Chap no ?

*Using Real Options to Frame the IT Investment Problem**

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Parts of synopsis have been incorporated into opening text, probably not altogether well. Modify where appropriate.

Note numbering changed (–1) as no. 1 is now first page footnote.

Investment in IT has become a dominant part of the capital expenditure budget of many organisations in both the service and manufacturing sectors. 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 justified prospectively, and how can success be measured retrospectively? What more (than technology) is needed to realise the full potential of IT? What are the risk implications of these investments? How can the value of IT investments be managed over time? These questions are not new, but they have not been answered satisfactorily. In this chapter we develop a formal and practical methodology to evaluate investments in information technology infrastructure.

Determining the value of IT investments is inherently difficult. Although 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 on the basis of 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 organisation 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

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a knowledge-sharing Lotus Notes database for the *entire organisation*. Typically, the diffusion of e-mail across the organisation 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 example suggests, the investment may be staged so that its ultimate scope becomes organisation-wide although the initial investment point may have been 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 organisation.

In this chapter 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 such investments: considering them as a way of bridging the gap in business capabilities and considering capabilities as providing options to cope better with uncertainty. By characterising 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 recognise that value is derived from business capabilities, not merely from specific investments in technology. Continuing with the e-mail example, when viewed simply as a technology, e-mail provides 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 reorganised 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 organisations to form new alliances with their customers and suppliers. This can create new opportunities for mass customisation 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 just an investment in technology.

We summarise the first part of our proposal by arguing that the design and justification of an investment in technology must begin with the desired set of business capabilities that unfold from the overall business goals of the firm. The investment problem can then 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 (eg, technology), but also changes to human capital (eg, training) and organisational form (eg, partnerships).

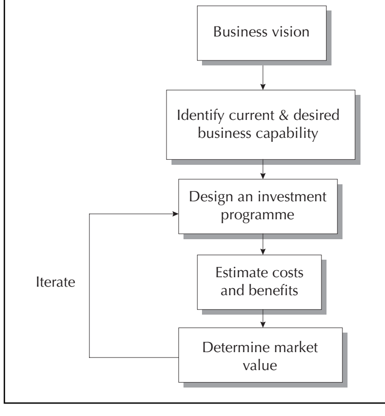
The second conceptual underpinning of our methodology recognises the real options created by the staging of investments.[1] These options create value by enabling management to react to changing conditions by altering the timing, scale and configuration of follow-on investments, thereby modifying the risk–return pattern of the investment outcomes. Using real options, decision-makers are 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, the project roll-out to other groups in the organisation can be accelerated. If conditions are good but not ideal, then a more conservative expansion plan may be pursued. If there are adverse conditions the project may need to be postponed, reconfigured or even abandoned. The procurement of the final business capability is often structured as a multistage process so that management can retain the ability to react to changing conditions on an ongoing 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 programmes.

We link the concepts of business capability and real options using the neoclassical 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 formalise our approach in a four-step process of investment design and analysis (Figure 1) that improves the alignment of the goals of information technology projects with a firm's overall business vision: (1) identify current and desired business capabilities; (2) design an investment programme to achieve the desired capabilities; (3) estimate costs and benefits (in terms of cashflows) resulting from realised capabilities; and (4) fold-back of the cashflows to obtain the market value of the investment.

Figure 1 Four-step investment design and analysis process



Implementing the real options approach requires periodic monitoring, re-evaluation and redesign of the investment programme. 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 implementation of the technology without adequate consideration of the appropriateness of the project in light 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 the requisite measurement metrics, monitoring schemes and decision-making authority.

The rest of the chapter is organised as follows: in the first section, we elucidate the concept of a business capability and describe it in terms of the constituent *operating drivers* of technology, organisation and process. The second section develops the four-step methodology and presents the rudiments of the real options valuation technique. In the third section, we illustrate the proposed investment management process by analysing how a Canadian mortgage banking firm leveraged imaging technology to build several important business capabilities. Finally, the fourth section concludes with the lessons learned and future research plans.

CHARACTERISTICS OF IT INVESTMENTS

IT infrastructure investments are highly risky to make but can offer huge rewards to a firm. Current evaluation practice to evaluate such investments falls into two traps: the trap of negative net present value (NPV) or the trap of vanishing *status quo* (Clemons, 1991). The first trap arises from the difficulty of identifying future benefits and of estimating them accurately 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 rejecting valuable opportunities. This could result in loss of market share and other bad outcomes due to actions by competitors.

In this chapter we introduce a methodology that explicitly takes into consideration market uncertainties and determines the value of investments on the basis of their impact firm-wide and over time. Further, we deal with IT investments at an organisational level and argue that IT, along with other operating drivers whose effects are influenced by uncertainties, enables the organisation to achieve a set of capabilities. These capabilities in turn have an effect 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, which can also be used to manage the investment process.

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 organisation through a series of identifiable cashflows. Thus, business capabilities distinguish an organisation from others and directly affect its performance.

