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In an effort to improve on the evaluation of IT investments in the AEC industry, this thesis develops a structured evaluation framework and analysis model for evaluating IT platform investments. Many IT investments have platform properties in the sense that they are essential requirements for further technology investments. IT Platform investments however, often do not generate sufficient benefits to be justified as standalone investments. These investments may nevertheless be shown to be profitable when contingent future investments are included in the analysis. The traditional capital budgeting methods are nevertheless not suitable for capturing the full benefits, risk and costs of IT platform investments.

The framework developed in the thesis provides a practical approach to analyse IT investments in terms of their impact on the firm's business capabilities. The focus is therefore not limited to the technology itself but on the combination of technology, business process design and the organisational restructuring necessary to generate a desired capability. The thesis develops an accessible and comprehensive Real Options analysis model for evaluating IT platform investments. The analysis model can be seen as an extension of the traditional Discounted Cash Flow analysis approach that incorporates sensitivity analysis and Monte Carlo simulation techniques, with a binomial lattice model derived from Option Pricing Theory.

The framework and analysis model are applied on a real investment case, which is based on a number of interdependent IT investment projects at a large global construction company. The application of the analysis model shows that the value of IT platform investments are considerably higher than traditional DCF analysis suggest

Key words: IT evaluation, Risk Analysis, AEC, Real Options Analysis, Platform Investment, Staged Investment, Compound Options

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Every day you may make progress. Every step may be fruitful. Yet there will stretch out before you an ever-lengthening, ever-ascending, ever-improving path. You know you will never get to the end of the journey. But this, so far from discouraging, only adds to the joy and glory of the climb.

Sir Winston Churchill (1874 - 1965)

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CHAPTER 1   Introduction

For myself I am an optimist - it does not seem to be much use being anything else

Sir Winston Churchill (1874 - 1965)

The last decade of the 20th century marked an important milestone in the information technology (IT) revolution. In 1991 American companies for the first time spent more on IT related investment than on investment in industrial, mining, agricultural, and construction machines combined (Stewart and Furth 1994). Since the introduction of computer technology into the mainstream corporate life, spending on IT grew continuously until peaking in the year 2000. This was followed by a slight downward trend in spending which reversed in 2003 (Davis, Rath et al. 2004). The World Information Technology and Service Alliance (WITSA) projects that global spending on IT will continue to increase on a steady path through 2007 (WITSA 2004). Despite heavy spending on information technology, the value of IT investments remains a heavily debated concern in both corporate boardrooms and academic circles. Few question however, that information technology has had a profound impact on organisations and productivity in many industries. Studies have shown a rapid rate of investment in IT in virtually every area from the manufacturing and financial industries to the healthcare sector (Ammenwerth, Kaiser et al. 2002). One sector in particular, however stands out in this development. This is the construction sector, which is typically defined to include Architecture, Engineering, and Construction (AEC) organisations.

Recent surveys have shown a relatively wide spread adoption of typical back office IT systems[1] by AEC organisations (Samuelson 1998; Andresen 1999; Samuelson 2001). However, the sector as a whole appears to remain surprisingly resistant to some important business transformations displayed in consolidation, productivity improvement and globalisation in typical benchmark industries such as automotive, aerospace and discreet manufacturing (Schwegler, Fischer et al. 2001). There is presumably no simple explanation to account for this. One interesting observation is that the overall rate of investment in IT is remarkably low in the sector. Andresen (2001) found that most Danish contractors spend less than 0,5% of their turnover on IT related investments[2]. Comparable surveys on the Swedish construction sector show similar spending levels of AEC firms (Howard, Kiviniemi et al. 1998; Samuelson 1998; 2001). International surveys further confirm that the industry as a whole lacks considerably behind most other industries in the rate of IT investment (WITSA 2004). This applies both to the rate of investment in absolute terms (Figure 1) and as percentage of total spending (Figure 2). In fact, only firms in the agriculture and mining industries invest less in information technology than firms in the construction industry. This is especially interesting considering that the construction industry is the single largest industry in the United States accounting for roughly 8 per cent of the gross domestic product and employing more people than any other industry (ENR 2000).

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[1] Back office systems generally refer to the computer infrastructure within an organisation that supports core business process applications but has no interaction with external stakeholders

[2] The study further showed that Engineering and Architect companies spend a noticeably larger part of their revenues, on average between 2% - 4%. Some of this difference is perhaps explained by the fact that construction contractors turnover generally comprise the gross value of the construction projects while the earnings of Engineering and Architect consultants are typically based on fixed fees. These specialised consultancy firms further normally invest in relatively expensive expert application systems such as Computer Aided Design (CAD).
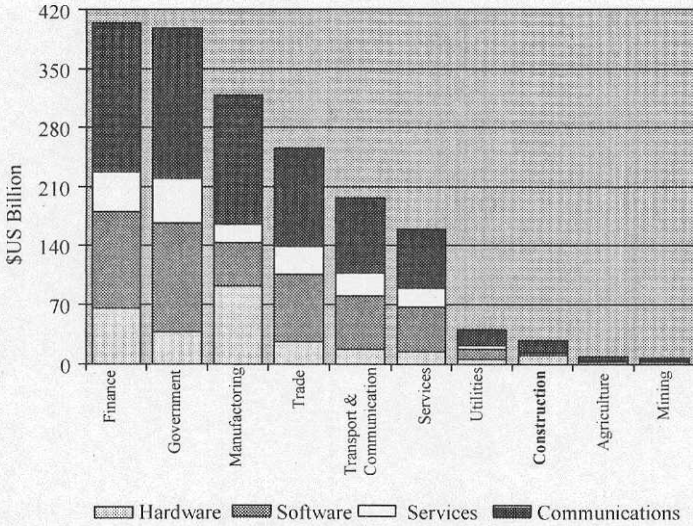
Figure 1: Global IT Spending by Industry Segment in 2003. Source: WITSA (2004)

Figure 1 shows the total level of spending on IT across industry segments by the 70 nations and regions that spent most on information technology in 2003 (WITSA 2004). The figure clearly shows that the level of spending is unevenly distributed across industry segments. Firms in the financial sector appear to spend most on IT in absolute terms, while Figure 2 shows that the public sector is the largest spender when looking at investments as a percentage of output.

The industry segments also differ in terms of the distribution of investments for the four technology groups (hardware, software, services and communications) represented in the data. IT investment in the construction industry appears to be most concentrated in communication technology and hardware while spending on software and services is low. This is consistent with data from other studies on the Scandinavian AEC sector, which show that roughly 50% of all employees in the sector have access to their own computer and mobile phones at their workplace (Samuelson 1998; 2001). The use of software applications is primarily focused on accounting and invoicing systems, and spreadsheet and word processing applications (Howard 1998; Howard, Kiviniemi et al. 1998; Samuelson 1998; Howard 2001).
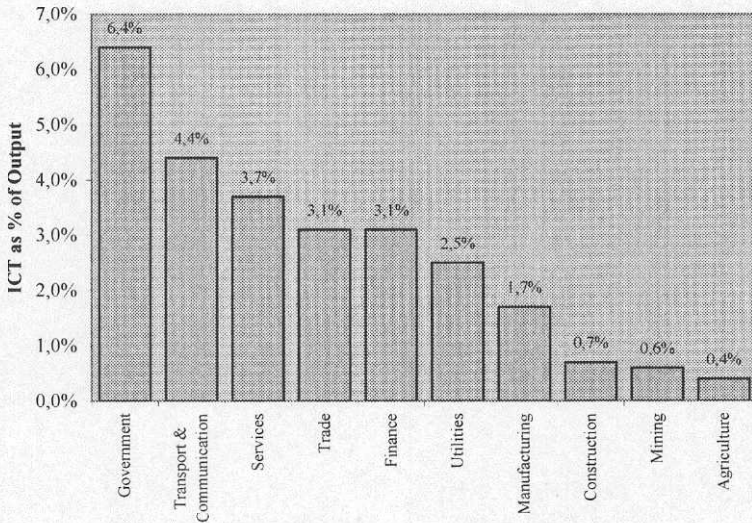
Figure 2: Global IT spending as percentage of Output/Total spending by Industry Segment in 2003. Source: WITSA (2004 p.18)

The general level of IT adoption in terms of employee access to PC's and basic administration systems is in line with typical benchmark industries. An increasing trend in the application of some expert applications, such as CAD, has also been noted in the industry. When it comes to more strategic applications and integration between different systems and with organisation design and work processes, AEC companies however appear to lack behind other industries (Andresen 2001; Samuelson 2001). Teicholz (2004) argues that despite the fact that there has been a significant adoption of information technology by the construction industry over the past 35 years, it has not had a significant impact on overall performance. Teicholz claims that most of the applications used in construction tend to run in a stand-alone mode, which does not permit improved collaboration by the project team. That is, individual designers tend to uses diverse and often incompatible systems. The fragmentation of the systems used causes multiple re-entries of data between different applications which ultimately leads to inefficiencies and reduced ability to realise the full potential of IT applications in the construction process (Teicholz 2004).

The increasing application of IT is frequently identified as an important reason for increases in productivity in many industries (Clemons and Reddi 1993;

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Brynjolfsson and Hitt 1995; 1996; Lehr and Lichtenberg 1999). At the same time there is significant evidence suggesting that the construction sector has experienced negative productivity development over a long period in the USA (Allen 1985; Gullickson and Harper 1999; 2002). A lack of investment in IT, relative to other industries, is frequently suggested as a plausible explanation for the poor productivity development of the construction sector (Andresen, Baldwin et al. 2000; Sharpe 2001). Andresen, Baldwin et al. (2000) argue that a primary reason for the slow IT investment rate is low level of perceived benefits from IT investments amongst construction business managers. The investment evaluation process has further been identified as a major barrier to implementing IT in many construction firms, with politics and communication being a major factor (Samuelson 1998; Love and Irani 2001; Samuelson 2001).

AEC companies particularly appear to lack behind regarding investment in strategic information systems enabling efficient exchange of information, as most of the systems in place today support only simple data manipulation (Fischer, Waugh et al. 1998; Lundegård 1998; Schwegler, Fischer et al. 2001). The type of investments required for this kind of capabilities could be labelled as *platform investments*. That is, investment that enables other future investments. The expected benefits are often long-term and thus difficult to justify in terms of a quick payback period. This is of course also a relevant issue in organisations in other industries. Nevertheless, most other industries have for some reasons chosen to commit resources to this type of investments. One possible explanation could be that the predominant project environment in AEC leads to a more short-term focus in capital budgeting compared to other industries (Schwegler, Fischer et al. 2001). In other cases, competitive pressure may have played an influential role in forcing organisations to invest to keep up with competitors and pressure from suppliers, consumers and other stakeholders. These factors in contrast do not appear to have had a sufficient impact to drive the development in the traditionally conservative AEC industry (Wikforss 2003). There are thus good reasons to suspect that today's IT investments in the AEC industry are biased towards a short-term focus due to the special characteristics of the industry. As a result, strategic and more long-term platform investments may be ignored or undervalued. Consequently, the development of the industry as a whole, in terms of productivity and effectiveness, is possibly being held back compared to other benchmark industries.

1.1 Understanding the object of the analysis: Information Technology

One of the early definitions in the literature describes information technology as comprising "the acquisition, processing, storage and dissemination of vocal, pictorial, textual and numeric information by a microelectronics-based combination of computing and telecommunications" (Eaton, Smithers et al. 1988). In the words of Powell (1992, p.29) "this [definition] does provide a flavour of the all encompassing nature of the beast" while on the other hand he argues that what does and does not constitute IT is often in the eye of the beholder (ibid). In a more concise phrasing, IT is traditionally defined to include three main components: computers, databases, and communications networks. In addition, it often referees to the associated software along with other companying devices such as voice mail systems, personal digital assistance, and similar electronic devices that promote computation, storage, and the communication of data (Lucas 1999).

The term Information Systems (IS) is a closely related term that is typically used in the context of the use of software applications to deliver information. In this thesis, the term information technology (IT) encompasses all forms of technology, hardware and software (and thus including IS) used to collect, store, create, exchange, present and use information in its various forms (Mähring 2002). The objective of the analysis is to value IT investment projects, not the IT artefact itself. IT investment projects are assumed to lead to the creation of valuable capabilities, or *business capabilities*. It is the value of these capabilities, which are the focus of this research.

1.1.1 IT evaluation

Early IT applications typically involved automation of manual tasks. A fairly easy way to estimate the value of these investments was to simply estimate the cost savings from replacing human labour with technology (Powell 1992). However, with a phenomenal increase in the processing power of personal computers and decreasing costs, the range of applications has increased up to the point when IT has now penetrated virtually every aspect of the modern organisation. Consequently, the complexity of determining the value of IT investments also increased and it has become difficult to establish the boundaries of different IT initiatives from each other. Despite the extensive level of integration of IT into the structure of organisations, many costly IT investments are perceived to have only modest direct benefits. This is perhaps, in part, because the costs of IT investments are often perceived to be more tangible or easier to measure than the benefits, although recent

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studies have shown that the expected costs are often just as erroneous as the expected benefits (see e.g. Love and Irani 2001). One important and widely debated problem is that there is a potential miss-measurement problem using traditional capital budgeting methods to evaluate certain types of IT investments. An important element of this miss measurement problem is that in many cases important IT investments may not have substantial direct benefits, but rather serve as investment *platforms* providing value in terms of enabling future potentially profitable investments. These investments would not have been possible (or much more costly) if the initial "unprofitable" platform investment had not been made. This type of IT platform investment can therefore, be seen as having an embedded option. Moreover, it may also entail significant managerial flexibility to tailor the investment strategy, based on the availability of information over time. Many authors have argued that traditional capital budgeting methods such as discounted cash flow analysis (DCF) and Internal Rate of Return (IRR) are not well suited to evaluate this kind of investments due to these special characteristics (Kambil, Henderson et al. 1993; Schwartz and Zozaya-Gorostiza 2000; Kognut and Kulatilaka 2001). These methods were designed to evaluate investments with clearly identifiable and stable cash flows with a predetermined operating lifetime and assuming a fixed investment strategy. Conversely, in the case of IT platform investments a large part of the investment value comes from the value of future options, but not stable cash flows. The value of the embedded options is further dependant on a flexible investment strategy rather than a fixed one and is often influenced by several sources of uncertainty. Ignoring the value of these embedded options can lead to the investment being seriously undervalued (Trigeorgis and Mason 1987; Dixit and Pindyck 1994; Grenadier and Weiss 1997).

Several studies have shown that managers tend to treat IT investments differently than traditional capital investments when it comes to evaluation. IT investment decisions are often described as being based on gut instinct, oral guidelines or other qualitative evaluation approaches rather than on the traditional capital budgeting methods (e.g. Powell 1992; Remenyi, Money et al. 1993; Renkema 2000). The value of future contingent investments is however subject to much uncertainty (Trigeorgis and Mason 1987; Dixit and Pindyck 1994; Kulatilaka, Balasubramanian et al. 1999). Basing the investment decision purely on intuition and qualitative evaluation is therefore likely to be suboptimal considering the complexity of the investment. A formal framework and an evaluation model is needed to incorporate

the potential value of contingent future follow-up investments, and managerial flexibility into the evaluation of IT platform investments.

1.1.2 Types of IT investment

As evident from the previous section, the term information technology covers a wide range of different types of hardware and software, and within each category, there is typically a plethora of different distinct classes, functions, configurations and suppliers. In the early stages of the so-called computerisation era IT investments, although costly, were relatively simple compared to today's IT investment projects. Typically, an IT investment involved the purchase of a computer mainframe, disk capacity, data terminals, developer time, and software licences. Nowadays technology investment projects are considerably more complex. Simple mainframe systems are replaced by integrated systems requiring advanced layers of servers, operating systems, network protocols and routers, database software, middleware, desktop hardware and software (Dempsey, Dvorak et al. 1998). These factors combined with the complexity of integrating new systems and applications in virtually every aspect and process in the organisational structure results in a complex investment evaluation.

The subject of IT evaluation has become a multidisciplinary task where it is useful to distinguish between investment evaluation (the resource allocation process) and IT project governance (IT management). Although the focus of this study is on IT investment evaluation, the framework developed here recognises the interrelationship between IT evaluation on the one hand and IT project governance on the other hand. The latter has a direct impact on the value of an IT enabled capability made possible by the investment[3].

Despite the vast amount of literature available on IT investment evaluation, relatively little attention has been placed on clarifying the distinctions between different types of technology investments. The introduction has argued that the role of technology in organisations today, compared to early applications, has changed significantly. It is therefore reasonable to assume that the type of evaluation appropriate for individual types of IT projects differs. Different types of IT investment projects suggest that the intended goal or objective of investing resources to individual projects varies. This implies that different investment goals might require distinct evaluation approaches. With this in mind, perhaps the two

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[3] For an excellent overview of the field of IT Project Governance see for example Mähring (2002).

extreme types of IT investments can be classified as thresholds investments on the one hand and strategic investments on the other.

Threshold IT investment involves information technology that is essentially required in order to compete in a given market place. This type of investment is often done in response to competitive pressure or governmental regulations. Powell (1992) for example argues that the banking sector is an example of a industry where the threshold level of information techrology required for participation is high. Majority of financial transactions are now made by electronic transfer. The existence of shared facilities in the sector forces the participating companies to make the necessary technology investments, which have become indispensable to participate in the industry.

Strategic IT investments often have long-term objectives, such as to change an organisations product or the way that the organisation competes in the market place. Strategic investment is often associated with a wide variety of strategic decisions including formation of joint ventures, research and development projects, major capital expenditures, and diversification into new products and/or markets. Kulatilaka and Venkatraman (2001) define strategic IT investment in terms of acquiring options on future investment opportunities based on coordinated actions across three domains: the business domain, information technology and finance. Nair (1995) similarly emphasises that strategic investment decisions are critical not only because of their usually large initial capital costs, but more importantly because they affect future production costs, revenues and the opportunity of the firm to perform operations that were not possible earlier. Powell (1992) on the other hand argues that in practice the word "strategic" is often used as a defensive avoidance term to bypass the normal capital budgeting process in organisations, especially regarding IT investments.

There are other types of IT investments, which fall between these two extremes. Flatto (1996) for example defines two additional types of IT investments: transactional and Informational. *Transactional IT investments* are projects that have as a function to support management in their day-to-day operations. *Informational IT investments* are made to provide information for the general management and often have medium term objectives.

Infrastructure investments in general are often associated with a high and often unpredictable total cost-of-ownership[4] and intangible benefits (Parker, Benson et al. 1988; Banker, Kauffman et al. 1993). They also frequently have far reaching consequences in terms of business efficiency, effectiveness, competitive positioning and the ability to innovate (Renkema 2000). Infrastructure investment decisions are hence amongst the most complex, delicate, and risky business decisions. Senior executives therefore find it particularly difficult to make IT-based infrastructure decisions that are aligned with the current and future needs of their business (Keen 1991; Hogbin and Thomas 1994; Weill and Broadbent 1998; Renkema 2000). Dempsey, Dvorak et al. (1998) identified three main categories of IT infrastructure investments: capacity additions, technology upgrades and the introduction of new capabilities. They argue that when adding capacity to an existing information system the key element of the analysis should involve establishing a base case in order to provide a yardstick by which the impacts can be measured. They further emphasise the importance of estimating the value of the flexibility the additional capacity will enable. The main challenge with upgrade investments is in identifying all the relevant transitions costs, potential flexibilities, risks and establishing an appropriate timeframe for the analysis. Finally, in the case of new capabilities special care needs to be on setting a relevant scope for the analysis, including eventual complexity costs, risks of and potential consequences of potential technological failure, as well as the commercial viability of both the technology and its vendor (ibid).

This classification is very wide and certainly not mutually exclusive, i.e. one investment project can fall under more than one of the categories. This especially applies to IT platform investments, which could essentially encompass all of the implied investment objectives above.

1.2 Platform investment

The defining characteristic of *platform investments* is that a substantial part of the total value of the investment requires that follow up investments be made (Amram and Kulatilaka 1999). Platform investments are therefore investments that provide a basis for future additional ("add-on") or complementary investments. They belong to a category of investments in stages, where a Stage-2 cannot be performed until Stage-1 is in place. However, a platform investment is a special kind of a Stage-1

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[4] Total Cost of Ownership (TCO) is typically defined to include all costs associated with a capital purchase over a given time period, including the cost of owning and operating an existing asset at a given point in time.

investment, namely where the first stage cannot be justified by itself. For Stage-1 to be potentially viable, it must entail an option on one, or several subsequent stages. Consequently, platform investments are often associated with a substantial risk-taking as it may be difficult at the time of the decision-making to estimate and to evaluate future add-on or complementary investments. Platform investments always involve staged investments, whereas all investment in stages does not necessarily entail platform investments.

In practice, there exist many examples of platform investments. This includes investments in Research and Development (R&D), Infrastructure investments, product- and country platforms:

- *R&D.* Investing in research and development can be seen as the classic example of a platform investment in the sense that ongoing R&D, such as the development of a new pharmaceutical product, usually does not provide any direct benefits to the firms in terms of cash flows. The value of R&D investments comes, however, from products it releases for further development that may lead to marketable products (Amram and Kulatilaka 1999).
- *Excess capacity transport infrastructure investments.* Examples of this are road/rail tunnels and bridges. When constructing new bridges or tunnels for road and rail, it is common that the facility is build for higher capacity than the initial road or rail track is designed for. For instance, by building a bridge designed for a four lane road in connection with a two lain road construction provides the option to expand the road capacity at a later date, at a lower cost than would arise if a new parallel bridge would need to be constructed (Bergendahl 2002). However, the road capacity will only be expanded should the traffic increase. In other words, the present traffic volume may not justify a four-lane bridge at present, but the value of the option to expand road capacity later may be sufficient to justify the additional cost of the higher capacity bridge.
- *Product platform.* What distinguishes a product platform investment from simple product development is a strategy of reuse and growth options. A recent example of an outstanding product platform investment is the iPod music player produced by Apple Computer, Inc. After many companies had turned down the original idea for the iPod developed by Tony Fadell, Steve Jobs the founder of Apple realised the enormous platform potential of the

product. In a sense this single product is about to change one of the worlds largest computer manufacturer into a music company. The iPod has provided the company a wide platform for selling other related products and services. The MP3 player was for instance launched in connection with the opening of a website (iTunes Music Store) that sells music, which can be downloaded directly into the player. Now the website has sold over 500 million songs and a wide range of products has been launched in connection with the iPod, both variations of the MP3 players and an enormous range of accessories. The initial development cost and large marketing campaign thus provided the company a lucrative platform on which to launch a number of future contingent projects.

- *Automobile platforms* are also an example of a product platform based around reuse. These are complex productions where different car models share a set of common components. This can range from literally shared frames from a previously engineered vehicle to using individual components in a number of different car brands. Different models from the same manufacturer may for instance share a large number of identical components but be very diverse in appearances and price. A good example is the Audi TT and Volkswagen Golf, which have much of the identical components but differ tremendously in external design. Volkswagen is recognized for manufacturing many different types of vehicles based on variations of common platforms. For instance, VW Polo is built on the same platform as Skoda Fabia and Seat Ibiza. Skoda Octavia is similarly built on the same platform as VW Golf, Audi A3 and Seat Toledo. Investing in a flexible automobile platform can thus entail multiple growth options into a number of different vehicles in different price classes.

- *Country platform*. It is common practice that initial investments of companies trying to establish themselves in foreign markets are not profitable as stand-alone investments. These investments are however, often made in order for a company to learn about the new market, build brand recognition, and establish distribution channels. This type of investments can therefore be seen as platform investments when the initial entry is designed to generate capabilities to launch other products and services (Kogut and Kulatilaka 1994; Kogut and Chang 1996).

IT investments often belong to this category of investments. Specific operating systems are for example typically required before any other applications can be run

on the computer hardware. These operating systems provide limited direct benefits but are essential *software platforms* for other applications to be functional and able to interact with other systems. Enterprise systems are, as well typically built in a similar manner. A basic software platform in the form of an integrated database system and some central application is typically required before any specialised applications can be installed. This is an example of a pure platform effect where the individual application is essential for any related subsequent application to be possible. Software applications may also produce other types of *platform benefits*. This type of contingent relationship can for instance appear in capacity related situations. One example may be an application, which is build with the ability of handling multiple languages and currencies, although the application user is currently only involved in domestic operations. Should the firm however decide to expand into other foreign markets, this extra capacity will enable them to adapt their software applications to these new conditions quickly. Other examples include oversized databases or investing in excess bandwidth in anticipation of increasing future demand.

The value of an IT platform extends far beyond the individual software platforms. In order for companies to derive business benefits from their software applications, the IT function needs to be closely integrated into the company's process and organisational design. New IT applications typically require extensive training of both the IT support staff and the intended end users of the system. Furthermore, the existing work processes in the firm often need to be realigned or even completely reengineered to fit with new work routines.

The capabilities that are created as a result of software platform investments, business process reengineering and investments in the human capital required to support and use the technology effectively, are often more an investment in opportunity rather than in instantaneously cash flow generating assets. This "opportunity" is perhaps best characterised as *growth options*. That is, the investment enables the firm to take advantage of future opportunities that would otherwise been beyond reach had the initial investment not been made. Depending on its characteristics, the IT platform may entail anything from a single easily definable growth option to a wide range of more or less uncertain potential applications and capabilities. Due to these options like qualities, IT platforms are more valuable than suggested in terms of the classical budgeting models. Many types of IT investments display these characteristic. One example is an investment

in an email system, which may provide some immediate benefits such as the ability to substitute email for other less efficient forms of communication. However, the real benefits of the email system is likely to come as its use spreads through the organisation and as other more sophisticated applications are added to the basic email platform (Kulatilaka, Balasubramanian et al. 1999). Renkema (2000) emphasises that "part of the difficulty with valuing IT infrastructure investments lies in its potential to not only improve current operations, but also more importantly, it has the potential (ability) to fuel (or prevent?) innovation and provide competitive advantage for years to come" (Renkema 2000 p.xvi).

For the AEC sector this type of investments are notable. The development of computerized techniques for drawing, design, and construction of new buildings will not gain any value until they are applied to a series of practical applications. However, at the time when such a development starts it is difficult to estimate the size and number of potential future applications. The type of IT platform investments in AEC are therefore not confined to building for extra capacity, but rather involve building IT enabled capabilities. Building IT enabled capabilities often requires considerable lead-time. Until recently, advanced IT capabilities often involved expensive large scale IT infrastructure in terms of hardware and software. Nowadays, however, hardware and software applications are becoming increasingly modular. This means that most applications can be run on any number of available hardware. Similarly, it is now becoming relatively easy to integrate different software applications, even from different vendors, through the use of enterprise application integration (Irani, Themistocleous et al. 2003). IT investments in AEC are often financed through individual construction projects. At the date of the evaluation, the future use of IT for individual projects are difficult to estimate and the project managers often take a conservative standpoint concerning the future use of IT. If the benefits of the investment do not seem sufficient to justify it in the individual project, the investment will likely not be made even though this kind of investment often produces benefits that extend far beyond the individual project.

1.3 Problem Statement

This study is primarily focused on a special set of problems related to the evaluation of IT platform investments in AEC industry. Specifically, investments where a substantial part of the expected benefits (and costs), are anticipated to come from contingent future "follow-up" investments.

Evaluation of IT platform investments presents several challenges. The type of questions this study attempts to answer includes:

o How to identify and evaluate IT platform investments with contingent future investments?

o What type of costs, benefits, and risks are involved in this type of investments and how can they be quantified?

IT platform investments are made by organisations in all industries, public and private alike. The basic challenges in determining the value of this type of investments are common to all investors, while specific organisational and industry settings may in some cases pose additional challenges to the evaluation. Unlike many other capital investments, IT has little intrinsic value due to high degree of organisational specificity and irreversibility of the investment costs. The value of IT is hence inherently derived from the organisational and industry context it is applied to create business capabilities. It is therefore inconsequential to study the evaluation of IT platform investments without a specific context. The specific focus of this study is on the evaluation of IT platform investments in the Architecture, Engineering, and Construction industry.

In addition to the traditional capital budgeting methods, a vide variety of methods and models have been developed to deal specifically with IT investments. Many of these methods are explicitly designed to address specific types of technology investments and organisations. However, many authors have argued that no one superior method exists that can be applied on all kind of IT investments in the context of different kinds of organisations and industries (Remenyi, Sherwood-Smith et al. 1997; Serafeimidis 2001). Application of specially designed IT evaluation models has also proved problematic, especially in complicated industry environments like the construction sector (Andresen 2001). The AEC sector is the largest industry in the world. According to Engineering News-Record Magazine, the world spent about $3.22 trillion on construction in 1998 which at the time represented about 10% of the world's economy (ENR 1998). This sector is often labelled as relatively "low-tech" and slow to adapt new innovative technologies (Björnsson 2003) and has received limited attention in the IT evaluation literature. Little is therefore known about what type of analysis are performed on IT investments in the industry. Apart from being the largest industry in the world this sector distinguishes itself in several ways from other industries.

- This is a relatively low margin industry which has not accumulated significant amounts of capital when compared to other manufacturing industries such as steel, petroleum or automobile, or service industries such as the financial or technology sector (Barrie and Paulson 1994). This puts tight constrains on the economic resources available for adopting new innovative technology, investments where the benefits are often substantial but long term.
- The sector is extremely project focused which also often results in a short-term focus on investments in infrastructure and innovations.
- The demand for construction services is highly sensitive to general economic conditions.
- The industry is traditionally made up of a multitude of different stakeholders and small operating units (Björnsson 2003 p. 68), everything from the facilities owner, the general contractor and clusters of sub contractors, to the engineers, architects, and the surrounding community.

Love and Irani (2001) argue that due to these characteristics, problems of IT evaluation are even more acute in construction than other industry sectors. It is therefore especially interesting, and challenging, to study IT platform investments in this dynamic industry setting. Given the added complexity of the industry environment also contributes to the possibility that the results of the study can be more easily generalised and adopted to other organisational and industry settings. Before presenting the specific research objectives of the study a more detailed problem discussion is presented in the following section in the form of a motivating example demonstrating some of challenges faced with this type of investments.

1.4 Motivating Example[5]

Constructive Inc. is a major Scandinavian General Contractor (GC) with active operations in all the Nordic and Baltic countries. Constructive offers full service in four major construction areas, namely Residential Construction, Building Construction, Industrial Construction, and Heavy Engineering Construction. These

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[5] This example is intended to demonstrate the kind of problems faced in AEC IT evaluation. The company in the case study, Constructive AB, is a fictitious company while the case is built on second hand data from four independent documented case studies on investments in Document Management Systems (Carter, Thorpe et al. 1999; Kulatilaka, Balasubramanian et al. 1999; Andresen 2001; Dahlgren, Lundgren et al. 2001), whereof three of those case studies relate to AEC companies specifically. The background of the case further builds on an example presented in Svavarsson *et al* (2002) and assumptions about investment costs are supported by first hand data from IT suppliers to make the case as realistic as possible.

four areas of operations are divided into individual operating units in each of the two geographic regions.
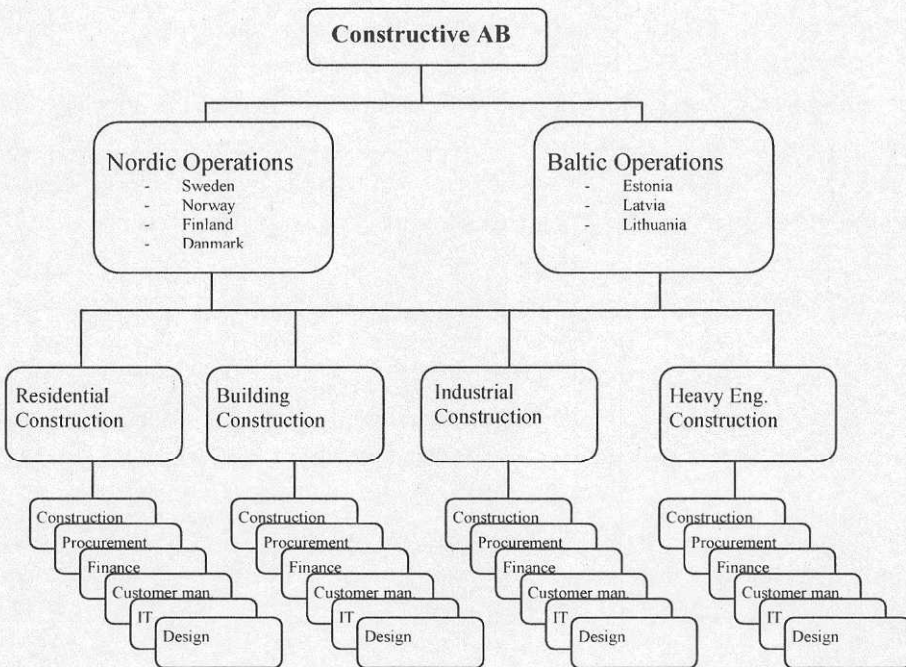
Figure 3: Organisational chart of Constructive AB

The Nordic Building Construction division has just been awarded a large design and build contract for a 55,000 m^2 office building in the south of Sweden. Top management is currently considering a proposal from the project team to sponsor an implementation of an Electronic Document Management System (EDMS) on the project. The client in this project has put as a requirement that he is to be provided access to all CAD[6] drawings with detailed version registration at regular intervals throughout the design and construction process. With the company's present capabilities, this can only be done by hand and would require substantial amount of manual labour at relatively high cost. The *construction project manager* has therefore proposed an investment in a new EDMS system, which would facilitate the production, management, and sharing of standard CAD drawings throughout the duration of the project. The total cost of hardware, software, and training is

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[6] CAD stands for Computer Aided Design. CAD drawings are one of the fundamental elements in any major construction project as a major part of the design and construction of buildings relies on these drawings

estimated at approximately SEK 2 million or 2% of the total contract. The project team believes that the use of EDMS, *if successful*, can save a total of SEK 1 million due to reduced costs by replacing time-consuming manual tasks and high printing and distribution costs. This new capability, would also contribute to improved efficiency and less rework due to more accurate document management by ensuring that all project stakeholders have access to the latest versions of the drawings. In addition, the timesavings will increase the likelihood of earning a SEK 1 million bonus from the client for early completion. However, all of these benefits are contingent on a successful EDMS implementation. This is far from certain.

