers' willingness to continue a troubled project.[a] Managers in 123 firms were each asked to assess several hypothetical situations, each consisting of a base investment project combined with a different combination of embedded options (e.g., stage, abandon, scale, switch, strategic growth) described in commonsense terms. For each project, they were asked to indicate the likelihood that the project had a positive payoff looking forward and whether it should be continued. Some of our findings indicated that managers intuitively view real options in ways consistent with options theory. For example, they did recognize that embedded options added value and that the presence of multiple options increased that value.

Interestingly, we also found that IT managers tended to look more favorably on some kinds of options than others, despite the fact that, in principle, no one type of option is necessarily more or less valuable than any other. Specifically, we found growth options and switch-use options were the most highly valued, while abandon options and stage options (presented in the form of stage-abandon) were valued least.

These results suggest that options representing positive opportunities to increase the potential upside of a project if things go well (i.e., options that are like adding an additional call option to an existing base investment) are more highly valued than options that provide opportunities to contain the most extreme downside losses if things do not go well (i.e., options that are like adding a put option to an existing base investment). Further research is required to establish exactly why this bias exists, but one plausible explanation is that managers anticipate that "positive" options (calls) associated with project success will be easier to exercise in practice, while "negative" options (puts) will prove more difficult to exercise.

Should You Adopt?

As noted, options thinking requires major changes to project management and complimentary changes to organizational culture. So managers need to assess the prevalence of real options and their readiness to undertake the challenges of options thinking before taking the lead as an early adopter.

Assessing the Prevalence of Real Options

The benefits from adoption of real options depend on how prevalent real options are in your firm. The following sorts of questions give insights on this point:

Does IT play a strategic or merely a supporting role in your business? Growth options are especially common in organizations where technology plays a strategic role.

Does your firm operate in a fast-moving environment with a high rate of innovation in areas dependent on IT, or does it operate in a more stable

One managerial implication of these results is that until organizations are able to overcome culturally embedded biases, it may be worthwhile to change how options are structured and portrayed so that they can be interpreted as positive opportunities (i.e., call options) rather than as hedging against negative outcomes (i.e., put options). Here are three examples of such tactics:

Tactic 1: Instead of bundling uncertain features as part of the initial base project with the understanding they may be taken out if things do not go well (which is like adding a put option), managers can shift these uncertain features to a second stage project (which is like adding a call option).

Tactic 2: Instead of immediately undertaking an uncertain project with the understanding that it may be abandoned later (which is like adding a put option), managers may choose to defer initiation of the project (which is like adding a call).

Tactic 3: Instead of using traditional staged funding (which embeds a stage-abandon option that behaves like a put), managers can seek to stage a project so that each completed segment produces the potential for business value as with the Carlson example (which produces a stage-growth option that behaves like a call).

a. A. Tiwana, M. Keil, and R.G. Fichman, "Can Escalation Be Rational? An Embedded Real-Options Perspective," Working Paper, 2005.

environment? Fast-moving environments tend to have more uncertainty regarding the value of IT investments, which, in turn, increases the value of associated embedded options of all kinds.

Does your firm often undertake very large and complex projects, or are most projects smaller and straightforward? Large, complex projects will usually have a wider variety of operating options.

Does your firm often undertake discretionary or leading-edge IT projects, or does it tend to wait until something becomes a competitive necessity? Discretionary and leading-edge projects tend to have high levels of uncertainty and flexibility, while projects that have become a competitive necessity have less of either.

Assess Organizational Readiness

Given that your firm operates in an environment where real options abound, the other main consideration is whether you are ready, in terms of skills and culture, to properly value and manage real options. Regarding skills, a key issue is whether an organization already performs sophisticated quantitative evaluations of IT investment projects that involve the estimation of future cash flows. If so, then the incremental effort to estimate the value of real options will be more manageable.