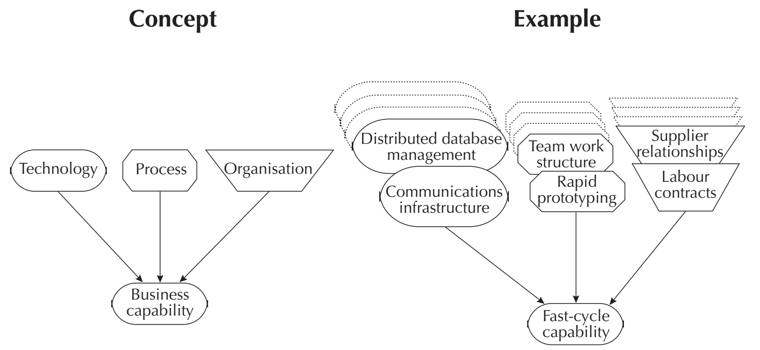
For example, Boeing's new concurrent design and manufacturing approach gives it the ability to deliver the 777 jetliner much more rapidly than under the conventional "design-then-build" paradigm (Norris, 1995). Engineers, marketing personnel and financial analysts from Boeing's airline customers actively participated in the design of this aircraft almost from the beginning of the project. Concurrent design and manufacturing has become a business capability for Boeing.

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

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 these 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 organisational components.

The effectiveness of a technology investment depends to a great extent on how work is organised around that technology (Kogut and Kulatilaka, 1994; National Academy Press, 1994). Furthermore, the structure of the organisation, 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 organisational 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; by the process component we mean procedures, workflows, management controls and human resources practices; and the organisational component includes relationships with other firms as well as the internal management structure. Figure 2 shows the relationship between business capabilities and operating drivers. It is the interaction of these business capabilities with market forces that creates value.

Figure 2 Business capability components



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 organisational changes. The benefits from investments depend 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 organisation may be more difficult than foreseen, or there may be cost overruns 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 products and services. In this case, even if the project unfolds as expected, the resulting business capabilities may not be appropriate for the realised 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, analyse and manage both sources of risk and manage them over time.

From capabilities to future cashflows

Capabilities alone do not generate cashflows. External market conditions and the firm's operating policies are also determinants of cashflows. Capabilities, however, determine management's ability to react to evolving market conditions.

More specifically, investing in operating drivers and acquiring a set of capabilities influence the firm's cost structure (eg, by increasing fixed costs and reducing variable costs) and its revenue sensitivity (eg, market share).

The capability analysis forms the foundation for building the cashflow models that are essential to any pro-forma cost–benefit analysis. Typical practice, however, entwines the cashflow effects of investments with a particular market scenario. For example, the cost reduction derived from an imaging project 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 cashflow model which includes the exogenous market conditions as variables. For instance, if uncertainty stems from the total size of the market for the product, a new capability may affect 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 cashflows that are generated under all potential future capabilities, investments and market contingencies.

Valuation of contingent cashflows

If a conventional discounted cashflow (DCF) valuation analysis were followed, we would first forecast the future cashflows, compute the expected cashflows, and then discount at the risk-adjusted opportunity cost of capital to obtain the present value. With a model that links capabilities to cashflow in hand, the valuation model requires only the growth rate (to forecast expected future cashflows) and the "beta" of the cashflows (to capture the systematic risk for the opportunity cost of capital). When an equilibrium market model (eg, a capital asset pricing model – 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 realised business conditions, it is not sufficient to focus on the expected growth rate of the uncertain variable. The future cashflows depend on the management's reactions to the particular realisation 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 cashflows are mapped out, the valuation and the optimal investment decisions can be obtained simultaneously by solving the event decision cashflow 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 (eg, volatility) that determine the probability structure of the future cashflow outcomes.

However, a further complication arises in the determination of the opportunity cost used in discounting the expected future cashflows. 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 that spans all exogenous uncertainty.[2] 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 eliminates the need for risk adjustment and valuation does not rely on a risk pricing model such as the 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 the 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 (Hull, 1999). In such cases the replication argument must be modified to overcome the risk-adjustment problem. 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.[3]

In summary, the real options approach deals with a complete spectrum of risks ranging from, at one extreme, the prices of traded securities and, at the other, unique events. Wherever possible, market information is used.

Table 1 Summary of risk evaluation techniques

Source of risk	Information required to value contingent claims	Analytic method
Prices of market-traded securities	Current prices, volatility	Black–Scholes and other financial option pricing models
Product/service or input market-related risk (eg, prices of goods and services, market size)	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	Risk-neutral "decision trees" (eg, binomial models)
Unique events affecting the firm (project-related risk)	History-based or subjective probability estimates of events	Risk-neutral decision trees

The information requirements as well as how the information is processed are markedly different from the more traditional DCF, decision-tree or simulation models. Table 1 summarises the spectrum of risks and the valuation methods.

