Managing Information Technology Investments: A Capability-based Real Options Approach

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Abstract

Investments in IT have become a dominant part of the capital budgets of many organizations. While the costs seem readily identifiable, many of the benefits are elusive. As a result decision makers are faced with difficult questions: How should IT investments be designed and managed to ensure alignment with corporate strategy? How should such investments be prospectively justified? What more (than technology) is needed to realize the full potential of IT? What are the risk implications of these investments? How can the value of IT investments be managed over time? In this paper we develop a formal and practical methodology to evaluate information technology infrastructure investments.

Our research provides a novel way of thinking about the elusive benefits of IT and proposes a new way of managing such investments. We recognize that the design and justification of technology investments must begin with the set of desired business capabilities that unfolds from the overall business goals of the firm. Investments are broadly defined as the physical assets (e.g., technology), the human capital (e.g., training) and the organizational structures (e.g., partnerships) that are needed to transform today’s business capabilities into those desired for the future. By investing in capabilities, an organization acquires options that enable management to react to changing business conditions by altering the timing, scale, and configuration of follow-on investments. Such actions modify the risk-return pattern of the investment outcomes. These options have significant value for the organization and can be estimated using a modified version of the techniques used to value financial options.

Implementing this approach requires periodic monitoring, re-evaluation, and redesign of investment programs. Hence, investment decisions are not simply made once and handed over to project managers for execution, but rather, investments are managed over time. This shift from a project management to an investment management view requires that firms put in place a capability to enact an investment management process with requisite measurement metrics, monitoring schemes, and decision making authority.

Finally, we illustrate the proposed investment management approach by analyzing how a Canadian mortgage banking firm leveraged imaging technology to build several important business capabilities. Further, we validate this approach by performing the analysis at a Research Center workshop whose participants were CIOs from large corporations. The results of this analysis are presented in the paper.
Investments in IT have become a dominant part of the capital expenditure budgets of both service and manufacturing organizations. Managing IT investments is complex and the implications of decisions are often not well-understood. Frequently asked questions include: How are IT infrastructure investments justified? How do we design and manage IT investments to ensure alignment with corporate strategy? How can we prospectively justify these investments? What more is needed to realize the full potential of IT? How can we retrospectively measure success? While these questions are not new, they have not been answered satisfactorily. In this paper we develop a formal and practical methodology to evaluate information technology infrastructure investments.

Determining the value of IT investments is inherently difficult. While the costs seem readily identifiable, many of the benefits are elusive. For example, consider the investment in an electronic mail system within a geographically dispersed workgroup. As with many other infrastructure investments, attempting to justify e-mail based on efficiency alone is likely to fail. E-mail may be a substitute for other forms of communication, but its real value comes as its use expands throughout the organization and as other, more sophisticated applications are added to the basic e-mail platform. Specifically, e-mail within a workgroup may develop into a workflow management system across workgroups, which in turn can evolve into a knowledge-sharing Lotus Notes database for the entire organization. Typically, the diffusion of e-mail across the organization and the evolution of e-mail to higher forms of knowledge sharing takes substantial time. Thus there is a significant time gap between the point of initial investment and the day when value is derived. As the e-mail example shows, the investment may be staged so that its ultimate scope becomes organization-wide although the initial investment point may have been within a single department. The complexity of valuing IT investments arises not only because it is difficult to quantify the value, but also because it is difficult to predict the trajectory and pace of the technology investment across the organization.

In this paper we propose a novel way of thinking about these elusive benefits, which leads to a new way of managing IT investments. Our proposal draws on two strands of thought about investments:
considering investments as a way of bridging the gap in business capabilities and considering capabilities as providing options to better cope with uncertainty. By characterizing business capabilities as arising from a set of operating drivers, we offer a way to improve the alignment between the project manager’s technology view and the general manager’s business view. We also view the initial investment in terms of the options it creates for the firm. Exercising these options, which usually requires further investments, then allows the firm to capture a greater set of benefits.

Both business and project managers must recognize that value is derived from business capabilities, not merely from specific technology investments. Continuing with the e-mail example, when viewed simply as a technology, e-mail provides people with the ability to speed up asynchronous communication, replacing or supplementing memos, phone calls, and face-to-face meetings. However, to derive higher value from the e-mail investment, work must be reorganized around this technology. There may be opportunities to improve document handling and coordination of tasks. Frequently, there is greater participation in decision-making. Additionally, higher order benefits may result when the simpler, less formal mode of communication engendered by e-mail leads organizations to form new alliances with their customers and suppliers. This can create new opportunities for mass customization and reduction in new product development times, both of which are examples of new business capabilities that may arise as a result of considering e-mail as more than a specific technology investment.

We summarize the first part of our proposal by arguing that the technology investment design and justification must begin with the desired set of business capabilities that unfold from the overall business goals of the firm. The investment problem then can be interpreted as the transformation of today’s business capabilities into those desired for the future. By focusing on capabilities, we broaden the scope of investment to include not only physical investment (e.g., technology), but also changes to human capital (e.g., training) and organizational form (e.g., partnerships).
The second conceptual underpinning of our methodology recognizes the real options created by the staging of investments. These options create value by enabling management to react to changing conditions by altering the timing, scale, and configuration of follow-on investments, thereby modifying the risk-return pattern of the investment outcomes. Using real options, decision makers will be able to evaluate not only the value of an investment but also its risk profile.

In the e-mail example, for instance, if after the first stage (implementation of within-group e-mail) business conditions turn out to be ideal, then the project roll-out to other groups in the organization can be accelerated. If conditions are good but not ideal, then a more conservative expansion plan may be pursued. If there are adverse conditions then the project may need to be postponed, re-configured or even abandoned. The procurement of the end business capability is often structured as a multi-stage process, so that management can retain the ability to react to changing conditions on an on-going basis. In fact, it is the very uncertainty about future business conditions that makes the option valuable. Recent developments in the theory of real option pricing can, with suitable modifications, be adopted to evaluate the flexibility that is inherent in such staged investment programs. (Dixit & Pindyck 1995, Kulatilaka & Marcus 1992).

We link the concepts of business capability and real options using the neo-classical economist’s notion of a production possibility frontier. Business capabilities allow a firm to transform its input factors into a set of products and services. Although products and services -- the outputs -- can be valued, any valuation is contingent on market conditions and the degree of success in attaining the capability. The capability-based real options approach provides the basis for making an investment decision that incorporates the effect of contingencies on the transformation of the input factors into the desired outputs.

We formalize our approach in a four-step investment design and analysis process which improves alignment of the goals of information technology projects with the firm’s overall business vision: (1) identify current and desired business capabilities; (2) design an investment program to achieve the desired

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2 The term real options is used to stress the analogy with options on financial assets, and to highlight the fact that they provide opportunities to acquire real assets.
capabilities; (3) estimate costs and benefits (in terms of cash flows) resulting from realized capabilities; and
(4) Fold-back of the cash flows to obtain the market value of the investment.

