Int. J. Business Information Systems, Vol. 1, Nos. 1/2, 2005 129

Communicating the value of uncertain information technology investments using an options approach

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Abstract: Valuing IT investments in hypercompetitive business environments remains an elusive task as traditional valuation tools fail to model inherent uncertainty. Real-options analysis presents a viable alternative to traditional valuation tools in planning and valuing IT investments in uncertain business environments. While much has been written about the quantitative and valuation aspects of real options, we believe that its use as a strategic tool to inculcate broader thinking about IT investment has been understated. Our objective is to illustrate how decision makers can use such thinking to articulate IT value in an environment characterised by high levels of uncertainty. We discuss cumulation, dynamism, and complexity as three major characteristics of uncertain IT-investment decisions and illustrate the use of a strategic real-options framework in each scenario. We hope to stimulate a mode of thinking that can facilitate better communication regarding IT investment and valuation in times of rapid growth and change.

Keywords: IT valuation; real options; IT business value.

Reference to this paper should be made as follows: Raman, R. and Grover, V. (2005) 'Communicating the value of uncertain information technology investments using an options approach', *Int. J. Business Information Systems*, Vol. 1, Nos. 1/2, pp.129–148.

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1 Introduction

The Chief Information Officer of a Fortune 100 company recently stated, "Perhaps the biggest barrier to effectiveness is demonstrating the value of IT investment." He is not alone in this sentiment, as reflected in a recent CIO (2003) survey. The problem is compounded during times of economic frugality and when some pundits even challenge the wisdom of Information Technology (IT) investments (Carr, 2003).

Why does valuation of IT investments remain so elusive? Perhaps it is the overreliance on traditional valuation tools that tend to focus on short-term quantitative value. By doing so, they rely heavily on accounting-based measures, and provide little indication of future long-term potential or qualitative value generation (Chatterjee *et al.*, 2002). Further, these tools either fail to consider the dynamic risk associated with IT investments in an interactive, transforming, and uncertain business environment or simply include static, unrealistic, and subjective estimates of risk in their computations, such as arbitrary probability assignments in decision-tree analyses or estimates of discount rates in Net Present Value (NPV) measurements.

Also, the characteristic time lag (latency) between IT investment and long-term value generation often blurs the link between the two, making it hard to trace a given outcome back to its source investment (Brynjolfsson and Hitt, 1996). The narrow focus of traditional valuation tools – NPV, for example – on short-term financial metrics such as cash flow, further exacerbates this problem. IT's impact on business makes the coordination between IT and business critical to value creation (King, 2002; Grover *et al.*, 1998). The nature and outcome of much of this coordination often lie beyond exclusive individual, departmental, or even organisational control. Successfully integrating organisational systems in an Enterprise Resource Planning (ERP) initiative, for example, requires enterprise-wide employee buy-in, which may not necessarily be forthcoming. Or, lack of industry acceptance of a technically competitive application could debilitate its commercial success irremediably. The unpredictability of such IT-business interactions magnifies the latency effect as well, when intermediate environmental influencers thwart long-term value generation. Traditional tools value IT projects in isolation without considering business interactions, thereby placing an undue burden of accountability on IT's shoulders. Consequently, IT investments often remain undervalued.

The factors confounding IT value measurement reveal three major characteristics of IT-investment decisions that reflect the underlying uncertainty in these decisions. These are:

1 Cumulation

Many IT investments are modular in nature, where intermediate investments are contingent on the success of previous stages and often generate long-term, intangible outcomes (Bharadwaj and Konsynski, 1997). For instance, the future strategic value of a networked communication system investment could require intermediate technology investments in Supply Chain Management (SCM) or Customer Relationship Management (CRM). Even a given technology implementation could proceed through contingent pilot stages, each contributing to overall long-term value in addition to their specific short-term benefits.

2 Dynamism

Fast-paced change in today's business environment requires dynamic IT that responds to the need for developing an adequately supportive IT framework. Dynamic IT refers to an integrated infrastructure where data, applications, and systems infrastructure are fully leveraged in a manner that is flexible and effective, while being managed and provisioned cost-effectively. In this emerging 'dynamic IT model' there is no room for isolated silos of technology that do not speak to each other or to the needs of the business (website, Jacques, 2005). Within this model, IT becomes a partner in an integrated set of business capabilities that work in concert towards resolving business needs. The dynamism of IT therefore places demands of flexibility and interoperability on technology investments, which becomes increasingly challenging, as business needs change in an uncertain world, thereby significantly increasing the range of IT standards that would be potentially valuable in the future.

3 Complexity

As implied by the rapidly emerging dynamic IT model, IT needs to interact with a myriad of business functions, mediating the process change necessary for value generation and touching almost every aspect of a business either in isolation, such as a financial management application; or in an integrative manner, as in organisation-wide ERP applications. The valuation of IT, therefore, cannot merely value the IT investment in isolation but needs to consider integrated IT-business capabilities as the value-generating unit.

Below, we describe and illustrate an approach based on real-options thinking that provides an alternative way to frame IT valuation problems exhibiting the above characteristics (Amram and Kulatilaka, 1999). While much has been written about the quantitative and valuation aspects of real options, we believe that its use as a strategic tool to inculcate broader thinking about IT investment has been understated. Our objective is to illustrate how CIOs and CFOs can use such thinking to articulate and communicate IT value in an environment characterised by high levels of uncertainty.

Conceptual foundation: the real-options approach

The concept of ‘real options’ has emerged as a variant of contractual stock options, which are popular financial market instruments (Ross *et al.*, 1996) used to hedge against the risk associated with trading in these assets (Amram and Kulatilaka, 1999). Call and put options serve as building blocks for more complex financial options. Both confer to the owner the right, but not obligation, to perform a future transaction involving the underlying asset, based on unfolding uncertainty. Call options allow the right to buy an asset at a predetermined exercise price, and put options, the right to sell, as per the choice of the owner sometime in the future. This safeguards against prematurely locking into an investment decision without knowing how its value may fluctuate in the future. The power of the options approach is in allowing the exploitation of the upside potential of uncertainty, while limiting exposure to its downside risk.