A METHODOLOGY FOR IT INVESTMENT MANAGEMENT

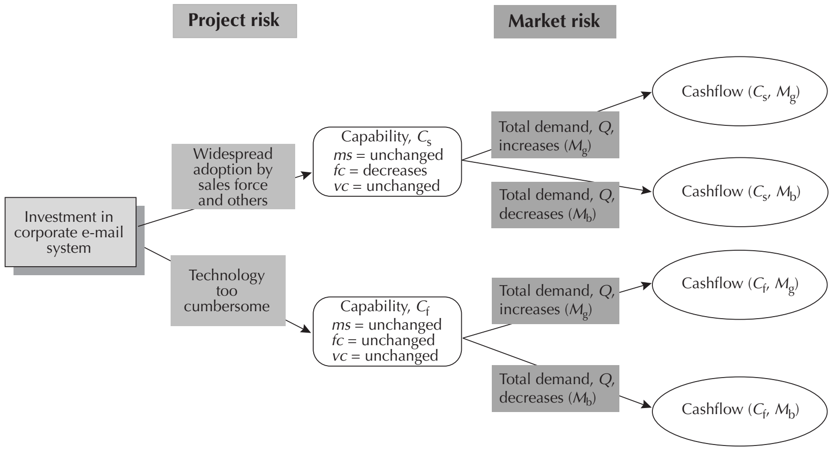
Our methodology consists of four steps: identification of current and desired business capabilities; design of a contingent investment programme to achieve the desired capabilities; estimation of the costs and benefits of realised capabilities in terms of cashflows; and evaluation of cashflows to obtain a value for the investment.

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 business capability 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/no-go decision at each stage is contingent on 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 downside losses and capture (or even enhance) the upside benefits.

Figure 3 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 cashflow = $(ms \times Q \times price) - fc - (vc \times ms \times Q)$

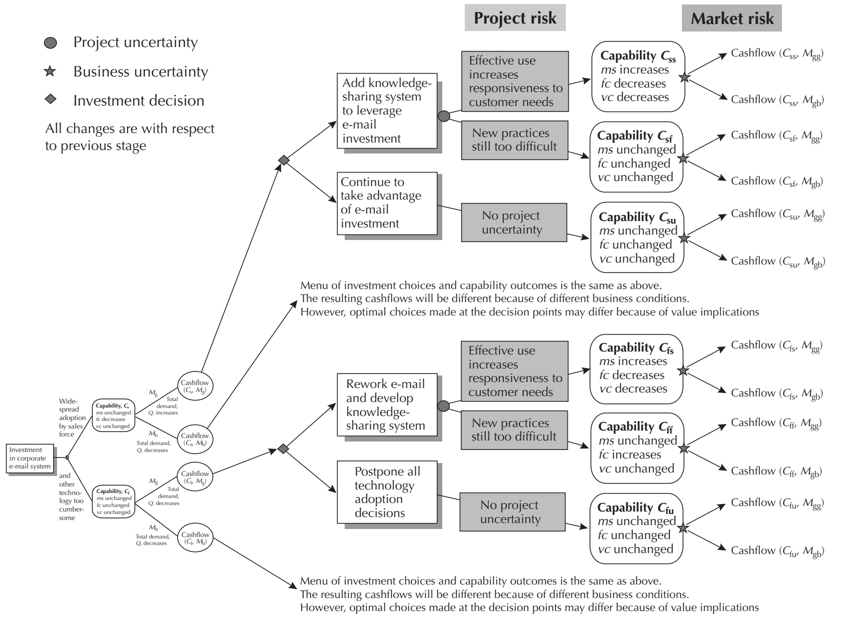
Design of an investment programme

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 characterise 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 those envisioned.

Let us revisit the e-mail project considered at the beginning of the chapter, where the investment is made in two stages. In Stage 1, workgroup 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 (Figures 3 and 4) by determining the menu of choices at each decision point based on the 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 cashflow outcomes at the end of Stage 2, which the decision-maker should evaluate. This valuation technique is described in the next section.

Figure 4 Second stage of e-mail project



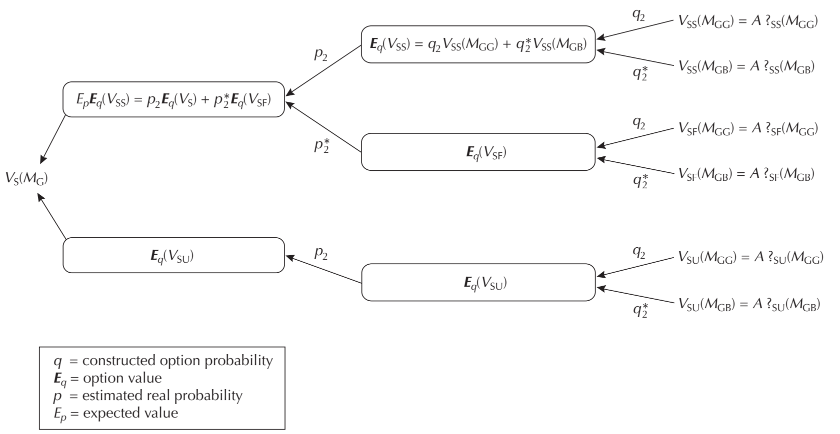
Estimation of cashflows

The third step in the investment management process involves determining the value associated with each business capability. We analyse the value impact at the overall firm level. Although more sophisticated cost–benefit models can be developed, for pedagogic clarity we use a simple cashflow model at each time period. Suppose that the firm faces an industry demand D. The firm's share of the market is ms. The firm's revenues are therefore the fraction, ms, of the total industry demand, D (ie, $Revenues = ms \times D$).[4]

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. 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 costs.[5] We capture this effect through the per-unit variable cost parameter, vc. Hence, the total variable cost is $vc \times ms \times D$, and the resulting net cashflow, π, is given by $(ms \times D) - fc - (vc \times ms \times D)$.