Implementing the real options approach requires periodic monitoring, re-evaluation, and redesign of the investment program. Investment decisions are not simply made once and handed over to project managers for execution, but rather, investments are managed over time. This is in sharp contrast to some current practice where, first, investment decisions are made and, then, projects are managed with a focus on technology implementation without adequate consideration of the appropriateness of the project in view of changing business conditions. This shift from a *project management* to an *investment management* view requires that firms put in place a capability to enact an investment management process with requisite measurement metrics, monitoring schemes, and decision-making authority.

The rest of the paper is organized as follows: In Section 2, we elucidate the concept of a business capability and describe it in terms of the constituent *operating drivers* of technology, organization, and process. Section 3, develops the four-step methodology and presents the rudiments of the real options valuation technique. In Section 4, we illustrate the proposed investment management process by analyzing how a Canadian mortgage banking firm leveraged imaging technology to build several important business capabilities. Finally, Section 5 concludes with the lessons learned and future research plans.

2. Characteristics of IT Investments

Strategic IT investments are highly risky to make, but can offer huge rewards to a firm. The major difficulty occurs in evaluating these investments and justifying them using current IS executive skills and approaches. Typically, organizations fall into two traps: the trap of negative net present value or the trap of vanishing status quo (Clemons, 1991). The first trap occurs due to the difficulty in identifying future benefits and in accurately estimating them in terms of cashflows. This results in conservative estimates of the benefit stream which, coupled with large investment costs, results in negative NPVs. The second mistake that firms make is in assuming a static market and not making any investments. This could result in loss of market share and other bad outcomes due to competitor actions.
In this paper we introduce a methodology that explicitly takes into consideration market uncertainties and determines the value of investments based on its impact firm-wide and over time. Further, we deal with IT investments at an organizational level and argue that IT, along with other operating drivers whose impacts are influenced by uncertainties, enables the organization to achieve a set of capabilities. These capabilities in turn have an impact on the value that a firm derives from its products and services. This link between the operating drivers and value is explained using the capability-based real options approach that can, also, be used to manage the investment process.

2.1 Capabilities

A business capability is a distinctive attribute of a business unit that creates value for its customers. Capabilities are measured by the value generated for the organization through a series of identifiable cash flows. Thus, capabilities differentiate an organization from others and directly affect its performance.

For example, Boeing’s new concurrent design and manufacturing approach gives them the ability to deliver the 777 jetliner much more rapidly than under the conventional “design-then-build” paradigm (Norris 1995). Engineers, marketing personnel, and financial analysts from Boeing’s airline customers actively participated in the design of this aircraft almost from the beginning of the project. In many cases, customer representatives were physically relocated to Boeing factories. Subcontractors were also involved in shaping the design and manufacturing processes. Concurrent design and manufacturing accelerated cash flow and allowed Boeing to become more responsive to customer needs. Moreover, Boeing is now able to use the lessons learned, design methodologies, and relationship knowledge for future aircraft development. Concurrent design and manufacturing has become a business capability for Boeing (Amram and Kulatilaka 1996).

In the consumer product sector, micro-marketing at Frito-Lay has been widely publicized (Applegate 1993). Their micro-marketing initiative was designed to respond both to local competition and to the increased information that supermarket scanners had made available to large chains. This had a direct impact on the revenue stream for Frito-Lay. Over the seven or eight years, Frito’s micro-marketing skills
developed to the point where a major competitor -- Annheuser Busch -- withdrew from the market. Thus, the micro-marketing evolved into a major business capability.

The notion of business capability is superficially similar to the idea of core competency described by Prahalad and Hamel (1990). Core-competence emphasizes technological and production expertise that is meant to explain a company’s myriad product lines, but cannot fully explain how companies successfully move into wide range of businesses. To explain this, Stalk et al. (1992) introduce the notion of capability, which includes the set of business process, in addition to the core-competencies. However, the focus of discussion in the literature about core competencies and capabilities is on leveraging tangible assets (individual technologies, production skills, and business processes) across a multi-divisional organization. In contrast, a business capability is similar to the notion of a value discipline, which Tracy and Wiersema (1995) define as the way in which companies combine systems, processes, and their environment to deliver value to their customers. We suggest that the constructs are similar only where an organization, such as Walmart, is essentially a single business unit. In general, business capabilities are associated with a single business unit and incorporate both tangible and intangible assets.

We suggest that a business capability such as concurrent engineering or micro-marketing is built by investment in "operating drivers." It is important to note that investment decisions take place at the level of operating drivers. Two firms may obtain the same business capability through investing in different kinds of operating drivers, which include not only tangible infrastructure, but also process and organizational components.

The effectiveness of a technology investment depends to a great extent on how work is organized around that technology (Kogut and Kulatilaka 1994, National Academy Press 1994). Furthermore, the structure of the organization, including outsourcing relationships and alliances, must be aligned with the technology and the work processes that are in place (Henderson and Venkatraman 1993). Thus, the operating drivers are the set of technologies, processes, and organizational elements that are necessary for a firm to achieve a business capability. For the purpose of this discussion, we assume that the technology
component of a business capability is information technology. An economist would think of this as physical capital. By process component, we mean procedures, workflows, management controls, and human resources practices. Organizational elements include relationships with other firms in the value chain as well as internal management structure. Figure 1 shows the relationship between business capability, operating drivers, and value.

With this definition of business capability, we are elaborating on the economist’s high level view of the production possibility frontier by explicitly recognizing that the production function consists of a set of operating drivers rather than a simple investment in technology. Collections of operating drivers together with the way they are deployed give the firm a business capability. It is the interaction of these business capabilities with market forces that create value.

For example, the operating drivers that support Boeing’s concurrent engineering business capability include several technology, process, and organizational elements. The technology elements that have been put in place include a telecommunications infrastructure (e.g., LANs, WANs), shared electronic workspaces, and knowledge management applications software (e.g., Lotus Notes). There is also an integrated 3-D CAD-CAM system. Process elements include designing and training users in a specific methodology for creating, storing, and using design rationale. The organization structure moved from department-based work to team-based work, with over 200 simultaneous design-build teams established. Externally, Boeing entered into formal strategic alliances with airlines and parts suppliers.

At Frito-Lay, the handheld computers formed an important part of their technology investment. But the technology investment was not alone sufficient to accomplish the change that senior management envisioned. Recognizing this a couple of years later, Frito initiated additional changes in management structure, workflow, and incentive compensation. As a result, Frito is now viewed as a very successful company.

In summary, we argue that there is a need to take a holistic view of the firm to analyze the impact of a technology, incorporating consideration of investment in people, processes, and policies. We also believe
that it is not sufficient to consider the incremental impact of information technology at the time of introduction; instead, it is necessary to look at how it permeates throughout the organization. And, since the permeation often takes time, and since the value derived from the capabilities changes over time, the two dimensions over which we have to consider value are across the organization and over time. These two important notions -- breadth and time -- imply a very broad view of the capability construct.