A Net Present Value (NPV) analysis of the investment proposal showed a *negative* NPV of SEK 750,000. The investment does therefore not meet the company's requirement for new capital investments. The decentralised structure and decision-making authority at Constructive AB would generally require this kind of investment to be charged directly on the project making use of it. The project manager nevertheless believes that the potential benefits from acquiring this capability on the project will likely extend beyond this isolated project. He therefore asks the central office to subsidize the investment in EDMS in order to avoid jeopardizing the profitability of the project.

1.4.1 An extended investment scenario

The top management group recognises that from an organisational perspective there are potential benefits from the EDMS investment that have been overlook in the initial NPV analysis. *Firstly*, there are substantial learning benefits from using EDMS on this project. If the project is successful, the company may consider using EDMS on all their projects in the future, the trained personnel could therefore deploy their skills on future projects and help train other users. Furthermore, the IT department would get valuable information on the technical feasibility of this particular system in terms of implementation and compatibility with existing information systems. *Secondly*, the use of EDMS on this and future projects would support the goal of the company of becoming a leader in the application of technology in all phases of the construction process. This would reinforce Constructive AB's reputation as an innovator, giving them a stronger position in the competition for new projects, as well as facilitating the recruitment of new "hi-tech" engineering graduates to the company. *Thirdly*, the company's IT experts believe that EDMS would provide a valuable platform for future IT investments. A wide spread implementation would mean that essential infrastructure and valuable

technical knowledge would be in place for possible future steps towards important future planned ventures such as e-business and 3D and 4D CAD applications. *Finally*, an EDMS implementation would be beneficial to other project stakeholders such as the owner, the architect as well as subcontractors and suppliers. Constructive AB believes that it would be useful to quantify these benefits as well. This could help in getting these participants interested, and maybe even make them willing to contribute to the investment.

Top management wants to know the value of a pilot investment in EDMS involving the Swedish construction project. They further want their evaluation team to make a more comprehensive analysis *including the above factors with a more extensive or even full implementation of this technology throughout the organisation in mind, and further what effect that may have on future plans for other technology investments.*

1.4.2 A multi-stage investment process

The initial investment proposal from the construction management team involved using EDMS to manage, store and share CAD drawings on a single construction project. Now a cross-divisional evaluation team consisting of experts from the financial and IT department and experienced project managers has been formed to perform a more thorough evaluation with the factors identified by top management in mind. After careful consideration, the team comes up with a multistage investment plan stipulating a gradual implementation of EDMS across the organisation. In connection with the implementation plan, a number of evaluation objectives need to be addressed.

1. Evaluate whether or not a pilot-investment in a single construction project is economically justifiable
2. Evaluate feasibility of full implementation of a Document management system in the Nordic Residential Housing division
3. Evaluate feasibility of full implementation across the whole Nordic division
4. Evaluate feasibility of limited implementation in Baltic region
5. Evaluate costs and benefits of full organisation wide implementation
6. Identify and evaluate potential platform benefits of expanding the Electronic Document Management capability to other applications

The individual investment stages are described in more detail below. The evaluation team has divided the expected impacts into two categories. On one hand are those

impacts that are expected to be directly related to the scale of the implementation, i.e. as the implementation gradually increases the effects are proportional to the number of project employing the technology. These impacts include:

- Reduction and ultimately elimination of manual work procedures involving the handling of CAD drawings documents, leading to increased efficiency and quality of the production and management of CAD drawings
- Ensure the accurate targeting and timing of information, reduce wasteful blanket issues, paperwork and filing costs, as well as prevent costly omissions
- Faster response to client instructions and quicker feedback on design through improved speed and efficiency in the drawing work

On the other hand, there are additional expected impacts from extensive or full implementation. These include for example benefits from *exploiting* documented projects for drawing *information and knowledge gained in earlier projects*. The wide spread use of the system will further support and enhance the quality management procedures of the company and ultimately enhanced the reputation of the company as a technology leader.

Phase 1 – Pilot project

The business areas within the company affected by a pilot investment will be limited as the system will be restricted to the operations of a single project. However, a number of different stakeholders involved in the project will be affected.

In addition to the actual software used for the management and sharing of the data, the implementation will consist of two servers providing a replicated database of project drawings and other documents. A number of workstations will also need to be installed in the offices of the main collaborating parties on the project. The workstations will then connect to the servers using ISDN lines. The success of the implementation of the technology is heavily influenced by the reaction of the key project stakeholders. To be able to realise any of the anticipated benefits requires both the internal and external project members to use the system as intended.
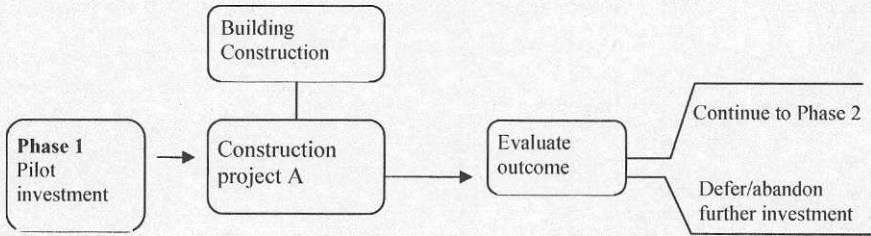
The pilot investment is evaluated at the project level, as it will only affect the specific construction project at this phase. In the case of no further implementation the net impact of the investment are hence confined to the single construction project.

Phase 2 – Implement across a single division
The second phase involves making EDMS available for all projects undertaken in the building construction division. The evaluation and implementation is consequently on a departmental level.
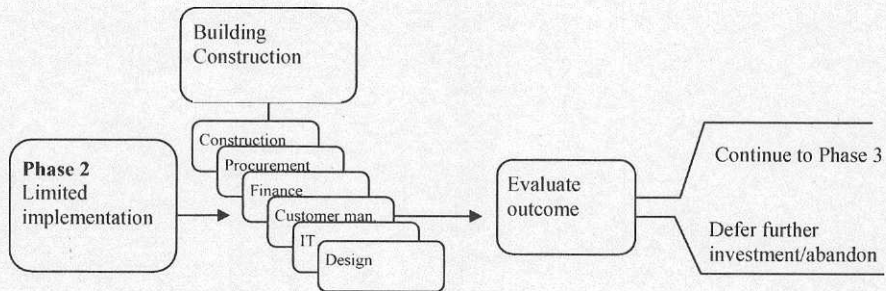
In addition to coordination issues with outside stakeholders, a major concern in the first phase, this stage involves implementing the new technology across all the different business functions in the building construction division, i.e. construction, procurement, finance, customer management, IT, and design. The implementation of this phase is estimated to take up to one year, after which the results would be evaluated before deciding on further implementations.

Phase 3: Full implementation in Nordic Operations
The third phase investment is evaluated at the regional level, as the capabilities are now expanded throughout all the relevant departments in the Nordic region. Phase 2

and 3 cannot be executed simultaneously because of limited number of IT personal
needed to support the implementation.
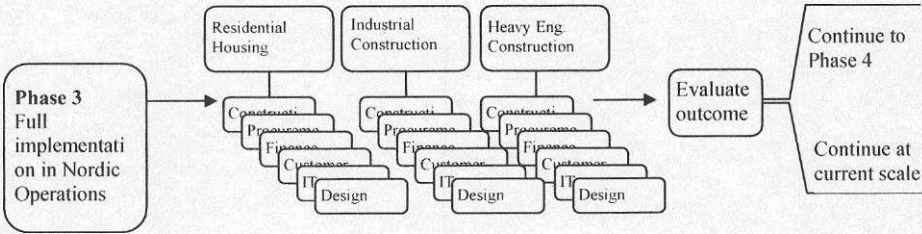
At this stage, the EDMS technology will be made available to all projects
undertaken in the Nordic Region.

Phase 4: Limited implementation in Baltic operations
Given successful implementation thus far, the next planned phase is to expand the
implementation of EDMS to the company's other geographical area, the Baltic
operations. This means that the evaluation is now on an organizational level as it
involves the organization as a whole. Due to technological factors, and a more
conservative interest of major stakeholders in this area, the project team believes
that limited implementation is preferable before embarking on a full roll out of this
technology to all the construction areas.
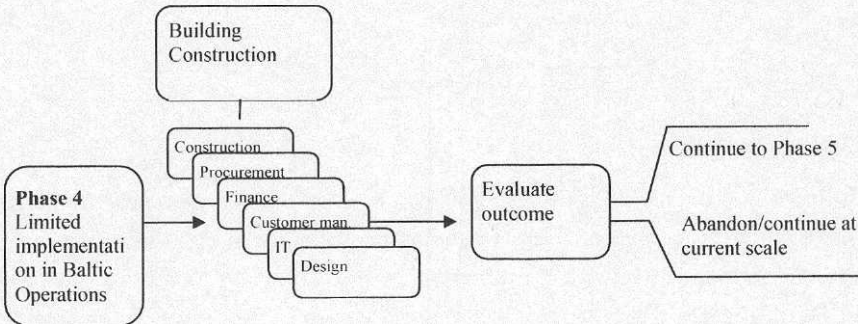
The project team has therefore devised a two stage strategy similar to the one
deployed in the Nordic operations. The first step, described in the diagram above,
starts the implementation in the building construction unit after which the outcome
will be evaluated before deciding on further action.

Phase 5: Full implementation in the Baltic operations

The final phase of the investment programme involves expanding the implementation to all the remaining construction divisions in the Baltic operations. A successful implementation of this stage would mean that the EDMS technology is available for all construction projects across the whole company.
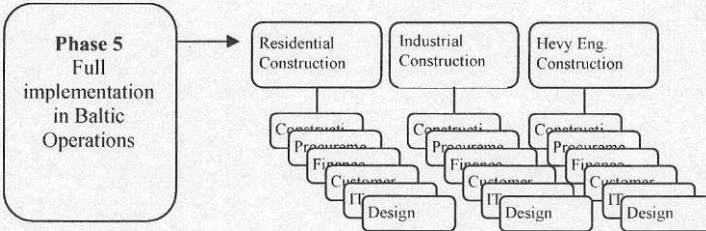
1.4.3 Additional Growth Options

The different investment stages and their relevant impacts descried above relate to the scale of the EDMS system itself. However, given a successful implementation of EDMS the groundwork is laid for the use of advanced applications such as 3D- and 4D-CAD[7] modelling. It will further serve as an important step in the companies plan to enter the e-business market place with automated electronic invoicing and on-line bidding systems. The evaluation team has therefore realised that even limited implementation of the EDMS technology can provide valuable insight towards these business objectives. Consequently, during any of the stages of the investment process discussed above the evaluation team identifies that company essentially holds a growth option to expand the scope of the investment by making additional investments in new capabilities that utilise the EDMS system in other areas of application.

Out of several different growth options enabled by EDMS, top management identified e-business and electronic invoicing as the potentially most valuable future capabilities. Due to the complexity, in terms of stakeholder cooperation, and the uniqueness of every construction project during the life cycle of a single project, an enormous amount of transactions take place between the different stakeholders. The company has estimated the cost of processing a single invoice typically lies between 600 and 800 SEK. Project specifications are also typically changed numerous times during different phases of the project, resulting in a large amount of transaction

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[7] 3D and 4D-CAD stands for three and four dimensional Computer Aided Design.

documents that need to be processed. The company estimates that over one percent of total project costs are spent on administration related to these transactions, which include for example telephone, printing and photocopying, mailing, and courier cost.

Full or even to some extent, partial implementation of the investment programme will mean that:

- Much of the necessary technical infrastructure for e-business is already in place
- Important experience is gained about potential internal user adoption of using a digital technology to exchange documents
- Information is gained about the willingness of external stakeholders to participate in an implementation of this kind of innovation.

The evaluation group recognize that all of the benefits listed above are important, although far from certain. However, lacking an investment analysis framework that includes and quantifies all long- and short-term benefits in a systematic manner, an economic assessment of the investment is difficult. After consulting with top management the evaluation team concludes that for this type of IT investment, the company's standard investment evaluation model is inadequate.

1.5   Problems identified

As realised by the management in the investment scenario above several elements of this type of investment are difficult to account for using traditional capital budgeting methods. This section summarise some of the major issues identified and discussed in the text thus far.

1.5.1   Stage-ability

This concept refers to the sequential and contingent nature of many IT investments. There are several reasons why an investment is executed in stages rather than all at once. One is that the investment needs to be divided up due to capacity constraints resulting from limited resources, such as financing and human resources. Another motivation may be that the investment is performed in stages deliberately as a means of managing uncertainty and the contingent nature of IT. The issue of contingency is perhaps more relevant in IT investment valuation than any other capital investments made by organisations. There is always a high probability that information system requirements may change at all stages of the development

(Remenyi, Sherwood-Smith et al. 1997 p.221). An investment process that can be divided into distinct implementation phases provides managerial flexibility to control the investment and decision making process. The employment of pilot projects and staged implementation provides the decision maker the operational flexibility, or options, to revise the investment strategy as more information about both positive and negative uncertain impacts becomes available. This flexibility includes options to slow down or speed up further implementation, and in some cases it may also be appropriate to expand or scale down, or even abandon, later phases. Depending on the outcome of the different investment stages, it might for example be more feasible to start the implementation in the Baltic region earlier than planned, run two or more phases in parallel and in other cases more appropriate to delay or completely abandon further investment plans. This flexibility of staged investment is therefore valuable, and needs to be included in the valuation of the investment proposal.

1.5.2 Comparing different alternatives

The investments scenarios only considered a single type of "off-the-shelve" EDMS system, implying that only minor system configurations of the original software are needed. In reality however, the organisation can choose between several different software vendors, in addition to the option to develop their own system internally. An additional alternative is to outsource this service either partially or fully to companies offering internet based project collaboration extranets. It is therefore likely that management will be interested in comparing these different investment alternatives. Different system alternatives are in most cases essentially mutually exclusive. This however depends on the modularity of the system itself and the company's current IT infrastructure. The decision maker is therefore faced with the challenge of comparing both *interdependent* and *independent* investment alternatives with often highly uncertain payoffs.

1.5.3 Expandability

There are two types of interdependence relevant to IT platform investments. First, the investment involves a sequence of investment stages that can only be performed in a given order, i.e. each completed stage provides the option to proceed to the next stage. The second type is when an initial investment or series of related investments provide a platform opportunity involving a group of independent investment options that are only contingent on the IT platform. These options therefore do not need to be exercised in any particular order and could in practice all, or in part, be exercised

simultaneously depending on individual investment scenarios. This applies to situations where the IT investment entails future opportunities, i.e., further potentially valuable applications can be added to the existing platform like was found to be the case with the EMDS system. In this case additional value results from the option to make additional follow-up investments that are dependent on the initial platform being in place (Trigeorgis and Mason 1987). Boer (2002) argues that many important IT projects do not produce enough benefits that are measurable in direct cash flows to justify their investment. In many cases, the IT investment's greatest value resides in its capacity to offer options for revenue generating investments later on, which however, can only be realised by further follow-up investments. This is in part due the fact that these kinds of investments have short economic lifetimes, seldom exceeding 3-5 year. Using simple Payback and NPV analysis will not work correctly if the time horizon is too short to include the contributions from assets that have yet to mature as cash contributors. Focusing solely on the return or Payback time of individual IT investments is therefore not likely to give meaningful results. Assuming that each IT investment generates a series of contingent investments over time, it is uncertain at the time of the initial investment, which will be the contingent future investments that will benefit from the platform investment. The total investment value of an IT platform will therefore consist of an initial investment associated with the value of one or more uncertain future investments.

The interdependence of this type of IT investment results in an asymmetry in the risk profile of the investment. Dividing the implementation and the platform opportunities into stages allows the investor to take advantage of uncertain events that are beneficial, while at the same time limit the down side value effects. As a result, the distribution of potential future values of the investment becomes skewed, i.e. there is a higher chance of a favourable outcome than an undesirable outcome.

1.5.4 Investment Timing

An additional problem is to determine the optimal timing or urgency of the IT investment. The classical theory behind evaluation of capital investments stipulates that an investment should be performed as soon as the net present value is positive or when the internal rate of return (IRR) is larger than the discount rate. It should be rejected if the NPV is negative. In general, classical capital budgeting methods are based on the implicit assumption that the decision maker is not interested in considering the advantage of alternative investment strategies, such as delaying an

investment to a later date when more information has been obtained, or when demand has grown to a satisfactory level. Rather than focusing solely on the investment as a "now or never" opportunity, in some cases it may be beneficial to wait for more complete information and therefore consider the option of investing "now or later". Can the investment be deferred for a period of time without loosing substantial part of its potential benefits or is this an "expiring" option that needs to be considered for an immediate exercise.

Marglin (1963) was among the first to observe that the NPV criterion is necessary but not sufficient in the case when two investment projects are interdependent. "Uncertainty will reduce the temptation to build ahead of demand in order to profit from economies of scale" (Marglin 1963, p.72). Marglin argued that under the conditions of substantial uncertainty it might be justifiable to postpone a project with a positive NPV today if the NPV of tomorrow will be even larger. The possible benefits of postponing investment however, depend on the type of uncertainty influencing the value of the investment. *Project specific uncertainty*, or risk relating specifically to the technological success of the investment, can for example usually only be resolved by going ahead with the investment. Therefore, in those cases where the investment can be done in stages, this type of uncertainty provides an incentive to proceed with the investment in small scale in order to get more information about these risks. Consequently, a pilot project with a negative NPV may be justifiable if it provides valuable information about the feasibility of further investment. As a result, the deployment of pilot projects and staged investment strategies is attractive as it creates a learning effect, which is not the case with an "all or nothing" strategy. This way new and more accurate information is gained continuously throughout the investment process. On the other hand, Pindyck (1993) showed that in the case of irreversible investment with long implementation time, input cost uncertainty (i.e. uncertainty related to the prices and quantities of labour and other input factors that cannot be influenced by the company) has the opposite effect on the investment decisions. This, he argues, is because the cost of completing the investment changes whether or not the investment is taking place, hence there is a value in waiting for new information before committing resources (Pindyck 1993 p.56).

1.5.5 Uncertainty

IT investments are by many managers described as being amongst the most risky investments made by their organisations. This is because they require a significant

commitment of resources in terms of financial capital, time and human resources, and the fact that the real cost and benefits of the investment are hard to estimate. In the investment scenario described above, there are a number of uncertainties that can have a decisive impact on the outcome of the investment. These uncertainties emanate from numerous different factors within the company, from outside stakeholders, and from the general economic and market environment. The expected impacts from the EMDS system are for the first dependent on the technological success of the system itself, namely that the system will deliver on its promise to provide the specified functionality. Furthermore, there are potential compatibility issues with the IT systems of the external stakeholders. Will the IT systems of future clients be compatible with the system solution chosen by the company, or will some other system prevail as the dominant standard. The issue of common standards is a long-standing problem in the construction sector. The numerous different actors have not been able to settle on a single or limited number of data standards, as is common in other industries. A further concern is uncertainty regarding the actual cost savings achieved from using the new technology on construction projects. A closely related issue is the estimation of how many projects will be able to take advantage of the system. These impacts are usually hard to estimate precisely. The final important factor mentioned here is the risk that the intended users will not be willing or able to use the system. An absolute requisite for the success of the EMDS investment is that the users will enter the relevant data into the system.

1.5.6   Learning

Many IT investments and IT platform investments in particular, are sequential in nature. The completion of each stage in the investment processes provides valuable information, or learning about both the system technical feasibility and the potential business capabilities they enable, as well as about other important underlying risk factors. Many risks can therefore be mitigated simply through the active management of the investment process, as uncertainty is resolved. Active management allows the decision maker to execute plans for implementing new valuable applications to the initial platform, while at the same time it provides the flexibility to abandon or postpone less promising investment opportunities.

An option to either stage the implementation of an IT investment project, or an option to produce a pilot, or a scaled down version of a single investment project can have an important effect in terms of transferring risk to early stages of the

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implementation process. This may have a decisive impact on the outcome of the investment and needs to be integrated into the valuation.

1.6 Purpose of the study

The purpose of this study is to identify, analyse, and develop means to evaluate interdependent IT investments related to platform investments in the context of the AEC industry. The purpose is addressed in three research objectives.

The first objective is to formulate a conceptual analysis framework to identify IT platform investments, and to formalise the evaluation with regard to the problems presented by this type of investment decisions with special relevance to the AEC industry environment.

The motivation for pursuing the first objective is twofold. *First*, a conceptual framework is needed for formulating the evaluation process and for the classification of essential concepts and variables for the evaluation model. A framework is useful for overcoming human's limited ability to process complex information and further plays an important role in making sure that the relevant information is identified and made available. S*econd*, rules or guidelines are needed to identify potential Platform investments from other types of IT investments. Kogut and Kulatilaka (1994) argue that this type of frameworks can sometimes be formalised to arrive at rather exact valuations while more often, however, they will serve to guide how opportunities should be identified and framed for analysis (Kogut and Kulatilaka 1994, p.59).

The second objective is to analyse and compare existing methods for evaluating independent and interdependent IT investments and to develop an evaluation model for deriving the value of IT Platform investments.

The evaluation model is to clarify the inter-relationship between different IT initiatives associated with platform investment, and provide a tool to determine their total value under different assumptions of fixed and flexible investment strategies under uncertainty. The model should therefore satisfactorily address the following issues:

- Integrate the effects of risks identified as relevant to the value of the investment.

- Incorporate the value of managerial flexibility associated with different investment strategies

The third objective is to test the framework and evaluation model empirically in a real industry case study, focusing primarily on the solutions applicability, assumptions, and mechanics.

Theoretical asset pricing models for financial assets have the advantage over capital investment and project evaluation models, that they are relatively easy to test empirically using high quality financial market data. Capital investment or project evaluation models are however, not as easy to test empirically due to obvious reasons. Most investment projects are unique in terms of their costs, benefits and risk, and are further often greatly influenced by the organisational and industry setting they are made in. This makes data collection on actual return on investment to compare to *ex ante* evaluation difficult. Therefore, these types of models are usually tested using case studies on individual companies.

1.7 Overview of the research approach

> *"Methodology is merely an operational framework within which the facts are placed so that their meaning may be seen more clearly" (Leedy 1985 p.91).*

This section presents a general overview of the research approach adopted in this study. A more comprehensive method discussion is presented in the relevant chapters. The objective with this overview is to describe the different steps in the research process and present the research approaches chosen to address the specific research objectives.

The first research objective is to formulise a conceptual and analytical framework for IT platform investments. Above all this involves the important task of defining IT platforms and their main characteristics, and further analysing how these investments are distinct from other types of IT and non-IT capital investments. A tentative definition of IT platforms is presented in sections 1.1 and 1.2 which is further refined throughout the research process, drawing on both the results from a literature analysis and empirical findings from an interview study presented in Chapter 2. It is further important to formalise and analyse the decision problem in terms of alternatives, expected impacts, major risks and the organisational and

industry environment. The fulfilment of this research objective includes the following research approaches:

- A literature study of the IT and information system literature, focusing on the special issues relating to IT platforms in general and more specifically the theory and praxis of IT investment in AEC industry

- An interview study for documenting and analysing the existing IT investment practice in the AEC industry

An extensive analysis of the IT/IS literature and industry journals, revealed that limited research exists that focuses on the evaluation of IT in AEC. Therefore an exploratory study aimed at gaining a deeper understanding on the problems formulated earlier, was performed in the specific AEC industry environment. The current investment praxis was studied using an in-depth interview approach with decision makers in AEC firms. The purpose of the interview study was threefold.

1. *Fact finding* for gaining an deeper understanding of the current evaluation practice, i.e. how are IT investments actually evaluated in AEC
2. *Problem identification* to assist in the establishment of future requirements
3. *Discussing possible solutions* regarding the problems faced by decision makers in the evaluation of IT investments in AEC

In-depth interviews were preferred over a standard questionnaire study for three main reasons. First, personal interviews allow for more detailed questions aimed more at understanding, rather than attempting to statistically describing the IT evaluation processes in AEC. This further allows the relevant questions to be explained to the required level of detail for the informant and the questions can be followed up directly. Second, the response rates of previous questionnaire studies in this industry have proved to be relatively low (Samuelson 1998; Andresen 1999; Andresen, Baldwin et al. 2000; Samuelson 2001), rendering the results statistically insignificant. Finally, a personal contacted is established with the organisation in question, making further cooperation easier at later stages in the research project. No formalised questionnaire was used in the interviews; however, a prepared interview guide (presented in appendix A) was used to insure that the predetermined scope of the interview is covered.

The second objective of the study is to develop a sequential evaluation model for deriving the value of IT platform investments. This objective is pursued through an

analysis of principles for investment analysis, focusing on theories, models, and frameworks relevant to sequential investment problems under uncertainty. This was principally a theoretical study based upon the work by Copeland and Atikarov (2001), Dixit & Pindyke (1994), Trigeorgis (1996), Luenberger (1998), and others. The theoretical study focuses on developing a method for *identifying, formulising and evaluating* strategies to manage the investment process. The contingent nature of IT platform investments, discussed in some detail previously in the chapter, naturally lead the focus of the search for an appropriate evaluation method to methods dealing with interdependent investments. Chapter 3 therefore focuses especially on new methodologies based on Real Options Theory. *Real Options* can be defined as opportunities, which arise in real investments where there exists flexibility to make future decisions in the light of subsequent information. A Real Option is thus the right, but not the obligation, to take action (e.g., deferring, expanding, contracting, or abandoning an investment project) for a predetermined cost, and for a predetermined period of time.

The final objective of the study is to test the developed framework and model empirically. This is done by applying the developed methodology on a real industry investment problem using the case study approach. This stage is important in order to demonstrate the practical application of the model.
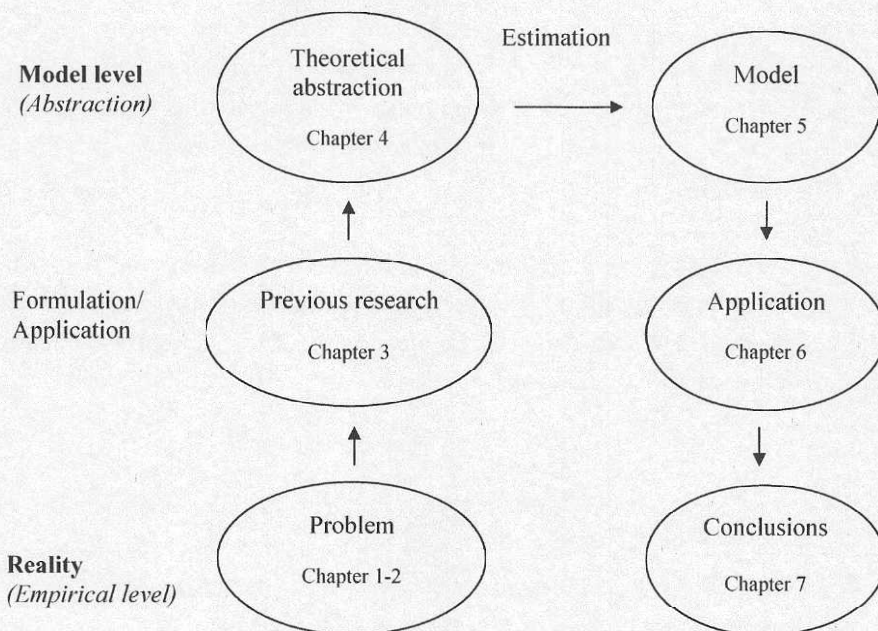
Figure 4: Overview of the research process

The research process is summarised schematically in Figure 4. The research starts with a practical problem of determining the value IT platform investment, which is observed in reality. The problem is formalised in an evaluation framework, in order to enable a more concise modelling of the relevant variables. The development of the evaluation model is principally a theoretical analysis which inevitably entails abstractions from reality (Ryan, Scapens et al. 1992). This abstracted formulation of the initial "real" problem represented in a formal model is then solved using an analytical approach. The application of the model and its analytical solution are then demonstrated on a real investment case.

1.8 Organisation of the thesis

The structure of this thesis follows a rather standard format. The thesis is divided into seven chapters. Chapter 1 has described the research problem and presented the research objectives.

Chapter 2 presents the results of an interview study involving IT managers and corporate executives in several major AEC companies in Sweden and the USA. The study explores the current practice for evaluating IT investments, focusing specifically on the type of methodologies used; the main types of costs and benefits

and on identifying principal risk factors. The study further examines whether there are significant differences in the evaluation approach depending on the type of IT investment involved, between different companies and/or different countries. The study also identifies distinct analysis requirements in the case of different types of IT investments and the industry context.

Chapter 3 presents and discusses previous focal work relevant to this study. The pros and cons of applying different theoretical approaches to the research problem are discussed. The final part of the chapter presents the study's theoretical point of departure and presents a comprehensive overview of previous research and in the area.

Chapter 4 describes the theoretical foundations of the evaluation model and outlines the conceptual framework on which the evaluation model developed in Chapter 5 builds upon. The conceptual framework provides a structured approach to identify, incorporate, and manage the diverse types of benefits, costs, and risks that shape the value of the IT platform investments investment at different times during the investment process.

Chapter 5 presents a *binomial evaluation approach* that extends the passive Discounted Cash Flow approach by encompassing the insights and tools from Real Options Theory. The chapter begins with a short discussion about the different modelling approaches available to evaluate contingent investments. Then the principles of binomial modelling are introduced and the necessary steps in the modelling process described. Finally, the application of the analysis model is described in a four-step evaluation process.

Chapter 6 In this chapter the evaluation framework and analysis model, developed in the thesis, are applied on a real-life case study. The goals of the case study are to demonstrate the application of the framework, and the mechanics of the analysis model on a real investment problem. The case involves an investment in an ERP system, and a number of related IT investment projects at Skanska, which is a large Swedish construction company. The chapter further compares the outcome of the analysis model to the results of a static Discounted Cash Flow analysis.

The final chapter presents a summary of the major results of the research and concludes with a review of the main contributions of the study along with suggestions for future research.

CHAPTER 2   IT Evaluation in the AEC Industry

The price of greatness is responsibility

Sir Winston Churchill (1874 - 1965)

2.1   Introduction

This chapter presents the results of an interview study where IT managers and corporate executives in several major AEC companies in Sweden and USA, were asked about theirs IT evaluation practices. The purpose of this chapter is twofold. First, the study explores the current practice for evaluating IT investments, focusing specifically on the type of methodologies used; the main types of costs and benefits and on identifying principal risk factors. The study further examines whether there are significant differences in the evaluation approach depending on the type of IT investment involved, between different companies and/or different countries. Secondly, the study aims to identify distinct analysis requirements in the case of different types of IT investments and the industry context.

2.1.1   AEC

The Architecture, Engineering and Construction (AEC) industry is composed of a diverse set of activities. Defined broadly it refers to all services required for the design, engineering, construction and maintenance of physical infrastructure investment projects. The industry consists of architect firms, consulting and engineering service companies, and physical construction service companies. The activities of these companies vary both within and between individual construction projects. Therefore, it is often difficult to delimit the actual boundaries of the construction engineering and design-services sectors (Soubra 1993).

Physical construction services pertain to investment projects of the infrastructural, industrial or agricultural type. They bring together labour, materials and equipment in order to translate the techno-economic specifications produced by engineering design services into concrete physical entities (e.g., industrial plants, infrastructure projects) (Soubra 1993 p.3).