Figure 5 Value derived at time 1



Note on Figures: subscripts g, b, s, u were upper case from Fig 5; ext has lower. Which to use? Easy to fix.

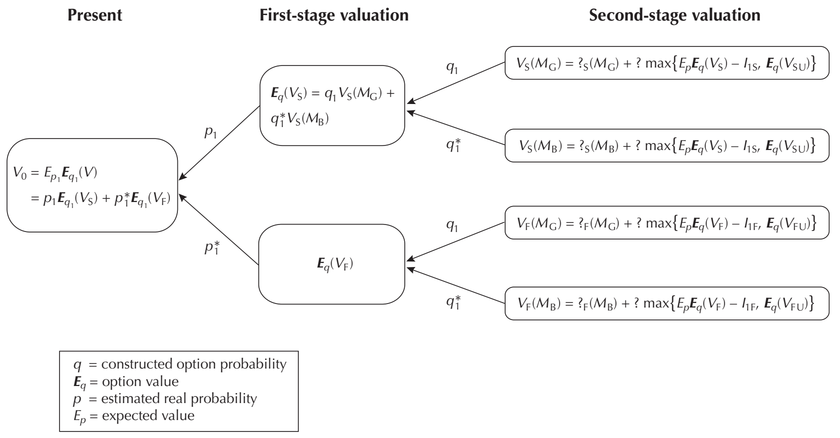
The parameters *ms*, *fc* and *vc* are influenced by making investments in operating drivers. Since making an investment does not guarantee its success, the realised partakers depend on the success or failure of the investment stage and on the context of the investment.[6] Although the investments position the firm in the market, the realised cashflow depends crucially on the realisation of the exogenous uncertain demand, *D*.

Evaluation of the cashflows

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 cashflows computed from the cashflows 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 4).[7] For instance, suppose that both investment stages are committed as planned and implemented successfully, and that the external business conditions turn out to be advantageous to the firm in both periods.[8] Then the firm will receive net incremental cashflow $\pi_s(M_g)$ in year 1 and $\pi_{ss}(M_{gg})$ in year 2, where the subscripts on π, the cashflow function, denote project success (s) or failure (f), and the subscripts on M denote market outcomes good (g) or bad (b). Figure 4 shows the year-2 cashflows 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 cashflow multiplied by

Figure 6 Net value at time 0



the present value annuity factor, A. For example, the year-2 value under the most optimistic scenario discussed above is $V_{ss}(M_{gg}) = A\pi_{ss}(M_{gg})$.

Once the contingent value at the terminal date (planning horizon) is known, we can solve the dynamic programme 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 (Figures 5 and 6). Consider the year-1 value if the first stage is successful and the market turns out favourably, $V_s(M_g)$. This value would be the incremental cashflow received at year 1 plus the present value of the expected cashflows from following an optimal investment decision thereafter. The menu of decisions at this node is to continue with the proposed expansion at a cost of I_{1s} or abandon the expansion plan. The expected values under the cashflows from the two decisions are as follows.

If expansion is undertaken:

$$V_s(M_g) = \pi_s(M_g) - I_{1s} + \rho p_{2s}\boldsymbol{E}_{q_2}\{V_{ss}(M_g)\} + (1 - p_{2s})\boldsymbol{E}_{q_2}\{V_{sf}(M_g)\}$$

$$= \pi_s(M_g) - I_{1s} + \rho E_{p_1}[\boldsymbol{E}_{q_2}\{V_s(M_g)\}]$$

and if expansion is rejected:

$$V_s(M_g) = \pi_s(M_g) + \rho\boldsymbol{E}_{q_2}\{V_{su}(M_g)\}$$

where $E_p(\cdot)$ is the expectations operator, $\boldsymbol{E}_q(\cdot)$ is the "option value" operator,[9] ρ is the risk-free discount factor, p_{2s} is the probability of successfully implementing the investment $I_{1\mathrm{s}}$, and subscripts s, f and u on V denote values under success, failure and unchanged capability sets, respectively. Management will choose the decision to maximise value. Hence,

$$V_{\mathrm{s}}(M_{\mathrm{g}}) = \max\left[\pi_{\mathrm{s}}(M_{\mathrm{g}}) - I_{1\mathrm{s}} + \rho\, E_{p_2}\boldsymbol{E}_{q_2}\left\{V_{\mathrm{s}}(M_{\mathrm{g}})\right\},\ \pi_{\mathrm{s}}(M_{\mathrm{g}}) + \rho\,\boldsymbol{E}_{q_2}\left\{V_{\mathrm{su}}(M_{\mathrm{g}})\right\}\right]$$

