Managing information technology investments using a 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. In this paper we develop a formal and practical methodology to evaluate information technology infrastructure investments. Our experience in using this approach has shown that it not only impacts the outcome but also improved understanding of how to align operating drivers with business capabilities and investment decisions. Thus, the real value of the real options approach is in how it informs the management process of IT investments. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

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. Recently researchers have proposed the use of the real options approach to investment decision making (Dixit and Pindyck, 1994; Kogut and Kulatilaka, 1994; Kulatilaka and Marcus, 1994).
1992) with Benaroch (Benaroch et al., 1999), Clemons (Clemons, 1991; Clemons and Weber, 1990), Dos Santos (Dos, 1991) and Kambil et al. (Kambil et al., 1993) being early examples of its application to IT investments. In this paper we go beyond the analytical tools to a management process. The result is the development of a formal and practical methodology to evaluate information technology infrastructure investments.

This methodology calls for 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,¹ 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.

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).

We link the concepts of business capability and real options using the neo-classical economist’s notion of a production possibility frontier (Varian, 1992). 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 capabilities; (3) estimate costs and benefits (in terms of cash flows) resulting from realized capabilities; and (4) fold-back 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

¹ Operating drives are the set of technologies, processes, and organizational elements that are necessary for a firm to achieve a business capability.
management view requires that firms put in place a process to enact investment management with requisite measurement metrics, monitoring schemes, and decision-making authority.

The rest of the paper is organized as follows. In Section 2, we explain 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.

Our methodology explicitly takes into consideration market uncertainties and determines the value of investments firm-wide and over time. 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.

The notion of business capability is superficially similar to the idea of core competency described by Prahalad and Hamel (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. (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 (Treacy 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 (business capability and core competencies) are similar only where an organization, such
as Wal-Mart, is essentially a single business unit. In general, business capabilities are associated with a single business unit and incorporate both tangible and intangible assets.

In our view, a business capability such as concurrent engineering (Norris, 1995) or micro-marketing (Applegate, 1993) 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; Quinn, 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. Fig. 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.

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 must make changes in technology, process, and organization. The benefits due to these changes face project-related and market-related uncertainties. Project-related risk is determined by how the firm chooses to design, implement and manage the operating drivers. Market-related risk is based on customer acceptance, competitor actions, and other factors that affect market demand for the firm’s product and services. Even if the project unfolds as expected, the resulting business capabilities may not be appropriate for the realized market conditions.

2.2.1. From capabilities to future cash flows

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 that 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.

The contingent nature of the future decisions, however, renders this approach inappropriate. 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.

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. 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. The critical insight of financial option pricing gets around this
problem by relying on the existence of a traded securities market that spans all exogenous uncertainty. The insight in financial 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 chap. 19, (Hull, 1999)).

As summarized in Table 1, the options approach deals with a complete spectrum of risks ranging, on the one extreme from the prices of traded securities, to 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 (see (Amram and Kulatilaka, 1999) for details).

3. A methodology for IT investment management

Our 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

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.
Fig. 2. First stage of e-mail project.

ms = firm’s market share of total demand Q
fc = fixed operating costs
vc = variable costs per sales unit
net cash flow = ms*Q*price - fc - vc*ms*Q

Subscript g implies good and subscript b implies bad outcome
Fig. 3. Second stage of e-mail project.
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.

Using our analytical framework, decision-makers build a decision tree 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. Figs. 2 and 3 show an example of a decision tree for e-mail deployment within a firm. In the example illustrated, 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 incremental cash flows generated by each business capability. While more sophisticated cost-benefit models can be developed, for pedagogic clarity, we use a simple cash flow model at each time period

\[
\text{Net Cash Flow} = (\text{market share}) \times (\text{total industry demand}) - (\text{fixed cost}) - (\text{per unit variable cost}) \times (\text{total industry demand})
\]

The parameters “market share,” “fixed cost”, and “per-unit-variable cost” are influenced by investments. Since making an investment does not guarantee its success, the realized parameter values depend on the success or failure of the investment stage and on the context of the investment. The “total market demand” evolves exogenously.
3.4. Valuation of the cash flows

Finally, using a dynamic programming algorithm, the event-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. For details on dynamic programming and a discussion on discount rates, see chaps. 4–9 of Amram and Kulatilaka (1999)).