Analogous noncontractual options on nonfinancial or real assets, such as technological investments, are useful tools to justify, plan, and value these risk-bearing assets (Benaroch, 2002; Benaroch and Kauffman, 1999). The organisational asset that is affected by the investment and by its option is the underlying asset in this case. For example, organisational divisions coordinated by a CRM implementation or data integrated in an ERP project would be assets underlying options on these investments. The exercise price of real options is the cost incurred when exercising the option. The payoff from the investment is its variable return in uncertain circumstances less its cost. The value of an option on the investment, which increases with the volatility of underlying uncertainty, is determined using standard options calculators like the binomial method or the Black-Scholes equation (Black and Scholes, 1973; Chriss and Chriss, 1997).

Understanding the nature and source(s) of uncertainty is a critical aspect of real-options thinking, given that the distinctive value of these options derives from decision making in uncertain situations (Benaroch, 2001). This method considers the total risk of a project – internal (firm-specific) as well as external (market-based) risk. Underlying uncertainty can be measured with a variable whose probability distribution closely resembles that of the uncertainty. The expected value of this probability distribution is considered the statistical estimate and the variance, a measure of the volatility underlying future uncertainty.

Payoff diagrams illustrate the future value of an uncertain decision by showing how future investment payoffs may vary with expected uncertainty. With favourable expected future value of the uncertain variable, the payoffs from investing in an expansive option increase while those from an option to contract decrease and vice versa. Increasing volatility of this uncertainty favours postponement of immediate and/or irreversible action until the uncertainty is partially resolved, thereby enhancing the value of any option. Real-options approach allows IT managers to be alert to the consequences of risk, hedge against its downside and favourably exploit its upside potential, choose between alternative investment strategies, and objectively justify the chosen alternative to top management and financial stakeholders.

2 Theoretical background

2.1 Beyond valuation: the real-options approach and IT investment decisions

In the context of IT investments, real options have typically been applied and studied as a valuation tool, like other capital budgeting techniques, such as the Discounted Cash Flow (DCF) method. IT investment decisions are often characterised by cumulation, dynamism, and/or complexity. These features can be meaningfully exploited by real-options analysis, thereby overcoming the limitations encountered by other traditional methodologies in valuing such assets. For instance, for cumulative IT investments, the use of contingency options limits the downside risk of large modular investments in uncertain environments while postponing successive stages of investment to take advantage of the upside potential of favourable future conditions. Real-options thinking also incorporates dynamism by valuing flexibility in IT investment decisions (Amram and Kulatilaka, 1999). In this mode, decision makers are encouraged to design investments that maintain flexibility in future-related decision choices, in keeping with their long-term potential. This could be flexibility in inputs, as in switching between an evolving nascent technology and a legacy system; or even flexibility in outputs, as with versioning products towards different market segments with fluctuating demands. Finally, real-options analysis recognises the complexity of IT projects by focusing on the outcome of a set of IT-business interactions. IT valuation by this method is not limited to a narrow view of each investment in isolation, but considers how this investment interacts with other organisational and technological components to generate ultimate business value (Bharadwaj, 2000).

Despite these relative advantages, however, when viewed simply as a valuation tool, real-options analysis also suffers from several limitations (Tallon *et al.*, 2002). Underdevelopment of measurement tools as well as the innate imprecision of real-options methodology limits its practical usefulness as a valuation tool. This has stalled widespread applicability of options-based analysis in real-world investment scenarios even in the case of cumulative, dynamic, or complex IT investments, which are most conducive to this valuation methodology. For instance, the Black-Scholes model – the most popular options-based calculator for determining the quantitative value of an option – was originally developed for tradable financial assets, and is, therefore, inadequate when applied to IT investments, which do not share these characteristics. Furthermore, imprecise and subjective predictions of future payoffs inherent in other valuation tools, such as Net Present Value, are a weakness of real-options valuation as well. Therefore, in spite of considerable attention in academic and practitioner journals, the actual use of real-options analysis in organisational decision making has remained elusive, as companies continue to fall back on more established traditional valuation tools, such as NPV.

The full potential of real-options analysis, however, extends much further beyond investment valuation, even as technical details of this functionality are in the process of further development. Real-options analysis has been recognised as an integrative way of thinking and overall strategic planning, more so than simply as a technique for ascribing precise dollar measures of value to individual investments (Teach, 2003). In suitable decision scenarios, real-options analysis guides the identification of a feasible set of alternative solutions and the choice between these alternatives by mapping expected future payoffs as a function of unfolding uncertainty. This part of the analysis is akin to the overall function of other valuation tools such as NPV. Unlike other valuation tools, however, real-options analysis contributes further as a strategic planning tool, to aid in determining the most value-adding *process* for implementing the optimal solution, once it has been identified. Thus, stepwise application of options thinking to finer levels of detail in the decision-making process outlines intermediate strategies necessary for successful implementation. Furthermore, real-options analysis allows this strategic planning to be dynamic, by decoupling future decision making from fixed points in time, and coupling this instead to requisite levels of uncertainty. Implementation strategies are then identified to accelerate the attainment of desirable uncertainty levels. As a strategic planning tool, therefore, real-options analysis extends beyond valuation tasks to guide not just *what* strategy is chosen, but also *when* and *how* it gets implemented so as to maximise the likelihood of desirable outcomes following implementation.

The practical feasibility of real-options analysis in such strategic planning has been hailed as much more realistic (Teach, 2003). Yet much academic and practitioner literature continues to focus on its use in IT valuation (Benaroch and Kauffman, 1999; Li and Johnson, 2002; Schwartz and Zozaya-Gorostiza, 2003), which although important, is neither an optimal nor a readily applicable benefit from options-based analysis.