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

$$V_{\mathrm{s}}(M_{\mathrm{b}}) = \max\left[\pi_{\mathrm{s}}(M_{\mathrm{b}}) - I_{1\mathrm{s}} + \rho\, E_{p_2}\boldsymbol{E}_{q_2}\left\{V_{\mathrm{s}}(M_{\mathrm{b}})\right\},\ \pi_{\mathrm{s}}(M_{\mathrm{b}}) + \rho\,\boldsymbol{E}_{q_2}\left\{V_{\mathrm{su}}(M_{\mathrm{b}})\right\}\right]$$

$$V_{\mathrm{f}}(M_{\mathrm{g}}) = \max\left[\pi_{\mathrm{f}}(M_{\mathrm{g}}) - I_{1\mathrm{f}} + \rho\, E_{p_2}\boldsymbol{E}_{q_2}\left\{V_{\mathrm{f}}(M_{\mathrm{g}})\right\},\ \pi_{\mathrm{f}}(M_{\mathrm{g}}) + \rho\,\boldsymbol{E}_{q_2}\left\{V_{\mathrm{fu}}(M_{\mathrm{g}})\right\}\right]$$

$$V_{\mathrm{f}}(M_{\mathrm{b}}) = \max\left[\pi_{\mathrm{f}}(M_{\mathrm{b}}) - I_{1\mathrm{f}} + \rho\, E_{p_2}\boldsymbol{E}_{q_2}\left\{V_{\mathrm{f}}(M_{\mathrm{b}})\right\},\ \pi_{\mathrm{f}}(M_{\mathrm{b}}) + \rho\,\boldsymbol{E}_{q_2}\left\{V_{\mathrm{fu}}(M_{\mathrm{b}})\right\}\right]$$

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

Sentence seems to be missing something.

Continuing with the dynamic programme 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

$$V(M_0) = -I_0 + \rho\, E_{p_1}\boldsymbol{E}_{q_1}\{V(M)\}$$

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

Thus far we have considered one possible investment configuration (ie, design). Typically, we would like to compare several mutually exclusive alternative investment designs.[10] For each such design an analysis similar to the above needs to carried out to arrive at the respective net present value.

While the current value, V_0, appropriately includes the risks of the staged investment programme, 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 possible reactions to future contingencies, the risk profile facing the firm is likely to be significantly modified when compared to a naïve take-it-all-or-leave-it investment design.

For instance, consider the top branch in Figure 4. For the investment stream of I_0 and I_1, to yield $\pi_{\mathrm{s}}(M_{\mathrm{g}})$ in year 1 and $\pi_{\mathrm{ss}}(M_{\mathrm{gg}})$ in year 2 (and some residual based on π_{ss} thereafter), Stage 1 investment must succeed, the year-1 market must be good, Stage 2 investment must be made and be successful, and the 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 cashflows provides the organisation with a process for managing risk.

THE METHOD IN ACTION: THE CASE OF NMT

As a testbed for the methodology we use a mortgage bank that was involved in making a large IT investment. In early 1994, National Mortgage Trust[11] (NMT) was a relatively small but aggressive financial institution that specialised in mortgage-backed lending in Canada. Its head office was in Montreal, with branches in Halifax, Toronto and Ottawa. Over the previous seven years NMT's assets had grown from zero to about C$6 billion, and many would say that it was a good example of a successful organisation in the 1990s – flat, fast, customer-orientated, and dedicated to a process of continuous learning and improvement. Within its industry NMT was viewed as a leader in the use of information technology, innovative work processes and management systems. It was also considered to be aggressive in the 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 its mortgage commitments and servicing these mortgages. Customers were reached directly through the branch offices, via realtors (estate agents) and with the aid of mortgage brokers. Like other firms in the industry, NMT offered customers relatively few mortgage financing choices. Current offerings were limited to two or three fixed-rate plans and about the same number of variable-rate plans. The following paragraphs summarise the three basic business processes of mortgage origination, funding and servicing.

Mortgage origination begins with the customer reaching agreement on a price with the seller of a property. If the customer has decided to finance the purchase through NMT rather than another financial institution (eg, a commercial bank), an application is submitted. NMT now has to obtain a range of information in order to approve or deny the application. Using the telephone, fax and mail, NMT verifies employment, marital status, credit history and bank balances. Property inspections, surveys, appraisals and title searches are also necessary. If there are no major problems, this process takes 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 the 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. These, of course, require evidence of a careful credit review process and supporting documentation to minimise 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 questions relating to status and file completion. These questions are handled by people within NMT who are responsible for each of the major activities in the approval process. Following closing, customers may also call 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 organisation, who often have to call the customer back after retrieving the required documentation.

NMT's capability gap

At the time we began studying NMT, the top management summarised NMT's current state and desired business capabilities as follows (Table 2).

Table 2 Transformation of capabilities

Current state	Desired business capabilities
Small menu of mortgage options	Mass customisation
Branches/brokers/realtors as channels	Direct delivery
Standardised, simple mortgages for resale	MBS placement, including CMOs
Fragmented, activity-orientated servicing	One-stop case servicing

By identifying mass customisation as a desired capability, NMT recognised that with diverse end-user need profiles, there was an opportunity to gain market share by delivering mortgages that were customised 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 home-owners rather than marketing via mortgage brokers and other intermediaries. The need to build MBS (mortgage-backed security) placement capability was an outcome of mass customisation. 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 collateralise these varied term mortgages 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 was in progress, was designed to support this goal.

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.