While there are alternatives to formal OPMs for organizations that lack the necessary skills, there is no substitute for cultural readiness. To employ

SIDEBAR 3. Guidelines for Bringing Options Thinking into Project Management

Place a value on flexibility in some systematic way. This can range from using a formal OPM, to decision trees, to a systematic but qualitative analysis of option value.

Be willing to initiate high-risk/high-reward projects when the risks can be contained with options. These projects have the most option value, and are most likely to be wrongly rejected using the NPV rule.

Look for ways to shift the balance from *must do* to *may do* project elements. This includes deferring non-critical items for later implementation stages and explicitly identifying future applications and enhancements at the time the initial baseline project is considered.

At the outset of a project, explicitly identify the factors that create uncertainty. Identify uncertain factors that determine whether *may do* items will be more or less attractive. Develop a set of explicit statements about how favorable and unfavorable shifts in these factors should affect willingness to continue. Put procedures in place to actively track uncertain factors as they evolve over the course of the project.

Be aggressive in the use of incremental project funding and staging. Work especially hard to structure implementation so that each stage creates value even if no further stages are funded.

Be willing to invest in design practices that create growth options by promoting future flexibility of delivered applications. This includes making systems more generic, multi-purpose, interoperable, and scalable.

Be generous in the use of implementation tactics that create operating options. These include simulations, prototypes, pilot projects, and incremental roll-outs. Use incremental roll-outs to phase introduction of different functionalities to the same population of users or to phase the same functionality to different sets of users.

options thinking requires frank discussions of uncertainty and risk. If the very admission that a project might not pay off or could be terminated altogether constitutes its death knell, then a major cultural change will be required. A related issue is whether the organization will be able to honor options contracts: Can managers imagine substantially curtailing or terminating projects that were defined upfront to include an embedded stage or abandon option and still say to everyone involved "job well done?" Is there a sufficient level of trust among stakeholders to institute staged funding and aggressive deferral of uncertain or discretionary items to later project stages? These sorts of questions reveal whether real options are culturally feasible.

Build-in explicit options checkpoints. These are analogous to options expiration dates, and should be located at points where a project can be most gracefully redirected or terminated (e.g., at the end of each stage) if uncertainty has been resolved unfavorably. At each checkpoint, the current status of uncertain factors and the project more generally should be re-evaluated and matched against expectations. Decision rule "triggers" for terminating a project should be articulated at the outset of the project to help guard against project managers "falling asleep at the switch."[a]

Nominate an "exit champion" to counter balance the regular project champion. An exit champion is a well-respected, senior person whose job it is to know when the time has come to pull the plug on a project, and to advocate for doing so when and if that time is reached.[b] A natural additional responsibility for an exit champion in the context of real options would be to track exercise decision performance (i.e., are projects continued or terminated as appropriate). This does not mean judging results of these difficult decisions with 20-20 hindsight. Rather, it means judging the quality of the analyses used to support exercise decisions at each check point, and whether explicit exercise decisions were in fact made, rather than the project simply continuing along by default.

Create incentives for proper options exercise. After procedures are in place to track exercise performance, organizations must then reward good performance with some combination of compensation, increased responsibility, and public recognition.[c] Additionally, the organization must clearly signal that pulling the plug on a failing project does not necessarily carry the connotation of admitting failure.

a. For a fuller discussion of triggers and other tactics to encourage appropriate exercise of real options, see T. Copeland and P. Tufano, "A Real-World Way to Manage Real Options," *Harvard Business Review*, 82/3 (March 2004): 90-99.

b. For a discussion of exit champions and other tactics for terminating projects see I. Royer, "Why Bad Projects Are So Hard to Kill," *Harvard Business Review*, 81/2 (February 2003): 48-56.

c. Copeland and Tufano, op. cit.

Conclusions

There are six essential points to options thinking on IT investment projects.

Real options can be a powerful tool for valuing the strategic and operational flexibility associated with uncertain IT investments. However, real options are not just a new methodology for valuing IT investments—they constitute a new *way of thinking* about how projects can be structured and managed.