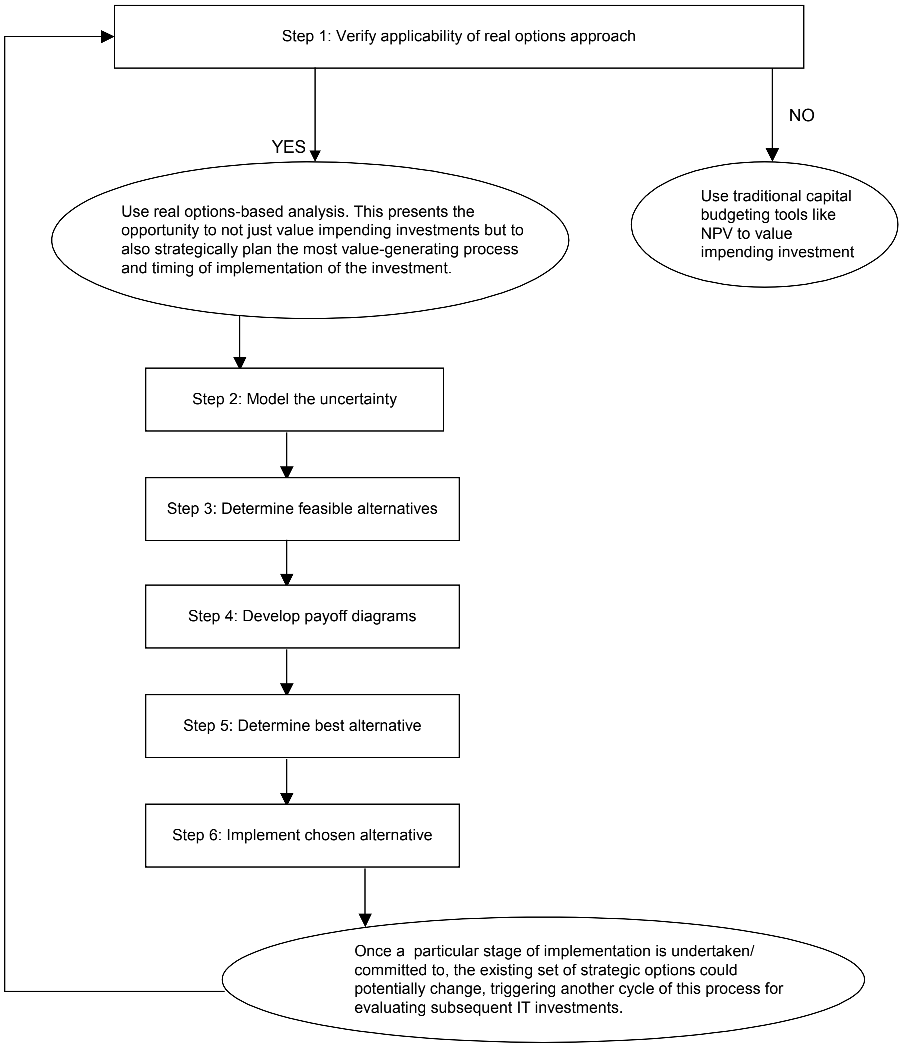
2.2 A sequential approach to real-options thinking

This article strives towards elucidating the more immediate practical applicability of this methodology as a way of integrated thinking and strategic planning involving organisational IT investments. A framework for the use of real-options-based *thinking* – as a contribution including, but extending beyond real-options-based *valuation* – is presented. This framework comprises a series of sequential decision-making steps, providing guidelines for appropriate decision choices at each stage, based on the outcome of previous decision choices. The validity of the proposed framework is then evaluated by applying this framework in three different types of IT-business decision-making scenarios, each exemplifying a different set of factors – cumulation, dynamism, and complexity – characteristic of IT investments. This vignette-based approach demonstrates the versatility of our proposed framework in a variety of decision-making scenarios and provides an illustration of the unique considerations that come into play when applying this framework in each situation.

Our approach towards real-options-based strategic thinking in this paper does not focus on valuation as its central concern. As such, explicit mathematical exposition of real-options-based valuation, which has been thoroughly and elegantly treated elsewhere in the literature (Amram and Kulatilaka, 1999; Benaroch and Kauffman, 1999), is considered as being beyond the scope of this article.

In Figure 1, we provide an outline of the sequential IT investment decision process within the real-options framework (Benaroch, 2002). Step 1 of this framework is concerned with verifying the applicability of the real-options approach to the investment decision at hand. This involves evaluating the decision scenario in order to determine its feasibility for options-based analysis. If the investment scenario is characterised by high degree of uncertainty, which could alter future outcomes, and if multiple actionable alternatives are available, then the evaluation in Step 1 would lead to the choice of real-options-based analysis. This is followed by Step 2, where the nature of uncertainty underlying the investment decision is modelled. This involves identifying the sources of uncertainty (risks) underlying decision making and finding ways to measure them. Step 3 determines feasible alternatives, which involves identifying suitable options that can control the risks identified in Step 2, by conducting comprehensive analysis of the scenario in the context of the uncertainty faced by the decision-making organisation. This is followed by Step 4, where payoff diagrams are developed, which shows how future payoffs from each solution alternative identified in Step 3 would vary with different levels of uncertainty. Following these analyses, the best alternative is chosen in Step 5 by using a decision rule based on the payoff diagrams, which guides the choice between alternatives depending on their relative dynamic future value under evolving uncertainty. Finally, in Step 6, the chosen alternative is implemented, thereby completing a cycle of the real-options-based decision-making process. Step 6 involves identifying the most value-adding process by which the chosen alternative may be implemented. This decision cycle is re-initiated all over again when a new IT investment decision faces the organisation.