Engineering design services are the complementary and related services which are provided by firms who are engaged in civil engineering and building design (Drewer 1993). These are knowledge intensive services that are essential to optimise the construction process, its choice, the technical process of its execution, and its management (Soubra 1993 p.2). The designs and specifications that these services produce should be the least-cost and highest-productivity solutions consistent with the economic and social constraints of individual markets. Many of these services are multidisciplinary in nature, requiring general and specialised engineering and other technical and economic skills to produce the requisite outputs (See for example Roberts 1972). Consulting and engineering design services can be classified according to the stage of development of an investment project. They would include: pre-investment services (e.g., opportunity studies, market studies, feasibility studies and location studies); project execution services (e.g., process and product design, *architectural* and structural design, design and layout of machinery and equipment, purchasing, inspection and testing of materials and equipment) and project implementation services, including production activities, technical and management personnel training (Soubra 1993 p.3).

2.1.2 Prior Research

Research on the IT investment evaluation practice of companies in the AEC industry is very limited. A survey on IT investment practice in the AEC industry in Denmark revealed that only about 56 per cent of the respondent companies either always or frequently perform an evaluation before making an IT investment (Andresen 1999). The survey further showed that primarily oral guidelines and subjective arguments are used in IT investment evaluation. This is consistent with studies by CIRIA (1996) in the UK and Love *et al.* (2000) in Australia, which found that the organisations in the construction industry generally do not use formalised methods to evaluate their IT investments. Aouad, Kagioglou *et al.* (1999) argue that the main problem related to IT adoption in construction is that most of the past IT investments have been motivated by operational rather than strategic and business requirements. This claim is supported by Songer, Young *et al.* (2002) which found that no clear IT investment priorities were established within the

organisations of US AEC firms. This, the authors argue, was possibly leading to excessive technology costs, delayed implementation, and a dilution of integration efforts.

Surveys by Samuelson (1998; 2001) show that IT use is widespread amongst AEC companies in Sweden, with 54 percent of employees on average having access to personal computers at the workplace. Application of IT is further reported to have improved productivity in administrative tasks and construction design, as well as providing better access to information as well as contributing to improved quality of the information produced. Similar results have been reported in surveys from Denmark and Finland (Howard 1998; Howard, Kiviniemi et al. 1998; 2001). Rivard (2000) conversely found that the complexity of work, the administrative needs and the costs of doing business was perceived to have increased as the result of IT in the Canadian AEC industry. Lautanala, Enkovaara *et al.* (1998) studied potential benefits of increased application of information technology in the Finnish construction industry. The study found evidence for potential net cost savings amounting to approximately 5 percent of the total output of the industry, ignoring any indirect benefits such as increased customer satisfaction and improved quality.

2.1.3 Research Approach

The prior research reported above gives some insight into the IT evaluation practices of construction companies. However, no attempt has been made to distinct between the diverse types of IT investments. An important objective in this research is to gain a deeper understanding of possible distinct analysis requirements for different types of IT investments. This type of information is difficult to obtain with standardised questionnaires. The choice and interpretation of question variables is problematic due to the complex nature of IT evaluations. Many concepts describing individual systems, costs, benefits and risks in the evaluation are not universally defined or accepted. The evaluation is further typically closely tied to the type of organisation involved and the context in which it is performed. Therefore an exploratory qualitative in-depth interview approach with a small sample of companies was chosen over a larger sample and a standardised mail questionnaire. An interview guide was used to ensure that the predetermined scope of the interviews was covered. The interviews were carried out in the summer of 2002 in two countries Sweden and the USA, to be able to compare possible regional differences. The drawback of this approach compared with using questionnaires is that the interpretation of the results is qualitative and lacks statistical significance.

The benefits, on the other hand, are a deeper understanding of the research object provided through instant feedback between the interviewer and the interviewee.

A total of seven companies were selected through purposive sampling, four companies based in Sweden and three based in the USA. Relatively large companies were handpicked for the study. Consequently the sample represents a comparatively large market share in each of the geographic regions. Although large organisations are not representative for the majority of organisations in the industry, large scale IT investments such as in ERP systems are generally limited to medium and big enterprises[8]. The Swedish companies included a major contractor involved in the design and construction of road and civil engineering facilities, telecommunication infrastructure, residential and commercial housing. The second company is a leading residential and commercial housing developer with extensive operations in all of Scandinavia. The third company was until recently a major construction company but is now focused mostly on Facilities Management of both public and private properties. The fourth company is a major architect and engineering consulting company. The US companies interviewed are all Design-Build contractors involved in engineering and construction services, providing technical management and directly related services to develop, manage, engineer, build, and operate facilities. One of the companies is a Californian contractor with operations in four US states while the other two companies operate both nationally and internationally. These three companies are all in the top 15 of the largest construction companies in the US[9]. Each company was represented by 1-3 people, usually IT managers and other project members involved in the decision making process. The interviews were conducted in Swedish and English and lasted between two and three hours. To encourage frank and honest responses and to protect potentially competitive sensitive data, the name of the interviewees and their companies are omitted from the text.

To study the possibly distinct analysis requirements, depending on different types of IT investments, the interviewees were asked about specific types of IT investments. Three types of investments were selected, primarily based on their potential size and complexity. First, to represent a major IT investment, the respondents were asked

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[8] A recent study on information technology evaluation and benefits management practices of small and medium sized enterprises in the construction industry found that firm size in terms of turnover and number of employees does not influence the general investment levels in IT (Love and Irani 2004).

[9] According to the Engineering News Record (www.enr.com)

about investment in Enterprise Resource Planning *(ERP) systems*. This kind of investment for a large contractor typically range from $5 to $10 million dollars and would therefore by most standards be considered a major investment. ERP is a software architecture that facilitates the flow of information between different functions within an organization. The system builds on an enterprise-wide database, operating on a common platform, which interacts with integrated set of applications to consolidate business operations in a single computing environment. Most ERP systems today are modular systems that allow for additional applications to be added to the original platform after the initial implementation (see e.g. Taudes, Feurstein et al. 2000; Björnsson 2003). Typical applications include Supply Chain Management, Customer Relationship Management, Product Lifecycle Management, E–Procurement, Financial Management et cetera. There are a number of "off-the-shelf" systems available today but many organisations choose to develop their own customised ERP systems internally. Consequently, the concept of ERP can have different meanings to different companies. The number of applications integrated into the environment varies and the level of the integration differs.

The second type of investment considered was *Project Extranets*. The aim with this type of application is typically to simplify the design and project management while facilitating communication and collaboration among General Contractors, Clients, Architects, Engineers, Construction and Project Managers and Subcontractors. The price for this type of application varies greatly depending on whether the system is developed and operated internally or an application service provider is used. In the later case, the monthly price is typically around $30 per user[10] often involving several hundred users in a single construction project which can take everything from few months to several years to complete. In any case this is a much smaller scale investment in terms of investment cost than an ERP system. The main motivation of studying this type of IT investment is that it is industry specific, i.e. the application is specially designed for construction companies.

Finally, to represent a relatively small-scale investment in terms its cost, the respondents were asked about investments in hand held computers or *Personal Digital Assistants* (PDAs). This equipment is usually used in combination with several types of standard software packages. The standard applications include personal organisers and email but with specialised software, this equipment is often used in more advanced applications. A common application for construction

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[10] Based on prices from application providers

companies has been the application of PDA's as wireless inspection devices and for transferring data to and from the construction site. The tool is then equipped with checklists, reference manuals and digital camera to wirelessly transmit data to central servers. The cost for a typical PDA application is estimated to be between $700 and $3000[11] per user per year, depending on the type and functionalities included.

These specific types of investments were selected because they are commonly known in the industry. Whether or not the individual companies have been involved in the specific investment, they were likely to have at least considered them. In the case when individual companies had not been involved with the specific IT investments described, the respondents were asked to inform how the investment would be evaluated if the question to invest came up, or alternatively discuss an actual comparable IT project.

2.2   Findings and Analysis

A large majority of the interviewees *described IT investment evaluation as being a very important and current issue in their companies*. The IT managers claimed to be under increased pressure from corporate executives to both demonstrate the value from past investments and to justify future IT investments. *A lack of simple but sophisticated tools to quantify the value of IT related benefits was seen as a major obstacle in this regard.* While the cost of the investments was believed to be relatively easy to quantify (although one manager emphasised that many IT investments had been made in the past without much idea of the real costs) *evaluating the expected benefits and the investment risks was generally seen as a major challenge.*

The Swedish companies were typically composed of several relatively independent operating units, with some common IT infrastructure and a central IT department, but with each service area also having an IT support unit of their own. The American companies appeared to be more centralised than the Swedish ones with individual divisions having relatively limited autonomy to make IT investment decisions.

A normal time span for an IT investment to go through the evaluation and implementation process ranged between 1 and 36 months, with the average IT

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[11] Based on prices from application providers

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projects taking about 6-8 months. *An important concern shared by all the companies was the problem of determining what costs and benefits should be classified as a direct result of the IT investments, and what effects were the results of associated process changes.* IT projects were in some cases identified to be the driver behind work process reengineering but in other instances a result of it.

The results from the interviews are summarised in table one, which shows the main factors identified by the companies as relevant to the various aspects of the evaluation process. The table is organised by the type of investment involved and the country of the respondent companies.

	ERP System		Project Extranet		PDAs	
	USA	Sweden	USA	Sweden	USA	Sweden
Benefits	Replace old systems/ reduce cost		Improved access to project documents		Time savings	
	Time savings/ Improve Business Process		Transparency		Reduced printing costs	
	Option to integrate further applications in the future		Risk mitigation	Improved sharing of information	Enforce best practice	Co-ordination benefits
	Real Time System/ User satisfaction				Learning benefits	Time management
Costs	Hardware/software		High speed internet access		Hardware/Software	
	Process reengineering		Develop software		Training	-
	People Time/Training		Service charges		System integration	-
	Consultants		User training			-
Risks	User adoption/internal		Internal User adoption		Having online and offline systems simultaneously	
	Technology risk		User external user adoption (Interaction risk)		User adoption	
	Vendor risk				Document security	-
	Data migration					
Evaluation	Payback, ROI, CBA		User surveys (ex post)	Only the Technical aspects of the systems evaluated formally	Surveys	Investment to small to justify evaluation
	User Surveys/Process analysis				User Reports	
	Formal evaluation process not defined	Multi stage evaluation processes				
	Pilot Projects					
Decision Process	Formal process involving cross-functional teams		Executive Sponsors	Pressure from clients	Grass Roots	Generally available to employees with selected job functions
	Final Decision at Executive Level				Required by client	
			Project Level	Department level	Project Champions	
Financing	Charged as General Overhead on individual business units		Project Level		Centrally	Department level

Table 1: Summary of the results from the interviews organised by the different factors in the IT evaluation, type of investment and the two sample countries.

2.2.1 Major IT investment projects

The reported investment costs ranged from $2 million to $40 million. The method by which the total cost of the investment was measured varied between companies in both countries. Those companies that reported relatively low investment costs had generally included only direct cost of hardware and software in their calculations and their system typically included only a single application, the most common being the Financial Management application. The companies reporting the higher investment costs had invested in systems with two or more applications. These companies had usually included the direct costs of training in the evaluation and in one case also the opportunity cost of taking employees off from other tasks during the training. *Interestingly, roughly half of the interviewees maintained that generally only around 20% of the total cost for this type of investment was related to direct software and hardware costs. The remaining 80% are made up of what one manager defined as "people time" which involves the training of both the IT personal and the end users, consultant hours and other people related costs.* The relatively low cost of hardware and software in comparison to total investment costs is consistent with findings by Love and Irani (2001) who further maintain that managers of construction companies frequently underestimate these indirect IT costs. The cost of reengineering internal work and business processes are also important items in this category. Most of the work involving the evaluation and implementation of the systems was done internally although all of the companies had also relied on outside consultants to some extent. Consultants were mainly involved in training the IT support personnel and when customised adjustments were required for the system development and implementation. In those cases when major customisation was required, the costs of consultants made up a substantial part of the total investment costs. The company that reported the highest investment cost, a Swedish contractor, described the ERP investment as an integral part of a larger IT investment program, involving organisation wide restructuring of IT activities spanning over a period of four years and costing between 35 and 40 million dollars.

The main motivation for making the investment was reported to be the need to replace old and outdated systems that were becoming costly to update and support. The type of benefits that were most frequently quantified, other than direct costs savings from replacing existing systems, were potential timesaving in the related business processes. Another type benefit that was identified as important but hard to quantify (and therefore usually left out of the analysis) was user satisfaction as the

ERP system was expected to facilitate the employee's daily tasks. Two contractors emphasized the importance of reengineering the relevant business processes in order to realise the full benefits of the system but that the cost of this should also be included in the analysis, which was usually not the case. Another benefit mentioned was the value of accurate real time information, enabling the contractor to increase the number of jobs, they were willing to bid on and hence increase revenues.

All the organisations that had *recently* been involved with the implementation of an ERP system emphasised that an important consideration in choosing between different system vendors was the *option to add future application modules* to the platform. The different types of systems thus entailed a range of future options entailing the opportunity to add new (but presently available) functionality to the existing system. In some cases, system vendors had even committed themselves to developing new applications that would be specifically designed to confirm with the project dominated construction industry characteristics. However, no attempt had been made to quantify the value of these future growth options and include them in the evaluation.

Risks and Evaluation
All managers identified poor user adoption as the major risk factor. If the end users are not willing to adapt to new business processes required to benefit form the applications, it will be difficult to realize any of the anticipated benefits. This is especially applies to users whose individual workload may increase as tasks are shifted to them from other points in the workflow. One IT executive emphasised that too many IT investments had been made in the past at a time when the internal processes in the organisation had not been ready to support the new system. Consequently, the new IT investments run the risk of being seriously underutilised when the applications do not conform to existing work routines. Other frequently mentioned risk elements can be classified as technology risk. This includes a multitude of different technical factors directly related to the operation of the system and its ability to provide the expected functionality. Three managers further identified data migration between the old and the new systems as major potential hazard. Another major risk identified by all the companies was vendor risk, which refers to the uncertainty of whether the system provider will be around in the future to provide service for the system. In one case, a contractor had developed a costly back-up plan to address the potential contingency of the vendor going out of business. An important aspect when choosing between different vendors was the

flexibility of the ERP system in terms of future expandability and the range of new applications that could be supported by the system. Larger and more expensive systems were considered less flexible with regard to expandability in terms of construction specific applications but at the same time subject to low vendor risk. Smaller vendors with more flexible systems typically offered more construction specific applications but the risk of the vendor discontinuing operations and therefore the system not being supported in the future was considered high. One contractor had plans to add an e-business application to his ERP platform, which would provide external stakeholders access to the central database. This kind application was believed to have enormous potential value to the company. However, several problems remained to be resolved for this option to be realistic, such as data security and how to share the potential costs and benefits of the system with the external users. In no case however, had any attempt been made to systematically quantify these different risk factors and analyse their potential impact on the business value of the different investment alternatives.

The process of implementing an ERP system was in most cases intuitively seen as a series of interrelated investments rather that a single IT project. The initial decision to invest was nevertheless generally treated as a "take it or leave it" proposition where once the decision was made the company followed a fixed predetermined investment strategy. Two of the Swedish companies had recently implemented a formalised evaluation process for new IT projects. In both cases, new projects would go through several evaluation stages, from a conceptual phase to full implementation. At each stage, a decision is made whether to proceed with the project, request further analysis, postpone, or even abandon the project completely. The focus of this analysis, like at the other companies, was to analyse the various technical aspects of system and implementation requirements, rather than potential business value of the investment.

The most frequently used financial evaluation criterion was the Payback method. This method measures the time it takes to recover the investment outlays. Some of the companies also applied simple return on investment (ROI) calculations and Cost Benefit Analysis (CBA) techniques. Only one company accounted explicitly for risk in the financial analysis by classifying how potential benefits were subject to different levels of uncertainty. None of the interviewees was willing to disclose the estimated ROI or Payback time of their ERP system evaluation. A majority of the respondents nevertheless disclosed that the simple financial evaluation alone had

not been sufficient to justify the investment. The final decision to invest had taken into consideration other strategic and non-quantifiable benefits.

All the IT managers further recognized the need for evaluating the investment after it had been made. However, in most cases no formalised processes or methodology was in place to do so. One manager was working on a process in which the end users would evaluate the actual cost and timesaving achieved since the implementation. Another IT manager acknowledge that project mangers were often reluctant to revisit past IT projects in the form of *ex post* evaluation due to fears of critique. At one of the Swedish companies, *ex post* analysis was planned to become an integral part of the project management process. Six to twelve months after full implementation, a review would be performed comparing the actual performance of the system to the estimated parameters. This however, had only been done for one IT investment project at the time of the interview.

Decision Process and Financing
The investment was in all cases financed centrally. The investment costs were then generally charged to the different operating units in the organisation based on different variations of a kind of technology fee per work hour, or as a monthly "computer fee" for each employee. One divisional IT manager identified lack of communication and coordination regarding IT investments within the organisation as an important issue. His division, unaware of any plans to switch to an integrated system, had recently invested in a new "local" financial and management support system shortly prior to the implementation of the ERP system. The IT manager explained:

> *"I see this as a general problem within the construction sector that we don't have a sufficient overview. There have been too many local investments on both different levels in the organisation and different locations"*

In all cases, the decision process for this type of investment involved decision makers at the highest level of the organisation. The decision whether or not to invest in an ERP system had in most cases been made at the executive level before the actual process of choosing between different software vendors and range of applications was initiated. The purpose of the evaluation itself was mainly focused on what functionalities to include, and which particular type of system to invest in. The general practice was to form a team consisting of end users, the relevant process owners, and the company's technology experts. The first step in the

evaluation typically involved business process analysis and a study of what functionalities to include in the system. In the next step the team usually evaluated proposals from several different vendors. Two companies had hired outside consultants to evaluate potential vendors. Having decided what to buy, the next step involved the reengineering of work processes, planning the implementation and training the users. The final decision of what to buy, and from which vendor, was again made at the executive level. The decision was based primarily on the functionality and technical aspects of the systems and in two cases also on a simple ROI analysis.

2.2.2 Medium-size IT projects – Project Extranets

The companies using an externally provided project extranet web service reported the main costs to be the price of procuring the application and the cost of providing bandwidth to the project sites. Two companies had developed the application internally in which case the cost of development was the main cost factor. The managers of the US companies listed enhanced schedule performance and increased transparency as the major expected benefits. Not only was the average project time expected to decrease, but also the project extranet was expected to reduce the risk of construction delays. As one executive explained:

"We are in the risk management business and we're looking to technologies to help us manage risks"

The Swedish managers contrary to their US counterparts were more sceptical about the benefits of this technology. The main motivation and reason for investing in the project extranets thus far had been pressure from the clients for more real time information and transparency. The clients felt it took too long time to react to information requests. Two of the companies had implemented this type of technology on a limited number of pilot projects as a response to this particular problem. The main benefits were anticipated to be involved with the different stakeholders in the construction project being able to share documents online and the documents being accessible with a standard internet browser. The initial experience of the system was that it did not live up to its expectations. The main problem was seen to be that the software platform and user interface was too complicated and not flexible enough to deliver the sought benefits.

Risks and Evaluation

None of the companies had performed a systematic risk analysis for an extranet project. The interviewees were however asked to identify what they considered important risks in this type of projects.

The IT managers identified user adoption as the primary risk for this type of investment. Although user adoption of internal users was an important concern like with the ERP investment, *the risk of low adoption by external stakeholders, or external adoption risk, was identified as the main concern.* Subcontractors who are not comfortable with using Internet technologies pose a substantial risk in this category. Architects have also resisted using this type of technologies claiming a substantial increase in requests for information and change orders resulting in an increased workload. A general concern stated by all the interviewees was that while the cost of this type of investment usually fall on the General Contractor, the bulk of the potential benefits accrues to the client or the facilities owner. The external stakeholders, who also experience indirect costs because of the system, therefore have little direct incentive to participate in the process re-engineering required for realising the full potential of the system. The magnitude of this effect was however dependant on the contracting environment of individual companies.

None of the companies had performed a formal cost-benefit evaluation of the project extranet. One US contractor had conducted a survey to monitor the use and user satisfaction with this type of tool. Another had conducted a simple ROI calculation for a single pilot project but this was not a standard procedure. In those cases where the construction project manager had authority to choose whether to use this technology, they were also accountable for making their own assessments of its potential value.

Decision Process and Financing

For most of the companies, the use of this type of tool was financed at the project level or explicitly charged to the client. One of the US contractors had adopted the Project Extranet as a standard tool on all projects. In this case the cost of the system was charged to the projects as part of their "technology tax" based on each hour worked. Top management had initially pushed for the development of this type of product by investing in a start-up company in this field.

For most of the companies, this type of investment is decided at the project, or department level. In case of the US companies, there was normally an Executive Sponsor, or project Champion, who pushes the project managers to test the technology. At the Swedish companies that had experience with this technology, the initiative had come from the clients, and the system application developed specifically at their request. An informal analysis had shown that the project extranet had provided limited benefits and no plans had been made for further implementation.

2.2.3 Small IT projects - PDAs

The basic hardware cost was generally considered insignificant with a more substantial part of the cost being the software and user training required for the specialised software applications. The main benefits of this type of solution were identified as costs savings through reduced printing costs and timesaving. One US contractor saw this as tool for the enforcement of best practice throughout the company. Another contractor had initiated a pilot project limited to one construction project in order to learn more about the value of the technology.

Risks and Evaluation

User adoption was once more identified as the predominant risk factor. Other concerns included the risk from migrating from offline systems to an online system resulting in incomplete documentation. Document security involving online data was also considered important.

Two of the US companies had conducted surveys of user needs and satisfaction to evaluate this type of investments. The Swedish companies had not performed a formal evaluation. The investment costs were considered too small to justify spending resources on evaluation. At two of the Swedish companies, this kind of investment fell under the corporate IT strategy that described the basic computing environment, i.e. what type of equipment is to be available for the different employees depending on their job functions. Another IT manager said that:

"If the project manager or software vendor can show that the application demonstrates a solution to a well defined problem we have, we invest".

Decision Process and Financing

In most cases, small investments like this were financed at the project or department level. One contractor saw this as a strategic investment and as such, it was financed through the main corporate IT budget.

The US firms had adopted this technology to function as wireless inspection device. The implementation had mainly taken place through a grass root process with the decision taken at the project level. In these cases there was a "project champion" involved in the project which had tested the technology and convinced the colleges of its benefits. At one US firm, this was seen as strategic investment, which was promoted by the central IT department in cooperation with the pioneer users. The next step involved writing a business case to be presented to an executive committee, which decides about any corporate wide investments. None of the Swedish companies used this equipment in connection with wireless inspection. However, two companies had made this kind of equipment available to its employees at their request. In both cases, the PDA's were only used with standard software packages including personal organisers and email. Both companies were aware of the possible application of these devices for wireless communication with construction sites but believed that the required investment was not justifiable at the time. An important obstacle was that a successful implementation would require substantial reengineering of current work process and that the necessary platform to compile and make the information collected useful was not in place.

2.3 Analysis of the results

2.3.1 Comparing the Swedish and the US companies

Overall, there were no great differences in the IT evaluation practices between the two countries. The main differences between companies in the two countries is perhaps that motivation for IT innovation was bottom up (grassroots) in the US companies while the approach was often top down at the Swedish firms. One explanation might be that the financing for new investments was more frequently provided at the project level at US firms while generally at the department or regional level at the Swedish firms. Perhaps because of this, the evaluation process at the Swedish companies tended to be more formal. The US companies seemed to rely more on executive sponsors and projects champions pushing for the investments. Uncertainty regarding user adoption of new IT investments was a common concern at all the companies in relation to all the different types of investment. It is interesting to note that the interviewees used various terms to

express these concerns and rarely used the term "user adoption risk". This is an indication of the different terms used in IT evaluation, both between different companies and within individual companies. This increases the risk of misunderstandings, which can lead to conflicts about the individual investment proposals and further highlights the need for a common evaluation terminology.

Another difference between the US and Swedish companies was that the investment rate in information technology was generally reported to have dropped substantially due to the economic downturn at the Swedish companies, while to have remained constant, and even increased in the US. The Swedish companies claimed that the focus now was on trying to make sense of past investments and trying to take full advantage of systems already in place. One Swedish IT executive explained:

"The focus is now on cost efficiency of the IT investments while in the 90's we were more focused on quality and less concerned about how much the systems would cost".

Their US colleagues arguments were that during slow times, the opportunity cost of "people time" was much lower than in boom times and as this cost factor was often a very substantial part of the investment cost, it was actually less costly for the companies to invest now.

2.3.2 Special Characteristics of IT Investments

The interviewees generally described the evaluation of ERP investments as a very complex and difficult task. Depending on the existing computing environment, the analysis ranged from deciding whether to replace a number of existing systems, what functionalities to include, whether to develop a system internally, or buy standard system solutions, to the problem of choosing between the different vendors. The outcome of the investment is further influenced by several risk factors such as uncertainty regarding adoption by both internal and external stakeholders, risk of vendors not being around in the future to support the systems and technological risks. Larger projects tended to be subject to a more rigorous technical evaluation, involving a grater number of people, than smaller projects. In fact, small IT projects were often not evaluated formally, as the scope of the investment was not regarded sufficient to justify spending resources on evaluation. Despite the strong culture of applying sophisticated formal financial evaluation methods (predominately risk adjusted Discounted Cash Flow analysis) on major projects

such as land development and tenders on construction contracts, a majority of the IT investments were generally not evaluated as rigorously. This even applied to large scale IT investments requiring extensive resources. This is consistent with results from other studies on IT evaluation in the sector (CIRIA 1996; Andresen, Baldwin et al. 2000; Love, Irani et al. 2000; Songer, Young et al. 2002).

Powell (1992) investigated whether the lack of formal evaluation of IT projects may be due to other factors than to a deficiency in the tools available to the evaluator. He maintains that an important contributing factor is that the evaluation was typically the responsibility of technologists that did not possess the necessary investment appraisal skills. This, he argues, has contributed towards a myth of intangible costs and benefits associated with IT investment, which are to be hard, if not impossible to quantify.

2.3.3 Identifying distinct analysis requirements

The evaluation of small to medium IT investment projects was generally not regarded difficult. This was mostly because these investments were either done on the bases of clearly identifiable benefits, or that the cost were too small to justify a formal evaluation. Large-scale investments involving for example Enterprise systems were perceived as more difficult to justify. Major IT projects are seldom easily definable entities with a clear scope and fixed boundaries. The integrated nature of information technology with business processes, organisation structure, and other existing and planned information systems reflects the contingent nature of these investments. Many of the IT managers characterised the ERP implementation as more of a series of multiple interrelated projects rather than a single project with a clear start and end. The task of justifying the investment costs using the simple Payback method and ROI was seriously challenged by a number of factors:

- The IT managers identified a number of different risk factors that were expected to affect the potential outcome of the investment. None of the methods used were however able to clearly account for these risk or incorporate them into the evaluation.
- Indirect benefits produced for, and derived from, other present and planned systems.
- Difficult to isolate benefits of IT from other process and organisational changes

Based on the scale and scope of individual IT investment initiatives, it is possible to classify them further into subgroups depending on distinct analysis requirements. One intuitive way of doing this is to distinguish between investments that are made as part of a general IT policy, IT investment projects that are clearly defined in terms of their objectives and scope, and finally IT investment programmes that encompassed two or more interrelated IT investment projects.

IT policy: describes a set of overall objectives set at a high level of the organisation. This type of policy often prescribes a minimum availability of IT resources for individual functions in the organisation, maximum acceptable downtime of information systems and hardware, timing of routine upgrades of hardware and software, etc. It further often contains the directives regarding the minimum IT security standard that is to be sustained throughout the firm.

IT project: is used to describe an initiative which is relatively strictly defined in terms of time, scope and budgetary allocation. The concept of IT project, covers a wide variety of different types of technology enabled or based initiatives, which can vary greatly in scope, in terms of the time frame and investment costs. A project can be defined as a management tool for moving an enterprise from its current internal structure, in terms of its products, organization, production facilities, management systems etc., to a new structure, to achieve the goals it has set for itself for the future (Hogbin and Thomas 1994).

IT program: refers to a set of interrelated initiatives, which extend over time and space, in parallel or in phases. New IT investments are often described as a step wise process where the initial investment is seen as an experimental pilot investment to learn more about the technology (Gibson and Nolan 1974; Dos Santos 1991; Panayi and Trigeorgis 1998). Depending on the outcome of the pilot investment, further IT project investments may follow which are contingent on the initial investment.

Large scale IT investments frequently create business capabilities and opportunities that extend beyond the boundaries of individual construction projects, business units and sometime even beyond the boundaries of the organisation itself. The complex nature of these investments in terms of the uncertainty, opportunity and managerial flexibility, is simply more than the conventional financial evaluation methods can handle appropriately. The widely applied traditions capital budgeting

methods systematically overlook or trivialise one or more of these issues. In the presence of high uncertainty involving contingent investments these methods tend to undervalue this type of investment (Kogut and Kulatilaka 1994; Trigeorgis 1995a; Kulatilaka, Balasubramanian et al. 1996). Therefore, applying these methods on the full range of different types of IT investments will result in a tendency to overemphasise projects that generate short-term revenues. The limited use of formalised methods in the evaluation may be seen as an indication of the inability of simple financial models to capture these benefits. In fact, the interviews revealed that managers often overrule the results of the simple ROI and Payback analysis, and base their final decision on their intuition and qualitative judgement. However, the study also showed that except in the case of the most extensive IT investment initiatives, like the ERP investment, high level management was rarely intimately involved in the evaluation and decision making process. Love and Irani (Love and Irani 2001) argue that one implication from corporate executives showing poor understanding of the importance of IT evaluation, is that it makes them easily susceptible to persuasion by software vendors and consultants.

2.4   Summary and tentative conclusions

This chapter has presented the results of an interview study that analysed the IT evaluation practices of several construction service organisations. Not surprisingly, given the predominant engineering culture in the sector, there is a strong focus on evaluating the technical aspect of the IT investments. Limited attention is put on the economic side, except for applying the simplest of financial metrics such as the Payback method and ROI. IT was in many cases essentially seen as an operating cost rather than a capital investment, especially in case of small and medium size investments. This attitude is further reflected in an almost total absence of strategic considerations in the evaluation, even in the case of large scale IT investments. The valuation is typically the responsibility of the companies IT experts and in some cases shared between the IT department and individual construction project managers. Generally these individuals have a strong engineering or technical background and limited experience of financial evaluation of complicated capital investments. No examples were found of any attempts to apply IT evaluation methods that focus on analysing and understanding the impact of new technological innovations on the role and culture of the organisations.

There appears to be no significant difference in the type of analysis models used to evaluate simple small-scale projects and IT platform investments. Although in the

case of the more complex projects, an additional effort was typically put into the evaluation process. As the motivating example in Chapter 1 showed, platform investments are more difficult to evaluate using conventional financial evaluation methods than small scale IT investments, which are seen as either threshold investments or have clearly specified efficiency enhancement objectives that are relatively easily quantifiable through pre-identified cost savings.

If AEC firms are to be able to appreciate fully the business and strategic value that information technology can bring to their organisations, the simple methods applied in the evaluation are not likely to be adequate. The strong focus on the technological aspect of the evaluation indicates a narrowly defined evaluation objective based on the formal paradigm derived in the early stages of IT evaluation (cf. Powell 1992), when the focus of new technology was manly to automate work processes and cut cost. This perspective lacks consideration for the integral role the information technology now plays in organisation design and business processes. Unlike many other capital investments, IT has little intrinsic value due to high degree of organisational specificity and irreversibility of the investment costs. Consequently the value of IT is inherently derived from the organisational and industry context it is applied to create business capabilities. Focusing solely on efficiency benefits can results in confined, fragmented and an often short-sighted time horizon. Ignoring important elements such as strategic value, managerial flexibility, the effect of uncertainty and opportunities for future applications in the IT investment evaluation prevents managers from comprehending the full potential value of IT investment opportunities. This is likely to lead to underinvestment in innovations, where the benefits might be substantial but long term. This may ultimately limit the opportunity for both individual companies and the sector as a whole to develop.

CHAPTER 3   Methods for IT Investment Evaluation

*All great things are simple, and many can be expressed in
single words*
                    Sir Winston Churchill (1874 - 1965)

Despite the large amount of literature dealing with IT evaluation there has to this date not been developed any grounded theory. The methodological problems, encountered in the evaluation of information technology, have been addressed within several different theoretical frameworks. Few examples include Financial Theory, Decision Theory, Management Information System Theory, Economics and Economics of Information, Contingency Theory, Organisational Theory, Agency Theory and Game Theory. The contributions to this point are essentially a collection of different methods and models from different theoretical backgrounds. Lubbe and Remenyi (1999 p.146) noted that:

> "Unlike other social sciences there is no John Maynard Keynes, Max Webber or Karl
> Marx in information systems management. Even the best known authors in the field
> of information systems cannot be considered to have developed any grand thesis or
> theory"

3.1   Understanding the task: IT investment evaluation

How evaluation is defined stands in close connection with its use. Consequently, there are many different approaches to carrying out evaluation and there are no ultimate or exact theories to depend on. The nature of the benefits of IT investments is such that that it is usually difficult to estimate with any confidence the payoff off the investment. This is due to the fact that these investments are inherently risky and the realisation of their potential benefits is usually dependant on the active

management of the investment even after the initial infrastructure is in place. Further, the objects in the evaluation are not always easily definable as the role technology plays as a driver or an enabler of new business capabilities are often blurry. One way to define the evaluation of Information Technology (IT) is as a process that places at different points in time or continuously, for searching for and making explicit, quantitatively or qualitatively, the relevant impacts of an IT investment (Love and Irani 2001).