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

Table 3 Operating drivers

Desired business capabilities	Technology	Organisation structure	Process
Mass customisation	WANs PSNs DBMS Imaging Workflow management software	Alliances with funding sources	Rapid application development Advanced training Market survey/ scanning Performance metrics
Direct delivery	WANs PSNs Imaging	Multiple input sources Alliances with credit reporting agencies	Maintenance/support Performance metrics
MBS placement, including CMOs	Financial model management	Alliances with funding sources	Financial modelling
One-stop case servicing	Imaging Integrated data access	Case-based approach Team-based problem solving	Advanced training Conversion of existing data

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:

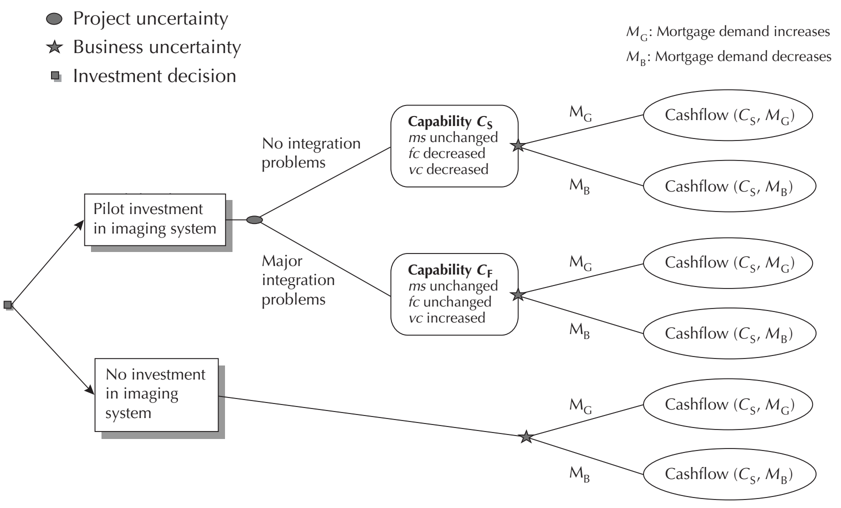
1. Implement the document imaging processing technology in a limited number of offices using off-the-shelf software, but implement it only for new mortgages.
2. Expand the data-capture capability to all offices and scan in all pre-existing mortgages. Also, design and implement new workflows throughout 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 mortgage interest rates) and market share were affected by regulations concerning the entry of US mortgage banks and the large Canadian commercial banks.

Entry into something?

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

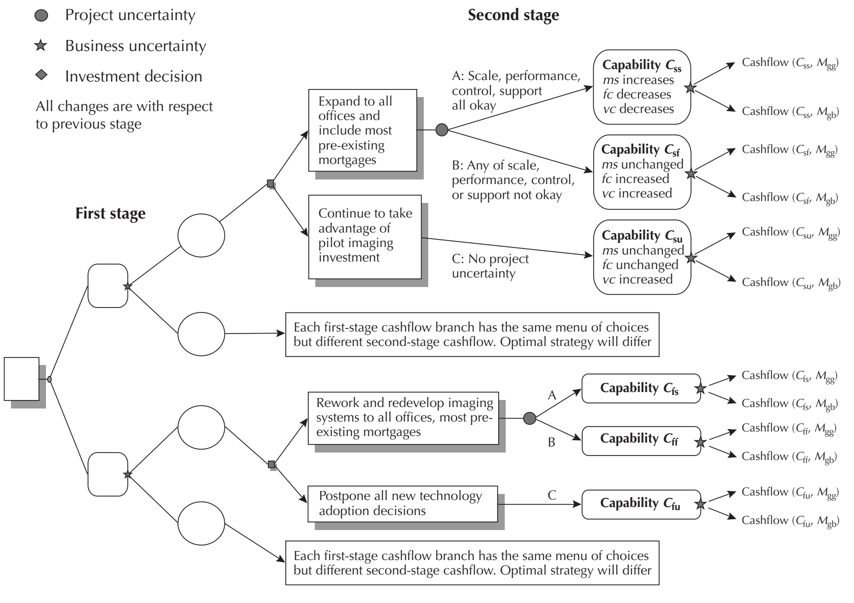
Figure 7 First stage: pilot limited number of offices; new mortgages only



were necessary to keep the imaging system operational. During Stage 2 the project risks were somewhat more varied, now including software/hardware performance and scaling issues. Since the data-capture capability was being extended to all offices, NMT could now be faced with a broader range of integration issues. It would also encounter control issues in converting the old documentation – ie, making sure that all 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 could now define decision points and decision menus for the imaging project. These are summarised in Figure 7. Note that the two alternatives facing the decision-makers were to invest in an imaging system and not to invest in one. The figure describes the potential impact of the internal and external uncertainties on capabilities and cashflows. 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 (Figure 8). The probability estimates for each branch in Figures 7 and 8 and the expected cashflows 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.

Figure 8 Second stage: expand to all offices



From capabilities to value

The above capability analysis provided the necessary inputs to developing contingent cashflow. Following the simple cashflow-modelling structure presented in the third section, the aggregate (firm-wide) cashflow 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 cashflows to the firm were affected according to the capability that was in place.

At the time of the case study, NMT generated annual revenues of C$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, 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 be felt only 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 expect any change in market share, again because improvement in mortgage servicing would occur only for new mortgages in a few geographical markets. If Stage 1 failed, 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 materialise.