4. The methodology in action: the case of National Mortgage Trust (NMT)

As a testbed for the methodology, we used a mortgage bank that was involved in making a large IT investment. In early 1994, NMT\(^3\) 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 NMTs 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 1990s — 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.

NMTs mortgage business was typical and consisted of three major business processes: originating residential mortgages, funding their mortgage commitments, and servicing these mortgages.

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\(^3\) 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.
Table 3
Operating drivers

<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>Wide-area networks (WANs)</td>
<td>Alliances with funding sources</td>
<td>Rapid application dev. Advanced training</td>
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<td></td>
<td>Packet switched networks (PSNs)</td>
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<td>Database management systems (DBMS)</td>
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<td>Imaging</td>
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<td>Workflow mgt software</td>
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<tr>
<td>Direct delivery</td>
<td>WANs</td>
<td>Multiple input sources</td>
<td>Maintenance/support</td>
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<tr>
<td></td>
<td>PSNs</td>
<td>Alliances with credit reporting agencies</td>
<td>Performance metrics</td>
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<tr>
<td></td>
<td>Imaging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MBS placement, including</td>
<td>Financial model management</td>
<td>Alliances with funding sources</td>
<td>Financial modeling</td>
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<tr>
<td>CMOs</td>
<td>Imaging</td>
<td></td>
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<tr>
<td>One-stop case servicing</td>
<td>Imaging</td>
<td>Case-based approach</td>
<td>Advanced training</td>
</tr>
<tr>
<td></td>
<td>Integrated data access</td>
<td>Team-based problem solving</td>
<td>Conversion of existing data</td>
</tr>
</tbody>
</table>
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 2).

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 mortgage-backed security (MBS) 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. Table 3 shows a list of operating drivers for each of the business capabilities identified by the top management.

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 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 management 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
Fig. 4. First stage — pilot limited number of offices; new mortgages only.
Fig. 5. Second stage — expand to all offices.
new mortgages are interest rates and Canadian business cycles. In addition, NMTs “spreads” (between the cost of funds and the mortgage interest rates) and market share were affected by regulations concerning the entry of US 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.

Figs. 4 and 5 illustrate the decision points and decision menus for the imaging project. Readers should note the increasing complexity, i.e. the number of possible outcomes increase rapidly as we go from Stage 1 to Stage 2.

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, variable costs, and market share. As the exogenous demand for mortgages 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
Table 4
Summary of cash flow impacts (all cash flow effects are incremental over prior period cash flows; Stage 2 cannot 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>
<thead>
<tr>
<th>Time-1 cash flow impact</th>
<th>Time-2 cash flow impact</th>
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<tr>
<td></td>
<td>Stage 1</td>
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<tr>
<td>Success p = 0.2</td>
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<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Failure p = 0.2</td>
<td>0</td>
</tr>
<tr>
<td>Not invest</td>
<td>0</td>
</tr>
</tbody>
</table>
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. 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 et al., 1979). Specifically, over a time interval $\tau$,

$$D_{\tau} = \begin{cases} uD_0 & \text{with probability } q \\ dD_0 & \text{with probability } 1 - q, \end{cases}$$

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, $u = 1/d = e^{\sigma \sqrt{\tau}}$ and $q = (e^{\sigma})/(u - d)$, 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
Fig. 6. Risk profile for the imaging project.
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.

In Fig. 6, the black bar denotes the outcomes generated by using the NPV technique and the checked bars indicate those generated by the real options technique. 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. Fig. 7 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 from NMT

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.
6. Conclusions

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 an 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 (Dataquest, 1996). Moreover, the market has assigned substantial value to this technology. Another example of interest is videoconferencing, which is 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. 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.

Practitioners could face several challenges while applying this methodology. The first challenge is to overcome executive bias towards traditional analytical tools and to get
buy-in for the options approach. After this is done, the difficult task of identifying the key capabilities of an organization has to be undertaken. Later the practitioner has to establish the link between a capability and change in market share. Another challenge is in estimating probabilities for each branch in the decision trees and the corresponding cash flows. Finally, a key challenge is to maintain rigor in the methodology by maintaining the process discipline.

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.

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