To date, the question of whether the evaluation of IT investment is fundamentally any different from the assessment of other types of capital investments remains debated. Powell (1992) maintains that there seems to be an almost blind acceptance in most of the IT literature as well as in practice that IT investment evaluation is different because IT is unlike other capital assets. This claim is partly supported by the results of the interview study, which showed that IT investments were in most cases treated differently than other types of investments. Powell (1992, p.33) however, argues that the problems inherent in many other types of investment considerations are of similar nature, and hence the solutions found there, "if solutions there are, may be the same".

The vast amount of literature on the subject however suggests that there is something special about IT investment evaluation. Numerous evaluation methods have been developed specifically to deal with IT investments, some short lived while others have gained some momentum in the literature. Authors like Carlson and McNurlin (1989), Powell (1992), Farbey *et al* (1993) and Renkema (2000), have compiled overviews of the most commonly known methods discussed in the literature to this date. Renkema (2000) identified as many as 65 distinct methods, all with the purpose of assisting organisations with their IT investment decisions.

3.1.1 IT investment evaluation Methods

IT evaluation methods can be classified into three main streams, technical or functional stream, economical or financial stream and interpretive evaluation stream (Serafeimidis 2001). The technical or functional stream focuses on the technical aspects of the IT and the evaluation is mainly concerned with efficiency in terms of the technical performance and the control of resources. The goal of the investment can be to: increase or improve capacity, reduce errors, enhance reliability, labor savings, or enhancing software performance development and quality. The economical/financial stream views IT as a capital asset rather than an operating

cost. The valuation thus focuses on the value creating potential of the IT investment, i.e. its output rather than the asset itself. The interpretive stream represents a move towards the inter-actionist role of the technology with the organizational structures, culture and stakeholders where the objective is to analyse and understand the social and subjective nature of the phenomenon (Serafeimidis 2001). This type of evaluation has more in common with the field of IT project governance and information system management rather than investment evaluation per se. The main characteristics of these different evaluate streams are summarized in table 2.

	Technical	Economic	Interpretive
Why?	Tech. performance Control of resources	Quality & Utilisation of IS outputs	Context-sensitive Understanding Org. Learning
What?	IT system Automate (cost red.)	IS outputs Informate Uncertainty/Risks	Broad portfolios Intermediate meas.
When?	*Ex ante* *Ex post*	*Ex ante* *Ex post*	Continuous benefits management
Who?	IT experts	IT experts Finance/business p.	"Evaluation party" Internal/external
How?	Quality related Cost related	Economic orientated Finance orientated Behaviour Science	Meta-methodologies Contemporary methods
Assuming?	Efficiency	Effectiveness	Understanding

Table 2: Overview of IT investment evaluation streams (source: Serafeimidis (2001))

If one were to place the results of the interview study from Chapter 2 into this table, the current IT evaluation practices in the AEC industry seem to match with the technical evaluation stream. That is, in those instances when the IT investments were evaluated at all, the evaluations were typically performed by the companies IT experts, focusing principally on technological performance, and reducing operating costs. At the same time, the IT managers descried themselves as being under increasing pressure from top management to justify financially both past and future IT investments. Using techniques focusing on the efficiency side of technology investment, the task of demonstrating business benefits from IT investments was in general described as difficult.

The focus this chapter and the analysis that follows, will primarily be on the type of evaluation that would correspond with the economic stream descried above. Much

of the challenges faced in IT investment evaluation are common to other types of investments. The study is therefore not limited to those research approaches advocated in the IT literature domain. The analysis that follows will therefore focus on the general characteristics of the different evaluation approaches and their applicability to the problems identified, rather than the purpose for which they were developed.

3.2   Subjective methods

The development and application of subjective or qualitative methods in the context of IT evaluation first arouse in the late 1970's. Powell (1992) suggests that the main motivation for this was to get the computer system out of the data processing domain and closer to that of the manager or user, and thereby giving the user a sense of participation, ownership and commitment. In order to deal with the intangible or soft nature of many benefits derived from IT investments, methods based on the multi-criteria approach were developed to deal with the non-financial aspects of this kind of investments. This implies that a single, or sets of measures, are created for each investment. Several different variants of this method have been developed with Information Economics, Scoring Models, Multi-Attribute Decision Making (MADM) and the Balanced Scorecard being among the best known and widely applied subjective methods (Remenyi, Money *et al.* 2000; Renkema 2000).

3.2.1   Information Economics

In the Information Economics (IE) approach, developed by (Parker, Benson *et al.* 1988), a broad concept of value is introduced based on the effect information technology investment has on the business performance of the organization. The methodology is based on three principle parts, which define the benefits of the investment: the economic domain, the business domain, and the technology domain. These individual domains are in turn made up of several different sub categories. Costs are defined to include all negative effects of IT investments and together these two factors, the benefit domains and the costs, are used to derive the "true economic impact" of IT investment. The approach does not impose a single evaluation technique but rather attempts to tie together a range of analysis methods, such as cost benefit analysis, value acceleration, value linking and restructuring, and innovation valuation, into a coherent structure. Information Economics further provides a framework for classifying risks associated with IT investments. Five different sources of risk are considered, strategic uncertainty, organizational risk, information system infrastructure risk, definitional uncertainty, and technological uncertainty. Although this method offers a rather comprehensive evaluation, it

requires extensive knowledge to be applied properly, and further calls for a large amount of information from different sources that can be time consuming and costly to obtain.

Serafeimidis and Smithson (1999) studied the empirical application of the IE approach in a case study involving a large global insurance company. The study spans over six years in which the company initially abandoned a traditional financed based cost benefit approach for evaluating their IT investments. This was done given that the company realised that the approach was unsuitable for dealing with the assessment of the complex returns and the strategic nature of the IT investments. The new analysis approach adopted was a generic method based on the theoretical foundations of IE and consisted of a financial cost benefit model, a risk management plan and a specific benefits profile. The study showed that although considerable resources had been put into developing and implementing the method, the introduction of the approach met much resistance from important stakeholders in the organisation and was consequently diluted substantially. Despite a significant effort in introducing intangible and strategic considerations to the evaluation, the evaluation model dealing with tangible benefits was the only one that survived the rather stormy implementation process.

Andresen (2001) tested the application of the IE approach to IT evaluation in the specific context of the AEC industry. The purpose of the study was to examine the usefulness of the methodology for IT evaluation for organisations in this particular industry setting. The analysis was based on a case study approach where IE, in conjunction with three other evaluation approaches, was applied on five IT investments in two construction companies and three engineering service companies in Denmark. The results of this exercise showed that the application of the method to real projects was very complex and resource intensive. Andresen further found that an important weakness of the approach was that its application is based on a complete framework, implying that every stage of the methodology needs to be completed in order for the results to be useful. This was especially a problem in the cases where the evaluation objective of individual companies was less ambitious than the complete evaluation solution offered by the methodology. A further drawback identified by Andresen was that discounting is not used when estimating the cash flows derived from the investment, which makes comparison of monetary benefits in different time periods meaningless. However, the most important weakness identified was the static nature of the approach in terms of solely focusing

on pre-investment or *ex ante* value of the system and ignoring both the need to manage the investment progress during implementation and ex-post value of the investment. The main advantage of the approach was found to be its wide scope reflected in the focus on tree domains discussed above.

3.2.2 Scoring Models

Scoring models are designed to deal with the subjective aspects of evaluation and they have been widely applied within the area of IT investments (Remenyi, Money *et al.* 1993). It may be hard to quantify the monetary value of effects such as "enhancement of employee IT skills" or "improved relationship with suppliers due to better communication". In scoring models, the decision-maker assigns weights to different strategic criteria in order to enable the assessment of the investment by rating how it will affect these criteria. The advantage of scoring models is that they do not exclude criteria only because they are difficult to quantify in monetary terms. They also make it easy to communicate the strategy of the enterprise by making the weights of strategic criteria explicit to lower lever decision-makers (Cooper, Edgett *et al.* 1998). Firstly, this can work top-down as top management make sure that their strategic goals are pursued at all levels. Secondly, the assignment of weights can also serve as a tool for top management to discuss and decide upon the overall strategy. The major disadvantage of scoring models is that the output is an abstract number. Everyone may understand what a net present value (NPV) of SEK 1 million means. However, realising whether the output of 6.7 from a scoring model makes an investment worthwhile requires an understanding of the model and the context. This problem becomes even greater when dealing with complex investment decisions in multi divisional and decentralised organisations, such as is often the case with AEC companies. It should however be noted that scoring models are not specifically designed to replace the traditional capital budgeting methods. They can be used to complement them to ensure the inclusion of qualitative values. Moreover, they do not sufficiently address the problems identified in Chapter 1 (cf. section 1.5).

3.2.3 Multi-Attribute Decision Making

Multi-Attribute Decision Making (MADM) models are more elaborated versions of scoring models. Numerous different techniques have been developed. One example is the Analytic Hierarchy Process (AHP) (Saaty 1980). This method provides a systematic approach for gathering and quantifying weights and ratings of both objective and subjective criteria in order to compare them on a common scale. Many of the MADM models also include methods for dealing with decision-maker

inconsistencies and disagreements (see e.g. Hwang and Yoon 1981; Hwang and Yoon 1987).

MBITI (Measuring the Benefits of IT Innovation), is a MADM model developed specially to deal with IT investments in the construction industry (Carter, Thorpe et al. 1999). The model is divided into two main parts: a strategic part and a benefit part. The strategic part is composed of seven questions about the background and the strategic aspects of the IT investment. The benefit part consists of three tables focusing on efficiency benefits (the economically measurable benefits), the effectiveness benefits (the other measurable benefits), and the performance benefits (non-measurable benefits). Each of the tables is divided into 10 general business processes that have been defined in terms of the AEC industry environment. The study by Anderson (2001) cited earlier in the chapter, also examined the practical application of this approach in five case studies involving Danish AEC companies. Practitioners found the method difficult to use when comparing different IT investments due to multiple types of output provided by the different parts of the methodology. The main strengths of the method were found to be the pre-defined process related benefits used for identifying the impact of the investment. However, the output of the model was described not to be particularly helpful as a decision support tool (Andresen 1999).

The advantage of MADM over scoring methods is that it is a more elaborate approach, which better reflects the decision-makers objectives. However, the often-complex calculations also introduce a "black box" approach where it is hard for the decision-maker to see the relationship between input and output. Another problem is that the output is a qualitative rating rather than a monetary number.

3.2.4 Ratio Measures

The Ratio approach refers to several different methods that are used to compare organizational and financial effectiveness in terms of ratios. These methods have been applied to IT investment valuations and are commonly used by consulting firms. A method that has attracted considerable attention is the Return on Management (ROM). ROM treats management as a scarce resource, that defines the extent to which business value is derived from IT deployment (Renkema 2000). The method essentially measures how effectively management uses available information. An advantage of this approach is that the required information is usually readily available from the traditional financial statements. A major

drawback is that the method essentially assumes that the information systems are only used by management. Further, it does not consider different factors affecting the ratio nor does it consider the causality relationships. This kind of methods are useful when benchmarking the IT expenditure to other organizations, or comparing IT expenditure to other investments, but not appropriate to evaluate competing projects within the organization (Flatto 1996).

3.3 Financial Evaluation Methods

Traditional financial or capital budgeting methods usually refer to the Payback method, Accounting Rate of Return (ARR), Net Present Value (NPV), Internal Rate of Return (IRR), Modified IRR (MIRR) and Profitability Index (PI). All these methods all have in common that they can be described as static and mechanistic evaluation techniques that implicitly view projects as producing specified streams of cash flows with a know distribution. They further presume that decision makers or agents, inside or outside of the organisation; do not play a significant role in the asset valuation. "If individual decision makers or agents appear at all, it is as idealised, ethereal creatures that act without consideration of their own interest and always maximize the value of the firm" (Brennan and Trigeorgis 2000 p.2). This section reviews some of the prevailing capital budgeting methods and their possible application to IT project evaluation.

3.3.1 The Payback method

The Payback methods was the first formal method used to evaluate capital budgeting projects and is still one of the most widely applied project evaluation methods, despite the fact that many authors have shown that the method is implicitly flawed as a stand alone method. The typical way in which the method is applied is to accumulate the project's net cash flows to determine the expected number of years or months required to recover the original investment cost. The main problem with this approach is that it ignores the cost of capital and time value of money and it further ignores all benefits of the investment beyond the payback period. The method may be suitable as a supplement to other evaluation approaches to provide an overview of how long funds are tied up in individual projects. A more accurate way to evaluate projects is to use some form of discounted cash flow analysis such as the NPV approach.

3.3.2 Discounted Cash Flow Models

In Discounted Cash Flow (DCF) analysis investments are represented as a sequence of negative and positive cash flows. Discounting is used to enable the comparison

of cash flows that occur at different points in time. The prevailing DCF methods are the Net Present Value method (NPV) and the Internal Rate of Return (IRR). In NPV cash flows are discounted using a discount rate that takes into account the time value of money and the companies cost of capital (typically the firms Weighted Average Cost of Capital (WACC)), while IRR seeks to calculate the discount rate that equalizes positive and negative cash flows. For an investment to be profitable in the two frameworks respectively, the sum of the discounted cash flows should be positive in NPV, or the IRR should be greater or equal to the company's cost of capital, i.e. its discount rate.

The basic formula for calculating the NPV of a project is:

$$NPV = \sum_{t=1}^{T} \frac{E(c_t)}{(1+k)} - I_0 \qquad (3.1)$$

Where $E(c_t)$ is the expected future cash inflow at time t, k is the companies cost of capital and I_0 *is* the investment outlay in period 0. The formula for IRR is essentially the same, except instead of k being an input variable in the model, the formula is solved for the discount rate that gives NPV=0. For all independent normal investment projects, the NPV and IRR methods will give the same accept/reject decision. In the case of comparing mutually exclusive investment projects, the two methods can give conflicting results[12]. This especially applies when mutually exclusive projects vary in scale and in timing of the expected cash flows. The NPV method is generally considered superior to the IRR method in all corporate finance textbooks (See for example Brigham and Gapenski 1996).

The major advantages of NPV method is that it is widely accepted, used and understood amongst industry decision-makers. Furthermore, the output is expressed in monetary terms. The NPV method works well when the cash flows are known with relative certainty and the investment is independent of other investment projects in the firm. Unfortunately, this is rarely the case with IT investment projects.

The basic DCF models have, however, been widely criticized for the difficulty in dealing with intangible assets, future cash flows, management flexibility and for the

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[12] The Modified Internal Rate of Return (MIRR) corrects some of the conflicts between the IRR and NPV methods. However MIRR is still generally considered inferior to the NPV method.

difficulty in determining an appropriate discount rate (Myers 1987; Santos and L. 1991).

Dixit and Pindyck (1994 p. 6) identify two important limitations of the basic assumptions of the NPV method. For the NPV to apply one of the two following conditions need to fulfilled. First, that the investment is reversible and can somehow be undone and the investment costs recovered should market conditions turn out to be worse than anticipated. This implies that the investment is essentially risk free. Second, if the investment is irreversible, it is a now or never opportunity which if not undertaken now will disappear. Most IT investment projects satisfy neither of these conditions. IT generally has low intrinsic value, which means if the investment project need to be abandoned, only a small part of the expenditures are likely to be recoverable. Investing in IT is also seldom a now or never opportunity. Typically, companies can choose between adopting a new technology now or later. The same usually applies to upgrade investments.

Trigeorgis and Mason (1987) argue that there are two main problems in applying NPV analysis on real investment projects. First, when there is operating flexibility available within a single project, which enables the decision, maker to revise the investment at a future date, and second, when the investment involves strategic value as a result of interdependence with future and follow-up investments. In both cases the NPV analysis is unable to capture the additional source of value derived from the flexibilities. This view is similar shared by Dixit and Pindyck (1994) and Myers (1987) which argue that the most serious shortcoming of the NPV approach is its inability to capture the sequential interdependence between investments.

Trigeorgis (1998) argues that the presence of managerial flexibility will alter the project's risk, and thereby alter the discount rate that would prevail without the flexibility. For example, the possibility to abandon an investment project would reduce the project's risk and lower the discount rate. It follows that using a constant discount rate as is done in the basic NPV approach will ignore the potential extra value from the possibility to abandon the project and thus undervalue the investment. Cortazar (1999) supports this argument by emphasising that whichever pricing model is used (CAPM or APT) to derive the discount rate, the risk structure of most investment projects will change over time. This means that the risk-adjusted discount rate will also change over time, which in turn will lead to errors in the evaluation results.

3.3.3 Certainty Equivalent Method

The Certainty Equivalent (CE) method, first developed by Robichek and Myers (1966), is closely related to the NPV approach. The main difference is that instead of adjusting the cash flows through a discount rate, the cash flows are adjusted directly and discounted with a risk free rate (r).

$$NPV = \sum_{t=1}^{T} \frac{\hat{c}_t}{(1+r)^t} - I \qquad (3.2)$$

The uncertain cash flow in each period, c_t is replaced by its certainty equivalent $\hat{c}$ amount, i.e. the certain cash flow in year t that has the same present value as the uncertain cash flow in that year (Trigeorgis 1998 p.34).

The CE method thus separates the effects of the time value of money under certainty and the effect of risk on the NPV. Each estimated cash flow stream is replaced with its certainty equivalent value in a given time (the numerator of the NPV equation) period and the then discounted back to present time with a risk free interest rate to account for the time value of money.

The CE method appears to solve one problem for which the DCF methods have been criticised for, namely the discount rate problem. The rationale of the method is to find a monetary amount at which an investor is indifferent between taking that amount with 100% certainty and deciding on an investment with an uncertain outcome. Therefore in principle, the CE method is directly dependent on the investor's preferences which can be expressed for example by his utility function (Hirschey and Pappas 1996).

Each cash flow is adjusted by a risk premium to enable risk-free discounting. The risk free premium can therefore be defined as: $p_t \equiv E(c_t) - \hat{c}_t$, and the certainty equivalent cash flow can as a result be written as $\hat{c}_t = E(c_t) - p_t$. In accordance with standard finance theory the relevant risk premium is that of the average investor in the market, or the market risk premium times the covariance of the period's uncertain cash flow with the expected market rate of return (Trigeorgis 1998 p.34). The risk premium can further be written as the ratio $\alpha_t = \hat{c}/E(c_t)$, where α_t is the certainty equivalent coefficient (CEC). Under the same assumptions, the standard NPV method and the CE approach will therefore lead to the same

result. If the cash flows from an investment extend over multiple periods, in general the individual cash flows may be associated with different levels of risk, which implies that the CEC is not constant. The problem of the discount rate therefore remains, as it is now replaced with finding the appropriate CEC for the cash flows in each period.

3.3.4 Risk adjusted discount rate

The risk adjusted discount rate approach is an extension of the standard NPV model. In this approach, opposed to the CE method the cash flow stream is not adjusted. Instead, to account for the uncertainty the discount rate is adjusted to reflect the uncertainty or risk of the project (in the denominator of the NPV equation). The greater the risk the higher will be the discount rate and therefore the lower will be the investments adjusted NPV.

In general, investment projects with average risk and within the core business area of the investing company do not have any impact on the total risk profile of the company. This type of projects can therefore typically be discounted at the firms weighted average cost of capital (WACC). Large-scale projects of either extremely low risk or above average risk can however change the total risk profile of the firm. In these cases, using the WACC is not appropriate. For this type of a-typical projects, the appropriate discount rate is the marginal opportunity cost of capital for the individual projects. This involves that investment projects with higher than average risk should be discounted at a cost of capital higher than the WACC and similarly low risk projects should be subject to lower discount rates.

Both the CE and the risk adjusted discount rate method are examples of an indirect approach to adjust the investment value for risk. The methods are indirect in the sense that no attempt is made to explicitly express the risk of the investment. In both approaches the value of the investment project is represented by a single indicator, i.e., a risk adjusted NPV. In their basic form, these two methods are equivalent, in the sense that they provide the same NPV if the respective risk adjustments are carried out appropriately.

3.4 Dynamic evaluation

The main problem with the evaluation methods reviewed above is that none of them adequately accounts for the managerial flexibility associated with Platform investments and staged investments in general. Dynamic evaluation here refers to investment project evaluation that recognises that the cash flows are, at least partly,

controllable. "The agent making the investment decision may be able to act in the future to influence the probability distribution of cash flows generated by the project, and will generally wish to do so as more information becomes available" (Brennan and Trigeorgis 2000 p.2). This option or managerial flexibility of the decision maker to take future actions that will affect the expected value of the project being valued must therefore be included in the evaluation. The idea of managerial flexibility is recognised in Agency theory developed by Jensen and Meckling (1976). Agency Theory recognises that the financial structure of the organisation has an important role for controlling the cash flows but that it also affects the size of the cash flows through the incentives it creates for the agents (mangers and investors). Brennan and Trigeorgis (2000 p.2) emphasise however, that there is an important difference when this is applied on investment project evaluation "project analysis generally assumes that the decision maker's objective is to maximize the net value of the firm's cash flows, whereas the agency theory of financial structure focuses on the conflicts of interest between managers and investors".

It is important when evaluating risky projects to recognise that possible future actions of the decision maker are acknowledged in the analysis. These future actions have the potential to affect the uncertainty of the cash flows and therefore the expected value of the project. Section 3.4 therefore reviews possible methods for dealing with this type of investments.

3.4.1 Sensitivity analysis

When evaluating financial securities it is typically not difficult to determine the expected cash flows. In investment project evaluation the cash flows used as an input in the NPV model are usually forecasts of other underlying variables. These variables may include future prices of a product sold by the firm, the cost of labour and material, and in most cases, some form of an estimation of expected market demand. For complex investments, such as in integrated computer systems, the number of underlying variables affecting the outcome of the investment can become very large.

Sensitivity analysis is a technique for identifying the most important sources of uncertainty that affect the profitability of an investment. At the outset, the analyst may be able to identify multiple sources of uncertainty that will potentially affect

the investment outcome. In reality however, some of these factors may have only minimal impact on the value of the investment.

> "A variable may itself be very risky (in having a large variance relative to other variables) but may nonetheless make an insignificant contribution to the risk of the project's NPV, in which case the investment decision does not crucially depend on the accuracy of its estimate; on the other hand, a less risky variable (having a small variance) may be crucial if even marginal errors in its estimate could have a significant impact on NPV" (Trigeorgis 1998 p.53).

Including all identified uncertainties in the evaluation is likely to over complicate the analysis. The objective of sensitivity analysis is not to directly quantify or evaluate risk, but rather to locate and assess the potential impact of risk on the investment value from changing key input parameters and assumptions (Pike and Neale 1996). It is useful to investigate under what range of specifications of a decision problem a particular action will be optimal under the NPV criterion. The most straightforward case of this type of analysis is where a single problem specification is allowed to vary while all other specifications are held fixed (Newbold 1995). In many cases, however, the bulk of the project uncertainty can be traced to only a few of the underlying specifications in the evaluation, while the rest may only have minimal impact on the total value of the investment. Including all identified uncertainties in the evaluation will run the risk of over complicating the analysis. By performing a sensitivity analysis on the different parameters in the model, it is easy to identify those that have the largest impact on the value of the investment.

A major drawback of Sensitivity Analysis is that it only considers the effect of one variable at a time, as all other variables are held constant. This can give misleading results when many uncertain underlying variables are correlated. Individual variables may also be serially correlated over time. This effect is difficult to analyse with sensitivity analysis for the same reason mentioned above.

3.4.2 Scenario analysis

Just as the sensitivity analysis helps reducing the number of uncertainties, and thereby simplifying the evaluation, scenario analysis is important for identifying those investment alternatives that are of greatest value. Scenario analysis is traditionally used to get a clearer picture of the total range of possible project outcomes, often in the form of best, nominal and worst case scenarios.

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Scenario analysis can be described as a disciplined approach for identifying possible future outcomes of decisions (Schoemaker 1995). Schoemaker identifies two main advantages of scenario analysis over other planning methodologies. First, this methodology enables the examination of the joint impact of multiple uncertainties while other methods tend to focus on one or a limited number of possible outcomes. Second, the scenario approach is useful for capturing new states that emerge as a consequence of major shocks to the system, as opposed to examining incremental changes. Along the same lines Clemons (1995) argues that scenario analysis is a useful tool to address management tendencies towards over confident forecasts and bias towards recent experience. He suggests that the method is practical in guiding technically complex undertakings, which may for example entail a wide impact on the organisational structure and processes. Under these conditions, the method is advantageous as it enables consideration of a wide range of impacts including operational and environmental contingencies that are typically overlooked or trivialised by other methods.

3.4.3 Simulation Analysis

Simulation analysis, which can be seen as an extension of scenario analysis, is an analytical method with the objective to imitate a real-life system (Mun 2002). An important step in addressing risk and managerial flexibility was the development of Monte Carlo analysis for estimating the expected project value dependant on a set of stochastic variables (Hertz 1964). Simulation analysis use repeated random sampling from a pre-specified probability distribution of the each of the stochastic variables underlying the project's cash flows. The simulated variable can be either the cash flows themselves or the NPV of the project. The output of the simulation provides the probability distribution of the cash flows, or the NPV, for a given investment strategy (Trigeorgis 1998 p.54). The Monte-Carlo simulation involves letting a computer generate a large number (usually in the thousands) of possible combinations of outcomes according to a specified probability distribution. For each individual experiment, the software is programmed to register the outcome of the simulated variable, usually the expected NPV value of the asset being evaluated. This results in a probability distribution of the simulated variable, which statistical properties can be calculated, analysed, and interpreted.

Simulation analyses is an attractive method for complex investment projects as it can essentially handle an unlimited amount of both independent and correlated

underlying stochastic variables. The main challenge is typically to define the probability distributions of the stochastic variables. A further problem with the practical application of this method for decision-making is that the analysis is typically handled by experts and management may find it difficult to understand the output of the analysis. That is, the output of a Monte-Carlo simulation may be an unbiased estimate of the probability distribution of the NPV of the investment project, from the decision makers perspective there is no rule for translating the output into clear-cut decision criteria. Trigeorgis further points out that Monte Carlo simulation is a forward-looking technique, which is based on a predetermined operating strategy. As such, it may be an appropriate model for path dependent investment problems. However, he argues that that it cannot appropriately handle the asymmetries in distributions introduced by managerial flexibility, that is, management's flexibility to review its operating strategy if future cash flows turn out differently than initially expected (Trigeorgis 1998 p.56).

3.4.4 Decision Tree Analysis

Decision tree analysis (DTA) was first suggested by Magee (1964a; 1964b) as a way to expand the DCF method to account for interdependency in sequential investments. Instead of presuming a single scenario of future cash flows, many different scenarios can be considered. This way, several possibilities of futures states of the world, and also the set of decisions made at each time in each state, can be incorporated into the analysis. In this case optimal future decisions are made contingent on future information about stochastic events that affect the project value.

In a sequential decision problem, in which the actions taken at one stage depend on actions previously taken in earlier stages, the evaluation of investment alternatives can become very complicated. In such cases, the decision tree approach facilitates project evaluation by enabling the firm to write down all the possible future decisions, as well as their monetary outcomes, in a systematic manner. The use of decision tree does make the implications of alternative possible courses of action more transparent and risk is incorporated into the analysis by assigning probabilities to each possible outcome. The total value of the investment is calculated based on the joint probability of occurrence of each final outcome in the tree.

The DTA approach incorporates up to a certain extent the issues concerning managerial flexibility into the analysis. This makes DTA analysis a better tool than

the basic NPV to evaluate projects. However, to find the appropriate required rate of return to use in the discount rate is a problem in both basic NPV and DTA.

Another critique of the DTA analysis refers to its complexity in the sense that when it is applied in most realistic investment settings, it can quickly turn into a unmanageable "decision-bush analysis", as the number of paths through the tree expands geometrically with the number of decisions, outcome variables, or states considered for each variable (Trigeorgis 1996).

Decision analysis (DA) (for a detailed overview see for example: Howard 1984; Howard 1988) is an advanced form of DTA which merges the logical foundations of statistical decision theory with the capabilities of modelling and solving complex problems developed in the fields of systems analysis and operations research (Matheson 1989). The technique typically involves braking down a decision problem into three general areas: problem structure, uncertainties in the outcome of the different decision alternatives, and the decision maker preference (Corner and Corner 1995). The principle difference from the DTA approach is the introduction of the preferences or utility curve of the decision maker, from using expected monetary values toward using multi-attribute utility theory to evaluate the outcome of a decision. Assuming that the true utility curve of the decision maker can be derived, and it can be assumed to represent the best interest of the company. This however, presumes that under uncertainty the decision maker is able to provide explicit subjective probability assessments for each possible state of nature that may occur, payoffs conditional upon the alternatives and the state of nature, and a completed specification of preferences for uncertain payoffs presented in the form of a utility function (Pearman 1987).

Although many examples can be found of the successful application of DA on complex investment problems (for an overview see for example: Corner and Kirkwood 1991), the method has proved difficult to implement in practice due to the stringent information requirements of the method (Pearman 1987; Moskowitz, Preckel et al. 1993).

3.5 The Real Options Approach

The problem of the appropriate discount rate remained unsolved until the seminal papers of Black and Scholes (1973) and Merton (1973) on options pricing. This work showed how to value a claim (option) which value is contingent on an

underlying financial asset, by means of constructing risk-neutral portfolios (Schwartz and Trigeorgis 2001). This theory was further developed by Cox and Ross (1976), Constantinides(1978), Cox, Ross *et al.* (1979), Harrison and Pliska (1981) and others.

Although at first, option pricing was almost exclusively applied to financial assets it has also had a profound influence on capital investment evaluation.

> "The far-reaching implication for project analysis is that if the expected rates of change in the underlying cash-flow drivers or stochastic state variables are risk adjusted, the resulting 'expected' (risk adjusted) cash flows can be discounted at the risk free interest rate, regardless of the types of future decision contingencies inherent in the project or of the nature of the relation between the stochastic state variables and the cash flows of the project" (Brennan and Trigeorgis 2000 p.3).

Real Options are opportunities, which arise in real investments in which there exists flexibility to make decisions in the light of subsequent information. A Real Option is thus the right, but not the obligation, to take an action (e.g., deferring, expanding, contracting, or abandoning an investment project) at a predetermined cost, for a predetermined period of time. *Real Options Analysis (ROA)* is the process in which Real Options are analysed and priced.

The insights from financial option pricing were first applied on real investments in the context of natural resource investments (Brennan and Schwartz 1985; McDonald and Siegel 1985) where the underlying asset is traded on a market. Many others have however argued that the assumption of a traded underlying asset or a twin security is not a necessary condition for applying the ROA. Schwartz and Trigeorgis for example argue that if an option is contingent on the value of one or more state variables that are not traded assets, an equilibrium model of asset prices can be used to value the option (Schwartz and Trigeorgis 2001 p.3). Following these early papers, ROA has been developed and applied in a number of industries including Pharmaceuticals and Aeroplane manufacturing. Several authors have also suggested using Option pricing theory to evaluate IT investments (see for example: Dos Santos 1991; Kambil, Henderson et al. 1993; Panayi and Trigeorgis 1998; Taudes, Feurstein et al. 2000; Schwartz and Zozaya-Gorostiza 2003).

The remainder of this section reviews the potential of the ROA in addressing the problems described in Chapter 1.

3.5.1 Dealing with multi stage IT investments

Dos Santos (1991) was the first to developed a real options based approach to evaluate new technology investments. His key argument was that the main benefits of new technology investments usually come from user benefits from future projects, which apply the technology, while little value is derived from the initial investment project. This especially applies to new IT projects or what he calls first stage IT projects. This is similar to the definition of IT platform investments presented in Chapter 1. The model developed by Santos builds on the assumption that investing in future projects that use the technology is optional which results in a higher NPV of the new IT investment than suggested by the traditional DCF techniques. Santos model is based on a closed form option pricing model (developed by Margrabe (1978)) for valuing of an option to exchange one risky asset for another. In Santos model, the development cost of the second stage of an IT project is uncertain just as the revenue flows, and the model is appropriate because the investor is essentially exchanging one risky asset, the development cost, for another, namely the revenue flows.