Estimates for the second stage of investment were developed as follows. If success in Stage 1 were followed by success in Stage 2, 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, fixed costs were projected to increase by 80%. Management believed that variable costs would fall 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 preoccupied with making the new systems work and because of negative customer perceptions about NMT's ability to service their accounts.

NMT also made estimates of impacts on cashflow 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

Table 4 Summary of cashflow impacts

	Time–cashflow impact				**Time–cashflow impact**		
Stage 1	***ms***	***fc***	***Vc***	**Stage 2**	***ms***	***fc***	***vc***
Success $p = 0.8$	0%	2%	−2%	Success $p = 0.8$	50%	100%	−10%
				Failure $p = 0.2$	−5%	80%	−5%
				Not invest	–5%	0%	0%
Failure $p = 0.2$	0%	2%	0%	Success $p = 0.7$	50%	100%	−5%
				Failure $p = 0.3$	−5%	80%	0%
				Not invest	−5%	0%	0%
Not invest	0%	0%	0%	Not invest	−5%	0%	0%

Notes: All cashflow effects are incremental over prior-period cashflows.
Stage 2 cannot be done without having done stage 1.
If stage 1 fails, stage 2 investment cost increases by 25% (to account for redoing parts of stage 1).
If stage 1 is not undertaken, it can be accelerated and implemented together with stage 2 at 50% higher cost and a lower probability of success (70%).

fall by 5%. This reduction 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, 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%, again mainly because staff would be preoccupied with making the new systems work and because of negative customer perceptions.

The impact of procuring capabilities is modelled via changes in the cost structure and the ability to generate revenues ("market share"). These assumptions are summarised in Table 4.

As described in the second section, in addition to modelling cashflows we also modelled sources of uncertainty, as follows. Total market demand for mortgages was assumed to follow a lognormal distribution with an annual standard deviation of 35% – ie, 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, σ, was based on the volatility of Canadian interest rates. If instead we had used GNP as a proxy for the mortgage demand, 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 lognormal distribution. Specifically, over a time interval τ

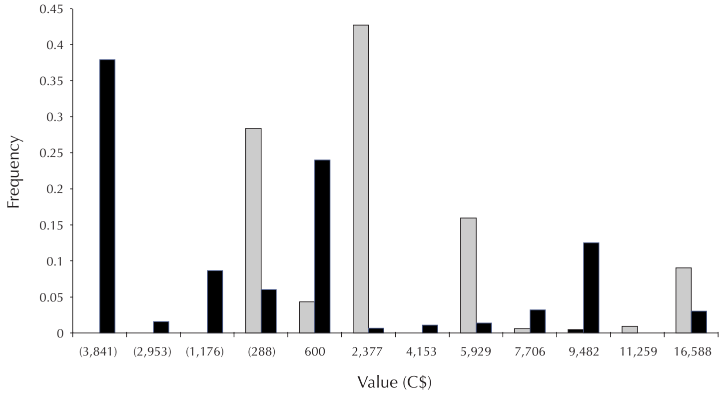
$$\begin{aligned} D_\tau &= uD_0 \qquad \text{with probability } q \\ &= dD_0 \qquad \text{with probability } 1 - q \end{aligned}$$

where u and d are the coefficients, chosen such that, for time interval τ, the expected return from the investment in time τ is $u\tau$ and the variance of the return is $\sigma^2\tau$. Also, $u = 1/d = e^{\sigma\sqrt{\tau}}$ and $q = (e^{r\tau} - d)/(u - d)$, 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. Utilising 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 success of the second stage is independent of the outcome of the first stage. This assumption can easily be relaxed. The cost of the Stage 1 investment was estimated to be C$500,000; Stage 2 was projected at C$5 million.

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

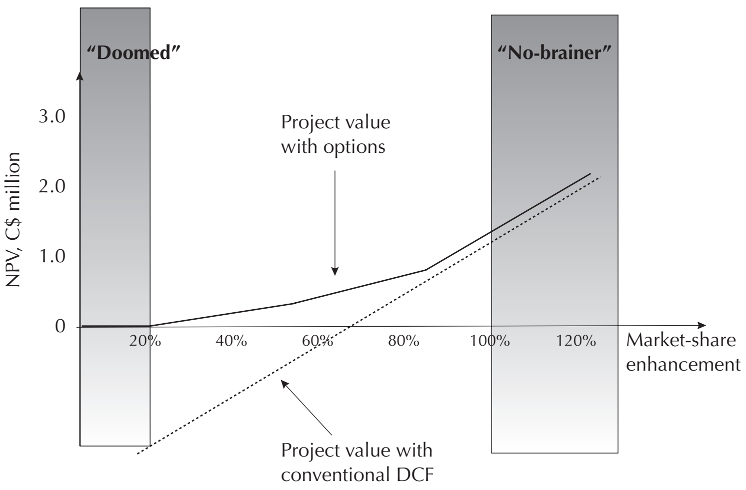
Figure 9 Risk profile for the imaging project



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 9). By staging the investment and making the follow-on decisions contingent on the realisation 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 can use its investment flexibility to capture the upside benefits. Nevertheless, the project may still 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 redesign the project to minimise such losses.