Figure 1 Real options-based evaluation and planning of IT investments: the sequential thought process



Although the subject of real options has been extensively engaged in extant literature, the real-options methodology delineated in this paper contributes by taking a systematic look at the real-options approach as a broad-based way of thinking about business problems in general, rather than simply as a method of valuing IT investments. The three illustrative examples that follow, demonstrate how this strategically focused framework can be applied to real-options thinking in three different IT-business decision-making contexts, thereby highlighting the versatile applicability of this approach. The examples also serve as a step-by-step guide on how to make key decisions and interpret important output (such as payoff diagrams) within this framework. In doing so, this work also contributes to managerial pedagogy from a practice-driven perspective.

The examples corresponding to three different aspects of IT-business decision making – cumulation, dynamism, and complexity – follow next. Each scenario is organised around Figure 1.

2.2.1 Applying the real-options approach

Example 1: IT decision involving cumulation-contingency options

Scenario: A large networking solutions company, driven by a customer-centric strategy, is implementing a CRM system. This would entail organisation-wide integration of front-end and back-end applications.

Step 1: Verify applicability of real-options approach

This investment decision lends itself well to options analysis on both criteria in the checklist (Figure 1). Significant uncertainty surrounding this decision results from the long-term nature of the application and its intended benefits. Furthermore, the company could also choose between multiple available alternatives for implementing the decision.

Step 2: Model the uncertainty

Both technical and nontechnical sources of uncertainty underlie implementation success. Given the technical proficiency of organisational personnel, however, future technical uncertainty seems only a minor risk to the project in this example. On the other hand, nontechnical issues arising primarily from cultural and behavioural reactions of business personnel and other intended users are a formidable challenge. Preliminary research suggests that lack of organisation-wide communication of the short- and long-term benefits of CRM primarily instigates the nontechnical problems that later confound success. The Level of Organisation-wide Communication (LOC), as measured by top-down transfer and bottom-up acceptance of information, reflects the uncertainty associated with this decision. Probability distribution of the volatility in LOC could be used as a surrogate measure of the distribution of overall uncertainty.

Step 3: Determine feasible alternatives

Let us suppose that after comprehensive analysis, the company arrives at the following available alternative pathways:

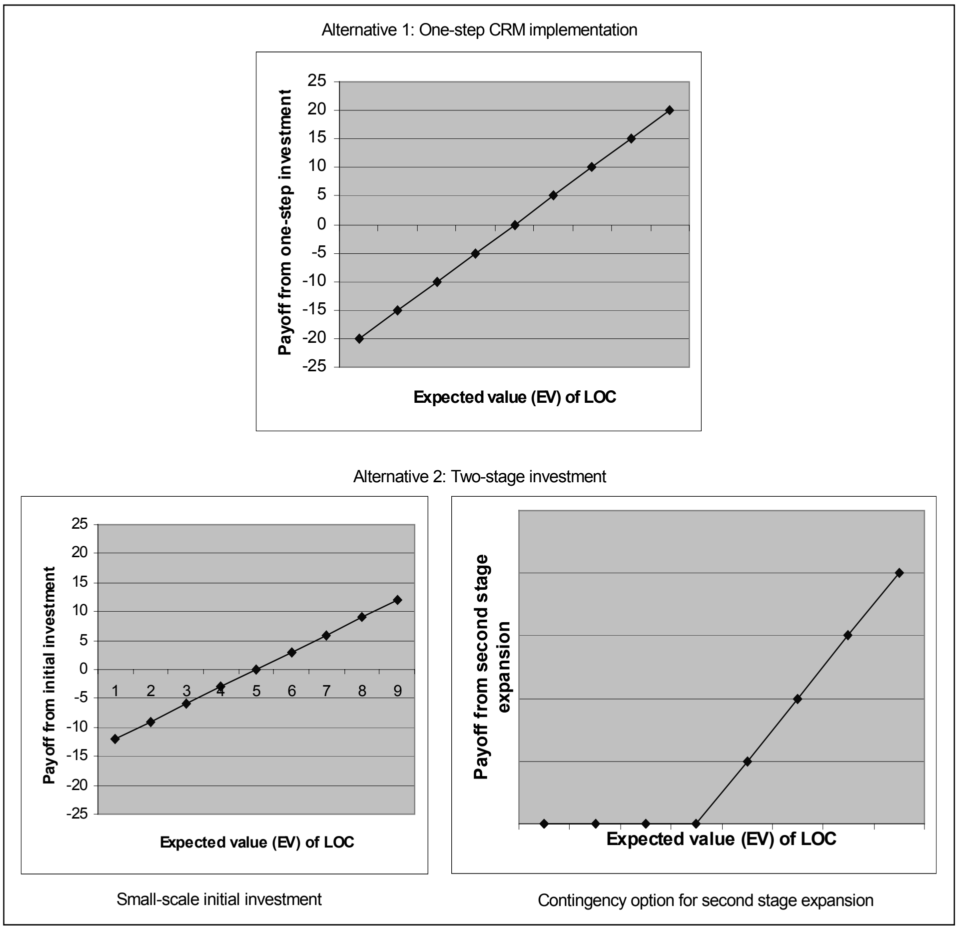
- time-saving one-step CRM implementation
- two-stage investment strategy, where the option to continue to the next stage of investment is *contingent* on the outcome of the previous stage.

Step 4: Develop payoff diagrams

In developing payoff diagrams for all three hypothetical examples in this paper, we have focused on the shape of these curves rather than on the absolute quantitative values undertaken by individual points on the graph. This approach seems reasonable, since the diagrams do not represent actual data sets, but simply provide a pictorial illustration of the shapes of future payoff curves over a given range of uncertainty under alternative decision choices. In some figures, the Y-axes have been labelled in order to facilitate comparative illustration between the payoffs from alternative decision choices, only when such comparison of absolute payoff values was deemed necessary for choosing the best alternative.

Future payoff from the investment is the increased return from implementing the technology, measured using different CRM-related organisational goals, such as employee use and/or satisfaction, improved productivity *etc.*, less the cost of implementation. These payoffs are uncertain and variable in response to future unpredictability of LOC, a measure of project uncertainty. Evaluation of how the payoffs to the decision alternatives vary with different expected values of LOC would facilitate choice of the optimal implementation strategy (see Figure 2).