Promoting flexibility in the systems development *process* or *result* creates a quantifiable value, and this value exists whether or not an organization actually attempts to quantify it using an options pricing model. Under conditions of high uncertainty, this value can be surprisingly high.

Real options exist in a variety of forms—stage, defer, abandon, switch, scale, strategic growth—that differ according to the conditions where they add the most value and in terms of associated pitfalls. Understanding these different varieties makes it easier to identify, value, and manage options in practice.

Options thinking requires the adoption of new project management guidelines that promote flexibility in the development process and delivered result; that allow sources of uncertainty to be explicitly identified and tracked; and that facilitate appropriate exit on projects where uncertainty has been resolved in an unfavorable way.

Real options are most abundant in firms undertaking IT projects that are complex, strategic, and/or innovative. These projects tend to have high uncertainty and longer time frames, both of which magnify option values.

Using real options effectively will require a cultural change in many organizations. Adopters must be able to hold candid discussions of project risks and the potential for failure at the outset and they must be willing to redirect or terminate projects without the fear of stigmatization or reprisals.

Real options are by no means a panacea—evaluating and managing uncertain IT investments will always be difficult. Nevertheless, options thinking provides a promising philosophy to promote the longstanding goals of "doing the right projects" and "doing projects right." By recognizing the value of real options, managers advance the first goal. By honoring options contracts and allowing appropriate exit, managers advance the second goal. By structuring projects to promote flexibility, managers advance both goals. Firms seeking to innovate using IT tread an unpaved path. Options thinking helps managers navigate the considerable uncertainties and exploit the fleeting windows of opportunity that present themselves along this path.

Notes

1. Failure rates of 50% and above have been observed for advanced manufacturing technology. See A. Majchrzak, *The Human Side of Factory Automation* (San Francisco, CA: Jossey-Bass, 1988). For business process re-engineering, see B.J. Bashein, M.L. Markus, and P. Riley, "Preconditions for BPR Success," *Information Systems Management*, 11 (Spring 1994): 7-13. For customer relationship management system implementation, see D.K. Rigby, F.F. Reichheld, and P. Schefter, "Avoid the Four Perils of CRM," *Harvard Business Review*, 80/2 (February 2002): 101-107.
2. In developing our ideas, we have been particularly influenced by M. Benaroch, "Managing Information Technology Investment Risk: A Real Options Perspective," *Journal of Management Information Systems*, 19/2 (2002): 43-84; M. Benaroch and R.J. Kauffman, "Justifying Electronic Banking Network Expansion Using Real Options Analysis," *MIS Quarterly*, 24/2 June 2000): 197-226; T.E. Copeland and P.T. Keenan, "How Much Is Flexibility Worth?" *McKinsey Quarterly*, 2 (1998): 38-49; R.G. McGrath, "A Real Options Logic for Initiating Technology Positioning Investments," *Academy of Management Review*, 22/4 (1997): 974-996; A. Taudes, M. Feurstein, and A. Mild, "Options Analysis of Software Platform Decisions: A Case Study," *MIS Quarterly*, 24/2 (2000): 227-244.
3. Thomke and Reinertsen provide a detailed discussion of tactics for promoting flexibility in the new product development (NPD) process. Much of this discussion is applicable to the

context of IT systems development. See S. Thomke and D. Reinertsen, "Agile Product Development: Managing Development Flexibility in Uncertain Environments," *California Management Review*, 41/1 (Fall 1998): 8-30.