The project value is most sensitive to the assumption of market share enhancement as a result of acquiring the business drivers. Figure 10 shows the sensitivity of value to this assumption. In fact, this was one of the most contentious assumptions within the firm's top management. Even when a project is deemed successful (the technology works, the processes run smoothly and organisational changes are enacted without a hitch), competitive conditions may prevent the firm from realising the planned gain in market share. If a conventional DCF analysis had been used, the project would have had to generate nearly a 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

Figure 10 The value impact of options



about possible reactions by competitors. In the case of NMT, the initial C$500,000 outlay for the first stage was tantamount to purchasing an option to undertake 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 organisational 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 investment in OCR was not justifiable.

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 its 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 that would have been achieved if the economy had been stronger and it protected NMT against downside losses. It may be argued that this is the advantage of 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 programme, valuing realised capabilities in terms of cashflow and solving the decision tree provided a basis for decision-making. If it had not used the four-step methodology, NMT might have made a different decision at Stage 1 (eg, 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 programme that was consistent with the vision of the organisation and 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 the impact on future cashflows.

In the NMT case, the classic IT investment questions seem to have been answered. 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 to evaluate different ways of achieving a particular capability, thereby providing them with different perspectives on the investment in infrastructure. Furthermore, the methodology highlighted the need for policy planners, project managers and financial analysts to work together to manage the investment process.

Prospectively, investments were justified by a combination of "think wide" and "think long" behaviour. Management focus on investment in operating drivers (the technology, process and organisational components of the investment) accomplished two objectives. First, cost estimates across the entire organisation were fully specified. Second, by thinking broadly about operating drivers, not only did the impact on business capabilities become more clearly defined but new and broader capabilities were also identified. For example, relationships with funding sources (an organisational 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" behaviour also helps to prospectively justify IT investment. The NMT case shows clearly how the staging of investments helped this organisation to cope better 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 realise the investment's full potential? – is in part answered by the identification of the technological, process and organisational 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 reassessment of *investment* decisions, and not just operating decisions, is not new. However, we also suggest that the real options methodology motivates consideration of alignment as a bidirectional 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 organisation, so their potential for enhancing business capabilities is clearly identified. As a result, investment decisions may be modified on the basis of either view of alignment.

Finally, the real options methodology provides a means of measuring success retrospectively. In particular, the methodology considers external business risk and internal project risk separately. The separation of risk provides organisations with an opportunity to assign management accountability. Project managers cannot control external conditions but they do have responsibility for identifying internal risks and possible outcomes of implementation. 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 chapter suggests two important questions for further research: Will decisions change if real options thinking replaces the traditional discounted cashflow-based approach for evaluating investment in IT infrastructure? And, Can we apply the real options approach to other contexts – eg, across divisions in a multidivisional firm, or to capabilities that are delivered by an alliance of firms?

In particular, the first question becomes increasingly relevant in a environment where the evolution of capabilities is discontinuous. For example, almost any organisation 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 totally re-engineered. Technology drivers of particular interest include those built around intranet technology, videoconferencing or data warehousing technology. Intranet technology represents both a major infrastructure investment for many firms and a potential solution to information access and intra-firm communication issues. We believe that intranet technology is especially interesting for real options thinking because substantial uncertainty is still associated with the technology with respect to standards and potential applications (Gartner Group, 1996). Moreover, the market has assigned substantial value to this technology. Videoconferencing is rapidly emerging as a medium for connecting dispersed workgroups at all organisational levels. Again, the investment required to make video broadly available on the desktop is substantial, primarily because of support (ie, 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 a systematic study will therefore help organisations to develop and manage investment programmes. In these situations we need to evaluate whether the DCF approach, with its focus on investments and specific paybacks rather than timing, will identify outcomes similar to those obtained with the real options approach.

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

Organisations are increasingly using alliances and partnerships to develop business capabilities. Although on the surface the methodology may appear to be directly applicable, there may also be a third category of risk – namely, interaction risk. This is the risk that participating firms cannot or will not meet their obligations to their partners. In addition to technological incompatibilities, the firms share a second-level of market risk in that they share each other's exposure to market uncertainties.

In this chapter, we have presented a framework for dealing with the complexities of large information technology projects. By providing a means of capturing and analysing the many internal and external uncertainties that are inherent in such projects, we are offering organisations the opportunity to derive greater value from these investments.

1 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. See Amram and Kulatilaka (1999).

2 Note that it is the existence of the market and the possibility of replication, rather than actually carrying out the replication, that allow options to be priced in an arbitrage-free fashion.

3 For additional information see Amram and Kulatilaka (1999).

4 Where the output price is normalised 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.

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 that are explicitly considered in the valuation.

9 This is operationally equivalent to taking risk-neutral expectations over the possible market outcomes and discounting at the risk-free 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 using an equilibrium asset pricing model. See Chapter 6, Hull (1994) or Dixit and Pindyck (1995). A tutorial on the risk-adjustment techniques is presented in Kulatilaka and Marcus (1992).

Note 9:
- 'Ch 6' refers to this book?
- No Hull 1994 in biblio and D & P given there as 1994.

10 One such choice is to recognise the ability to postpone the project.

11 National Mortgage Trust is a pseudonym for a real organisation. The events described here are based on a case study conducted by one of the authors together with John Henderson, 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.

Pls complete refs as indicated.

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