Figure 2 Payoff diagrams for contingency option example



At high values of expected LOC, future payoffs to the one-step investment are high. At low expected LOC, however, the irreversible linear payoff from the one-step implementation decreases. This alternative yields zero payoffs at a certain threshold LOC at which the return from implementation decreases to the same level as its cost. As returns continue to decrease with further reduction in expected communication levels, negative payoffs are realised. The one-step strategy, therefore, has a significant downside potential as expected LOC varies in the future.

In the contingent option strategy (Option 2 in Step 2), the initial investment has a fixed linear payoff as in Alternative 1. However, the smaller scale of this initial investment allows the magnitude of this payoff and, therefore, its downside potential, to be limited to only a fraction of that in Alternative 1. When the expected LOC is high, and therefore favourable, the contingent option to implement the second stage investment can be exercised, yielding a positive payoff. At low expected LOC, scaling up to the second stage of investment would be unprofitable, rendering the corresponding contingency option valueless. A part of the total investment for this CRM implementation strategy, therefore, has no downside potential irrespective of future uncertainty of organisational acceptance.

Step 5: Determine best alternative

The option to scale up investment contingent upon initial success, in Alternative 2, allows managers to resolve part of the risk of project failure before committing to a larger project. The payoff diagrams indicate actual payoffs corresponding to different possible levels of uncertainty that, at the time of decision making, can be expected to occur in the future. Each point on the diagram, therefore, corresponds to a possible outcome of implementation. The outcome that does occur, however, will depend on what the actual level of the uncertain factor (in this case, LOC) turns out to be in the future. At the time of decision making, as the volatility of future LOC increases (*e.g.*, as organisational leadership changes or preliminary feedback from users suggests), the contingent option built into the staged investment strategy becomes more valuable since it minimises exposure to this increased risk. This makes decision Alternative 2 a better choice.

Step 6: Implement chosen alternative

This step provides process-oriented guidance on implementing the particular alternative chosen in Step 5, based on real-options-driven strategic planning. Drilling down deeper into the core cause of uncertainty and understanding the interrelation between causal factors at different layers of detail would facilitate maximum value-generation from such implementation.

The payoff diagrams in Step 4 illustrate the Level of Organisation-wide Communication (LOC) corresponding to desirable future payoffs from the chosen two-stage implementation strategy. In order to maintain this optimal level of communication between employees throughout implementation, the decision maker would need to dig deeper into its underlying driving forces. This could be accomplished by applying an analytical strategy very similar to that in Step 4, with LOC now being treated as the underlying asset of interest. Following such analysis, it may be found that the most immediate driver of relevant organisational communication is the extent to which participants have a common understanding or shared vocabulary for discussion. We will call this factor the level of cognitive overlap between participants. Uncertainties in the level of cognitive overlap, therefore, contribute to the uncertainty inherent in levels of communication, which, in turn, is the most immediate cause of volatility underlying successful CRM implementation. Payoff diagrams similar to the ones illustrated in Step 4 could then be constructed to determine how net payoffs from different LOC vary with future levels of cognitive overlap between individuals. LOC payoffs could be measured as the value realised from communication, in terms of its reach or range, as appropriate, less its cost. These diagrams would identify particular levels of cognitive overlap that would be most value generating in the context of the CRM application.

Moreover, future levels of cognitive overlap may, in turn, be dependent on organisational structure. Organisational structure, encompassing the location of different skill sets in the firm as well as the linkages between them, is the most upstream factor in this causal chain. It is distinct from other factors in the chain, being under the predictable control of decision makers in the organisation. It, therefore, constitutes the last stage of this iterative, sequential planning process. A diagram indicating the levels of cognitive overlap potentially attainable under different kinds of organisational structure would then provide an action plan by which the chosen strategic alternative can be implemented. A suitable organisational structure chosen on this basis would increase the likelihood of unfurling desirable sequential outcomes – appropriate levels of cognitive overlap that would facilitate levels of communication most conducive to successful value generation from implementing Alternative 2.

Repeat cycle (1–6 for next phase of investment life cycle)

As different phases of the impending CRM application get implemented, this plan of action should be revisited in order to ensure its continued relevance to the planning process. However, the plan is robust to the more unpredictable and random fluctuations driven by uncertainty in these decision-making environments.

Example 2: IT decision involving dynamism-flexibility options

Scenario: A large financial services company planning to offer wireless-enabled mobile computers to its sales personnel is trying to decide the particular technology standard to invest in for the long-term.

Step 1: Verify applicability of real-options approach

Wireless Local Area Networks (WLANs) nationwide, use one of two networking standards, 802.11b and 802.11g, with considerable uncertainty underlying the future emergence of a particular dominant mode. Thus, this decision scenario clearly lends itself to options-based analysis on both grounds: availability of multiple feasible technology alternatives as well as future environmental uncertainty.

Step 2: Model the uncertainty

Possible networking incompatibilities due to the use of different WLAN technology standards is a more immediate source of uncertainty, which could limit the mobile work efficiency of the sales force and lead to organisation-wide consequences in terms of lost revenue or untapped sales opportunities. There is also long-term uncertainty regarding the future of these different technology standards: will one of these emerge as the leader, rendering others obsolete or will both continue to exist simultaneously?

The average frequency of the need to switch between alternate networking standards over a certain period of time for a representative sample of users, could serve as a measure of this uncertainty. As any one standard assumes dominance over the other, the need and, therefore, frequency of switching from this standard to the other should decrease. Conversely, high frequency of the need to switch would imply comparable dominance of both technology standards. Only switching requirements arising from work-related connections, which, if not made, could result in lost revenue or sales opportunities are considered. Again, in quantifying frequency-of-switching need, the focus is primarily on the overall magnitude of wireless workload that requires use of one system versus another, rather than on the individual number of technology switches made.