4. The following provide useful introductions to real options models: M. Amran and N. Kulatilaka, *Real Options: Managing Strategic Investment in an Uncertain World* (Boston, MA: Harvard Business School Press, 1999), p. 246; A. Dixit and R. Pindyck, *Investment Under Uncertainty* (Princeton, NJ: Princeton University Press, 1994); T.A. Luehrman, "Investment Opportunities as Real Options: Getting Started on the Numbers," *Harvard Business Review*, 76/4 (July/August 1998): 51-60; L. Trigeorgis, "Real Options and Interactions with Financial Flexibility," *Financial Management*, 22/3 (1993): 202-224; L. Trigeorgis, ed., *Real Options and Business Strategy: Applications to Decision Making* (London: Risk Books, 1999).
5. The application of real-options to R&D is described in: D.I. Angelis, "Capturing the Option Value of R&D," *Research Technology Management*, 43/4 (2000): 31-34; R.G. McGrath, "A Real Options Logic for Initiating Technology Positioning Investments," *Academy of Management Review*, 22/4 (1997): 974-996; M. Perlitz, "Real Options Valuation: The New Frontier in R&D Project Evaluation?" *R&D Management*, 29/3 (1999): 255-269. The application of real options to IT is illustrated in M. Amran, N. Kulatilaka, and C.J. Henderson, "Taking an Option on IT," *CIO Magazine*, 12/17 (1999): 46-52; Benaroch and Kauffman (1999), op. cit.; B.L. Dos Santos, "Justifying Investments in New Information Technologies," *Journal of Management Information Systems*, 7/4 (1991): 71-89; R.G. Fichman, "Real Options and IT Platform Adoption: Implications for Theory and Practice," *Information Systems Research*, 15/2 (2004): 132-154; A. Kambil, J.C. Henderson, and H. Mohsenzadeh, "Strategic Management of Information Technology: An Options Perspective," in R.D. Banker, R.J. Kauffman, and M.A. Mahmood, eds., *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage* (Middleton, PA: Idea Group Publishing, 1993); M. Keil and J. Flatto, "Information Systems Project Escalation: A Reinterpretation Based on Options Theory," *Accounting, Management & Information Technology*, 9 (1999): 115-139; Y.J. Kim and G.L. Sanders, "Strategic Actions in Information Technology Investment Based on Real Option Theory," *Decision Support Systems*, 33/1 (May 2002): 1-11; R.L. Kumar, "Managing Risks in IT Projects: An Options Perspective," *Information & Management*, 40/1 (October 2002): 63-74; Taudes, Feurstein, and Mild, op. cit.
6. Longer holding periods are more valuable because the estimate of a project's value will have had a longer time to shift up or down due to new information.
7. For a discussion of these six options types, see Trigeorgis (1993), op. cit.
8. Benaroch, op. cit.
9. B.W. Boehm, "A Spiral Model of Software Development and Enhancement," *IEEE Computer*, 21/5 (1988): 61-72.
10. S.D. Scalet, "Stage Managers," *CIO Magazine* (2000).
11. R.G. Fichman and S.A. Moses, "An Incremental Process for Software Implementation," *Sloan Management Review*, 40/2 (1999): 39-52.
12. C. Shapiro and H.R. Varian, *Information Rules: A Strategic Guide to the Network Economy* (Boston, MA: Harvard Business School Press, 1998).
13. B.W. Chew, D. Leonard-Barton, and R.E. Bohn, "Beating Murphy's Law," *Sloan Management Review*, 32/3 (1991): 5-16.
14. M. Keil, J. Mann, and A. Rai, "Why Software Projects Escalate: An Empirical Analysis and Test of Four Theoretical Models," *MIS Quarterly*, 24/4 (2000): 631-664.
15. R. Adner and D.A. Levinthal, "What Is Not a Real Option: Considering Boundaries for the Application of Real Options to Business Strategy," *Academy of Management Review*, 29/1 (2004): 74-85; R. Fink, "Reality Check for Real Options," *CFO Magazine*, 17/9 (2001); E. Teach, "Will Real Options Take Root?" *CFO*, 19/9 (2003): 73-75.
16. Benaroch and Kauffman, op. cit.
17. M.A. Schilling, "Technological Lockout: An Integrative Model of the Economic and Strategic Factors Driving Technology Success and Failure," *Academy of Management Review*, 23/2 (1998): 267-284.
18. Taudes, Feurstein, and Mild, op. cit.
19. A. Taudes, "Software Growth Options," *Journal of Management Information Systems*, 15/1 (1998): 165-185.
20. S. Panayi and L. Trigeorgis, "Multi-Stage Real Options: The Cases of Information Technology Infrastructure and International Bank Expansion," *Quarterly Review of Economics and Finance*, 38/4 (1998): 675-692.