2.2 Dealing with Uncertainty

In order to move from their current business capabilities to their desired capabilities, firms have to invest resources to make technology, process, and organizational changes. The payback from investments depends on the capabilities that are actually achieved and also on prevailing economic conditions. Thus firms are faced with two types of investment uncertainties: project-related and market-related. Project-related risk is determined by how the firm chooses to design, implement and manage the operating drivers. For example, the investment may not pan out as expected because the technology may not deliver on all its promises, or integrating the technology into the organization may be more difficult than foreseen, or there may be cost over-runs and time delays. The second type of risk, market-related, is based on customer acceptance, competitor actions, and other factors that affect market demand for the firm’s product and services. In this case, even if the project unfolds as expected, the resulting business capabilities may not be appropriate for the realized market conditions. For example, a system that is successfully built to handle one million inquiries per month will be inappropriate if demand halves (or doubles). Hence, to achieve the desired capabilities, firms must periodically identify, analyze and manage both sources of risk and manage them over time.
2.2.1 From Capabilities to Future Cash Flows

Capabilities alone do not generate cash flows. As indicated earlier, external market conditions and the firm’s operating policies are also determinants of cash flows. Capabilities, however, determine management’s ability to react to evolving market conditions.

More specifically, investing in operating drivers and acquiring a set of capabilities influences the firm’s cost structure (e.g., increase fixed costs and reduce variable costs) and its revenue sensitivity (e.g., market share). The capability analysis forms the foundation for building the cash flow models that are essential to any pro-forma cost-benefit analysis. Typical practice, however, entwines the cash flow effects of investments with a particular market scenario. For example, cost reduction derived from imaging projects is closely tied to the volume of documents processed. Volume is projected by assuming a particular demand for the firm's products or services. In contrast, our approach makes explicit a cash flow model which includes the exogenous market conditions as variables. For instance, if uncertainty stems from the total size of the market for the product, then a new capability may impact the firm’s fixed cost, the variable (per-unit) cost, and the market share. As a result, we can create a map of the incremental cash flows that are generated under all potential future capabilities, subsequent investments, and future market contingencies.

2.2.2 Valuation of Contingent Cash Flows

If a conventional discounted cash flow valuation analysis (DCF) were followed, we would first forecast the future cash flows, compute the expected cash flows, and then, discount at the risk-adjusted opportunity cost of capital to obtain the present value. With a model that links capabilities to cash flow in hand, the valuation model requires only the growth rate (to forecast expected future cash flows) and the “beta” of the cash flows (to capture the systematic risk for the opportunity cost of capital). When an equilibrium market model (e.g., CAPM) is used to derive the discount rate, the resulting net present value gives the market value of the project.
The contingent nature of the future decisions, however, renders this approach inappropriate for two reasons. First, since the subsequent investment decisions are contingent on the realized business conditions it is not sufficient to focus on the expected growth rate of the uncertain variable. The future cash flows depend on the management's reactions to the particular realization of uncertainty. Hence, we must open up the uncertainty to consider all possible future business conditions and assess the optimal investment decisions. This is messy but feasible and can be handled with an event-decision tree or a Monte-Carlo type simulation model.

Once the contingent cash flows are mapped out, the valuation and the optimal investment decisions can be obtained simultaneously by solving the event-decision cash flow tree as a stochastic dynamic program. The information needed to create the tree includes not only the growth rate of the exogenous variable but also other properties of its stochastic process (e.g., volatility) which determine the probability structure of the future cash flow outcomes.

However, a further complication arises in the determination of the opportunity cost used in the discounting of the expected future cash flows. The risk characteristics of the investment project change every time the business conditions change. Since future business conditions evolve stochastically deriving the opportunity cost of capital becomes impossible.

The critical insight of financial option pricing gets around this problem by relying on the existence of a traded securities market which spans all exogenous uncertainty. The intuition behind this result is straightforward. Since all risk arising from movements in the underlying asset price contained in the contingent claim can be eliminated by taking appropriate positions in the underlying marketable asset, we can create a portfolio that is riskless relative to the underlying asset. When the contingent payoffs to this portfolio are known, it can be valued using riskless discounting. The presence of the traded asset eliminated the need for risk adjustment and valuation does not rely on a risk pricing model such as the

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3 Note that it is the existence of the market and the possibility of replication, rather than actually carrying out the replication, that allows options to be priced in an arbitrage-free fashion.
CAPM. This insight forms the foundation of the Black and Scholes (1973) and binomial (Cox, Ross, and Rubinstein 1976) option pricing models.

Hence, with the existence of a traded market for the underlying source of uncertainty, the information needs are reduced to the volatility of the exogenously uncertain variable and other observable variables, the current price of the asset and the risk free rate of interest. Any option can be valued by replacing the actual growth rate of the underlying asset with the risk-free rate of interest in laying out the potential future payoffs (the event-decision tree) and solving the dynamic program by discounting at the risk-free rate. It is important to note that, although this approach is operationally equivalent to a more traditional decision tree method, the information needs are different. We rely on market information to adjust for risk by using the volatility, rather than subjective probabilities or CAPM-based risk adjustments, to capture the effects of uncertainty.

In some special cases the investment valuation can use Black-Scholes or other financial option pricing models. We must first draw a correspondence between the option embedded in the investment problem and a known financial option. For instance, the option to wait-to-invest is analogous to an American call option and the option to abandon to an American put. If the underlying source of uncertainty comes from a price of a traded security the investment project can be evaluated using the appropriate call or put valuation model.

The insight in option pricing can be extended to devise a more general contingent claims valuation model even when the uncertainty arises from sources other than traded security prices (see Hull 1993). In such cases the replication argument must be modified to overcome the risk-adjustment problem. The exact modification depends on the source of risk and the availability of market traded securities that proxy it. Note that when there are traded securities that can capture this demand uncertainty, we do not need to estimate the mean of the distribution. That is, we do not need to forecast the trend of the demand, but only its volatility (for additional information see Kulatilaka and Marcus 1992).
In summary, the real options approach deals with a complete spectrum of risks ranging on the one extreme from the prices of traded securities and the other extreme, on unique events. Wherever possible, market information is used. The information requirements as well as how the information is processed is markedly different to the more traditional DCF, decision tree, or simulation models. Table 1 below summarizes the spectrum of risks and the valuation methods.

<table>
<thead>
<tr>
<th>Source of Risk</th>
<th>Information required to value contingent claims</th>
<th>Analytic Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prices of market-traded securities</td>
<td>Current prices, volatility</td>
<td>Black-Scholes and other financial option pricing models</td>
</tr>
<tr>
<td>Product/service or input market-related risk (e.g.,</td>
<td>Traded prices as proxies, volatility of proxy variable OR Actual growth rate, measure of systematic risk (β), volatility and convenience yield of the risky variable</td>
<td>Risk-neutral “decision trees” (e.g., binomial models)</td>
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<td>and services, market size)</td>
<td></td>
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<tr>
<td>Unique events affecting the firm (project-related</td>
<td>History-based or subjective probability estimates of events</td>
<td>Risk-neutral decision trees</td>
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<td>risk)</td>
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Table 1: Summary of risk evaluation techniques

In the next few sections, we describe capability analysis and as a method which helps planners connect the overall business vision with the individual technology projects.