Kambil, Henderson *et al* (Kambil, Henderson et al. 1993) developed a binomial option pricing model to evaluate a simple two phase IT investment project. The first phase of the investment is a pilot investment involving the use of hand-held computers at a hospital. The full implementation of the technology is then assumed contingent on the outcome of the pilot investment. The outcome of the analysis shows that although full implementation of the technology is not justifiable at the initial stage, the option value of undertaking the pilot investment justifies the initial investment to learn more about the underlying uncertainties. The model is very intuitive but limited to only two possible outcomes of the investment, an optimistic scenario and a worst-case scenario and the probabilities for each outcome are based on subjective estimates.

Panayi and Trigeorgis (1998) also emphasises the importance of including the value of managerial flexibility when evaluating sequential IT investments. They argue that in order to capture the true value of this type of investments the traditional NPV approach needs to be expanded to take into consideration the value of options embedded in the investment. That is:

Expanded (Strategic) NPV = Traditional NPV + Value of option flexibility

The authors suggest the value of the option flexibility can be determined using standard option pricing, although no formalised model is presented in the paper.

Taudes (1998) examines methods for evaluating sequential exchange options in order to obtain estimates for the value of software growth options. Taudes defines software growth options as information systems functions that are embedded in an IT platform and that can be employed once the particular base system is in place. Building on this study Taudes, Feurstein et al. (2000) discuss the practical advantages of real option evaluation techniques for the selection of a software platform. They argue that due to the long planning horizon required because of the time-consuming and resource-intensive implementation process, it is not possible to exactly predict which applications will, in fact, run on the system over time. Thus, the investor is faced with the problem of valuing "implementation opportunities". The total value of a software platform is hence defined as the sum of the NPV of a fixed application portfolio and option value of implementation opportunities.

Schwartz et al. (2003)[13] classify IT investment projects into two categories, development projects and acquisition projects, depending upon the time it takes to start benefiting from the investment after the investment decision has been made. They present an evaluation model, which considers the possibility that the investment costs of IT projects may change even though no investment takes place.

Kulatilaka, Balasubramanian et al. (1999) developed an option pricing model for technology investments, where the technology is seen as one of three components, of business capabilities. That is, instead of focusing on evaluating the technology itself, the authors present a framework for evaluating the business capabilities that are achieved through combining investments in IT, process engineering, and organisational change. The study presents a systematic approach for applying a binomial option-pricing model on IT projects. The major drawback of the approach however, is that it requires the enumeration of all possible outcomes from the investment. In the case of complicated multi-phase investments, this can be very difficult as the number of possible outcomes increases exponentially.

3.5.2 *Incorporating the effects of uncertainty and flexibility into the valuation*

Benaroch (2001) argues that Real options, in terms of operating flexibility to change the timing, scale and scope of the investment project, are usually not

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[13] See also an earlier version of the paper (Schwartz and Zozaya-Gorostiza 2000)

inherent in technology investment, but can be designed and planed to fit each investment differently. The author presents a methodology to map specific investment risks to different types of real options, in order to maximise the value of IT investments with respect to their underlying risks. The different investment alternatives derived from the framework are then evaluated using a binomial log-transformed option evaluation technique developed by Trigeorgis (1991). This approach however, quickly comes very complicated as the number of options and time periods grows. It further implicitly assumes that the underlying risk remain constant. Kulatilaka and Venkatraman (2001) similarly argue that framing IT investments as options goes far beyond the justification of the business case. It involves a continued interaction among business, IT and finance executives in assessing opportunities, acquiring options, nurturing those options, and finally, when conditions are ripe, capturing value. The study uses illustrative examples to develop a strategic management process, which the authors name the Strategic Options Navigator.

Jeffery, Shah *et al.* (2003) analysed multi-stage options embedded in enterprise data warehousing projects using a binomial approach. The study focused on projects that already have a positive NPV whereas the concern is the role of real options in management's project selection under the risk of potential project failure.

3.5.3 Investment timing

Grenadier and Weiss (1997) apply option pricing techniques to analyse optimal migration strategies of new innovative technologies. During the early stages of innovation, the firm is seen as holding an option on an option, or a compound option. On example from the study is when a firm must choose whether to upgrade to a new generation of technology, it must contemplate exchanging a current technology for a new generation of technology, minus the cost of upgrading. The firm is then essentially holding an option to exchange one innovation for the next. The authors considers four possible IT investment strategies: *compulsive* strategy of pursuing every new innovation, *leapfrog* strategy of skipping an early innovation but adopting the next generation of innovation, *buy-and-hold* strategy of only pursuing an early innovation, and a *laggard* strategy of waiting until a new generation of innovation arrives before investing in the previous innovation. Based on the model developed, the probability that a firm will pursue each of the four migration strategies as well as the expected time of adoption is calculated in the context of a specific type of firm and market conditions. The analysis shows that

firms may choose to adopt an initial innovation, depending on the nature of technological uncertainty, despite the potential for more valuable innovations occurring in the future. The firms' optimal migration strategies will be path dependant, that is to say they will differ according to their previous histories of technological adoption. Practical application of this model is difficult and perhaps not useful as a general evaluation model from the individual firm's perspective, as the exogenous stochastic variable is the state of technological progress rather than expected benefits of the investment.

Alvarez and Stenbacka (2001) also developed a real options approach to characterize the optimal timing of investing in incumbent technologies. The current investment is seen as containing as an embedded option a technologically uncertain prospect of opportunities for updating the technology to future superior versions. In this approach, the real options values are influenced by two independent sources of uncertainty, technological and market uncertainty. As in Grenadier and Weiss's model, the investment outlays of adoption are cast as a sequence of embedded options in the prospect of successive generations of new technologies building on each other with an uncertain arrival time in the future. The authors analyse how the prospect of technologically uncertain future innovations affects the real options value associated with the adoption of currently available technology, which generates knowledge and experience enabling the firm to exploit future technological progress. They find that that increased market uncertainty will increase both the investment and the option value of adoption and demonstrate that increased technological uncertainty increases the optimal investment threshold if the NPV of the cost reduction is smaller than the irreversible sunk cost of adoption, thereby postponing the optimal timing of exercising the option.

3.5.4 Applicability on real investment cases

Benaroch and Kaufman (1999; 2000) provide an example of applying real options analysis on a real IT investment case. The analysis model focuses on the investment timing of point-of-sale debit services in a shared electronic banking network. The case involves analysing how long it is viable to defer entry into the market in question. The model is limited in the sense that it only considers a single *option to defer* the investment, in a nearly monopolistic market environment. The study is however, valuable in the sense that it is the first attempt to apply Option Pricing techniques on a real IT investment case and thus addresses some of the practical difficulties in gathering the required information to estimate the input parameters.

The authors use a procedural model called *Black's approximation*, which is an extension of the standard Black-Scholes model which is only suitable for evaluating a European stile call options, i.e. an option that can only be exercised at the given expiration date. The Black's approximation however allows for early exercise of the option, which is more realistic for most real or non-financial investments. The benefit of using a closed for solution like the Black-Scholes model is that it makes sensitivity analysis of the different input parameters relatively easy and intuitive. The drawback however is that the model provides a sort of black box solution and its application requires a strong background in advanced mathematics, which makes its results difficult to explain and justify to management. In most cases this kind of models are only a viable option for the simplest investment scenarios with one or few simple options. The authors further argue that the application constraints placed by the underlying assumptions of both the Black-Scholes option pricing model and binomial pricing models are similar to those implied by traditional DCF methods.

Panayi and Trigeorgis (1998) present an actual case study on the application of option pricing techniques on IT investment. The case involves an IT infrastructure investment by a telecommunications authority. The option valuation found the strategic investment was financially justifiable although the application of the traditional NPV approach suggested otherwise. Kulatilaka, Balasubramanian *et al.* (1999) also present a real case study involving a mortgage bank which is considering an investment in a document management system.

Taudes, Feurstein et al. (2000) present the results of a real-life case study where closed form solution Black-Scholes option pricing models were used for deciding whether or not to upgrade and companies enterprise system. The authors compare different valuation techniques for this task and discuss their respective advantages and drawbacks. Zhu (1999) developed a model for IT infrastructure investments (based on Geske's (1979) model for valuing compound options). The model is applied on a case where FedEx is considering launching a corporate wide IT infrastructure, called Web-based Information System for connecting over two thousand FedEx locations with its several hundred thousand corporate customers. The investment is valued as a compound option as it is to be implemented in two contingent stages, a smaller scale pilot project, and a full implementation stage. Zhu findings show a large difference in the value derived by the traditional NPV approach, where the investment is not justifiable, and the Real Options analysis showing the project to be well justifiable from the corporations set requirements.

Shishko, Ebbeler *et al.* (2004) reported that NASA has adopted a ROA for the evaluation and prioritisation of advanced technology development projects. The main uncertainties affecting the value of these investments are classified as development risk referring to development costs, schedule and technical performance, and programmatic risk, which refers to the uncertainty surrounding whether missions using the technology will be flown. The methodology focuses on the evaluating the real options NASA holds in terms of options to invest in specific missions, wait, abandon or change missions in response to better information as part of these uncertainties are resolved. Each project is modelled similar to an R&D project where the project goes through different non-income generating development stages. The value of the project is associated with a call option on future cash flows from a completed and operational technology. At the end of the development period, the decision-maker is further assumed to hold a deferral option on delaying the operationalisation phase of the technology project if demand, which is reflected in the programmatic risk, turns out to be insufficient. The option value is estimated through a series of advanced Monte Carlo simulations and the total project value derived in connection with a closed form option pricing formula and a decision tree depicting technology development costs, schedule, and probability of project success.

3.6   Summary

One of the major weaknesses of the subjective methods is related to the ambiguity that prevails when comparing different investment alternatives or competing investment proposals. The IE method, the scoring models and the MADM approach all enable a comparison of various types of costs and benefits (although the sophistication of the different methods varies) on a common scale. The problem is however, that the output of the methods used to support the decision making process is an abstract number.

Net Present Value analysis, which is the most sophisticated of the traditional capital budgeting tools, does not work well for IT platform investments. The NPV is flawed when applied on high-risk investments, which embed managerial flexibility to revise the investment strategy at a later date. Consider for instance the following example. In the case of two competing projects, a high risk and a low risk project, with identical NPVs, under the NPV framework the decision maker should be indifferent on which project to choose. In practice, the decision maker would

however be likely to choose the low risk project. Assuming that both projects also entail equal amount of managerial flexibility, the ROA would suggest that the project with the higher risk should be chosen. The asymmetric nature of returns from options, and the ability to revise the investment strategy if uncertainty develops unfavourably, makes the high risk project more valuable under the ROA (Kambil, Henderson et al. 1993).

Sensitivity, Scenario and Simulation Analysis are useful tools for analysing investment projects subject to risk. As stand-alone methods, however, these tools are not sufficient for dealing with the complexity of IT platform investments. Each of the methods has attractive properties in dealing with specific issues pertaining to the risk profile of investments, but do not provide a clear decision making criteria for evaluating interdependent or competing investments. The methods can, and should be used in combination with other methods such as the DTA and ROA, to give a better insight into the stochastic properties of investments subject to uncertainty.

The Decision Tree Approach can be seen as an extension to the NPV method. It enables the decision maker to map out the potential development of a risky investment and make the optimal investment strategy contingent on pre-defined state variables. The DTA approach is based on forward induction, which incorporates the probabilities of different events and expected return. The problem with this process is that it presents a problem in determining the appropriate discount rate when folding back the tree to determine the project value.

The Real Options Approach provides a convenient framework for analysing IT platform investments. The investment can be evaluated using binomial option pricing formulas, which makes it operationally similar to the DTA method. This approach however, has the advantage over the other methods that it avoids the problem of finding the appropriate discount rate when managerial flexibility influences the development of the underlying risks over time. "The presence of managerial flexibility in the form of embedded real options changes the nature of risk and invalidates the use of a constant discount rate" (Trigeorgis 1998 p.51). Most of the previous work applying real option techniques on IT investments does however not fully consider the case of multiple contingent growth options, as may be the case with IT platform investments. The remaining chapters therefore focus

on developing a specific framework, and an evaluation solution for dealing with this type of investments.

CHAPTER 4   Theoretical and Conceptual Framework

From now on, ending a sentence with a preposition is
something up with which I will not put.

Sir Winston Churchill (1874 - 1965)

4.1   Introduction

In the preceding chapters, IT platform investments were described as having specific aspects of extra value. These aspects are not fully addressed in standard financial evaluation methodologies such as the DCF, or in other more subjective evaluation frameworks such as Multi Attribute Decision Making. Firstly, there are aspects involving the managerial or operating *flexibility* of revising the investment strategy of a multi-stage IT investment programme. This flexibility can involve options to adjust investment decisions at a future date, for example in terms of deferring, expanding or abandoning further investments. Secondly, additional characteristics involve the *strategic value* resulting from interdependencies with future follow-up investments and interactions with both internal and external stakeholders. Real Options theory offers great potential for addressing these concerns as it provides a framework for dealing with the contingent nature of IT platform investments. This chapter describes the theoretical foundations of the Real Options Approach and outlines the conceptual framework on which the evaluation model developed in Chapter 5 builds upon. The conceptual framework will focus on providing means to identify, incorporate, and manage the diverse types of benefits, costs, and risks that shape the value of the IT platform investments investment at different times during the investment process. The structure of the chapter is described in figure
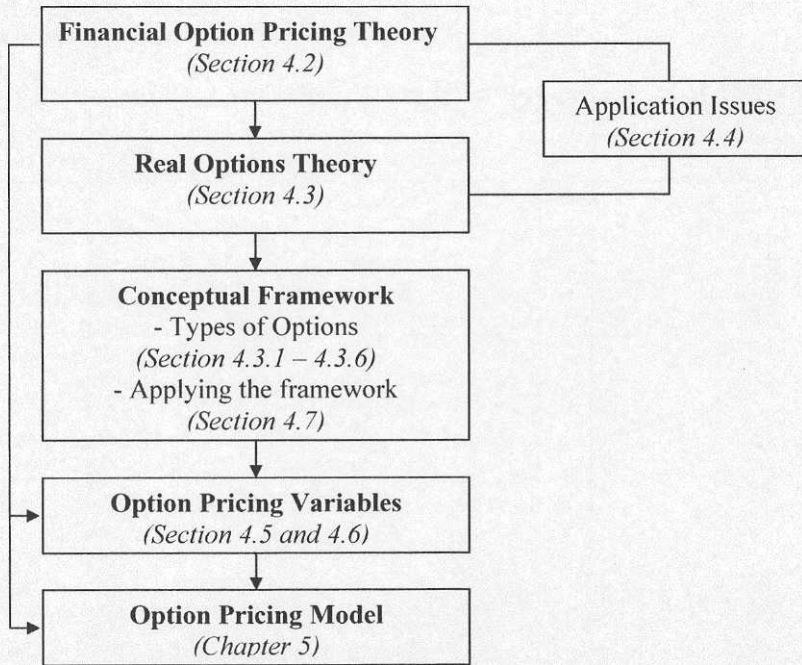
Figure 5: The structure of Chapter 4

4.2 Option Pricing Theory

Option pricing theory builds on the pioneering work of Black and Scholes (1973), Merton (1973) and Cox and Ross (1976), which introduced the idea of pricing securities by arbitrage methods. Options are defined as special contractual arrangements giving the owner the right to buy (call option) or sell (put option) an asset at a fixed price on a specific date (European options), or anytime before a given day (American Options). The option is valued relative to the underlying security assuming that the option value can be replicated synthetically by constructing a risk-free portfolio of the underlying security and the option. The payoff of the portfolio exactly matches the payoff of the option and therefore has the same value assuming no arbitrage opportunities. This risk neutral condition permits the option value to be discounted at the risk-free rate.

One of the fundamental attributes of option contracts is that the option holder exercises the option *only* if the payoff from exercising exceeds zero, which is the cost of letting it expire. When the exercise price of a call option is lower than the

cost of the underlying security at expiration, the option is "in the money" meaning that the option has a positive intrinsic value.

There are innumerable different types of both standard options contracts (which are traded on financial markets) and custom-made contracts (which are traded over the counter) available to investors today for hedging financial risks, reallocating resources or speculation. Most option contracts however belong to either the *American* type options or the *European* type. The distinguishing feature of American options is that they are more flexible as they can be exercised at any time prior to maturity, whereas European options can only be exercised at the given expiration date.

The value of standard option contracts at maturity is determined by the difference between the exercise price and the current price of the underlying asset (also called intrinsic value). If X is the strike price and S_T is the final price of the underlying asset, the payoff from a European call is: Call option = Max $(S_T-X, 0)$. This reflects the fact that the option will be exercised if $S_T > X$ giving the option holder $S_T - X$, but it will not be exercised if $S_T \leq X$, in which case the value of the option is zero. Conversely, the payoff of a European put option is: Put option = Max $(X - S_T, 0)$. The option is exercised if the value of the underlying asset is lower than the exercise price $S_T < X$ and the option holder receives a payoff $X - S_T$ while the option is left to expire if $S_T \geq X$.

The net payoff of both European and American options are depicted graphically in Figure 6. The diagram further illustrates that although the option may be in the money, the net payoff is only positive when the exercise price is sufficiently higher (or lower in the case of a put option) than the value of the underlying asset to cover the option premium, or price of the option contract.
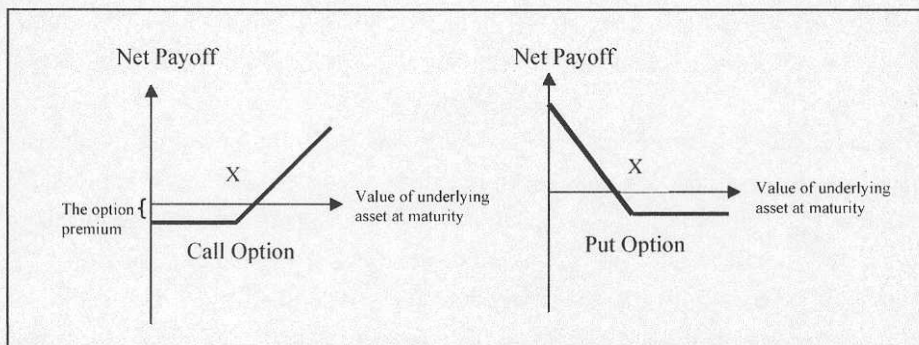
Figure 6 Net Payoff from Call and Put options in relation to the value of the underlying asset

The Black-Scholes (B&S) formula (Black and Scholes 1973) is the most common method to value financial options and one of the most important ones in finance. In the original B&S model there are five variables that influence the value of the option: underlying stock price, exercise price, time to expiration, the risk-free interest rate, and volatility the of the price of the underlying security. Later extensions to the model further include the effect of dividends. These variables are summarised in Table 3 along with the direction of the impact a change in each variable has on the value of the options.

Option type	European Call Option	European Put Option
Exercise price (X)	-	+
Stock price (S)	+	-
Interest rate (r)	+	-
Time to maturity (t)	+ (-)	+ (-)
Volatility (σ)	+	+
Dividends	-	+

Table 3 The Fundamental Option pricing variables and their impact on the value of the option

The plus sign indicates that the value of the option changes in the same direction as the value of the variable and the minus sign indicates the value of the option moves in the opposite direction. As indicated, an increase in the exercise price would result in a lower call option value and an increase in put option value. At the exercise date, the payoff of the option is the maximum of either the difference between the strike price and the stock price, or zero. A call option gives the owner the right to buy the

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underlying stock at a predetermined exercise price it hence follows that the higher this price, relative to the stock price, the less valuable the option becomes. The put option on the other hand gives the owner the right to sell the underlying stock at the exercise price and therefore rationally, the higher the exercise price the more valuable the option contract. An increase in the stock price has the reverse effect on the option values, for the same reasons as listed for the exercise price. An increase in the nominal risk-free rate increases the value of call options and decreases the value of put option contracts. In general, an interest rate increase is expected to have a positive effect on stock prices while at the same time the expected value of the option payoff decreases through higher discount rates. The combined effect on the value of put options is hence negative. In the case of call options, however, the stock price effect has a positive influence on the price of the option while the time value effect has a negative impact. Nonetheless it can be shown that the first effect always dominates the second effect, consequently an increase in the risk-free rate will always increase the value of call options (Hull 1997).

An increase in the time to expiration of European stock option contracts has an indefinite effect on their value due to potential dividend effects. Dividend payments decrease the price of stocks and therefore enhance the value of put options and decrease the value of call options. A short-term call option contract with expiration prior to the dividend date may for example have higher value than a same type longer-term contract that expires after dividends have been paid out. The same argument applies to a put option contract. Both European call and put options on a non-dividend paying stock increase in value with longer exercise dates. American option contracts, however, can be exercised at any time prior to the expiration date and therefore generally become more valuable as the time to expiration is increased.

The volatility of a stock price measures how much the price of the stock fluctuates in a given time period. The higher the volatility the more likely the price of the stock will move strongly up or down. The option contract limits the down side risk compared to owning the stock as the intrinsic value of the option is never lower than zero. An increase in volatility will therefore always increase the value of both call and put options as the potential upside value effect increases with greater price fluctuations of the stock (Hull 2003).

4.3 Real Options

The term "Real Options" was first presented by Stewart Myers (Myers 1977) who observed that financial option pricing methods could be used to evaluate certain type of high risk real investments. The basic intuition behind Real Options is that many types of capital investments display characteristic similar to financial options. Specifically, a firm may have, or be in a position to acquire, an option to make a potentially profitable, albeit uncertain investment at a future date without having any commitment to do so.

The risk-neutral framework of Option Pricing Theory has three major advantages for capital investment evaluation. First, it provides a practical way to represent and account for the flexibilities, or options, that any given project might have. Second, it uses all the information contained in market prices with known or measurable statistical distributions when such prices exist. Finally, it leads to formulas or processes which can be computed using powerful analytical and numerical techniques developed in contingent claims analysis to determine both the value of the investment project and its optimal operating policy (Schwartz and Trigeorgis 2001).

The real options approach has been applied on many different types of investments and scenarios. Conceptual frameworks and analytical models have been developed for dealing with different "types" of real options that are relevant for individual investments. Typically, large-scale investments have different types of flexibilities implicit in the investment opportunity, such as options to defer, contract or abandon contingent investments. On other occasion, management may also find it advantageous to plan the implementations is such a way that creates flexibility, such as performing the investment in stages rather than all at once. Lastly, options may be build- in to the investment project at additional cost, for example to create options to expand capacity at a later date (Trigeorgis 1995b). The remainder of this section presents many of the different types of Real Options that have been identified and analysed in the literature, and further describes how they relate to IT investments.

4.3.1 Growth options

Myers (1977) suggested that a firm's discretionary investment opportunities could be seen as *corporate growth options*. For example, a firm that has introduced a new product on the market may hold a option to expand the project by making further

investment if it turns out that the product is better received than originally anticipated (Trigeorgis and Mason 1987). Should the product introduction, however, turn out worse than expected, the option to expand may be of no value and thus simply allowed to expire. The flexibility involved with holding the option at the time of the product introduction is however valuable and should therefore be included in the project evaluation.

Figure 7 shows the potential gains from exercising a simple growth option when NPV increases while at the same time losses are avoided if NPV turns out to be negative by not exercising the option (Kester 1984).
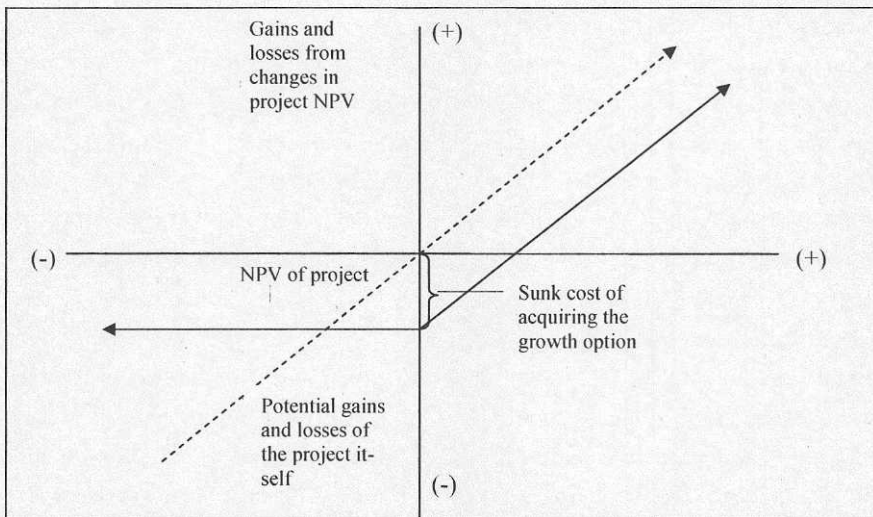
Figure 7: The asymmetry between upside gains and downside losses in option ownership (source: Kester (1984))

The simplest type of growth options are options on investments that create additional growth in standard business situations, such as investments in advertising and improved customer service (Amram and Kulatilaka 1999). These options are simple in the sense that they are typically independent of other investments and real options that the firm may hold, and therefore relatively easy to evaluate.

The above were examples of simple options to expand the scale of an individual investment project, i.e. the return on the investment could be enhanced by making an additional investment. Another important type of growth options are strategic growth options which enable platform opportunities. Kulatilaka and Perotti (1998)

define strategic growth options as initial investments that result in the acquisition of a capability that allows the firm to take better advantage of future growth opportunities. An example of this type of initial investments is research into building a technological advantage, an advertising campaign leading to identification and name recognition by consumers, and organizational and logistic planning leading to lower costs in building production capacity (Kulatilaka and Perotti 1998 p.1022). This type of growth options is considerably more complex than the simple expansion options as their exercise requires that further investments be made and the expected benefits are often in the form of acquiring additional options. That is, the situation basically involves options on options, or *compound options*. Accordingly the value of growth options is essentially the present value of expected cash flows of the underlying assets plus the value of any new growth opportunities expected through ownership and employment of the assets (Kester 1984). An example of this type of growth option from the AEC industry is a contractor's investment in high capacity internet access on all construction sites. Although at present this capability may only be utilised for electronic exchange of information between the construction site and the contractor's main office, it contains a growth option to move the entire project management to a web based platform at a later date. The value of the investment is hence not limited to the immediate benefits derived from the internal electronic information exchange but should include the value of the growth option to expand the initial capabilities. One could however argue that the contractor could simply install the necessary infrastructure at a later date when the new capabilities are needed, and therefore the additional capacity is not essential at the present time. This argument overlooks the important characteristic of many IT investments that its value is not obtained solely from implementing the required hardware and software, but rather from people using the technology to create business capabilities. By having the necessary infrastructure in place and starting of with more simple applications such as e-mail communication at construction sites, the intended users gain valuable training in using the "new" technology, training which is valuable for the implementation of more sophisticated applications in the future. The important implication here is that the immediate benefits of the initial investment may not be sufficient to "justify" the required platform investment using the standard NPV approach as it ignores the value of the future growth options. A comprehensive evaluation of the investment should therefore include the value of these future growth options, which value may be sufficient to justify the initial platform investment.

4.3.2 Switching options

The option to switch refers to the opportunity of choosing among alternative operating modes, locations, or technologies. For example, a chemical plant may have the flexibility of switching among alternative energy sources depending on energy prices, or a multi national company may hold an option to switch production between various locations internationally (Micalizzi and Trigeorgis 1999). The ability to choose between families of different sized aircraft, manufactured on the same production line can also be valued as a switching option (Stonier 1999). The value of switching options is directly related to shifts in the supply and price of the relevant underlying input or output factors. Consider for example a utility company that has the choice between three boilers: natural gas, fuel oil, and dual-fuel. When comparing these different investments the flexibility created by the dual-fuel boiler of allowing the company to always use the cheapest fuel needs to be included in the evaluation. The dual-fuel alternative therefore contains a valuable switching option (Mauboussin 1999). The greater the volatility of the price of the two fuel alternatives, and the less (positive) correlation there is between the prices, the higher the value of the option.

Switching options essentially involve both a put option and a call option. The put option represents the opportunity to abandon one mode of operation while the call option represents the opportunity to adopt another in its place. Switching options are relevant to certain types of IT platform investments, which for example, involve the flexibility to choose between different software vendors when adding new applications to an existing platform. Another example is when an IT infrastructure has alternative application potential and can hence be switched from supporting one business capability to another, depending on which capability produces the most value. Finally, this type of options is also relevant to high-risk projects where companies maintain more than one system solution during implementation of new systems. One of the companies in the interview study (cf. Chapter 2) for example had developed a relatively expensive contingency plan for the implementation of their ERP system. During the implementation and initial operation of the system, an alternative system was run parallel to the ERP system, ready to "take over" should the implementation prove unsuccessful. Thus by making an additional investment in flexibility, the company reduced the potential future cost of altering its strategy. The value of this flexibility is observed by comparing the cost of the "backup system" to the potential costs and losses due to business disruption imposed by a failed implementation of the primary system.

4.3.3   Option to defer investment

The traditional financial evaluation models implicitly assume that the investment at hand is either a "now or never" investment opportunity, or that the investment costs are fully reversible (cf. section 3.3). The investment project should be undertaken if the NPV is positive or when if the internal rate of return (IRR) is larger than the required hurdle rate, failing this, the investment should be rejected. Many authors have however argued that under conditions of high uncertainty regarding the value of the investment opportunity, the option to defer the investment to gain additional information may be of substantial value. Marglin (1963) for instance found that the NPV criterion is a necessary condition for profitability, but not sufficient in the case two investment projects are interdependent, as it may be justifiable to postpone a project with a positive NPV today if the NPV of tomorrow may be even larger.

McDonald and Siegel (1986) argue that when an investment project is irreversible and has no alternative use, the NPV rule is inappropriate if the decision to invest is deferrable. The investment scenario should instead involve a comparison of the value of investing immediately with the present value of investing at all other possible times in the future. Trigeorgis and Mason (1987) similarly maintain that the NPV criteria is not a necessary condition in the case where a company holds an exclusive right to a deferrable investment opportunity, as the value of option to defer the investment can suffice to justify a negative NPV project. The investment opportunity is thus equivalent to a call option on the value of the underlying project with the one time investment cost as the exercise price. Assuming that the project value fluctuates randomly, the value of the option (the option infers no obligation on its owner) to invest, exceeds the NPV of cash flows from immediate investment by the value of the flexibility to defer the investment. The investment opportunity may therefore be economically justifiable even if the investment itself may have a negative NPV (Trigeorgis and Mason 1987). The option to defer is particularly important when evaluating investment decisions in industries where there is high uncertainty about output prices and market development. Real Options analysis have been applied in this context to evaluations in natural-resource extraction industries, real-estate development, farming and the launch of new products (Micalizzi and Trigeorgis 1999).

The option to defer is only valuable if a substantial part of the investment value is not lost to competitors as a result of delaying the investment. In the case of technology investments, many situations can emerge where holding an option to

delay immediate investment may be of great value. This presumes a new technology innovation which cannot be easily replicated and is somehow exclusive to the firm through legal restriction or other entry barriers, and gives its owner a competitive advantage in the market (Benaroch 1999; Benaroch and Kauffman 2000). In the AEC sector however, depreciation of investment value due to competitor actions when delaying investment does not necessarily pose a big threat. The greatest advantages from new IT investments are expected to come from technologies that enable more efficient exchange of information between different stakeholders (Lundegård 1998; Aouad, Kagioglou et al. 1999; Schwegler, Fischer et al. 2001). For this to be possible, the technology has to be readily available for to number of different actors in order to realise the full potential of the systems. The interview study in Chapter 2 further found that many decision makers involved with IT investments in AEC companies are especially concerned with the timing of upgrading investments, which involves both hardware and software applications. The evaluation routinely involved the decision of when to upgrade the current software to the latest version, or whether to skip the current upgrade and wait for the next. This option to delay the investment is usually limited to the time when the software suppliers announce they will stop supporting the older software versions. At which time, the company is typically forced to either invest in a later version of the current software or switch to another system.

4.3.4 *Option to abandon*

The option to abandon involves the flexibility to abandon an undertaken project for its salvage value before the end of its economic life, in the case it turns out to perform worse than expected, or if market conditions turn (Trigeorgis and Mason 1987). This also includes the option to default on planned staged investments during implementation. If the future investment outlays exceed the expected marginal value of investment, management may save subsequent investment costs by abandoning further implementation (Trigeorgis 1995b). An abandonment option is thus equivalent to American put option and is inherent in essentially all operating businesses. Specifically if a project is abandoned midstream, the payoff is equivalent to the money saved from future investment instalments. When a completed project is abandoned, the payoff is equal to the salvage value of the assets in place. The value of this option can often be substantial (Berger, Ofek et al. 1996), but is naturally directly related to the liquidity of the assets in place and the investment costs saved as a result of further implementation.

A large number of IT projects end in failure (cf. section 4.5) costing companies enormous resources. Abandoning an ongoing project has, however, proven to be difficult in many companies due to project stickiness and business psychology (Staw 1981; Mun 2004). The real options approach offers a quantitative analytical framework to support the analysis of optimal abandonment of unprofitable investment projects. When dealing with IT investment projects this is especially relevant during staged investments because in the options framework the decision to proceed to the next phase is explicitly dependant on the current value of the investment and the value of any future options. The methodology thus offers an important tool in which to manage the implementation process and allocate resources effectively.