Step 3: Determine feasible alternatives

Following comprehensive analysis, management is considering the addition of 'compatibility mode capability' on these computers. This would expand the mobile work zone of sales personnel by allowing them to connect to both types of networks. Although this strategy would have long-term benefits, given the uncertain future of wireless networking standards, however, it may become redundant with the emergence of a particular dominant standard.

The alternative decision choices corresponding to this situation are:

- Choose computers with one or the other type of standard, without the compatibility mode functionality.
- Build in the compatibility mode add-on component into all computers, which would provide flexibility options.

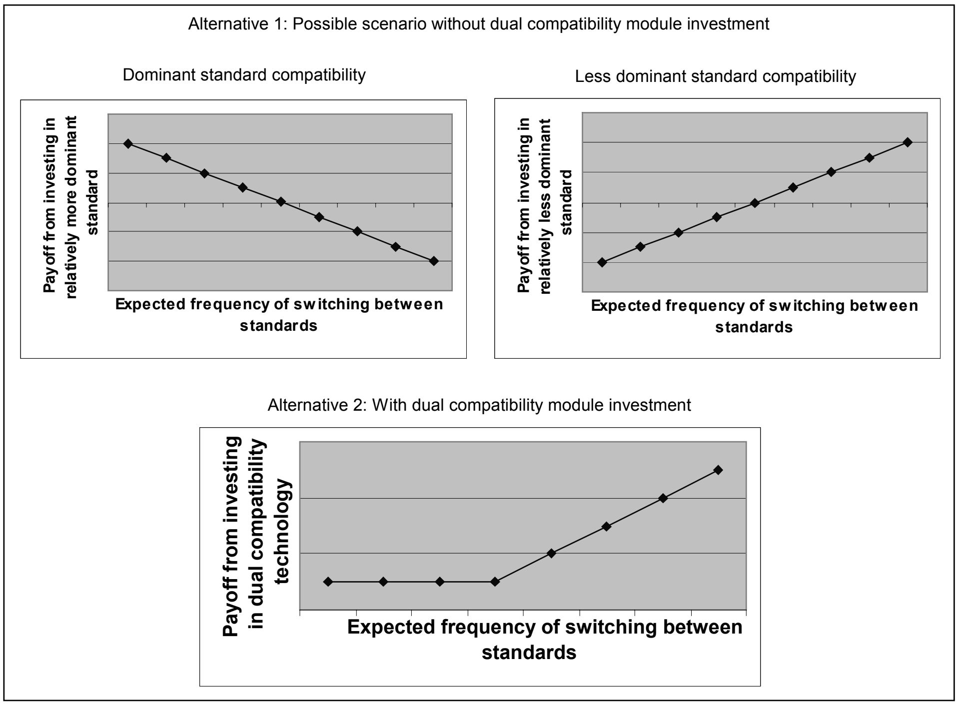
Step 4: Develop payoff diagrams

The payoff from this wireless technology investment results from the average value of cumulative wireless use and the cost savings from not having to invest in separate wireless standards, less the cost of the investment. Other benefits, such as the long-term value of compatibility, are reflected in the kinked shape of the payoff diagrams, illustrated in Figure 3.

Under decision Alternative 1, when the expected future frequency of switching is low, implying the dominance of one standard over the other, an upfront investment in the former (dominant) standard would yield positive payoff while that in the less dominant standard would be negative. As the frequency of switching increases, reflecting greater underlying uncertainty between the two standards, the payoff from the investment in the first standard decreases relative to that in the second, as the latter standard gains in relative importance to the former. Thus, regardless of which standard is irreversibly invested in, there is always a negative payoff to this alternative.

Decision Alternative 2, which includes the dual compatibility functionality, hedges against this downward potential through a flexibility option. When the expected frequency of switching is low, this mode enjoys a certain base level positive payoff resulting from a level of wireless use comparable to that observed under similar conditions in Alternative 1. As the expected frequency of switching increases beyond a certain level, however, the compatibility module allows the user to exercise the option to flexibly switch between connecting to either standard as needed, resulting in substantial increases in payoffs reflected in the kinked payoff diagram.

Figure 3 Payoff diagrams for flexibility option example



Step 5: Determine best alternative

An increase in future uncertainty, reflected in greater volatility underlying the frequency of need-to-switch-between-standards, would yield higher payoffs from the flexible choice (Alternative 2). The value of the corresponding flexibility option is also higher under these situations. This analytical method, grounded in the discipline of financial markets, brings long-term as well as immediate value of this technology out of the realm of intuition, to present a common ground for objective understanding by diverse stakeholders.

Step 6: Implement chosen alternative

Having chosen Alternative 2 as the preferred strategy in Step 5, we now focus on implementing this choice in the most value-adding way. The payoff diagrams in the previous step already show us the levels of switching frequencies that are associated with high payoffs from investment in Alternative 2. Options-based thinking can now be used to sequentially explore the causal factors underlying uncertainty in these switching frequency levels, until the most controllable factor is reached. Thus, the most immediate (downstream) source of volatility in the underlying asset – frequency of switching between standards – could be dependent on the relative concentration of industry involvement with each standard. Concentration of industry involvement reflects the extent to which the industry, as a whole, is intensifying commitment to any given standard by focusing on the development and promotion of its underlying infrastructure and associated technologies. It may, therefore, be related to the level of innovation as well as to the extent of strategic alliances underlying complementary technologies relating to each wireless mode. Payoff diagrams would illustrate the relation between these sequential sources of uncertainty, with industry-wide innovation and strategic alliances being the most upstream and controllable factors in this causal chain. The levels of these upstream uncertainty factors that would need to be maintained in order to encourage value-generating levels of downstream factors, such as switching frequencies, could then be assessed. This insight would help top management plan their internal as well as external strategies. These could include the kinds of R&D projects that need to be undertaken and the skill sets that need to be acquired for the purpose as well as the types of strategic alliances that need to be supported to maximise value generation from the chosen alternative. Of course, there may always be issues that are beyond direct intervention, such as innate limitations in the relative usefulness of different wireless modes, which could lead to the dominance of one mode over the other. Furthermore, there are no guarantees that levels of uncertainty would be desirable in spite of the best strategic efforts of the organisation. In the case of such eventualities the firm could at least fall back on the no-loss outcome from implementing the flexibility option in Alternative 2. In reality, decision making at this level would typically involve consideration of tradeoffs between many such decisions that need to be made simultaneously, although the basic process of planning would still be the same.