21. J.D. Hofman and J.F. Rockart, "Application Templates: Faster, Better, and Cheaper Systems," *Sloan Management Review*, 35/1 (1994): 49-60.
22. R.G. Fichman and C.F. Kemerer, "Incentive Compatibility and Systematic Software Reuse," *Journal of Systems and Software*, 57 (2001): 45-60.
23. R. Howe, "At Starbucks, the Future Is in Plastic," *Business 2.0*, 4/7 (2003): 56-63.
24. The Rubenstein binomial model allows non-constant variance in expected payoffs, and the additive form of the model forms also allows expected payoffs to be normally distributed with the potential for non-negative values. The latter form of flexibility is important since it allows for the possibility that an IT system will actually decrease the performance of the firm. For further explanations, see T. Copeland and V. Antikarov, *Real Options: A Practitioner's Guide* (New York, NY: Texere, 2001), p. 372.
25. T. Copeland and P. Tufano, "A Real-World Way to Manage Real Options," *Harvard Business Review*, 82/3 (March 2004): 90-99.
26. Schwartz and Zozaya-Gorostiza have developed an OPM that explicitly models uncertainty in the cost of follow-on projects and allows an additional form of uncertainty, which is the possibility of catastrophic event during development. E.S. Schwartz and C. Zozaya-Gorostiza, "Valuation of Information Technology Investments as Real Options," #6-00, UCLA, Los Angeles, CA, p. 37. In addition, Monte Carlo simulation methods can be used that permit a great deal of flexibility in modeling options. See Amran and Kulatilaka, op. cit., p. 246.
27. For more discussion of challenges to the use of OPMs in practice, see R. Fink, "Reality Check for Real Options," *CFO Magazine*, 17/9 (2001); E. Teach, "Will Real Options Take Root?," *CFO Magazine*, 19/9 (2003): 73-75.
28. For more details on counter-arguments and remedies to OPM challenges, see M. Benaroch and R.J. Kauffman, "A Case for Using Real Options Pricing Analysis to Evaluate Information Technology Project Investments," *Information Systems Research*, 10/1 (1999): 70-86; Copeland and Tufano, op. cit.
29. N.A. Nichols and J. Lewent, "Scientific Management at Merck—An Interview with CFO Judy Lewent," *Harvard Business Review*, 72/1 (January/February 1994): 88-99; P. Buxbaum, "Tapping Into Real Options," *Computerworld*, 36/2 (2002): 28-29; E. Teach, "Will Real Options Take Root?" *CFO Magazine*, 19/9 (2003): 73-75.
30. See the following for discussions of the limitations of decision trees Benaroch, op. cit.; Copeland and Keenan, op. cit.
31. An example of a qualitative approach to valuating real options in the context of R&D is provided in R.G. McGrath and I.C. MacMillian, "Assessing Technology Projects Using Real Options Reasoning," *Research Technology Management*, 43/4 (2000): 35-49.
32. Useful advice on managing real options is also provided in: Amran and Kulatilaka, op. cit, p. 246; Copeland and Antikarov, op. cit., p. 372; Copeland and Tufano, op. cit.; W.F. Hamilton, "Managing Real Options," in G.S. Day, P.J.H. Schoemaker, and R.E. Gunther, eds., *Wharton on Managing Emerging Technologies* (New York, NY: John Wiley & Sons, 2000).