3. A Methodology for IT Investment Management

As described in the introduction, the methodology consists of four steps: identification of current and desired business capabilities, design of a contingent investment program to achieve the desired capabilities, estimation of the costs and benefits of realized capabilities in terms of cash flows, and evaluation of cash flows to obtain a value for the investment. A prerequisite for use of this methodology is development of a business vision, which is frequently embodied in a mission statement for the organization. The details of these four steps are described in the following sections.
3.1 Identification of Current and Desired Capabilities

The planning effort involves translating the vision into a set of specific desired business capabilities. In addition, the firm must decide what operating drivers are needed to support each of the business capabilities. This involves taking stock of the firm's current operating drivers and determining how to enhance, substitute, and build on these drivers to enable the firm to deliver the desired business capabilities. For each of the business capabilities, there is an associated value, and, similarly, for each of the operating drivers, there is usually an associated investment.

The business capability analysis has several important implications for the valuation of IT projects. End business capabilities are secured by making a series of investments, where the go-nogo decision at each stage is contingent upon the success of the preceding stages and the business conditions. The investment manager reacts to changing conditions by changing the scope, timing, and scale of the investment stages to mitigate down-side losses and capture (and even enhance) the up-side benefits.

3.2 Design of an Investment Program

So far, the capability definition step may appear to be quite traditional. However, when considering that events in the future are inherently uncertain, the firm needs techniques to characterize the uncertainty associated with capability deployment and associated values. As noted earlier, we identify two sources of uncertainty: market-related (price and demand) and project-related uncertainty, which may cause the firm to achieve different capabilities than the ones envisioned.

Let us revisit the e-mail project from Section 1, where the investment is made in two stages. In Stage 1, work group e-mail is installed in a single product high tech company. The objective is to improve communication and reduce costs. In Stage 2, the company intends to leverage its e-mail investment by implementing knowledge-sharing practices. This will allow the company to respond more effectively to customer needs.

Using our analytical framework, decision makers build a decision tree (see Figures 2 and 3) by determining the menu of choices at each decision point based on outcomes of prior states, and identifying
the internal and external sources of uncertainty. Assuming binary outcomes and binary decisions, this process results in 24 potential cash flows outcomes at the end of Stage 2, that the decision maker should evaluate. This valuation technique is described in the next section.

3.3 Estimation of Cash Flows

The third step in the investment management process involves determining the value associated with each business capability. We analyze the value impact at the overall firm level. While more sophisticated cost-benefit models can be developed, for pedagogic clarity, we use a simple cash flow model at each time period. Suppose the firm faces an industry demand $D$. The firm’s share of the market is $ms$. Then the firm’s revenues are the fraction $ms$ of the total industry demand $D$. (i.e., Revenues = $ms \cdot D$)

Fixed Costs ($fc$) are the total annual fixed costs of the firm. Since investment costs ($I$) are explicitly accounted as a cash outflow, neither investment costs nor depreciation allowances are included in $fc$. But rather, $fc$ represents the portion of operating costs that is unaffected by the firm’s output volume. Typical items included in $fc$ are overhead costs that are usually allocated in accounting cost calculations.

Variable costs depend on the firm’s output volume. For instance investing in a more efficient process will reduce the amount of energy and input material consumed, thus, lowering variable cost. We capture this impact through the per-unit variable cost parameter $vc$. Hence the total variable cost is $vc \cdot ms \cdot D$.

The resulting net cash flow, $\pi = ms \cdot D - fc - vc \cdot ms \cdot D$.

The parameters $ms$, $fc$, and $vc$ are influenced by making investments in operating drivers. Since making an investment does not guarantee its success, the realized partakers depend on the success or failure of the investment stage and on the context of the investment. Although the investments position the firm in the market, the realized cash flow depends crucially on the realization of the exogenous uncertain demand, $D$.

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4 Where the output price is normalized to 1, without loss of generality.
5 These do not include an allocated portion of fixed cost.
6 More generally, there is a continuum of degrees of project success/failure. For now we will treat this as a binary outcome.
3.4 Evaluation of the Cash Flows

Finally, using a dynamic programming algorithm, the decision tree can be collapsed to determine an optimal value at each stage. We define value to be the current worth of expected future cash flows computed from the cash flows associated with each terminal node belonging to a stage within the decision tree. The dynamic programming evaluation continues until the initial decision point is reached.

We illustrate the valuation technique using the two-stage investment in e-mail, again with binary sources of uncertainty and binary decision choices (see Figure 3).\(^7\) For instance, suppose both investment stages are committed as planned, implemented successfully, and the external business conditions turn out to be advantageous to the firm in both periods.\(^8\) Then the firm will receive net incremental cash flow \(\pi_s(M_g)\) in year 1 and \(\pi_{s\pi}(M_{gg})\) in year 2, where the subscripts on “\(\pi\)”, the cash flow function, denote project success (s) or failure (f); subscripts on “\(M\)” denote market outcomes good (g) or bad (b). Figure 3 shows the year-2 cash flows for each of the potential contingencies. Since the benefits of the project are likely to accrue for a period of time after the second year, the value (\(V\)) of the project at year-2, will be the year-2 cash flow multiplied by the present value annuity factor, \(\Delta\). For example, the year-2 value under the most optimistic scenario discussed above is \(V_{s\pi}(M_{gg}) = \Delta \pi_{s\pi}(M_{gg})\).

Once the contingent values at the terminal date (planning horizon) is known, we can solve the dynamic program to fold back the value of the project by taking expectations over each of the sources of uncertainty and building-in the decision criteria at each stage (see Figures 4 and 5). Consider the year-1 value if the first stage is successful and the market turns out favorably, \(V_s(M_g)\). This value would be the incremental cash flow received at year 1 plus the present value of the expected cash flows from following an optimal investment decision thereafter. The menu of decisions at this node is to continue with the proposed

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\(^7\) If we need a richer set of outcomes, we can take smaller time steps between stages. As a result, the event tree unfolds with thicker foliage. Investment decisions, however, are made only at periodic (annual) intervals.

\(^8\) Although this outcome is contingent on a particular sequence of events occurring, many business plans are based on equally specific scenarios. Even in this highly simplified example, this is only one of 24 potential outcomes which are explicitly considered in the valuation.
expansion at a cost of $I_{1s}$, or abandon the expansion plan. The expected values under the two decisions cash flows are:

if the expansion is undertaken,

$$V_s(M_g) = \pi_s(M_g) - I_{1s} + \rho \ E_{q2} \{ V_{ss}(M_g) \} + (1 - p_{2s}) \ E_{q2} \{ V_{sf}(M_g) \}$$

$$= \pi_s(M_g) - I_{1s} + \rho \ E_{p2} \{ V_s(M_g) \}$$

if expansion is rejected,

$$V_s(M_g) = \pi_s(M_g) + \rho \ E_{q2} \{ V_{su}(M_g) \}$$

where $E_p(\cdot)$ is the expectations operator, $E_q(\cdot)$ is the "option value" operator, $\rho$ is the riskfree discount factor, $p_{2s}$ is the probability of successfully implementing the investment $I_{1s}$, and subscripts $s, f,$ and $u$ on $V$ denote values under success implementation, failure, and unchanged capability sets, respectively.