4.3.5 Compound options: Option to invest in stages

In the case of large IT investment projects, it may be feasible to break up the investment outlays into distinct stages over time, rather than committing to the whole project upfront. When implementing new information systems in large firms, it is not uncommon that applications are installed in stages in individual departments, gradually leading to a full implementation across the whole organisation (cf. section 1.4). The ability to structure the investment strategy in this manner is dependent on the modularity of individual IT projects and possible contingencies with other IT investment projects. Modularity is a term that is used to describe contingencies within a module, or a unit, whose structural elements are intimately connected among themselves but relatively weakly connected to elements in other units. This suggests that there are degrees of connections or gradations of modularity. That is, the modules are units in a larger system that are structurally independent of one another, but work together (Baldwin and Clark 2000). A higher degree of modularity would thus result in greater flexibility to manage to investment process. Similarly, the greater the flexibility, the more valuable it becomes under conditions of high uncertainty.

High modularity implies for example, that a specific information system can be implemented in individual departments in a firm relatively independent of each other. Partial implementation provides certain capabilities independently, while the bulk of the benefits are achieved through a connection with a common platform. Similarly, individual contingent IT projects may be seen as modules in distinct business capabilities. That is, individually these IT projects may produce distinct benefits, but combined they form the pillars of a more complex business capability

that is more valuable than the sum total of the individual contributions (cf. also section 1.5.1).

As highlighted in the motivated example in Chapter 1, a staged implementation may be the inevitable result of capacity constraints in the organisation or, it may the part of a deliberate investment strategy to mange risk. The potential advantages of this type of strategy are mainly twofold. First, in the case where the potential demand or need for the capabilities in question is highly uncertain, a staged expansion policy will allow for new information about the future demand to be incorporated into subsequent investment decisions. Consequently, if demand turns out to be smaller than expected, the firm may decide to scale down its plans for further expansion and even abandon the venture completely. This way the company is able to limit economic losses from unprofitable investments. Equally, if demand turns out to be greater than expected the company has options to expand its capabilities and continue introducing new applications that are contingent on the initial platform. The potential disadvantages of staged investment, on the other hand, are foregone earnings from a fully implemented project, as well as possible loss of economies of scale derived from an all-at-once investment strategy (should that have been possible). Delayed implementation may further potentially involve loss of market share due to competitors' actions (cf. section 4.7.5 and 4.7.6).

A staged investment strategy thus creates a series of time to build options, which entail the option to abandon the undertaking if new unfavourable information is obtained. In theory, this option is available on an ongoing basis, i.e. the company should be able to abandon the project at any time. This is akin to an American option that can be exercised at any time prior to its expiration. In practice, however, new decisions are usually taken at discrete points in time when the investment strategy is revised. This is comparable to a European stile option that can only be exercised at a given expiration date (cf. section 4.2). Each stage in the investment process can thus be viewed as option to continue to the next stage until the project is completed (Trigeorgis 1995b). The ability to perform an investment in stages therefore resembles a compound option. A compound option is used to describe situations where the payoff from exercising an investment option is essentially another option. Compound options are therefore basically options on options (Geske 1979). This is in principle very different from a *simple option*, which has as its payoff the cash flows generated by its underlying asset. The distinction between simple and compound options is important because many IT Platform investments

entail strategic growth options with multiple independent investment opportunities or path dependent sequential investments (Smit and Trigeorgis 2004a).
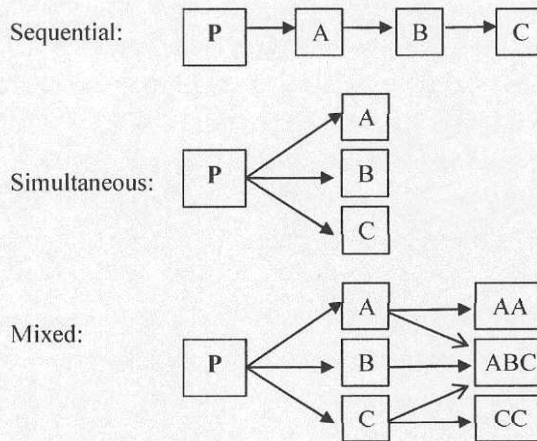
Figure 8: Different types of contingencies involving staged investments

As suggested in the analysis in Chapter 2, in many cases different IT projects within an organisation are interdependent. Based on this conjecture, it was proposed that IT related investments might be classified into three subgroups: *IT policy related investments*, *IT investment projects*, and *IT investment programmes* (cf. section 2.3.3). The focused in this study is on the later two. IT investment projects are herein meant to describe an IT investment that is strictly defined in terms of its scope, timeframe, and budget. IT investment programme, on the other hand, refers to a *set of IT projects* that are interrelated and extend over longer periods. This interrelationship means that there are contingencies stemming from a common platform linking the projects together and also between individual projects internally. As demonstrated in Figure 8, the contingencies may be of sequential nature, simultaneous, or a combination of the two. In the sequential case, a platform investment (P) may for example enable three follow up projects: A, B, and C, which can only be implemented sequentially. That is, to execute project B requires that both the initial platform is in place and that project A is completed. A platform investment may also enable a number of simultaneous IT investment projects. Specifically, after having invested in the platform all three projects can be initiated simultaneously and independently of one another. In the third case, the mixed IT investment programme involves a combination of the two previous investment

scenarios. Here projects A and C are essentially two-stage projects that can be implemented independently of one another. However, to complete the second stage of project B (ABC) requires that the first stage of both project A and C be completed.

From this, it is evident that compound options are relevant to IT investments in at least two fundamental ways. First, there is the case of staged investment involving time to build options. Each stage in the IT investment programme essentially provides the option to continue to the next stage. The project therefore contains a series of options on options or compound options. Trigeorgis (1996) referees to this as "*intra-project compoundness*" (cf. also section 4.7). The investment outlay is not viewed as a single one-time expenditure at the beginning of the project, but rather as a sequence of investment "instalments", starting with the current investment and continuing throughout much of the project lifetime. This is reflected in the mixed investment strategy in Figure 8, where for example, A and AA can be seen as two phases in a single project. The second type of compound options is observed in situations where different projects are interdependent and thus involve *inter-project* compound options. This entails investment scenarios where the first project is a prerequisite for the next one as a link in chain of interrelated projects. This is equal to a sequential compound option where subsequent projects can only be initiated upon the completion of the previous project.

4.3.6 Summary

For a better overview of the different types of Real Options discussed above, they are summarised in Table 4. The table offers a short description of the individual type of options, how they relate to IT investments and a list of some useful references. The following section will focus more on some practical implications from applying this theoretical and conceptual framework on real investment cases.

Type of Real Option	Description	Relevance to IT investment	Useful References
Option to Defer	The organisation may choose between investing now or later	Optimal timing of investing in new technologies is a perpetual issue in most organisations.	(Benaroch and Kauffman 1999; Alvarez and Stenbacka 2001)
Option to invest in stages	Provides managerial flexibility that may have substantial value in the face of great uncertainty	Step wise implementation vs. big bang, all at once project execution of large IT projects can make or break the project.	(Kambil, Henderson et al. 1993; Alvarez and Stenbacka 2001; Smit and Trigeorgis 2004a)
Growth options	An investment may open up opportunities for future capabilities that require further investments but would not been possible without the initial investment.	New applications added to existing systems (platforms) or existing applications spread wider through the organisation.	(Dos Santos 1991; Taudes, Feurstein et al. 2000; Herath and Park 2002)
Scaling options	An option that allows for the scaling of current capacity or capabilities either up or down depending on market conditions	The capacity of many systems such as databases and network servers can sometimes be expanded to meet new requirements	(Kulatilaka, Balasubramanian et al. 1999)
Option to abandon	Abandoning on-going implementation on a new system or use of an existing unprofitable technology	A large number of IT projects end in failure. Knowing when it's time to call it quits can potentially save the company enormous resources.	(Clemons and Weber 1990)
Option to switch	A flexibility option that allows the company to switch between alternative technologies or systems depending on market conditions and customer preferences	Modular system architecture may allow the company to switch to another system vendor for individual applications and/or system support. An IT capability may offer support to multiple business capabilities allowing the company to switch support to the most valuable application	(Dos Santos 1991; Kulatilaka and Trigeorgis 1994)
Compound options	Inter project and intra project compound options	Many extensive IT investments involve a series of interrelated IT projects. Individual projects can further often be implemented in contingent stages that resemble compound options.	(Trigeorgis and Mason 1987; Trigeorgis 1996)

Table 4: Summary of different types of Real Options

4.4 Application Issues

A number of problems have been identified when applying option-pricing theory to real investments. Clearly some of the assumptions on which the basic Black-Scholes valuation model builds on are unrealistic when applied to non-financial assets (the B&S model is discussed in more detail in section 5.1.1). However, many

of these assumptions have later been relaxed. Rubinstein (1976) for example, established that the value of standard options can be derived under risk aversion and that continuous trading opportunities enabling risk free hedging or risk neutrality are not required. Much of the criticism has also been directed towards the limitations of the ROA when it comes to investments where the underlying asset is not traded or there is no clearly identifiable traded twin security.

4.4.1 Traded underlying asset

Financial options models are based on the principle assumption that the underlying asset is traded in liquid markets. This is the fundamental assumption underlying the B&S model enabling that the payoff of the option can be replicated through a portfolio containing a combination of a risk-free financial instrument, and a position the underlying asset. There is however, no requirement that the options themselves be traded on a market. In fact in the original development of the B&S option pricing model was a purely theoretical model with essentially no reference to empirical data as motivation for its formulation (Merton 1998).

Most of the early applications of the Real Options Approach focused on investment projects involving natural resources that are traded in markets. This enabled the analyst to observe the historical price volatility and use as an input variable in the model. For certain types of real investments, such as investments in oil reserves or gold mining rights, there is a clearly identifiable traded asset that drives the volatility of the expected returns on the investment. The problem with this approach, however, is that the volatility of the price of oil is not perfectly correlated with the volatility of the return on an investment in land for oil development. That is, there are other uncertainties than just the price of oil that are likely to affect the return on the investment. This includes for example the amount of oil that can be processed, drilling costs, and the price of other important factor prices such as labour costs, transport and refinery costs.

In most cases, however, the underlying asset is not traded at all. For instance, the value of IT platform investments is typically not directly derived from the technological platform itself. IT has little intrinsic value as it is first when the technology is deployed in combination with other resources that value is produced. That is, IT enabled capabilities are a combination of the technology and the organisational structure and process in which the technology is implemented (cf.

section 4.5). The value of the capability is therefore in most cases industry and firm specific.

4.4.2 Traded twin Security

An increasing number of authors however, maintain that the fundamental framework of options analysis can be applied in situations even though the underlying asset is not traded (see e.g.: Kulatilaka, Balasubramanian et al. 1999; Copeland and Antikarov 2001; Schwartz and Trigeorgis 2001; Mun 2003)[14]. The main argument for this is that if the traditional discounted present value of the investment project itself is used as the under variable for options pricing, the value of real options can be estimated as if the project were traded in a market. That is, the valuation gives an estimation of the real options as if the project were traded in a market. This approach is for example advocated by Trigeorgis and Mason (1987) which argue that the Real Options Analysis makes no stronger assumptions that the traditional NPV analysis. Their approach however requires that a traded "twin" security can be identified and used for deriving the volatility of the return on the asset, which is a required for pricing the option. In an example provided in the text they evaluate an opportunity to build a manufacturing plant and assume that a listed stock price of an identical plant is observable. They justifiably argue that the existence of such a twin security is implicitly assumed in the traditional NPV analysis for estimating the required rate of return. Although in unique cases a twin security may be identifiable for individual IT investment projects, in general however this is likely to be an unattainable task.

4.4.3 The Marketed Asset Disclaimer (MAD)

It has also been shown that assumption of a traded twin security is not a necessary condition for evaluating contingent investments using option-pricing techniques. Constantinides (1978) for example derived the value of an option on an asset, that is not traded in the market, using the Capital Asset Pricing Model. Cox *et al.* (1985) also argue that any option on an asset, whether its traded or not, can be evaluated using the risk neutral environment. They show that "the equilibrium price of a claim is given by is expected discounted value, with discounting done at the risk free rate, when the expectation is taken with respect to a risk-adjusted process for wealth and the state variables. The risk adjustment is accomplished by reducing the drift of

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[14] Some authors just implicitly assume that there is a traded asset in the market, but make no attempt to identify it and the input variables for the option valuation are estimated subjectively (see e.g.: Luehrman 1997; 1998b; a; Howell, Stark et al. 2001)

each underlying variable by the corresponding factor risk premium" (Cox, Ingersoll et al. 1985, p.380).

Copeland, Koller et al. (2000 p.406) and Copeland and Antikarov (2001 p.94) propose a somewhat simpler approach which does not rely on a traded twin security, but rather suggest that the risk adjusted present value of the project itself be used as the twin security. They argue that Real Options evaluation can be applied on any capital investment, based on the assumption that the present value of the cash flows (without flexibility) is the best unbiased estimate of the market value of the project were it a traded asset. They call this assumption the *Marketed Asset Disclaimer* (MAD) assumption. A similar approach is also suggested by Trigeorgis (1998, chapter 4) and Brealey and Myers (2000, p. 636-637). However, the MAD assumption implies a greater applicability of Real Options Theory than can be inferred from other approaches. This is because it also entails that the volatility of the rate of return on the project itself should be used in the evaluation. Copeland and Antikarov motivate this important assumption by drawing a parallel to Samuelson's proof that properly anticipated prices fluctuate randomly (Samuelson 1965). This suggests that the "properly anticipated" value of investment projects, like that of asset prices, follows a geometric Brownian motion even though the underlying factors that affect the cash flows are not random (see Copeland and Antikarov 2001, p. 221-236).

The evaluation model presented in Chapter 5 likewise builds on the MAD assumption. The main types of risks and uncertainty involved with IT platform investments are discussed in the following section, and the issue of estimating the project volatility is discussed in detail in section 5.3.2.

4.5   Risks and Uncertainty in IT Investment Projects

Although often used interchangeably, the meaning of the concepts risk and uncertainty are not completely the same. Risk is traditionally meant to refer to situations where the randomness of the outcome of an event can be expressed in terms of numerical probabilities. Uncertainty is, on the other hand, used to describe situations were probabilities *cannot* be assigned to the possible outcomes. Uncertainty is thus a generic term used to describe something that is not known, either because it occurs in the future, or has an impact that is unknown. Certainty refers to those unusual (or purely hypothetical) situations when the investor knows with probability 1 what the return on his investment is going to be in the future.

Uncertainty is when a collection of values (associated with individual uncertain "states of nature") can happen, with strictly positive probabilities for, at least, two different possible values (Levy and Sarnat 1984). Under uncertainty, a future variable is thus not characterized by a single value, but by a probability distribution of its possible outcomes. The amount of dispersion or volatility of possible outcomes is a measure of how risky that uncertain variable is.

There are many different ways of classifying risk and uncertainty depending on the characteristics of the investment at hand. For the purpose of investment evaluation, it is customary to distinguish between two main categories of risk: project risk (or private risk) and market risk (or external risk). Each of these categories in turn contain several different types of risks that are specifically relevant to IT investment evaluation. One important advantage of this classification is that the two risk categories have different, and sometimes opposing, implications on the investment decision. Each of the two categories of risk is described in this section and the potential implication for the investment decision analysed.

4.5.1 Project risk

Project risk is composed of different elements of uncertainty that pertain to the investment at hand, but are unique (idiosyncratic) to each investment and the individual firm making the investment. This type of risk has also been called technical risk. In their influential book, Dixit and Pindyck (1994) define technical risk as the uncertainty relating to the costs and likelihood of accomplishing technical success. As a result, often the only way reduce, or mange this type of risk is to proceed with the investment in some form in order to gain more information about the underlying factors.

These are therefore risks that the investing company can influence to a certain degree. Internal experts and project analysts, and experience with similar projects are typically the only major sources of data required to assess them. The Standish Group, a USA based technology consultancy firm, has regularly surveyed success and failure rates of IT projects since 1994. Figure 9 summarises the outcome of five surveys spanning from the year 1994 to 2003.

Project Resolution History

Year	Succeeded	Challenged	Failed
2003	34%	51%	15%
2000	28%	49%	23%
1998	26%	46%	28%
1996	27%	33%	40%
1994	16%	53%	31%

□ Succeeded □ Challenged ▨ Failed
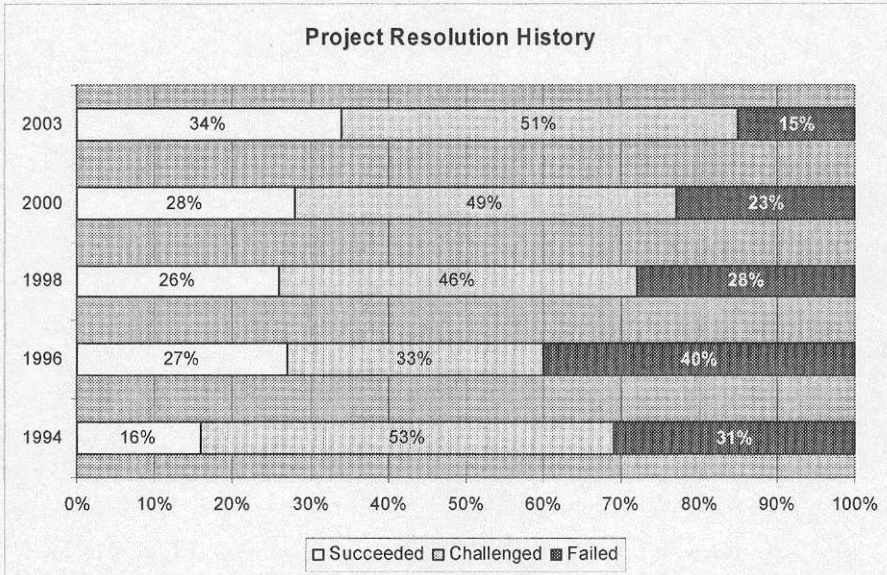
Figure 9: Project resolution in terms of project success, challenged results or failed projects (data source: Standish-Group (1995; 2001; 2004))

The chart summarises the resolution of over 43 thousand IT applications projects in large, medium, and small cross-industry US companies surveyed since 1994. The Standish Group categorizes projects into three resolution types (Standish-Group 2001 p.3):

- Successful: The project is completed on time and on budget, with all features and functions originally specified
- Challenged: The project is completed and operational, but over-budget, over the time estimated, and with fewer features and functions than initially specified.
- Failed: The project is cancelled before completion or never implemented.

This classification suggests that the survey focuses exclusively on the project specific risk characteristics of the IT projects, i.e. the technical success of the implementation. The survey results indicate that, although the success rate has increased dramatically since 1994, still the majority of IT projects do not live up to expectations. The study does however not distinguish between different types of IT projects so the results are therefore very general. A similar study form 1996 in the UK reports comparable results, where on average between 80-90% of investments

in new technology were describe to have failed to meet all their objectives (Clegg, Axtell et al. 1997). Based on these studies it seems fair to conclude that project risk in IT projects is substantial, and that it plays an important role in the value derived from these investments.

The interview study with AEC firms, discussed Chapter 2, identified a number of risks that both directly, and indirectly, pertain to the technical success of IT investments.

User adoption risk: pertains to uncertainty surrounding the willingness and competences of the employees to adapt to, and use the new information system. If the intended application users are not willing to buy into the new system and business processes, it will be difficult to realize any of the specified benefits. This is especially relevant for users, whose individual workload may increase as processes are shifted to them from other points in the organization. Additional factors identified in the interview study that tend to delay or inhibit user adoption included the design of the user interface and significant changes in the affected work processes. Dissatisfaction with current work processes and information systems, has on the contrary been found to influence the speed of user adoption positively (McGrath and MacMillan 2000), and may therefore contribute to lower user adoption risk. In the interview study, extensive user training and information campaigns (within the organisation) were further mentioned as a key factor in reducing user adoption risk.

Interaction Risk: can be described as a form of external user adoption risk. The success of many important IT investments in AEC is closely dependant on efficient interaction between external stakeholders, such as architects, contractors, sub-contractors, and material suppliers. For instance, a successful implementation of a project extranet (cf. Chapter 2) is not only contingent on the willingness of the employees of the implementing organisation to use the system. In order to realise the full potential of the capabilities the investment enables, other actors involved in the construction project need to adopt the technology.

Technology risk: includes a multitude of different technical factors related directly to the implementation and operation of the system, as well as its ability to provide the promised functionality. Technology risk is especially relevant when a technology is new, or unproven, in the context of the intended use, users, volumes, and performance requirements (Keen 1991). Although the investment may involve a

standardised system, different organisations and processes embody different levels of experience and knowledge, which influences the risk level, and thereby implies that it is generally specific to individual firms.

An important factor in analysing this type of risk is to establish a contingency scenario, that is to say, what will happen if the system fails and how will it affect the company's business operations. One common way in dealing with this risk in evaluation is to consider the replacement cost of the system. This could for example involve replacing the system with an alternative technology from a different vendor. An alternative scenario is when a new investment is made to replace existing systems or applications, in which case the replacement cost could involve the re-instalment of the existing system. The consequences of a technology failure can however, in some cases be even more severe. The failure of a crucial technology capability could result in serious disruptions in the daily business operations of the organisation. Suh and Han (2003) argue that many organisations have become so dependent on IT that even a relatively short loss of the availability of a critical system can lead to a total failure of the business.
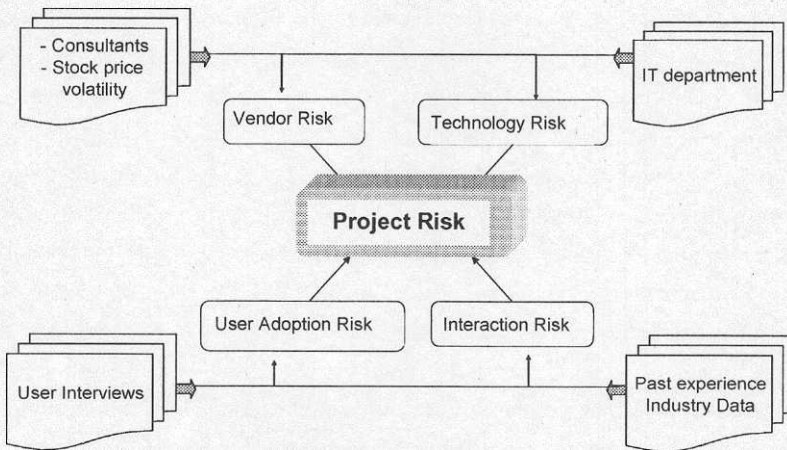
Figure 10: Example of IT project risks in the construction industry and potential information sources

Implementation risk refers to problems in software design, project management, component integration that might impede the system from providing the intended functionality in a reliable and consistent manner (Keen 1991). In the interview study (cf. Chapter 2) one manager, for example, identified data migration between the old and the new systems as major potential hazard. Another element of this risk is when

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AEC companies begin applying their new IT capabilities in the construction projects and the team members experiment with the technology. Thomas (1999, p. 25) reports that many general contractors have experienced a pronounced learning curve effect during the early phases of implementation of new IT capabilities in construction projects. This may lead to construction delays and performance penalties, and in worst cases scenarios this can seriously damage the firms' reputation.

One way of quantifying technology risk is to define scenarios and assign probabilities to different outcomes. The assigned probabilities should be based on historical data from past projects when available, but in other case on subjective estimates from technology experts can provide valuable information.

Organizational risk: refers to the possibility that a technically functional innovation will fail to secure support within the organisation, threaten key aspects of the firm's traditions, norms, management process, or culture, or require skills that the organisation does not poses (Keen 1991).

Vendor Risk: describes potential situations where the interaction with the system vendor (or the system developer) has a negative effect on the value of the IT investment. The companies in the interview study (cf. Chapter 2) expressed two main concerns in this context. First, the system vendor may go out of business, and as a result not be around in the future to support the system. Secondly, the system vendor may not live up to agreements about system configurations, customisations, integration, or continued application development. The former concern is a risk that is present in all outsourcing relationships. In the case of extensive IT investments such as ERP implementations, the downside cost effect can be very severe if the firm is forced to switch to another system. The best way to analyse and mange this risk is to evaluate the vendor's economic stability (credit ratings and annual reports) and its past performance. Oftentimes the system is expected to be used for a number of years, which makes it important to periodically update this risk assessment after the system is in place. The second case however, is often more of a legal concern involving contract non-compliance or unclear contracts and misunderstandings. Whichever the case, the consequences can be disastrous. A good expel[15] of how bad it can actually go is the case of the Bröderna Nelsons Frö Inc., a Swedish seed

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[15] This example builds on an interview with Torsten Nilsson, the CEO of the company, in Computer Sweden (Byttner 2001)

company with an annual turnover of around SEK 150 million. The company first attempted to implement an ERP system called Jeeves in 1996. The system however turned out to contain many minor system faults and a number of the requested functions were missing. The project ended with a lawsuit against the system vendor in which some of the investment costs were recovered. Next, the company decided not to take any chances and decided to go with a more expensive system called Visma. The contract involved that the system vendor would develop and implement a customised ERP system. Two weeks after the system was implemented the system vendor was declared bankrupt and the system crashed a short time later. The third time around, the company decided to invest in the well-established SAP enterprise system. The system was to be implemented by a subcontractor to, although SAP AB. would guaranty the system functionality. However, after repeated project delays, broken promises and lawsuits, the company was forced to switch to yet another implementation firm to get the system operational. More than four years, SEK 40 million in direct costs, and several close to bankruptcy situations later, the company finally had a functional enterprise system.

This type of risks can be quantified in the same way as technology risk: by defining scenarios and probabilities. In choosing a technology standard, for example, the base case may that the technology and system vendor succeeds in the market while the alternative scenario could be that the vendor goes bankrupt, or the particular system loses a standards battle against an system from another vendor. Quantifying the alternative scenarios then involves calculating the cost of converting to the successful system (Dempsey, Dvorak *et al.* 1998).

4.5.2 Market risk

In addition to the project risk, IT investments are also subjected to *market risk*. This type of risk is due to exogenous factors and typically driven by macroeconomic forces and is therefore generally not controllable by individual companies. In AEC, market risks include, for example, labour costs, the number of available projects to bid on, interest and mortgage rates, and currency fluctuations. The potential of an IT capability to generate cash flows is thus influenced by such factors as: reactions from competitors and external stakeholders, systemic shifts in the industry and technological development.

Exogenous or market risks can be classified further depending on how they affect the profitability of the IT investment. Many of these risks can be assessed from macroeconomic and financial market data as well as from construction indexes[16].

Competitive risk encompasses the risk of competitors adopting a new technology innovation first and thus eliminating potential first mover benefits in the form of competitive advantages. Equally, a competitor may respond to an implemented IT investment capability by developing a better application that may make previous technologies obsolete.

Environmental risk describes the possibility of negative reactions of external stakeholders such as customers, suppliers, and business partners. In special cases the investment decision this may also be influenced by changes in laws and regulations. Regulatory risk refers to a situation where the implementation of a new IT capability can potentially be blocked by regulation, government policy, social debate, or interest groups (Keen 1991).

Systemic risk refers to situations where a new technology has such a great impact that it changes the industry so dramatically that the anticipated benefits fail to materialise to the investing companies. A study on the effects of early adoptions of automated teller machines (ATMs) in the banking sector found evidence that early ATM adoption resulted in a sustained increase in income. However, banks that started adopting this technology only a year later were not able to markedly raise neither income, nor market share (Dos Santos and Peffers 1995). This indicates that a systemic shift took place in the sector where investing in the new technology quickly became a cost of doing business in the industry rather than a source of strategic competitive advantage.

Thus far, however this has not been a major concern in the AEC sector. Adoption of new technologies and innovations has generally taken place over long time periods. IT applications applied in construction have further often been applied in other industries before being adopted in AEC. Sudden technology shifts have therefore been infrequent.

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[16] In the USA there are a number of organisations supplying statistical data and analysis for the AEC industry, see for example: Reed Construction Data (http://www.reedconstructiondata.com) and FW-Dodge (http://www.construction.com/). Similar services are available in Sweden from organisations such as Sveriges Byggindustrier (http://www.bygg.org/) and SCB (http://www.SCB.se).
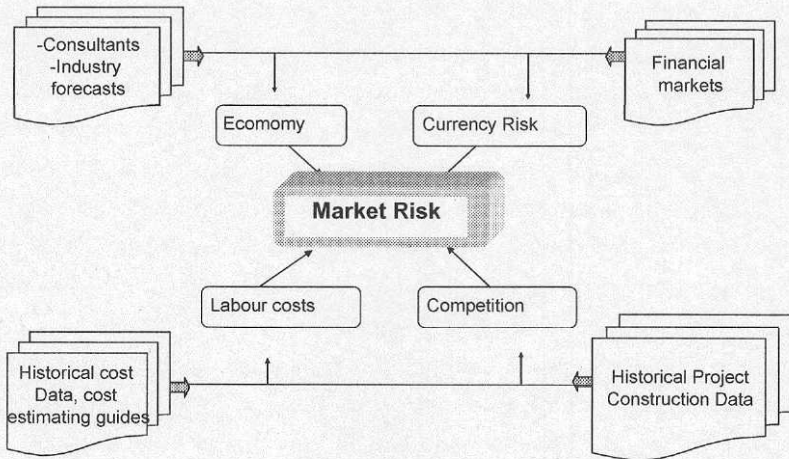
Figure 11: Different components of the market risk and potential information sources

4.5.3 The role of risk in the IT investment decision

In the case of private risk, it is generally difficult to resolve the underlying sources of uncertainty prior to making the investment. For instance, the company may in advance be able to assess potential levels of user adoption of a particular system, and even to some degree of certainty estimate the potential implications of technological complications during the implementation. However, only by making an initial investment, for instance through a pilot project, will the organisation obtain real information about these risks. High levels of project risk will therefore generally function as an incentive to make an initial investment to gain further knowledge about the underlying risk factors.
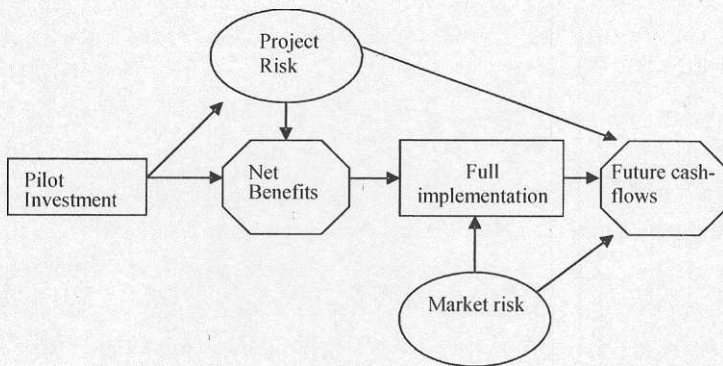
Figure 12: Relevance diagram showing project and market risk at different investment stages

Market risk, on the other hand, tends to have the opposite effect on the investment decision. This type of risks is external to the organisation and no actions are therefore likely to have any significant effect on them. In most cases, only the passage of time will reveal the actual outcome of variables subject to market uncertainty, such as general demand conditions in the economy and labour costs. Figure 12 depicts graphically how project risk and market risk effect the investment decision. Performing a pilot investment, before deciding on whether to implement an IT project fully, provides information about the project risk. However, the benefits of implementing a specific IT application in a single construction project are likely to be independent of market risks. Should the company, however decide to implement the new IT capability on all its future construction projects; market risk is likely to have a substantial impact on the expected cash flows.

4.6   IT and Business Capabilities

Information technology investments by themselves, when viewed as a bundle of software and hardware, rarely have any significant stand-alone value. It is first when the information technology is combined with other resources that value is created from the investment. Consequently, the process of determining the value of IT investments can become very complex due to difficulties in establishing the boundaries of different IT initiatives. Information technology is also often highly integrated in the structure of organisations and the design of their work processes (Berghout and Renkema 2001). The rationale for making an IT investment can therefore be to support a change in the organisation or individual work process. Conversely, a new IT system may act as the factor that provides the motivation or push for a change in these operating drivers.

To be able to identify the relevant costs, benefits and risks of technology investments they need to put into the appropriate context. Achieving benefits from IT is therefore by no means limited to technological concerns. Many authors have emphasised the importance of considering organisational issues for successful implementation of IT systems (see e.g. Farbey, Land et al. 1993; Remenyi, Money et al. 1993; Farbey, Land et al. 1999; Serafeimidis and Smithson 1999). In line with this view, the IT evaluation process itself and its content are closely intertwined and heavily dependant on the context of potential organisational change associated with the development, and implementation of new information technology (Serafeimidis and Smithson 1999). The wider context encompasses both the organisational context, that is, multilevel systems and structures within which the organisation is

located, and the environmental context referring to the social, cultural, political and economic environment in which an organisation operates (Serafeimidis and Smithson 1999). *IT platforms* therefore encompass more than just hardware and software investments or the appropriation of software licences. The value of IT platforms is inherently derived from the organisational and industry context it is applied to create *business capabilities*.