Example 3: IT decision involving complexity-postponement options

Scenario: XYZ, a manufacturing company, is transitioning to a task-oriented virtual team environment, uniting people, processes, and workflows across geographical and functional cross-sections within the organisation. An effective way to successfully implement this transition is being sought. IT decision makers are contemplating investment in supplemental team-building software, given the importance of team trust and interaction for long-term value generation in this new work environment.

Step 1: Verify applicability of real-options approach

The multiplicity of the ways in which task-oriented teams can be implemented, as well as the uncertainties associated with the future success of this new work culture in the organisation, makes this scenario a good choice for options-based analysis.

Step 2: Model the uncertainty

The future value of the impending team-building software investment varies with the uncertainty underlying the productivity of virtual teams at XYZ. The latter is, in turn, driven by the successful creation of complex IT-business capabilities through the interaction of technological infrastructure investments with nontechnological factors, such as employee acceptance; mutual trust and geographical distance between team participants; task complexity; and team management. Long-term uncertainty in the value of virtual teams and, therefore, of team-building software investments, could be modelled in terms of future unfavourability of some composite measure of these nontechnological determinants of team performance. Additionally, the specific mathematical composition of this complex uncertainty metric could also be modified over the long run to reflect variations in the relative importance of each individual determinant in this measure.

Step 3: Determine feasible alternatives

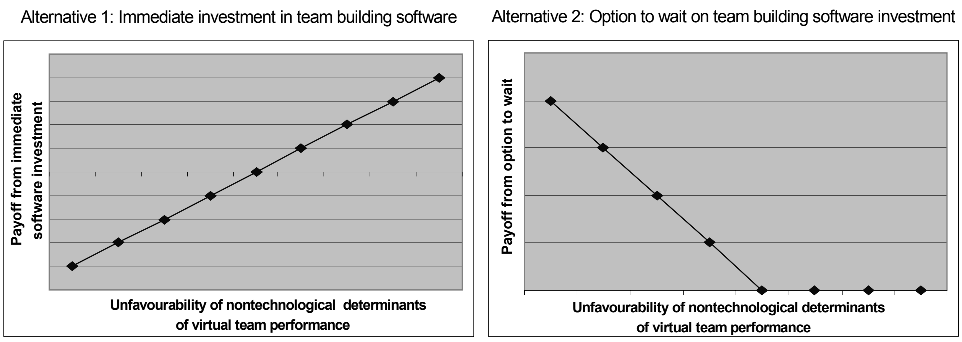
The decision then boils down to the following investment alternatives:

- Immediate investment – this alternative would provide immediate access to team-building software. However, this is also costly and risky, given the transforming nature of the organisation's needs and its nascent familiarity with virtual work environments.
- Option to wait or postpone investment – this strategy overcomes the limitations of the first alternative by requiring negligible upfront investments and being lower in risk. Moreover, this decision choice would also inform the optimal timing of future investment in team-building software, thereby avoiding the high costs of underproductive teams that could potentially result from waiting too long.

Step 4: Develop payoff diagrams

Figure 4 illustrates how future net returns from each decision alternative vary with underlying uncertainty, which is represented by the expected value of future unfavourability of nontechnological determinants of virtual team performance. Net payoffs from immediate investment in team-building software include productivity gains and/or cost savings from improved team interactions less the cost of the investment. Payoffs from the option to wait on investing in the team-building software is the cost savings from delaying investment less potential opportunity costs of lost team productivity improvements.

Figure 4 Payoff diagrams for complexity option example



Step 5: Determine best alternative

When future expected value of the unfavourability of nontechnological determinants of virtual team performance is low, indicating successful generation of value-adding IT-business capabilities, then additional software investments facilitating team building may not be necessary. Under these conditions, therefore, the cost of immediate investment in team-building software, as per Alternative 1, exceeds its returns while the option to wait (or postpone) investment, under Alternative 2, yields positive payoffs. In other words, under more favourable levels of nontechnological contributors to virtual team performance, Alternative 2 is a better investment strategy. However, as the expected value of this unfavourability increases, the growing costs of underproductive teams from further postponing investment in team-building software under the option-to-wait strategy outweigh the cost savings from postponing investment. The option to wait, in Alternative 2, would then be discarded in favour of immediate investment, yielding zero payoffs. The flexible investment strategy of Alternative 2 thereby hedges against the risk of negative payoffs resulting from Alternative 1, making the option-to-wait strategy a better choice under uncertain conditions. Also, greater volatility in the future expected value of unfavourability implies increased uncertainty underlying the decision-making scenario and, consequently, increased value of the option to wait.

Step 6: Implement chosen alternative

Value generation following the chosen Alternative 2 would occur when the underlying nontechnological determinants of virtual team performance, such as employee acceptance of the new work mode or their mutual trust for each other, are more favourable. As before, the uncertainty associated with these determinants could be traced back to other controllable causal factors. Some examples of these factors include: the magnitude of change in work culture warranted by the new team-based environments or the level of cognitive overlap between team members. Thus, if the new team-based work structure imposes drastic changes in work culture or if individual participants do not have a unified, fundamental understanding of these impending changes, then the transition may face greater resistance. Levels of these factors can be controlled with a reasonable degree of certainty by appropriately choosing the goals and compositions of teams. Diagrams illustrating the variation of nontechnological determinants of virtual team performance with different levels of these controllable causal factors could then be constructed. These tools would guide management on designing teams where resistance to the new work mode is low, thereby accelerating value-generation following the option-to-wait strategy.