Management will choose the decision to maximize value. Hence,

$$V_s(M_g) = \text{Max} \{ \pi_s(M_g) - I_{1s} + \rho \ E_{q2} \{ V_s(M_g) \}, \pi_s(M_g) + \rho \ E_{q2} \{ V_{su}(M_g) \} \}$$

Similarly, we can obtain the year-1 values under all possible contingencies.

$$V_s(M_b) = \text{Max} \{ \pi_s(M_b) - I_{1s} + \rho \ E_{q2} \{ V_s(M_b) \}, \pi_s(M_b) + \rho \ E_{q2} \{ V_{su}(M_b) \} \}$$

$$V_f(M_g) = \text{Max} \{ \pi_f(M_g) - I_{1f} + \rho \ E_{q2} \{ V_f(M_g) \}, \pi_f(M_g) + \rho \ E_{q2} \{ V_{fu}(M_g) \} \}$$

$$V_f(M_b) = \text{Max} \{ \pi_f(M_b) - I_{1f} + \rho \ E_{q2} \{ V_f(M_b) \}, \pi_f(M_b) + \rho \ E_{q2} \{ V_{fu}(M_b) \} \}$$

By building in the decision criterion (in this case, choosing the maximum of two alternatives) these continent values incorporate the flexibility to manage the investment program in the future. Hence, the valuation includes, not only direct effects, but also the option-like platform value of the investment.

Continuing with the dynamic program using a similar notation, we can obtain the net present value of the investment $I_0$ (ensuring that all future decisions are made optimally) can then be written as,

---

9 This is operationally equivalent to taking risk-neutral expectations over the possible market outcomes, and discounting at the riskfree rate of interest. When the uncertain market variable, $M$, is a traded security price, the Black-Scholes options price can be used to value the option-like project. When $M$ is a non-traded asset, a similar computational technique can be adopted by first transforming the probabilities into their risk-neutral equivalents.
\[ V(M_0) = -I_0 + \rho \mathbb{E}_{q_1} \{ V(M_{s1}) \}. \]

Clearly, we can generalize this approach along several dimensions: (a) a larger menu of alternative decisions, (b) more possible outcomes for the project's successful completion, and (c) more general distributions for the exogenous uncertainty, \( M \). While the computational complexity will grow rapidly, the methodology remains conceptually similar.

We have thus far considered one possible investment configuration (i.e., design). Typically, we would like to compare several mutually exclusive alternative investment designs.\(^{10}\) For each such design, an analysis similar to above needs to be carried out to arrive at the respective net present value.

While the current value, \( V_0 \), appropriately includes the risks of the staged investment program, this approach provides a much richer picture of the risk characteristics faced by the firm. Since we make uncertainty explicit and consider the firm's potential reactions to potential future contingencies, the risk profile facing the firm is likely to be significantly modified when compared to a naive take-it-all-or-leave-it investment design.

For instance, consider the top branch of Figure 3. For the investment stream of \( I_0 \) and \( I_1 \), to yield \( \pi_s(M_{g1}) \) in year 1 and \( \pi_{ss}(M_{gg}) \) in year 2 (and some residual based on \( \pi_{ss} \) thereafter), Stage 1 investment must succeed, the year-1 market must be good, Stage 2 investment must be made and be successful, and Stage 2 market must also be good. This has a probability of \( p_1 q_1 p_2 q_2 \). But the very decision to go-ahead with \( I_1 \) is determined endogenously within the valuation model. Hence, if the parameter values are such that abandoning the project is preferred at the node \( \{ s, g \} \), this branch may be “trimmed” from the tree of possible values. In effect, the construction of the decision tree and the real options approach for evaluating cash flows provides the organization with a process for managing risk.

4. The Methodology in Action: The Case of NMT


\(^{10}\) One such choice is to recognize the ability postpone the project.
As a testbed for the methodology, we used a mortgage bank that was involved in making a large IT investment. In early 1994, National Mortgage Trust\(^\text{11}\) (NMT) was a relatively small but aggressive financial institution that specialized in mortgage-backed lending in Canada. Their head office was in Montreal, with branches in Halifax, Toronto, and Ottawa. Over the past seven years NMT’s assets had grown from zero to about $6 billion, and many would say that this was a good example of a successful organization in the ‘90s -- flat, fast, customer-oriented, and dedicated to a process of continuous learning and improvement. Within their industry they were viewed as a leader in the use of information technology, innovative work processes, and management systems. They were also considered to be aggressive in their pursuit of innovative ways of gaining market share and packaging mortgages in ways that are attractive to the funding sources.

NMT’s business consisted of three major activities: originating residential mortgages, funding their mortgage commitments, and servicing these mortgages. Customers were reached directly through the branch offices, via Realtors, and with the aid of mortgage brokers. As with other firms in their industry NMT offered customers relatively few mortgage financing choices. Currently offerings were limited to two or three fixed rate plans and about the same number of variable rate plans. The following paragraphs summarize the three basic business processes -- mortgage origination, funding, and servicing.

Mortgage origination begins with the customer reaching agreement on price with the seller of a property. Assuming that the customer has decided to finance the purchase through NMT rather than another financial institution (e.g., a commercial bank), an application is submitted. NMT now has to obtain a variety of information in order to approve or deny the application. Using the telephone, fax, and mail to communicate, NMT verifies employment, marital status, credit history, and bank balances.

\(^{11}\) National Mortgage Trust is a pseudonym for a real organization. The events described in this article are based on a case study conducted by one of the authors, along with Robert Materna and Janet Wilson. Also, we note that some of the data for Stages 2 and 3 came out of the CIO meeting and some are derived from the case study performed at NMT in 1995.
Property inspections, surveys, appraisals, and title searches are also necessary. If there are no major problems, this process takes from two to four weeks. On approval of the loan, a closing date is set. At that time, a settlement statement is used as the basis for the exchange of documentation and funds.

The funding process consolidates the potential requirements of the many mortgage applications that are being processed simultaneously. NMT tracks potential funding requirements on a daily basis so that a market assessment of funding availability can be continuously made. As deals reach the closing date, mortgages are packaged together for resale to the funding sources. Funding sources of course require evidence of a careful credit review process and supporting documentation in order to minimize the risk of non-payment and title defects.

The mortgage servicing process includes dealing with customers both before and after the mortgage is approved. Before they receive approval, customers frequently call NMT with a variety of questions relating to status and file completion. These questions are handled by people within NMT responsible for each of the major activities in the approval process. Following closing, customers may also call NMT for various kinds of service. In this case, questions are predominantly related to monthly payments (or, non-payment!). However, issues relating to refinancing, home improvements, and insurance may also arise. Again, answers to these mortgage servicing questions are provided by specialists within the NMT organization, who often have to call the customer back after retrieving the required documentation.