The concept of organisational or business capabilities[17] has developed under the resource based view of the firm (see e.g., Dierickx and Cool 1989; Barney 1991; Peteraf 1993; Maritan 2001). This view stipulates that competitive advantages are established primarily based on internal and firm specific capabilities and resources. Maritan (2001 p. 514) defines a *capability* as "a firm's capacity to deploy its assets, tangible or intangible, to perform a task or activity to improve performance" (see also: Barney 1991; Grant 1991; Kogut and Zander 1992; Amit and Schoemaker 1993; Teece, Pisano et al. 1997; Barney 2001). Maritan (2001) argues that an important characteristics of capabilities are that they are knowledge based, firm specific and socially complex. Consequently they generally cannot be simply acquired in factor markets but rather need to be developed within the firm. Despite the relatively extensive literature focusing on organisational capabilities, few studies have addressed the subject of evaluating investment in capabilities. One notable exception however, is a study by Maritan (2001, p.515) which defines three types of investments in capabilities:

1. Investments to maintain the stock of an existing capability
2. Investments to add to the stock of an existing capability
3. Investments to build a new capability

The first two types of investments; maintaining and adding to existing capabilities, entail no qualitative changes to the capital stock of the firm, but are rather aimed at preserving or increasing the quantitative nature of a capability. Investments involving the creation of new business capabilities, on the other hand, entail a qualitative change in the firms existing range of capabilities. Maritan argues that there are different levels of risks associated with these quantitative and qualitative changes in capabilities. Investments aimed at maintaining an existing capability would typically be exposed to the lowest risk since the objective is to preserve an

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[17] The concepts of organisational and business capabilities are assumed to be identical, and are used interchangeably in the text.

existing condition. Expanding an existing capability involves more risk although the firm may have some valuable experience with the capability. The added risk element comes from uncertainty surrounding the successful exploitation of the increased capacity derived from the expanded capabilities. Investments to build new capabilities involve the highest degree of risk. This is because the firm will not possess any experience in neither accumulating nor using the capability (Maritan 2001).

Kogut and Kulatilaka (1994) argue that organisational capabilities are the most important platforms that a firm can build as they support investment strategies into a wide spectrum of opportunities. Kogut and Zander (1992) argue that firms invest in assets that correspond to a combination of their current capabilities and expectations regarding future opportunities. The knowledge of a firm can therefore be seen as consisting of platforms containing a portfolio of options on future developments. Kogut and Zander maintain that eventually there are decreasing returns to a given technology or method of organizing that consequently results in an incentive to build new, but related skills. These investments in new ways of doing things, they suggest, serve as platforms on future and uncertain market opportunities (Kogut and Zander 1992, p.385). An important aspect in acquiring this type of "platform" capabilities is therefore linked to technologies. Technological expertise is, however not confined to acquiring the set of necessary tools, but is directly dependant on the capacity of the firm to leverage these tools to produce new or improved products and services over time. Consequently there is an significant lead-time in establishing IT related business capabilities which makes them *hard to imitate* or *pre-empt* by competitors (Kogut and Kulatilaka 1994; Sheng 2004).

Focusing the evaluation on the business capabilities created by the new technology investment further addresses the problem of separating the costs and benefits from the technology investment itself and impacts from other operating drivers. The operating drivers are the set of technologies, processes and organisational elements that are necessary for the firm to achieve a business capability (see Figure 13). The *process* driver includes procedures, workflows, management controls and human resources practices; and the *organisational* driver includes relationships with other firms as well as the internal management structure (Kogut and Kulatilaka 2001). The cause and effect issue, described earlier, becomes less relevant as the focus is

on determining the impacts from the new business capabilities rather than the individual components that enable them.
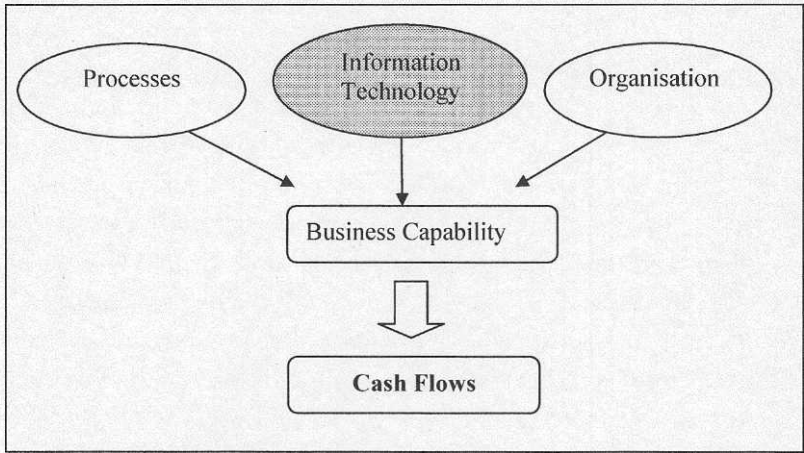
Figure 13: Main operating drivers of a business capability (adapted from Kulatilaka, Balasubramanian et al. (1999))

As asserted above, the elements related to information technology are only one of the operating drivers upholding the IT platform required to achieve a desired capability. Two firms may obtain the same business capability through investing in different kinds and combinations of operating drives, such as process and organisational components (Kulatilaka, Balasubramanian et al. 1999). Different firms faced with the opportunity to acquire in a new capability enabled by the same technology investment, are also likely to place a different value on this capability. This is above all because they will have different costs involved in acquiring this capability. The cost depends on the current platforms of the company, platforms consisting of the technology infrastructure, technical expertise, organisational structure, and internal work processes. The total cost is therefore the sum total of the costs related direct investment in hardware and software, organisational costs, and costs from process re-engineering required to successfully obtaining the new capability. More importantly, the business capability will also produce benefits. The costs and benefits of the business capability are therefore reflected in the cash flows it generates (cf. Figure 13). The cost and benefit impacts are thus displayed in the model through negative and positive cash flows respectively. This is discussed in more detail in the remainder of this section.

4.6.1 Cost impacts

The costs associated with IT are often perceived to be easier to estimate than the benefits (Remenyi 1999; Renkema 2000). This is however, not necessarily the case as the cost impact of an extensive IT investment can often be hard to predict and much wider than anticipated (Dempsey, Dvorak et al. 1998; Remenyi 1999; Love and Irani 2001). Hides *et al.* (2000) suggest that an important reason behind the difficulty in realising anticipated IT investment benefits may be the relatively large amount of indirect and intangible costs associated with the implementation of new systems. Direct costs, on the other hand, typically include those expenditures that are easy to measure and can be directly attributed to the IT investment. The interview study in Chapter 2 for example showed that the AEC companies included in the study focused almost exclusively on the cost of hardware and software, software development costs, and in some cases also the direct cost of user training. Many companies have found out the hard way that extensive IT projects generally have much more extensive cost implications than this. Dempsey, Dvorak *et al.*(1998) for example argue that support and maintenance costs, business costs associated with making the transition to new information systems, and other hidden costs can be difficult to predict accurately, and can easily more than double the cost of the initial investment. The cost estimation should further include the costs associated with the change in organisation and business processes. The authors suggest that there are mainly two categories of costs that are often missed in the evaluation: transition costs and complexity costs. They define transition costs as the all the onetime costs incurred by the move to the new system, other than the costs of hardware, software and integration. This type of cost is for example encountered in the case normal business operations are interrupted due to the IT implementation, and when contingency IT solutions are required to avoid this type of loss. Complexity costs include the ongoing increases in operating costs that arise when a company needs to supports multiple technologies or standards. "Investing a new database technology, for instance, means that an IT organization must acquire a new set of skills, create a mechanism to support the day to day operation of the technology, and maintain both skill sets and mechanisms throughout the life of the technology" (ibid p.131). Many authors have focused on these so-called indirect costs. Love and Irani (2001), for example, suggest that two additional cost categories should be included in the IT investment evaluation. They call these categories the indirect human cost portfolio and indirect organisational cost portfolio, and propose a detailed taxonomy for how they can be measured.

Disregarding this type of costs is liable to have significant consequences, especially for AEC firms, which are often heavily dependant on short-term cash flows to support daily business activities. However, they should not be treaded as indirect costs. This type of classification fails to recognise the fundamental property of IT investments. Namely, that there is essentially no such thing as a pure IT investment. Seeing that IT has little value when viewed out of context, focusing the evaluation solely on the technology components of the investment, and treating other cost impacts as indirect or insignificant, is likely to give misleading impressions. For this reason, the framework developed here does not distinguish between different types of costs. All costs that have to do with the changes in the technology infrastructure, process, and organisational elements, and are required to attain the desired business capability, are to be included in the analysis. A number of authors have developed detailed taxonomies and evaluation procedures that are helpful for identifying and measuring these costs. These are generally easily accessible and will therefore not be reproduced here. This type of classifications are however undoubtedly helpful in measuring these impacts and incorporate into the financial analysis (for a general framework see for example: Remenyi, Money et al. 2000; see also Love and Irani 2001 for a framework that focuses specifically on AEC firms).

4.6.2 Benefits

Evaluation of the different types of benefits associated with IT investment has been extensively researched, although no universal methodology applicable to all types of IT investment has yet been developed (Renkema 2000; Serafeimidis 2001). The focus of IT evaluation (at least in the academic literature) has shifted from the early strong cost reduction perspective towards assessing the strategic and business value of the investments (cf. Chapter 3). Renkema (2000) describes the business value assessment of IT-based infrastructure as "a highly organisational and communicative process, in which 'hard' financial appraisals and strategic evaluations interact with 'softer' issues of managing the assessment process in terms of stakeholder agreement, management ownership, conflicts of interest, power and politics" (Renkema 2000 p.xviii). Currie (1989) also found that in order to get board approval for expensive IT investments, IT managers often resort to "playing the system" and producing spurious predictions of increased productivity as a result of their proposed projects. However, as Willcocks and Graeser (2001) maintain; for the benefits of IT investment to be worthwhile, they must be related to the goals of the organization, and not just merely goals for the sake of technology.

As in the case of IT investment costs, most of the IT literature makes a somewhat clear distinction between direct or *hard benefits* and *soft benefits* (Brown 1994). The so-called hard benefits are usually associated with efficiency gains as a direct result of the implementation of a new system and can in most cases be relatively easily quantified in financial terms (Giaglis, Mylonopoulos et al. 1999). A classical example of this type of benefits would be cost reductions due to the replacement of manual tasks with technology and savings in terms of upgrade costs and maintenance of older systems. The soft benefits on the other hand are perceived to be more difficult to quantify. Many companies do not formally evaluate their IT investments because they maintain that many of the important benefits cannot be quantified in monetary terms and are hence left out of the evaluation. These hard to evaluate benefits are therefore often labelled as *soft benefits*. This type of benefits typically includes such factors as:

- Improved coordination
- Better reputation
- Greater flexibility
- Increased market share
- Enhanced productivity
- Standardised work processes
- Making life easier for the employees
- Quality improvement
- Increased variety
- Increased innovation

The effect of this type of benefits can be substantial. Shin (1999) for example found that IT spending is strongly associated with a decline in coordination costs. Better responsiveness and coordination may not always directly increase the amount and quality of the product or service of a firm (Brynjolfsson 1993). However, they have been shown to contribute to making sure that the product or service is supplied at the right time, at the right place, and with the right attributes for each customer (Shin 1999). This type of benefits is therefore of great importance in AEC as construction projects are heavily dependent on effective project- and supply chain management. One of the most important issues, perhaps even the main core of IT investment research lies in the notion that this kind of benefits are difficult, if not impossible, to quantify. Not all researchers though share this view. Dempsey, Dvorak *et al* (1998) for example argue that "many supposedly unquantifiable

impacts such as market share gains or improved customer retention are not really unquantifiable at all, and should be estimated"[18]. One straightforward approach for this is benchmarking. Evaluation without alternatives is generally not informative. In order for the expected impacts of the investment to be quantifiable, they generally need to be benchmarked against some other credible alternative action. In the simplest case the alternative course of action to investing would be compare to what happens if no action is taken (often called a zero alternative). In practice, this means evaluating the cost of doing nothing, which in fact can often be costly when compared to alternative actions (Dempsey, Dvorak et al. 1998). In other cases though, there may be several alternative ways to achieve a desired business capability. This may for instance simply entail choosing between alternative software platforms, but may also include different configuration of the operating drivers, i.e. changes in the organisational structure, business processes, and technology. Therefore, in the case of more complex capability investments, the benchmarking approach should be used in combination with scenario and simulation analysis (cf. section 3.4). A decrease in the risk of construction delays (which is often associated with large costs) is an attribute often associated with AEC specific IT investments. Estimating the effect on the probability of construction delays from the proposed investment (benchmarked against current practice) is good example of how this type of "intangible" benefits can be quantified and thereby included in a formal evaluation. Quantifying the amount of benefits achievable this way may require some effort, but for that reason should not be excluded from a formal evaluation.

One intuitive approach to describe soft benefits, suggested by Brown (1994) and developed further by Giaglis et al. (1999), is to distinguish between intangible, indirect and strategic benefits. *Intangible benefits* are defined as those impacts that can be ascribed to particular applications but cannot be easily expressed in quantitative terms. *Indirect benefits* are potentially easy to measure but cannot be wholly be prescribed to the proposed investment as they can usually only be realised as a result of other non-IT related investments. *Strategic benefits* refer to positive long term impacts, typically resulting from synergistic interaction among several contributing factors and additional future investment opportunities (Giaglis, Mylonopoulos et al. 1999).

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[18] A similar view is presented by e.g. Dos Santos (1991), Kulatilaka, Balasubramanian *et al.* (1996), Taudes, Feurstein *et al* (2000) and Dahlgren, Lundgren *et al.* (2001).

As summarised in Figure 14, this typology provides a relatively complete framework to describe the different types of benefits of IT investment. The horizontal axis provides a relative scale between quantifiable and supposedly non-quantifiable benefits. The vertical axis provides a yardstick for the extent to which benefits are realised as a result of the introduction of the information system, and those that are also contingent on other operating drivers (ibid p.52).
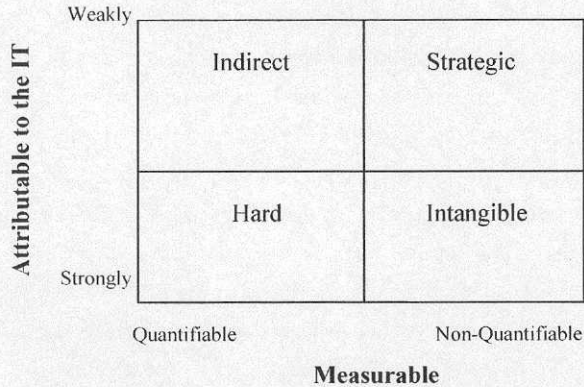
Figure 14: Different types of IT benefits (From Giaglis, Mylonopoulos et al. 1999)

A closer examination of these different types of "soft" benefits shows that may of them are captured by the theoretical and conceptual framework outlined in this chapter. The *strategic benefits* for example, are in many cases comparable to what was defined earlier as future contingent growth options. These strategic benefits accrue because of future investments in applications leading to enhanced capabilities, which would not have been possible without the initial platform in place (cf. section 4.3). The strategic benefits further include other flexibility options (e.g. options to defer, scale, switch, and abandon). Dempsey, Dvorak et al. (1998) argue that future flexibility value is a crucial factor in IT investments. An investment in an inflexible system, which hampers the responsiveness of the companies existing system, entails a cost to the company in the sense it may obstruct future advancement. Equally, they maintain that "an investment in a robust, simple infrastructure may have modest immediate benefits, but a dramatic effect on the speed of systems development and deployment in the longer term" (ibid p.132). *Indirect benefits* are further captured in the business capability framework. By shifting the focus away from the IT components themselves, over to the business

capabilities they enable in combination with other operating driers, the IT specificity of the benefits becomes less relevant. Many of the alleged *intangible benefits* can similarly be quantified using the framework and methods described above. Benchmarking, scenario and simulation analysis, combined with a staged investment strategy (including pilot projects), is likely to provide reasonable estimates of even the most elusive benefits that can expected as a result of the investment.

	Weak		
		Indirect Benefits	*Strategic Benefits*
Benefits Specificity to IT	↑	Business Capability Approach	Growth options Flexibility options
		Cash-flow analysis	Staged Investment strategy Benchmarking, scenario and simulation analysis
		Hard Benefits	*Intangible Benefits*
	Strong		

Low   **Required Evaluation effort**   High
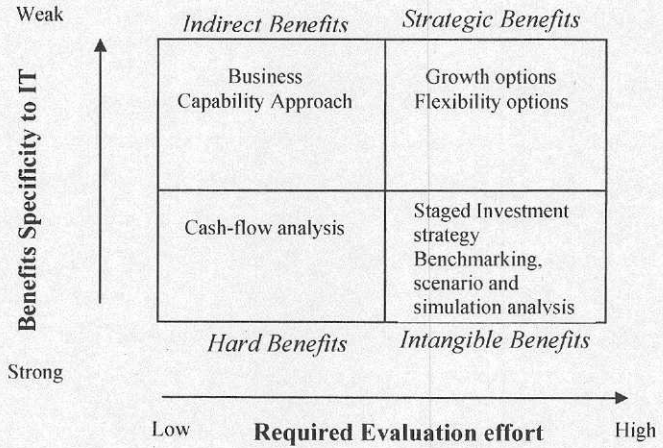
Figure 15: Improved framework for quantifying the benefits of IT investment

Finally, the hard benefits such as direct cost savings and efficiency gains are typically easy to quantify directly in terms of cash flows. This framework for evaluating the different types of benefits associated with IT investment is summarised in Figure 15. The initial framing of the investment valuation can be divided into three steps. The first step is to determine whether the investment entails *platform opportunities* in the form of future contingent investments. The second step focuses on potential *managerial flexibility* before and during the building phase of the desired capabilities. The third step is then to analyse potential *operating flexibility* after the initial investment phases. These three phases are listed in Table 5 which further shows the type of options which are of most interest at each stage.

Identify Platform Opportunities	Building capabilities	Manage Capabilities
Growth options:	Defer	Abandon
- implicit	Explore (pilot)	Contract
- explicit	Stop/resume	Expand
- strategic		Switch

Table 5: Different types of options associated with individual phases in the investment process

In the remainder of this chapter, these concepts are developed further, and steps outlined in which the framework can be operationalised.

4.7 Identifying IT Platform Opportunities

The most challenging aspect of evaluating platform investments is that the payoff from future contingent investments is typically subject to much uncertainty. First, the feasibility of these future investments is contingent on the successful implementation of the initial platform. Secondly, the profitability of the future investments themselves is subject to their own risks. These characteristics of platform investments result in an asymmetry in the risk profile. The platform opportunities of an IT investment program allow the investor to take advantage of the upside of uncertainty while at the same time limit the down side value effects. This means that although the future value of the contingent investments is uncertain today, market uncertainty is resolved with the passage of time and information about private risks is gained through the completion of earlier investment stages (see also Figure 12). Subsequent contingent investments are only executed if market conditions and technical uncertainties turn out favourably, i.e. the benefits of the investments exceed the investment cost. As a result, the distribution of potential future values of the investment becomes skewed, i.e. there is a higher chance of a favourable outcome than an undesirable outcome. The most important implication here is that investments with a negative NPV may now potentially be justifiable because of the value of future investment opportunities (options) which is normally ignored or trivialised in a simple NPV analysis. Intuitively that also suggest that the more uncertain the payoff of the IT investment, the more valuable the contingent options become.

In some cases, it may be obvious that an investment entails platform opportunities and contingent growth options are easily identified. In other cases however, it may be difficult to predict precisely what future investments will actually be able to benefit from the initial platform (MacDougall and Pike 2003). These future

investments may involve anything from applications simply being added to a software platform, to new related business capabilities building on the established IT platform[19]. Platform opportunities may further materialise as unexpected by-products of an IT investment designed to achieve a specific goal (as was the case in the motivating example in Chapter 1), or they may be part of carefully planned strategy to build or enhance business capabilities. IT platform investment evaluation will therefore typically involve one of the following scenarios:

1. The platform investment involves obvious (*explicit*) growth options
2. The investment does not produce sufficient benefits to be justifiable as a stand-alone investment, but may potentially entail valuable (*implicit*) growth options
3. The platform investment is a part of a deliberate strategy to build business capabilities (contains *strategic* growth options)

4.7.1 Explicit Growth Options

In order for the investment to be seen as a platform investment, it must contain at least one growth option. *The first scenario* assumes that an investment is identified as having obvious future opportunities. When analysing this kind of investments it could therefore be useful to classify the different applications into standard, limited and likely expanded use (Thomas 1999). The standard application of a 3D-CAD[20] system might for instance include visualisation, interference checking, layout, and material take-off. Limited use might entail colour coding design checks, equipment feasibility/safety/time and cost studies as well as structural and electrical applications. Likely expanded use could involve more components being added to design and increased integration with engineering analysis software. To realise the additional benefits usually requires that follow up investments be made. ERP systems are also a good example of IT platform investments with both explicit and implicit growth options, as the systems are typically composed of multiple applications that are integrated into a single platform. In many cases, individual applications can further be implemented in stages throughout the organisation. In a survey of 163 organisations (in the United States, Europe and Australia) that had implemented enterprise solutions, Davenport et al. (2002) found that only 69 percent of organisations choose to implement the systems in most or all functions,

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[19] Note here the distinction between a software platform, which provides the technological prerequisites for additional applications, and an IT platform that incorporates the technological infrastructure as well as organisational and process related capabilities.
[20] 3D-CAD stands for three-dimensional computer aided design

and business units. As shown in Figure 16, 2 percent of the organisations choose to abandon further implementations after a pilot implementation, and 27 percent of the organisations chose to implement the system only in half, or fewer of their business units.
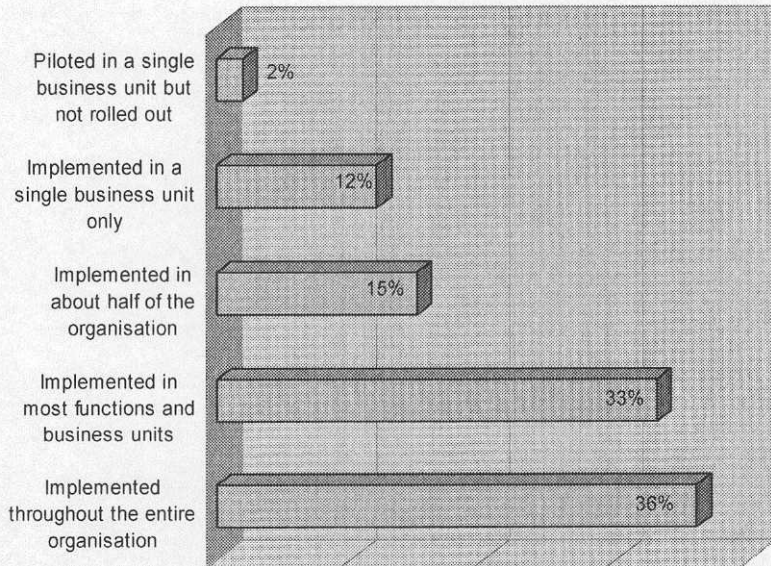
Figure 16: Survey results on the extensiveness of ERP solutions installed in organisations (source: Davenport et al. (2002))

This is especially relevant in the AEC environment as the companies are often highly decentralised in terms of operating units, and geographically dispersed. An application could for example be implemented in a single division, and later gradually expanded into other business units depending on both market conditions, and technical viability. This type of flexibility can therefore be likened to implicit growth options. New applications can also be added to the platform in the same fashion depending on the capabilities desired by the company. This opportunity to expand the range of business capabilities of the platform is thus more of an explicit growth option.

IT platform investments may further involve multiple path dependent growth options, where the exercise of one option generates another growth option. Previously in the chapter this was defined as a compound option. Depending on the characteristics of the future opportunities, they can thus be implemented either

simultaneously or sequentially at distinct time periods, or continuously, throughout the investment process.

4.7.2   Implicit Growth Options

In the second scenario, a closer examination of an individual IT investment project may reveal that the project, either in its current form or through adjustments in the implementation strategy, entails future growth options. In this case, the total value of the investment is not only the NPV of the immediate cash flows generated by the investment, but also the value of the future implementation opportunities. In the case of most large IT initiatives, there is flexibility to control the investment and implementation process using pilot projects and staged implementation. This provides the investment manger the operating flexibility to change the investment strategy as more information about project specific uncertainty becomes available. The strong project focus of the AEC sector could actually be seen as beneficial for the implementation of this kind of investments. Mini-scale versions of the investment can be implemented gradually, starting for instance with an implementation in a single construction project, and then continuing progressively until full-scale implementation is reached. A contractor could for example, decide to invest in a Project Extranet on a single construction project in order to later decide whether to move the entire project management to a web-based platform. The value of the first investment is then not only the potential benefits on the single project, but also the increased flexibility associated with being able to swiftly move to a web-based platform if this is found to be appropriate.

When the platform investment is tied to a specific software platform, one way of identifying future implementation opportunities is to analyse the system specifications with regards to applications known to operate on the specific platform. The number of implementation opportunities depends on the amount of applications supported by the system vendor, and in the case of modular platforms, applications from other vendors can also be integrated into the system. An open source software platform may also enable the company to develop and customise their own applications into the platform. The value of a platform investment is therefore related directly to the breadth of both the current and the future opportunities it entails. "It stands to reason that an investment with many potential applications is more valuable than one with a narrow set of opportunities" (Kogut and Kulatilaka 1994 p.60). IT platform investments were defined earlier as investments where a substantial part of the value of the investment is expected to

come from future contingent investments. This does not exclude investments where the platform itself generates significant direct benefits, but rather implies that these benefits are not sufficient to justify the investment in terms of the traditional financial evaluation criteria. Should the investment be shown to be profitable irrespective of the future potentially valuable growth options there may be no need to "over value" the investment further. If this is not the case however, further steps need to be taken in order to incorporate the platform benefits into the evaluation.

The traditional DCF analysis approach assumes that *all relevant impacts* of the investment are quantified in terms of cash flows. However, identifying and evaluating all possible future implementation opportunities may not be practical (or even desirable) for IT platform investments. Another way to frame the evaluation is to reverse the analysis. That is, instead of trying to derive an exact estimate of the value of the investment, the evaluation focuses on how much benefits are needed to justify the investment. Therefore, rather than putting a large effort on trying to quantify all possible future impacts, it may be sufficient to focus on what is required, in terms of particular outcomes and payoffs from future investments, to justify the initial investment (Amram and Kulatilaka 1999). Giaglis, Mylonopoulos *et al.* (1999) advocate a similar incremental benefit evaluation approach to IT investment evaluation. Namely that, "the benefit measurement exercise should start with those benefits which are realised as a direct outcome of the system under examination and are readily quantifiable" (Giaglis, Mylonopoulos et al. 1999 p.53). Should this analysis not be sufficient to justify the investment, indirect, intangible and strategic benefits are incrementally added to the evaluation. The main motivation for this approach is that evaluation is a complicated and resource demanding task. Limiting the evaluation to the point where benefits exceed the estimated costs to an acceptable degree may therefore save valuable time, resources and effort when complex benefits need not be quantified in great detail (Giaglis, Mylonopoulos et al. 1999).

4.7.3 Strategic Growth Options

The third scenario assumes that IT platform investments are part of a strategic plan to acquire new business capabilities. Under this setting the evaluation is focused on a staged investment plan designed to move the company from their current level of business capabilities to some future level of desired capabilities. The evaluation could benefit from some sort of gap analysis focusing on the type of investments required to achieve a specific future development. Kulatilaka, Balasubramanian et

al. (1999) presented an intuitive evaluation framework for this type of evaluation. The methodology involves translating a business vision into a set of specific business capabilities. This requires that the firm chooses a specific set of operating drivers (technology platforms, applications, business processes and organisation resources), which are required to support individual business capabilities. The analysis thus requires an examination of the firm's current operating drivers and the formulation of a strategy to on how to enhance, substitute, and build on these drivers to enable the desired business capabilities. Accordingly, the investments required for the individual operating drivers are identified and the anticipated cash flows evaluated.

4.7.4 Simultaneous or Sequential Growth Options

Figure 17 shows an example of a platform investment with three possible follow-up investment projects that are contingent on the initial platform. In this case, the growth options A and C are independent which implies that they can be exercised in any order, one at a time or both simultaneously. Growth option A and B are however interdependent. This means that to be able to exercise option B requires that option A has been exercised, implying that the option is sequential. However, in both cases, the investor needs to make an initial investment in the platform in order to be able to take advantage of any of these future opportunities. The investment opportunity can hence be described as an *inter-project compound option* (Trigeorgis 1988). The payoff of option A is another option (it may also involve some cash flows). The payoff of option C is however "only" cash flows, which entails that it is a *simple option.*
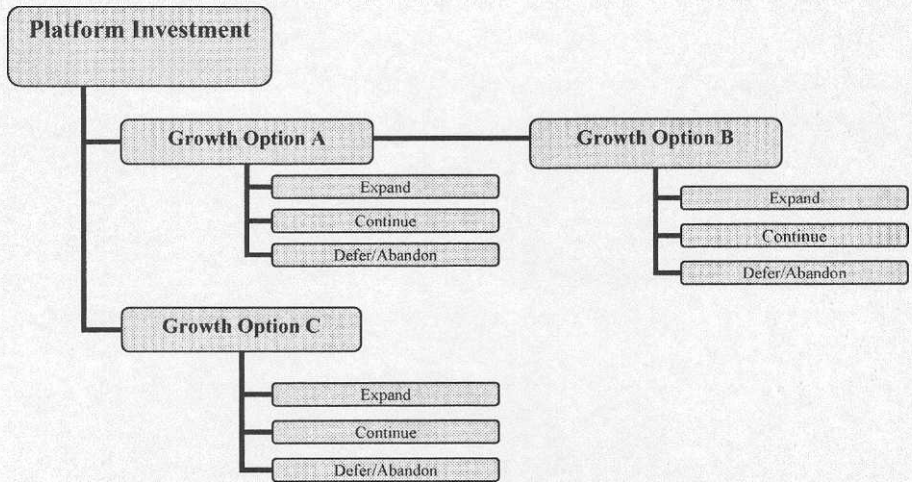
Figure 17: Example of a platform investment with both simple and compound growth options

4.7.5 Shared or proprietary growth options

Unlike financial options, where the actions of individual actors or option holders has no effect on the value of the underlying asset, the actions of both the owner of a real option and external stakeholders, such as suppliers and competitors, may have a significant influence on the value of real options. In the case of growth options, Kester (1984) defines two types of options: *proprietary* and *shared*. The proprietary options involve situations where the option provides highly valuable and exclusive rights to an investment opportunity. This type of option would typically involve a patented technology or product development, or other types of situations where the company holding the option possesses unique knowledge of a market, or a technology, that other market actors cannot easily duplicate. Shared growth options involve opportunities that are collective in the sense that competitors may have identified the same opportunity, or could replicate the investment once the option has been exercised which reduces the expected payoff. This may for example involve the opportunity to enter a new market which is unprotected by high barriers, or to build a new plant to service a new market (Kester 1984). Trigeorgis (1988) showed that proprietary options have higher value when management has the flexibility to abandon a project early, or even temporarily interrupt the project's operation in certain "unprofitable" periods. He also notes that if competitors share the right to exercise the option they may be able to acquire part (or all) of the project's value, thereby reducing or pre-empting the option value. A similar view is presented by Kester: "only if a company is in a sufficiently strong competitive

position to ward off assaults and grab the lion's share of project's value can a shared growth option be valuable" (Kester 1984). Figure 18 summarises some of these fundamental properties of growth options (expiring and deferrable options are discussed in the next section).

```
                              Growth option
                   ┌───────────────┴───────────────┐
              Proprietary                        Shared
         ┌────────┴────────┐              ┌────────┴────────┐
      Simple          Compound         Simple          Compound
    ┌───┴───┐       ┌────┴────┐      ┌───┴───┐       ┌────┴────┐
Expiring Deferrable Expiring Deferrable Expiring Deferrable Expiring Deferrable
```
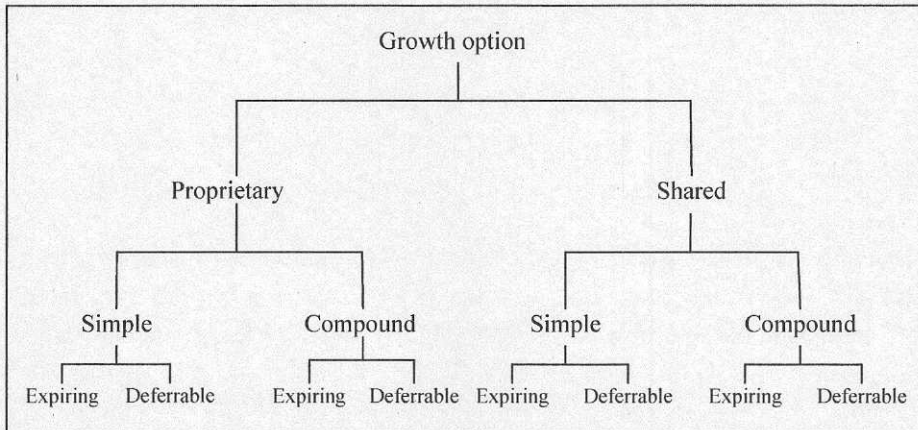
Figure 18: Important properties of a growth option

Although the option to invest in many IT applications at first may appear to be a shared growth option, this is not necessarily the case. Panayi and Trigeorgis for instance point out an interesting example where long lead times enhance the proprietary properties of a seemingly shared growth option:

"During the 1970s some manufacturing firms invested in automatic and electronically controlled machine tools. Returns on the initial investment were reported as modest. However, microprocessor-based technologies arrived in the early 1980s, bringing about the opportunity for much more dramatic returns (greater performance at lower cost). Firms that had previously invested in electronically controlled machines tools were able to migrate quickly and cheaply to the new technology. Because operators, maintenance personal, and process engineers were already comfortable with electronic technology, it was relatively simple to retrofit existing machines with powerful microelectronics. Companies that had deferred investment in electronically controlled machine tools quickly fell behind" (Panayi and Trigeorgis 1998 p.675).