The three types of decisions and descriptors of the option process are summarised in Table 1.

Table 1 Snapshot of real options application scenarios

	Cumulation	*Dynamism*	*Complexity*
Scenario	CRM implementation towards a customer-centric strategy	Wireless-enabled mobile computers for sales support	Transitioning to task-oriented virtual teams
Step 1 – Verify applicability	Conducive to real options analysis based on both criteria on the checklist- high uncertainty, and availability of multiple actionable alternative solutions		
Type of option	Contingency	Flexibility	Postponement
Step 2 – Model uncertainty	Expected value of Level of Organisation-wide Communication (LOC) about project value	Expected frequency of switching between usage of two standards, with particular focus on relative magnitude of usage	Expected value of unfavourability of nontechnological determinants of virtual team performance
Step 3 – Determine alternatives	CRM implementation – one-step versus staged	Whether or not to invest in dual compatibility mode wireless computers capable of functioning in 802.11b as well as 802.11g standards	When to invest in team-building software to support the productivity of flexible virtual teams
Step 4 – Develop payoff diagrams	Returns from CRM-related organisational goals, such as employee satisfaction, customer visibility *etc*. in excess of cost	Average returns from wireless use plus value due to cost savings from not investing in both standards less cost of investment	Cost savings from delaying investment less opportunity cost of under-productive teams
Step 5 – Determine best alternative	Under high volatility of LOC, staged contingency option is optimal. As expected value of LOC increases, payoff from second stage investment and value of contingency option increase.	Greater volatility of the frequency of need to switch between standards implies high value of flexibility option generated by dual compatibility mode. As expected frequency of switching increases, relative dominance of one standard over another decreases and payoff from dual compatibility as well as value of corresponding flexibility option increase	Greater volatility of underlying unfavourability implies greater uncertainty of decision-making and higher value of option-to-wait. Under low expected unfavourability of drivers of virtual team performance, value-adding IT-business capabilities are readily formed and payoffs from option-to-wait on supplemental team-building software investments are high
Step 6 – Implement chosen alternative	Organisational structure -> level of cognitive overlap -> level of organisation-wide communication -> future payoffs from chosen two-stage implementation strategy	Level of innovation; strategic alliances -> concentration of industry involvement -> switching frequencies between different wireless standards -> future payoffs from chosen Alternative 2	Magnitude of impending change in work culture; level of cognitive overlap -> employee acceptance of new work mode; mutual trust -> underlying uncertainty in future success of virtual teams -> future payoffs from team-building software investment

3 Conclusion

Valuing IT investments in hypercompetitive business environments characterised by uncertainty, rapid transformation, and economic hardship is a challenging task. Traditional valuation tools, while appropriate for many nontechnological investments in relatively stable business environments, are not effective for valuing dynamic, cumulative, and complex technological investments in times of rapid growth and change. Real-options analysis presents a viable alternative to traditional valuation tools in planning and valuing IT investments in uncertain business environments. Being derived from well-established financial market principles, the central thesis of the real-options methodology is objectively justifiable to financial, technical as well as business stakeholders within and outside an organisation.

By using real-options thinking to understand and profitably exploit future uncertainty, IT managers can mitigate the considerable risks of decision making in dynamic business environments, safeguarding against threats while also embracing opportunities as they evolve through time. For instance, organisations can make flexible investments in dynamic technologies, with the option to modify the scale of investment in response to how uncertain events turn out in the future. This is particularly useful in alleviating the risks involved in large cumulative IT projects, such as ERP implementations, for instance, requiring massive organisation-wide investments in time and coordination.

Forward visibility of how investment payoffs vary with different levels of future uncertainty allows decision makers to use option payoffs, not simply as a valuation tool, but also in guiding the strategic planning of future investment portfolios. The ability to evaluate complex IT investments as integrated IT-business capabilities helps align technology investments with other areas of business and increases investments in technologies with greatest potential to advance intended business objectives. The long-term view of IT value, as afforded by real-option payoff diagrams, further enables IT decision makers to convince top management of the value-generating potential of many powerful technologies with synergistic, and often qualitative, benefits that become apparent only over the long run.

In spite of significant advantages in appropriate decision-making scenarios, real-options analysis is not a universal solution to all kinds of investment decisions. This analytical mode adds distinctive value in decision making marked by material uncertainty or where future follow-on decisions depend on the outcome of earlier investment choices. Traditional tools can just as efficiently value other kinds of decision-making scenarios where the level of uncertainty is not enough to influence the choice between alternatives or where isolated investment decisions are involved. Organisations should, therefore, evaluate each impending IT investment decision for its conformability to real-options thinking before investing valuable managerial resources towards the intensive and time-consuming analysis that typically goes into such calculations.

In this paper, we have shown how real-options-based thinking can be used as a framework in evaluating IT investment decisions marked by uncertainty arising from three different sources – cumulation, dynamism, and complexity. While these scenarios are important considerations encountered by most organisations, more complicated cases also frequently arise in firms, where IT infrastructure and/or business applications are simultaneously subjected to these three forces. Although treating the three sources of uncertainty in isolation is convenient for illustrative purposes, more in-depth analyses of real-options thinking in organisations would need to consider these factors operating in concert during IT investment decisions.

Real-options thinking has important implications for IT managers struggling to find objective long-term justification for large-scale investments, or developing an overall strategic plan for the use of technology in business. With uncertainty being innate in many IT investment scenarios, failure to effectively consider its implications will often result in understatement of the value of investments. The framework and examples described in this article attempt to put a practical face on the sometimes-obtuse approach.

While the issue of real options has been extensively studied in extant literature, the contribution of this piece has been primarily in highlighting the importance and versatility of this method as a tool in IT-business decision making under a variety of contexts. We offer this article as a modest attempt in facilitating business learning from a practice-oriented perspective, going beyond formal valuation, and using real options to stimulate a mode of thinking that can enable better communication regarding business problem solving, IT investment, and valuation.

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