4.1 The Vision

A framed copy of NMT's vision statement is in each office: “To be Canada's leading, most innovative, most service oriented, residential mortgage lender and mortgage-backed securities (MBS) issuer.” In the words of the President of NMT: "We're focused -- not to be confused with rigid. We're very resilient.” At the time we began studying NMT, the top management summarized NMT’s current state and desired business capabilities as follows:
<table>
<thead>
<tr>
<th>Current State</th>
<th>Desired Business Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small menu of mortgage options</td>
<td>Mass customization</td>
</tr>
<tr>
<td>Branches/brokers/realtors as channels</td>
<td>Direct delivery</td>
</tr>
<tr>
<td>Standardized, simple mortgages for resale</td>
<td>MBS placement, including CMOs</td>
</tr>
<tr>
<td>Fragmented activity-oriented servicing</td>
<td>One-stop case servicing</td>
</tr>
</tbody>
</table>

Table 2. Transformation of Capabilities

By identifying mass customization as a desired capability, NMT recognized that with diverse end-user needs profiles, there was an opportunity to gain market share by delivering mortgages that are customized in terms of rate, structure, and duration. With direct delivery, NMT wanted to expand the scope of the existing delivery channels to sell mortgages directly to homeowners, rather than marketing via mortgage brokers and other intermediaries. The need to build MBS (mortgage-backed security) placement capability was an outcome of mass customization. Because the make-up of the package of mortgages being sold to funding sources would have changed from mortgages with homogeneous terms to mortgages with varied terms, NMT needed the ability to collateralize these varied term mortgages in order to secure attractive funding. Further, the dynamic nature of financial market conditions had to be accounted for in determining the rates. Finally, management decided that they wanted NMT to establish long term relationships with their customers by providing a high level of service before and after a mortgage was approved. The one-stop case servicing approach, with the ability to access customer records while a phone call is in progress, was designed to support this goal.

4.2 Business Decisions and Opportunities

Having agreed on the desired business capabilities, the top management team identified imaging systems as the key technology driver. Imaging systems convert documents and images into digital form so that they can be stored and accessed by the computer. To confirm the view of top management of NMT, we took the facts of NMT’s business and presented them to a group of CIOs attending a meeting of the Systems Research Center (SRC) at Boston University. We first asked them to identify the operating
drivers for each of the business capabilities identified by the top management. The outcome of this exercise is shown in Table 3.

<table>
<thead>
<tr>
<th>Desired Business Capabilities</th>
<th>Technology</th>
<th>Organization Structure</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass customization</td>
<td>WANs PSNs DBMS Imaging Workflow mgt software</td>
<td>Alliances with funding sources</td>
<td>Rapid application dev. Advanced training Market survey/scanning Performance metrics</td>
</tr>
<tr>
<td>Direct delivery</td>
<td>WANs PSNs Imaging</td>
<td>Multiple input sources Alliances with credit reporting agencies</td>
<td>Maintenance/support Performance metrics</td>
</tr>
<tr>
<td>MBS placement, including CMOs</td>
<td>Financial model management</td>
<td>Alliances with funding sources</td>
<td>Financial modeling</td>
</tr>
<tr>
<td>One-stop case servicing</td>
<td>Imaging Integrated data access</td>
<td>Case-based approach Team-based problem solving</td>
<td>Advanced training Conversion of existing data</td>
</tr>
</tbody>
</table>

Table 3: Operating Drivers

As indicated in Table 2, one technology driver that featured in most of the business capabilities was an advanced imaging system, thus confirming the intuition of top management of NMT.

Proceeding to the next step in the proposed investment methodology, we discussed with the CIOs and the CIO of NMT the staging of the imaging investment and the sources of risk. As a result, we identified two investment stages:

1. Implement the document imaging processing technology in a limited number of offices using off-the-shelf software, but only for new mortgages.

2. Expand the data capture capability to all offices and scan in all pre-existing mortgages. Also, design and implement new workflows throughout the mortgage servicing division.

We then asked both the management and the CIOs to consider the risks that NMT was exposed to. The market risks were clear and identical for all stages. The primary drivers of the overall demand for new mortgages are interest rates and Canadian business cycles. In addition, NMT’s “spreads” (between the cost of funds and the mortgage interest rates) and market share were affected by regulations concerning the entry of U.S. mortgage banks and the large Canadian commercial banks.
The project risks, however, were harder to identify, as they were dependent on the technology used. At Stage 1, the project risks with the technology were essentially systems integration risks -- whether NMT had the expertise to make the technology components work together. NMT also risked not having the expertise necessary to institute process changes that were necessary to keep the imaging system operational. During Stage 2, project risks were somewhat more varied. These risks now included software/hardware performance and scaling issues. Since the data capture capability was being extend to all offices, NMT could now be faced with a broader range of integration issues. NMT would also encounter control issues in converting the old documentation, i.e., making sure that all the documents were accurately indexed and captured by the imaging system. Moreover, since NMT was planning to make changes to the workflows, support requirements would be more complex in Stage 2.

We now could define decision points and decision menus for the imaging project. These are summarized in Figure 6. Note that the two alternatives facing the decision makers were to invest in an imaging system and not investing in one. Figure 6 describes the potential impact of the internal and external uncertainties on capabilities and cash flows. The combination of internal and external uncertainties implies that there are six possible outcomes at the end of Stage 1 and 28 at the end of Stage 2 (see Figure 7). The probability estimates for each branch in Figures 6 and 7 and the expected cash flows are discussed in the next section. These estimates were obtained in part from the case study at NMT and in part by our analysis of the results of the CIO meeting.

4.3 From Capabilities to Value

The above capability analysis provided the necessary inputs to developing contingent cash flow. Following the simple cash flow modeling structure presented in Section 3.3, the aggregate (firm-wide) cash flow effects of an investment on the resulting business capability were captured via the three parameters: fixed costs \((fc)\), variable costs \((vc)\) and market share, \((ms)\). As the exogenous demand for mortgages \((D)\) fluctuated, the net cash flows to the firm were affected according to the capability that is in place.
At the time of the case, NMT generated annual revenues of $200 million. Its fixed costs were 20% of revenue and the total variable costs were 70% of revenue.

From the capability analysis, NMT estimated that if the first stage were successfully implemented, then the fixed costs would increase by 2% because of new support and maintenance processes associated with the introduction of imaging technology. Because the efficiency effects of the investment would only be felt for new mortgages in a limited number of offices, NMT estimated that variable costs firm-wide would be reduced only by 2%. Management did not anticipate any change in market share, again because improvement in mortgage servicing would only occur for new mortgages and only in a few geographical markets. If Stage 1 failed, then the increased overhead of the imaging systems would be carried without any productivity improvements; hence, the fixed costs would increase by 2%, but the variable cost reductions would not materialize.

Estimates for the second stage of investment were developed as follows. If success in Stage 1 were followed by success in Stage 2, then new firm-wide support and maintenance requirements would double fixed costs. Variable costs, however, were conservatively estimated to decrease by 10%. This relatively small change was attributed to the fact that paper processing comprises a small part of the variable cost (review and analysis of the credit application are the major components of variable cost). Finally, with success in stages one and two, management estimated there would be a 50% increase in market share as a result of NMT being viewed as a service leader in the industry.

If success in Stage 1 were followed by failure in Stage 2, then fixed costs were projected to increase by 80%. Management believed that variable costs would decrease by 5% in the case of a Stage 2 failure, compared to a 10% decrease if Stage 2 was successful. Market share was projected to decrease by 5%, principally because staff would be pre-occupied with making the new systems work and because negative customer perceptions about NMT’s ability to service their accounts.
NMT also made estimates of impacts on cash flow in the situation where Stage 1 failed and Stage 2 was successful. In this case, as with success in both stages, the new firm-wide support and maintenance requirements would double fixed costs. Variable costs were conservatively estimated to decrease by 5%. This decrease is less than that achieved with success in both stages because of lower levels of efficiency gains. Finally, management estimated there would be a 50% increase in market share.

If failure in Stage 1 were followed by failure in Stage 2, then fixed costs were, again, projected to increase by 80%. Also, variable costs were projected to remain the same, because of the continued use of the old systems. Market share was projected to decrease by 5%, principally because staff would be pre-occupied with making the new systems work and because negative customer perceptions about NMT’s ability to service their accounts.

The impact of procuring capabilities is modeled via changes in the cost structure and the ability to generate revenues (“market share”). These assumptions are summarized in Table 4 below:

<table>
<thead>
<tr>
<th>Time-1 cash flow impact</th>
<th>Stage 1</th>
<th>ms</th>
<th>fc</th>
<th>vc</th>
<th>Stage 2</th>
<th>ms</th>
<th>fc</th>
<th>vc</th>
</tr>
</thead>
<tbody>
<tr>
<td>success</td>
<td>p=0.8</td>
<td>0</td>
<td>2%</td>
<td>-2%</td>
<td>success</td>
<td>p=0.8</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>failure</td>
<td>p=0.2</td>
<td>0</td>
<td>2%</td>
<td>0</td>
<td>failure</td>
<td>p=0.2</td>
<td>-5%</td>
<td>80%</td>
</tr>
<tr>
<td>not invest</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>not invest</td>
<td>-5%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>success</td>
<td>p=0.7</td>
<td>0</td>
<td>2%</td>
<td>0</td>
<td>success</td>
<td>p=0.7</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>failure</td>
<td>p=0.3</td>
<td>0</td>
<td>2%</td>
<td>0</td>
<td>failure</td>
<td>p=0.3</td>
<td>-5%</td>
<td>80%</td>
</tr>
<tr>
<td>not invest</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>not invest</td>
<td>-5%</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes: All cash flow effects are incremental over prior period cash flows. Stage 2 can not be done without having done Stage 1. If Stage 1 failed, then Stage 2 investment cost increases by 25% (to account for re-doing parts of Stage 1). If Stage 1 was not undertaken, it can be accelerated and done together with Stage 2 at a 50% higher cost and a lower probability of success (70%).

Table 4: Summary of Cash Flow Impacts
As described in section 3, in addition to modeling cash flows we also modeled sources of uncertainty, as follows. Total market demand for mortgages was assumed to follow a log-normal distribution with an annual standard deviation of 35%, i.e., if the current demand for mortgages is \( D_0 \) and the time-\( t \) demand is \( D_t \), then \( \ln(D_t / D_0) \) is normal distributed with standard deviation of 0.35. Our estimate of volatility (\( \sigma \)) was based on the volatility of Canadian interest rates. If instead, we had used GNP as a proxy for the mortgage demand, then the volatility around the mean growth rate would have yielded similar volatility estimates.

For purposes of our discrete-time model we developed a risk-neutral binomial approximation of the log-normal distribution (Cox and Rubinstein, 1976). Specifically, over a time interval \( \tau \),

\[
D_{t+1} = u D_t, \quad \text{with probability } q
\]

\[
= d D_t, \quad \text{with probability } 1-q,
\]

where \( u \) and \( d \) are the coefficients, chosen such that, for time interval \( \tau \), the expected return from the investment in time \( \tau \) is \( u \tau \) and the variance of the return is \( \sigma^2 \tau \). Also, \( u = \frac{1}{d} = e^{\sigma \sqrt{\tau}} \) and \( q = \frac{(e^{r \tau} - d)}{(u-d)} \), where \( r \) is the risk-free rate of interest. Under this structural assumption, the only two pieces of market information that we require are the volatility of demand (35%) and the riskless rate of interest (5%).

Project uncertainty was estimated using subjective measures. Using the real options methodology, we assumed that Stage 1 would fail with probability 10% and Stage 2 with probability 20%. For the analysis reported here we assumed that the second stage success is independent of the first stage. This assumption can be easily relaxed. The cost of the Stage 1 investment was estimated to be $500,000; Stage 2 was projected at $5 million.

Using the real options approach and the data discussed above, we modeled the investment program using a spreadsheet and estimated the value of the imaging project to be $2.1 million. This result was quite different from the result obtained from the most simplistic traditional NPV technique, which yields a negative project value ($380,000). The real options valuation includes not only the NPV obtained by
following the optimistic path of assumed success, but also adds the contingent value of the project at each
decision point in all possible paths.

An important benefit of this analysis is that in addition to a value, decision-makers are provided
with a risk profile. We used the spreadsheet model to produce a histogram which conceptually compares
the probability of obtaining a range of values through the NPV technique and the real options approach
(Figure 8). By staging the investment and making the follow-on decisions contingent on the realization of
the external (market demand) and internal (project) uncertainty, the firm is able to protect itself against
some of the most undesirable outcomes. At the same time, if the future market conditions turn out to be
good, the firm will use its investment flexibility to capture the upside benefits. Nevertheless, the project
still can end up making a loss. Tracking through the decision tree, managers can identify the scenarios that
bring about these losses and may be in a position to re-design the project to minimize such losses.

The project value is most sensitive to the assumption regarding market share enhancement as a
result of acquiring the business drivers. Figure 9 shows the sensitivity of value to the market share
assumption. In fact, this was one of the most contentious assumptions within the firm’s top management.
Even when the projects are deemed successful (technology works, the processes run smoothly, and the
organizational changes are enacted without a hitch), the competitive conditions may prevent the firm from
realizing the planned market share gains. If a conventional DCF analysis had been used the project would
have had to generate a nearly 75% increase in market share to be viable. A business case built around such
an assumption is likely to be looked at with suspicion by senior management, who would be concerned
about potential competitor reactions. In the case of NMT, the initial $500,000 first stage was tantamount
to purchasing an option to do the second stage.

We note that in fact a third stage of investment was identified by NMT management. They considered
using Optical Character Recognition (OCR) technology to automate the conversion of the information in
the images into digital form for their transaction processing systems. The OCR investment would have
built on the process and organizational drivers that were needed for the first two stages of the imaging
project. However, using the real options approach, the nature of the project risks in this case revealed that the OCR investment was not justifiable.

5. Lessons Learned

As it turned out, NMT reached the decision point for the Stage 2 investment when economic conditions in Canada were not conducive to further development of their mortgage business. However, by staging the imaging investment, NMT had explicitly hedged this risk. The structure of the project enhanced the value of upside gains which would have been achieved if the economy had been stronger and protected NMT against downside losses. It may be argued that this is the advantage obtained from any pilot or prototyping approach, where management may decide to abort a project due to cost. However, we suggest that the real options methodology allowed NMT management to quantify both its initial and periodic assessments of project value, taking into account internal risks and market risks. The four-step cycle of identifying desired business capabilities, designing the investment program, valuing realized capabilities in terms of cash flow, and solving the decision tree provided a basis for decision-making. If they had not used the four-step methodology, NMT might have made a different decision at Stage 1 (e.g., given the strong economy prior to Stage 1, they might have elected to deploy the imaging technology for all mortgages, rather than new mortgages only). The real options method helped NMT to design an investment program that was consistent with the vision of the organization and that took into account the unpredictability of future business conditions. Moreover, the methodology motivated the definition of the business capabilities and associated operating drivers. It was necessary to identify the operating drivers in order to develop estimates of impact on future cash flows.

In the NMT case, the classic IT investment questions seem to have been answered. In order to apply the methodology, the infrastructure investment question was recast in terms of the capabilities that could be achieved. As a result of this, decision makers could perform "what-if" types of analysis, keeping in mind alternative design configurations, investment timing decisions, etc. This helps decision makers evaluate
different ways to achieve a particular capability, thereby providing them with different perspectives on the infrastructure investment. Furthermore, the methodology highlighted the need for policy planners, project managers, and financial analysts to work together to manage the investment process.

Investments were prospectively justified by a combination of “think wide” and “think long” behavior. Management focus on investment in operating drivers (the technology, process, and organizational components of the investment) accomplished two objectives. First, cost estimates across the entire organization were fully specified. Second, by thinking broadly about operating drivers, the impact on business capabilities not only became more clearly defined, but also new and broader capabilities were identified. For example, relationships with funding sources (an organizational driver) might support a new critical business capability such as home equity lending, which is not in the current list of desired capabilities. As indicated in Table 2, some drivers support the development of more than one capability. Hence, interdependencies are vital.

“Think long” behavior also helps to prospectively justify IT investment. The NMT case clearly describes how staging of investments helped this organization better cope with uncertainty. Stakeholders were able to capture the option value of managerial flexibility, which, as it turned out, increased with increasing uncertainty. This more explicitly quantified long-term view provides a stronger basis for strategic planning.

The fourth classic IT investment question -- “What more is needed to realize the investment’s full potential?” -- is in part answered by the identification of the technology, process, and organizational operating drivers necessary to create the business capability. In addition, the real options methodology allows management to understand the dynamic impact of internal and external risks in the project design as well as the contingent nature of follow-on investment decisions.

The investment management process itself provides an answer to the second question: How do we design and manage investments to ensure alignment with corporate strategy? Obviously, the concept of
periodic re-assessment of investment decisions not just operating decisions is not new. However, we also suggest that the real options methodology motivates consideration of alignment as a bi-directional process. The traditional direction is to go from investment decisions to business capabilities to operating drivers. Using the real options approach, operating drivers are considered on a broad scale in the organization, so that their potential for enhancing business capabilities is clearly identified. As a result, investment decisions may be modified based on either view of alignment.

Finally, the real options methodology provides a means of retrospectively measuring success. In particular, the methodology considers external business risk and internal project risk separately. The separation of risk provides organizations with an opportunity to assign management accountability. Project managers cannot control external conditions but do have responsibility for identifying internal risks and possible implementation outcomes. Further, by asking business managers to specify market scenarios and other changes in competitive dynamics, they take responsibility for monitoring external factors. By partitioning the retrospective analysis of outcomes into internal and external factors, planning and decision-making should improve.

The capability-based real options approach described in this paper motivates two important research questions: Will decisions change if real options thinking replaces the traditional DCF based approach for evaluating IT-infrastructure investment? Can we apply the real options approach to other contexts (e.g., across divisions in a multi-divisional firm, or to capabilities that are delivered by an alliance of firms)?

In particular, the first question becomes increasingly relevant in a environment where capability evolution is discontinuous. For example, almost any organization has multiple options to change the way it delivers value to its customers. Such changes can be radical. There can be new technologies, operating units can be outsourced, and processes can be dramatically reengineered. Technology drivers of particular interest include those that are built around intranet technology, videoconferencing, or data warehousing technology. Intranet technology represents both a major infrastructure investment for many firms as well as a potential solution to information access and intra-firm communication issues. We believe that intranet
technology is especially interesting for real options thinking because there is still substantial uncertainty
associated with this technology with respect to standards and potential applications (Gartner, 1996).
Moreover, the market has assigned substantial value to this technology. Videoconferencing is rapidly
emerging as a medium for connecting dispersed work groups at all organizational levels. Again, the
investment required to make video broadly available on the desktops is substantial, primarily because of
support (i.e., process) costs. The major uncertainty with respect to video is that people do not yet have
sufficient experience to understand applications issues (Idelson, 1996). Data warehousing is a technology
with similar characteristics (Inmon, 1996). Effective deployment is dependent on understanding these
uncertainties and therefore a systematic study will help organizations to develop and manage investment
programs. In these situations we need to evaluate whether the DCF approach, with its focus on investments
and specific paybacks rather than timing, will lead to similar outcomes as the real options approach.

In considering the real options approach in other contexts, we believe that the approach might have
particular value in inter-divisional settings and inter-organizational relationships. In particular, the
approach will be useful to evaluate investments when capabilities are transferred from one division to
another or when capabilities are jointly developed by two or more divisions. Evaluating the potential for
capability transfer is interesting because we would have the experience and data from the first
implementation context to apply to the second. The second situation raises issues that are similar to those
faced during an inter-organizational relationship.

Organizations are increasingly using alliances and partnerships to develop business capabilities.
While on the surface the methodology may appear to be directly applicable, there may also be a third
category of risk namely: interaction risk, among the participating firms. Interaction risk is the risk that
firms will not or cannot meet their obligations to their partners. In addition to the technological
incompatibilities, the firms share a second-level of market risk, in that they share each others exposure to
market uncertainties.
In this paper, we have presented a framework for dealing with the complexities of large information technology projects. By providing a means of capturing and analyzing the many internal and external uncertainties that are inherent in such projects, we are offering organizations the opportunity to derive greater value from these investments.

References


Figure 1. Transformation of capabilities into value.

Figure 2. First Stage of E-mail project
Menu of investment choices and capability outcomes is the same as above. However, optimal choices made at the decision points may be different because of value implications. The resulting cash flows will be different because of different business conditions. Menu of investment choices and capability outcomes is the same as above. However, optimal choices made at the decision points may be different because of value implications. The resulting cash flows will be different because of different business conditions.

Figure 3. Second Stage of E-mail project

Stage-1 Value

Stage-2 Value

Figure 4. Value derived at Time 1
$$V_i = E_p(V) = p_1 E_p(V) + p'_1 E_p(V)$$

$$V_i = E_q(V) = q_1 E_q(V) + q'_1 E_q(V)$$

Figure 5. Net value at Time 0

Figure 6. First Stage - Pilot Limited Number of Offices; New Mortgages Only
Menu of investment choices and capability outcomes is the same as above. However, optimal choices made at the decision points may be different because of value implications.

Figure 7. Second Stage - Expand to all offices

Figure 8. Risk profile for the Imaging Project
NPV

Market-share Enhancement

20% 40% 60% 80% 100% 120%

Project value with Options

Figure 9. The Value Impact of Options