The broader the capabilities made possible by a platform investment, the longer time it will take to integrate the key operating drivers needed to complete the investment. If the firm is able to use the platform as the enabling element for business innovation, it may provide a source of sustained advantage and thereby enhance the

proprietary nature of the growth options. The long lead-time becomes a hindrance to competitors without compatible platforms, and therefore face long lead-times before they can respond (Keen 1991).

4.7.6 Investment timing

Once the platform opportunities have been identified, it is important to consider the timing element or urgency of the investment opportunity. Can the investment be deferred for a period of time without loosing substantial part of its potential benefits, or does it involve "expiring" options that needs to be considered for an immediate exercise?

Deciding not to go ahead with an investment opportunity immediately does generally not preclude the company from investing later. In options terminology this means that the company may hold an option to defer the investment (cf. 4.3.3). Conversely, due to the complexity of IT platform investments in terms of integrating technology, process and organisational elements into fully functioning business capabilities, this type of investments normally have long lead-times from the time of initiation until the time they are operational. Consequently there is an important time dimension between the time the decision to invest is made until implementation is completed, during which the value of the investment is likely to change (Kognut and Kulatilaka 2001). Postponing the investment may therefore result in a diminishing of the value the company is be able to derive from the new capabilities if, for example, competitors are first out with a new innovative capability. Kogut and Kulatilaka argue that an early commitment to a new technology is often the only way in which uncertainty is resolved. By early commitment, a firm may gain the power to influence the evolution of the industry to favour their technology platform. As a result, they conclude: "early commitment in such industries will tend to dominate the advantages of waiting" (Kogut and Kulatilaka 1994 p.69).

Dos Santos and Peffers (1995) studied the effects of early adoptions of automated teller machines (ATMs). They found evidence that early ATM adoption resulted in a sustained increase in income. Those banks which where amongst the first adopters were able to increase and sustain their market share, while banks that started adopting this technology only a year later were not able to markedly raise neither income nor market share. The learning benefits of IT investment are captured in the time dependency of the investment value. Not all IT investment that is characterised

by an uncertain payoff provides platform benefits. There has to be clearly identifiable opportunities from early investment. If investing early provides substantial learning benefits, implying that the investment cannot be easily imitated later in time when uncertainty about the future benefits is resolved, the value of early investment has to be included in the evaluation (Kognut and Kulatilaka 1994).

4.7.7 Managing the capabilities

Getting the maximum possible value out of the platform investment requires that the investment manager continuously follows the investment process. As new information becomes available and uncertainty about future costs and benefits is resolved, individual projects allow for various degrees of flexibility to depart from and revise the investment strategy (if there is no uncertainty about the outcome of the project flexibility is of little value). It is important to monitor the incremental benefits identified as a result of new capabilities and the value of flexibility options as new information becomes available. This implies that possible options to expand the project be exercised at the right time if internal and/or external conditions turn out more favourably than expected. It is just as important to observe the progress of the investment if conditions turn out worse than expected. Optimal exercise of options to slow down, delay or even abandon completely further investments can save the company from spending valuable resources on hopeless investment projects. The boundary conditions and exercise triggers of operating options need to be clearly defined in advance and managers committed to following the investment strategy.

4.8 Summary

One problem with IT investments in the AEC sector has been that due to decentralised decision-making authority, the responsibility of achieving profitability to major IT investments often rests on the managers of individual construction projects. Although these managers might identify new technology initiatives as having high potential for use in construction, the uncertainty of whether enough benefits will be achieved to recover the investment outlays in a single project is usually so high that they are not willing to jeopardise the profitability of their own project by investing in the new technology. Using the framework presented here will help in identifying platform investments that might justify that the investment costs be underwritten at a higher level in the organisation.
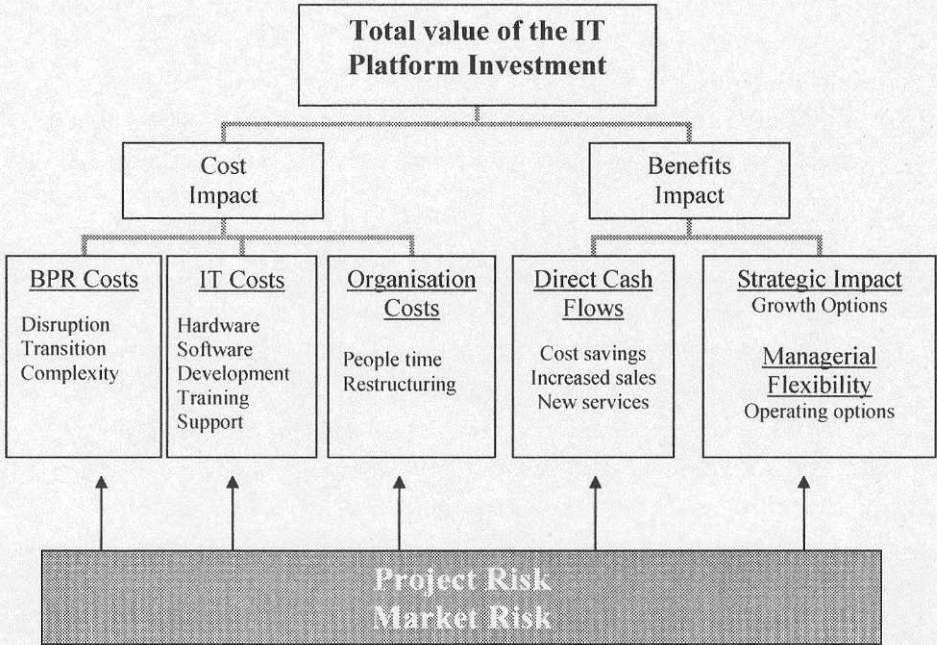
Figure 19: Overview of different factors contributing to the net impact of IT investment

Figure 19 summarises the different factors in the evaluation framework influencing the value of an IT platform investment. As is the case with all investments, the net impact of an IT platform investment is determined by the difference between the cost and the benefit impact. The total cost impact is determined by the cumulative cost of building the necessary technology infrastructure; the results of the organisational transformation needed and costs of the associated business process reengineering. The benefits impacts are further identified through two channels. First there are direct, easily measurable benefits in terms of new services, increased market share, costs savings, etc. Secondly, there are benefits that are often classified as indirect, strategic and intangible, which are captured using the real options framework. Finally, all the different factors contributing to the net impact of the investment are subject to a number of uncertainties. How these different factors can be quantified and the underlying uncertainty incorporated into the evaluation is the subject of the next chapter.

CHAPTER 5   The Analysis Model

*It is a mistake to try to look too far ahead. The chain of
destiny can only be grasped one link at a time*

Sir Winston Churchill (1874 - 1965)

5.1   Introduction

This chapter presents a dynamic *binomial evaluation approach* that extends the
passive DCF model by encompassing the insights and tools from Real Options
Theory. The model incorporates the value of possible contingent growth options,
and the managerial flexibility that allows the investment manager to alter the
investment strategy when new information becomes available. The model further
explicitly integrates the different sources of risk affecting the value of the
investment, throughout the investment process. The chapter begins with a short
discussion about the different modelling approaches available to evaluate contingent
investments. Then the principles of binomial modelling are introduced and the
necessary steps in the modelling process are described. Finally, the application of
the analysis model is described in a four-step evaluation process, starting with a
DCF analysis of the investment programme. This is followed by a risk analysis that
consolidates multiple sources of uncertainty into a single measure of volatility
through a Monte Carlo simulation. In the final two steps, the total value of the
investment programme is analysed by constructing first a binomial lattice
describing the distribution of the investment value. Finally, a sequence of option
lattices are created and solved to derive the value the contingent investments.

5.1.1   Analytical Option Pricing Models

The most straightforward way to value a financial option is to write down the set of
partial differential equations and boundary conditions that describe the payoff of the

contingent claim. Thereafter, solve these equations analytically for the option value[21]. This is however no easy task as many partial differential equations have no known analytical solution. This has nonetheless been achieved for a number of different types of options where the most famous solution is the Black and Scholes (B&S) formula (Black and Scholes 1973). Fischer Black, Robert Merton and Myron Scholes introduced the idea of constructing a tracking portfolio consisting of traded securities with a payoff identical to the option contract. Given that a certain set of assumptions are fulfilled, and as long as the payoff of the two assets (the tracking portfolio and the option contract) has identical payoffs, they must be of equal value.

The B&S model is thus an analytical solution to partial differential equations that reflect the payoff of a European call option. The model is based on the assumption that it is possible to construct a risk-free portfolio consisting of options and the underlying stock. Assuming that markets are efficient, which excludes the opportunity of arbitrage opportunities, the portfolio of options and underlying stock will earn the risk free rate of return. Such a risk-less portfolio can be constructed because the option and the stock have the same source of uncertainty, namely the volatility of the stock price. Assuming that the portfolio has the right proportion of sold options and owned shares, for very small changes in the stock price the gains on the option contract in the portfolio will be offset by the losses on the stock side and vice versa, depending on whether the stock price moves up or down. The value of the portfolio is therefore known in advance in the short term. Using this argument in the Black-Scholes model, it is possible to derive the valuation of options regardless of risk preferences (Hull 1997).

The importance of the B&S model for the valuation of financial options cannot be overstated, and it has equally served as the fundamental building block in Real Options theory. The model presented a radically new way in how to value contingent claims on financial securities. The current use and influence of the model extends far beyond the type of application for which it was originally derived. "The underlying conceptual framework originally used to derive the option-pricing formula can be used to price and evaluate the risk in a wide array of applications, both financial and no-financial" (Merton 1998).

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[21] The partial differential equation (pde) in this context is a mathematical equation, which relates the value dynamics of the option contract to observable changes in the price of market securities. The boundary conditions specify the option characteristics in terms of maximum and minimum value as well as its value at known points.

The B&S valuation formula relies on "ideal conditions" in the market. This implies for example that the value of the underlying stock (S) follows a random walk described by a geometric Brownian motion of the form: $dS = \mu S\ dt + \sigma S\ dz$, were dz is the increment of a Wiener process[22], σ is the stock price volatility which is assumed constant over the given period, and μ is its expected rate of return. The random walk assumption further entails that the future price of the stock, or underlying asset, are log-normally distributed as the price can never be negative. The short-term interest rate is assumed to be known and constant over the lifetime of the option. The original Black and Scholes equation applied only to non-dividend paying stocks, this assumption has been relaxed in later extensions of the model. A further assumption in the model is that the markets are considered to be frictionless. That implies that there are no transactions costs involved with buying, or selling the stock or the option, there are no restrictions on short sales[23], all shares of all securities are infinitely divisible, and borrowing and lending is unrestricted at the risk free rate.

The Black and Scholes formula for the valuation of a European call option is given by:

$$C = N(d_1)S - N(d_2)Xe^{-rT}$$

Where:

$$d_1 = \frac{\left[\ln(S/X) + (r + 0.5\sigma^2)T\right]}{\sigma\sqrt{T}}$$

and

$$d_2 = \frac{\left[\ln(S/X) + (r - 0.5\sigma^2)T\right]}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

N (.) is the cumulative probability function for a standardised normal variable. In practice this means that it returns the probability that the variable, which is assumed to have a standard normal distribution N (0,1), will be less than d_1 and d_2 respectively. The other variables are familiar from Table 3, C is the current value of the call option, S is the current price of the underlying asset, σ is the volatility of

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[22] A Wiener process is type of Markov stochastic process, which is a particular type of stochastic process where only the present value of a variable is relevant for predicting the future. This entails that the past history of the variable is irrelevant (Hull 1997)

[23] Short selling involves selling securities that are not owned by the seller but are borrowed from an other investor through the services of a stock broker

value of the underlying asset, T is the time to expiration of the option and r is the risk free interest rate.

The value of relatively simple real options can sometimes be found using closed-form analytical expressions such as the Black and Scholes formula. Most investment projects, however, involve complex sets of payoffs and options where the closed-form formulas do not provide solution. The alternative when using analytical methods is then to try to generate partial equilibrium conditions describing the payoff of the investment and then attempt to solve the resulting set of differential equations. Many investment problems are so complex that just deriving the set of partial differential equations is an impossible task (Trigeorgis 1995b). Even if this can be achieved, the equations often have no analytical solution. This problem is not only confined to real investment problems as the pricing of many financial option contracts is confronted with the same challenge. Examples of financial contracts where no analytical solution exists (Geske and Shastri 1985) includes: callable and convertible coupon bonds, insurance contracts and the term structure of interest rate models for bond valuation. Consequently analysts and researchers have to turn to the more flexible numerical methods to solve complex options related problems (Trigeorgis 1991).

5.1.2 Numerical Option Pricing Methods

The numerical techniques can in general be defined to belong to one of two groups. First there are those that approximate the underlying stochastic process directly (and are therefore commonly considered more intuitive) while the second category of techniques provides means to approximate the solution of the partial derivatives (Trigeorgis 1991). The most common approaches include the binomial and multinomial methods, Monte Carlo simulation (both belonging to the direct approach group), and the finite difference techniques (indirect approach).

Binomial and multinomial[24] *lattices* are discrete tree representations of the stochastic processes, which govern the evolution of the value of the underlying asset. As the intervals in the tree become smaller, this approach returns an equivalent solution (in the limit) to the diffusion process in the continuous time models. The most widely applied of these is the binomial tree approach first suggested by Cox Ross *et al.* (1979) for evaluating options.

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[24] For an example of the use of a multinomial approach in project evaluation see for example Kamrad and Ernst (1995).

Simulation solves for the value of the option indirectly and does therefore not require setting up the option's partial equation and boundary conditions. The procedure is straightforward and involves simulating numerous times the possible paths the value of the underlying asset may take from present time until the option expires. For each simulation, the value of the option is calculated based on the value of the underlying asset at expiration. The present value of the option is then simply found by averaging the discounted value of the payoff at expiration. The advantage of this approach is that it is very flexible and can relatively easily incorporate a number of intricate factors relevant to the option value. These include for example complicated decision rules, path dependant options, multiple uncertainties and other complex relationships between the value of the option and the underlying asset's value (Amram and Kulatilaka 1999). Simulation is a forward-looking method, which is suitable for valuing European options. Simulation is however not as suitable for valuing American type options or a sequence of interrelated options (compound options) as each possible decision starts a new path (Amram and Kulatilaka 1999).

The *finite difference technique* can be used to approximate the solution of the partial differential equations when no analytical solution can be found to the differential equation representing the evolution of the value of the underlying asset. "The finite difference techniques analyse partial differential equations by using discrete estimates of the changes in the options value for small changes in time or the underlying stock price to form difference equations as approximations to the continuous partial derivatives" (Geske and Shastri 1985 p.51). In practice, this involves setting up a grid that spans the entire range of values for the underlying asset until the option expires. Once the grid has been defined, the option value can be solved for by using either the so-called implicit or explicit technique. As the terminology suggests, the explicit approach solves for the option price at each nod of the grid explicitly in terms of previous known option price nodes. The implicit technique is more complicated as it requires that a set of simultaneous equations be solved (Geske and Shastri 1985). The main disadvantage of this approach, when compared to the binomial and simulation methods, is that it requires the determination of the partial differential equations.

5.1.3 Choosing an appropriate option pricing approach

Both the binomial- and finite difference approach are backward induction procedures inferring the current value of the contingent claim based on a known future value, which is usually the value of the option at expiration. Both techniques are based on a given set of boundary conditions and solve simultaneously for the asset value and the optimal way in which to exercise the options (Cortazar 2001). Simulation models on the other hand are forward-looking techniques where the option value is calculated based on numerable possible future values of the underlying asset, inferred from its present value, and statistical distributions.

Although the Black and Scholes option pricing formulas and many other analytical solutions to particular types of options are elegant, unfortunately they are not very practical for evaluating complex real options. The models are very complex due to the sophisticated mathematics behind them. As a result, many practitioners view them as sort of black-box models. Citing Robert Merton, "of course, all that is elegant and challenging in science need not also be practical; and surely, not all that is practical in science is elegant and challenging" (Merton 1998).

Most of the early options valuations models applied to real investments relied on a traded underlying asset to value the contingent options in the investment projects. In most cases this is an unrealistic assumption as most real investment projects are not traded assets with price characteristics, which are easily observable from market data. This has lead to some questionable applications of real options models to investment projects, where in many cases the traditional B&S model is applied directly to derive the project value. As discussed in Chapter 4 this involves several problems. First, real investments are seldom perfectly correlated to an observable traded asset. Although some investment projects are a close match, such as investments in oil drilling exploration projects and investment projects involving exploration and extraction of other traded minerals, the match is at best approximate. The volatility of the price of oil is for example not perfectly correlated with the return on an oil exploration project as there are several other factors besides the price of oil that will affect the return on the project.

The second problem is that the B&S option-pricing model could perhaps give a reasonable approximation of the value of an investment project involving a single option. This may for instance involve an option to postpone a single investment project. Most real investment projects are much more complex as they typically

involve several different options. Some studies have addressed this challenge by evaluating each option separately using the B&S model and then simply add the value of individual options together to find the total value of the investment project. This praxis may however, produce highly questionable results as the value of different types of real options combined is generally not equal to the sum of individual options (Trigeorgis 1993). This due to potential inter-dependencies, i.e. where the exercise of individual options may affect the value of other implicit options, and in some cases even cancel out other contingent options.

For the real options approach to be applicable as a general approach for a number of different IT platform investments, numerical techniques present the most flexible alternative. As discussed above, there are a number of different techniques available for this task, such as the finite difference approach, Monte Carlo simulation, and binomial modelling. Although each of these techniques poses relative strengths over each other in unique circumstances, the binomial approach offers the greatest general flexibility. The binomial approach is further commonly considered the simplest of these methods, in terms of its mechanics and the ability to communicate the results to decision makers. It is also the most widely applied ROV technique by organisations today (Lander and Pinches 1998; Anderson 2000; Copeland and Antikarov 2001; Triantis and Borison 2001; Mun 2002). The evaluation model presented in this chapter therefore builds on the binomial option pricing approach.

The reason for choosing the risk-neutral binomial approach in this study can therefore be summarised in the following four arguments:

- *Applicability*: together with the Marketed Asset Disclaimer assumption (cf. section 4.4.3) the risk-neutral binomial approach can be used with the present value of the project, without flexibility, as the estimation of the value of the underlying asset (see also, e.g. Trigeorgis 1991; Kelly 1998; Hodder, Mello et al. 2001; Neely and Neufville 2001; Copeland and Tufano 2004).
- *Flexibility*: the binomial equations can be used to describe the payoff of essentially any type of investment.
- *Simplicity*: requires only basic skills in elementary algebra.
- *Acceptability*: Mun (2002) argues that the implementation of real option model in practice and adoption by industry has to a large extent been in connection with the use of binomial lattices.

5.2 The General Binomial Evaluation Model

The binomial approach to option pricing is based on a simple discrete representation of the evolution of the value of the underlying asset. At distinct points in time (determined by the step size in the lattice) the present value of the underlying asset can develop to one, of two possible states, i.e. the value can go up, or down. These up and down movements lay out the possible future paths that the value of the underlying asset can follow based on the estimated volatility. Specifically, in the general multiplicative binomial model the current value of the underlying asset is V_0 in present time[25]. Within a predefined period of time (the step size in the lattice described by Δt) it will either move up by a factor of u (u>1) becoming Vu, or down by a factor of d (d<1), and become Vd. Correspondingly in the next period the process is repeated and the second period values become Vu^2, Vud and Vd^2. As a result this step-by-step approach makes it possible to simulate the potential value of the project at every point in time.

Using the same risk neutral assumption as in the Black and Scholes model (cf. section 5.1.1) the expected return of the underlying asset is assumed to be the risk free rate (r). The expected value of the underlying asset at the end of a single time interval (Δt) is therefore $Ve^{r\Delta t}$ using continuous compounding[26] (V is the value of the underlying asset at the beginning of the time period). It follows that:

$$Ve^{r\Delta t} = pVu + (1 - p)Vd \qquad (5.1)$$

Dividing trough the equation by V gives:

$$e^{r\Delta t} = pu + (1 - p)d \qquad (5.2)$$

The probability p weights the outcomes to obtain the risk-free rate of return and is generally called the risk-neutral probability. The volatility of the value of the underlying asset is typically measured by the standard deviation of the return of the asset over one year. The standard deviation of the proportional change in the value of the asset in time T is therefore $\sigma = \sqrt{T}$. The proportional change in V during a small time interval Δt can therefore be expressed as $\sigma\sqrt{\Delta t}$, where Δt = T/t . As the variance of a variable Q is defined as: $E(Q^2) - [E(Q)]^2$, it follows that:

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[25] Note that V is used here in stead of S used previously to emphasise that the underlying asset is not necessarily a stock but rather could be any type of real investment.

[26] The derivation of the binomial formula in this section draws from Hull (2003 p.393).

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$$\sigma^2 \Delta t = pu^2 + (1-p)d^2 - [pu + (1-p)d]^2$$

Substituting for p from equation 5.2 gives:

$$\sigma^2 \Delta t = e^{r\Delta t}(u+d) - ud - e^{2r\Delta t} \qquad (5.3)$$

Equations 5.2 and 5.3 pose two conditions on p, u, and d. The third boundary condition is that the up and down movements in the lattice is symmetrical, i.e. the tree is recombining. This holds as the relative price changes in a log normal distribution are equally likely. This means that:

$$u = \frac{1}{d} \qquad (5.4)$$

Provided that Δt is small, the boundary conditions in equations 5.2, 5.3 and 5.4 imply:

$$p = \frac{e^{(r\Delta t)} - d}{u - d} \qquad (5.5)$$

$$u = e^{\sigma\sqrt{T/t}} \qquad (5.6)$$

$$d = e^{-\sigma\sqrt{T/t}} \qquad (5.7)$$

The value of the underlying asset is first derived in a binomial lattice using equations 5.6 and 5.7. The value of the option is then derived through backward induction based on the binomial tree, starting at the end of the tree and working backwards through each step until the present time. As discussed in section 4.2, the value of a call option (C) at expiration is the maximum of either, the difference between the value of the underlying asset and the strike price (investment cost), or zero. That is, the value at the terminal node in the lattice is: $C = \text{Max}(V_T - X, 0)$. The value of the option can then be calculated for each nod in the binomial lattice, working backwards from the end using the risk neutral probability and discounting with the risk free interest rate. Equations 5.5-5.7 can be applied consistently to all real options binomial modelling regardless of its complexity (Mun 2002).

Consider first a simple example involving a one-year call option on the underlying asset V. This is depicted in a one-step binomial model in Figure 20. For the sake of convenience, the option is valued in two steps. The first step involves describing the evolution of the underlying asset in a *value lattice*. The second step is then to evaluate the call option in an *option lattice*, which draws on the information generated in the value lattice. As the value lattice shows, at the end of one year V

will have moved either to Vu or Vd, where *u* and *d* are determined using equations 5.6 and 5.7. The option lattice shows that at the expiration date (t=1), the option will be worth either C_u = Max (Vu– X, 0), if the value of the underlying asset goes up, or C_d = Max (Vd – X, 0) if the value goes down. The solution present value of the option can therefore be determined using the risk neutral probabilities from equation 5.5 and discounting the outcome to present time: $C = [p\ C_u + (1\text{-}p)\ C_d]\ e^{-r}$.
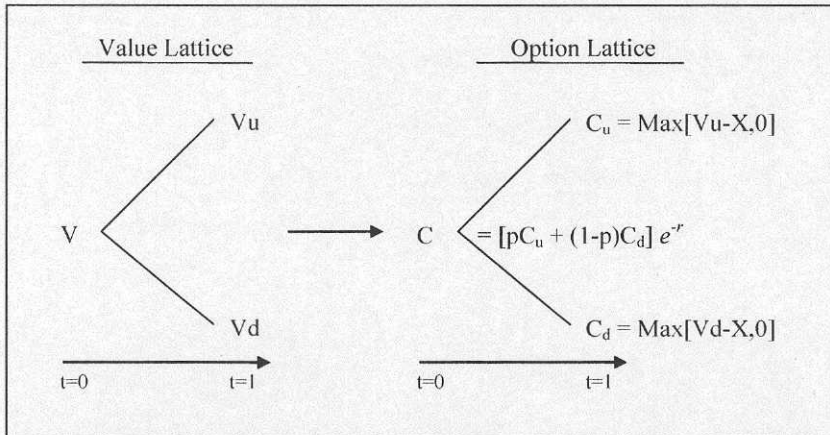
Figure 20: A two-step valuation of a one year call option

Extending the analysis to multiple periods, the next example considers an option to defer an investment project for 3 years. The project has a present value of MSEK[27] 100 today (based on end of period cash flows, discounted at the project's risk-adjusted cost of capital) and will cost MSEK 110 to implement. If the project were executed today, it would therefore have a net present value of MSEK -10. The company, however, has the exclusive opportunity to delay the investment for three years. This option gives the company the right, but not the obligation, to invest in the project at the fixed investment cost of MSEK 110 in three years time (which is akin to simple 3-year European-stile call option). The annual standard deviation of the project return is estimated to be 30% (σ = 0,3) and the risk free rate is found to be 7%, based on the return on a 3 year government bond (r = 0,07).

Like in the previous example, the first step in estimating the value of the option is to construct the value lattice. Starting from V_0, at each time period the value of the

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[27] Million Swedish kronas

investment can either increase by the factor u or decrease by the factor d as shown in Figure 21. Applying equations 5.6 and 5.7 gives:

$$u = e^{0.3\sqrt{1}} = 1{,}35 \text{ and } d = e^{-0.3\sqrt{1}} = 0{,}74$$

$\sigma = 0.3$, $r = 0.07$, $\Delta t = 1$
$U = 1.35$, $d = 0.74$,
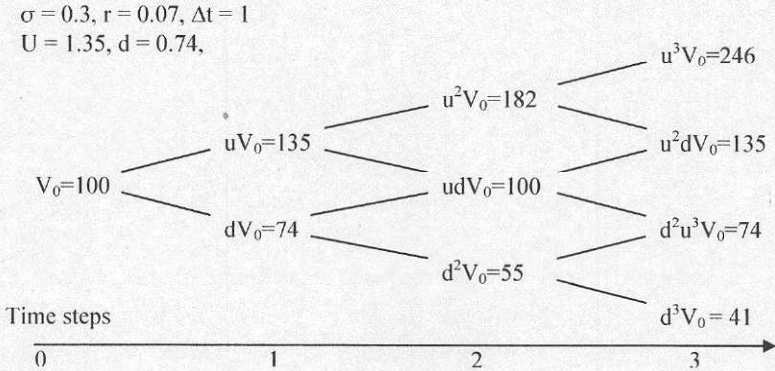
Figure 21: Three step Value Lattice of the underlying asset value

Based on the value lattice, the option is valued using the risk neutral probabilities, starting at the end and working backward (backward induction) through the lattice to the first period. As demonstrated in Figure 22, the value at each nod at the end of the lattice is the maximum of exercising the option (V-X) or letting it expire worthless: Max [V - X, 0]. The intermediate values are found by multiplying the up-value the in the following period with p and multiplying the down-value with 1-p and summing up these two values and discounting it with the risk free rate. Using equation 4.5

$$p = \frac{e^{(0,07)} - 0{,}74}{1{,}37 - 0{,}74} = 0{,}545 \text{ and } 1\text{-}p = 1 - 545 = 0{,}455$$

This process is repeated for each nod in the lattice back to the present time period to obtain the value of the option.

$(p*136 + (1-p)*25) \exp(-0.07) = 80$

Max $(246-110, 0) = 136$

80

46

Max $(135-110, 0) = 25$

p

C=26

13

1-p

6

Max $(74-110, 0) = 0$

0

Max $(41-110, 0) = 0$

0   1   2   3
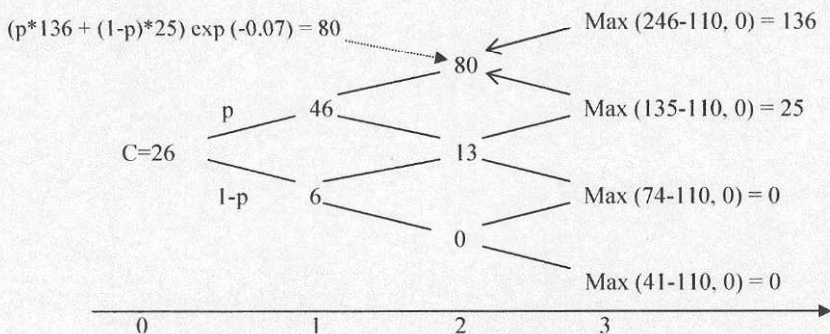
Figure 22: Option valuation lattice

Using the standard DCF analysis showed that the project had a negative NPV of MSEK 10 if undertaken now. However, the option to make the investment in three years time has a positive value of MSEK 26. The deferral option is valuable as the company has the option to make the investment if the uncertainty influencing the project value turns out to be favourable. If however, the value of the investment turns out to be less than the exercise price at the exercise date, the company simple lets the option expire.

5.3   A four step evaluation process

The evaluation proceeds in a four steps:

1. Compute the base case present value without flexibility using DCF analysis
2. Quantify risk and combine through simulation
   a. Define the properties of the stochastic variables
   b. Define possible interdependencies between the stochastic variables
   c. Perform a Monte Carlo simulation for deriving a consolidated measure of the volatility of the return on the investment programme
3. Derive the Value lattice which describes the possible paths that the value of the investment programme may follow
4. Derive the Option lattices

5.3.1 Transforming Costs and Benefits into Cash Flows

Like most other real investment projects, AEC IT platform investment projects are rarely markedly traded entities. As discussed in Chapter 4, the basic framework of options analysis can be applied in situations even though the underlying asset is not traded (Kulatilaka, Balasubramanian et al. 1999; Copeland and Antikarov 2001; Schwartz and Trigeorgis 2001; Mun 2003). Most of the early application of the real

option approach focused on finding a closely correlated market traded twin security, on which to establish the value and volatility of the underlying asset. This process is however, implicitly flawed as the correlation will at best be approximate, and always based on the subjective reasoning of an analyst. In most cases, there will be no better substitute for the value of an investment project than the project itself. A net present evaluation of the underlying asset is therefore arguably the best unbiased estimate of the market value as if it were a traded asset (Copeland and Antikarov 2001; Mun 2002). Copeland and Antikarov (2001) argue that this assumption is no stronger, or more unrealistic, than those used in NPV analysis.

Despite the critical shortcomings of the NPV methodology discussed earlier in the thesis, this approach serves an important function in the model developed here. The NPV approach implicitly assumes that the investment project is a now-or-never opportunity and the decision-maker will follow a fixed implementation strategy (or alternatively that the project's outcome will be unaffected by future decisions of the firm). If the investment strategy is not revised when new information becomes available, it is reasonable to assume a fixed risk-adjusted discount rate (which was earlier argued to be one of the main problems with the DCF approach in the case of uncertain investment payoffs with implicit managerial flexibility). The specific characteristics of the DCF model are therefore well suited to estimate the net present value of the IT platform assuming no managerial flexibilities. The changing risk characteristics of the investment programme are instead incorporated into the valuation by allowing for non-constant volatility of the rate of return. The output of the DCF analysis thus provides one of the fundamental input variables in the real options valuation, namely the value of the underlying asset.

The NPV model developed here is a simple DCF model tailored to the AEC environment, specifically to the organisational environment of a General Contractor (GC). Specific models could also be derived for the context of Architect and Engineering service companies, or a standard generic DCF models could be used.

The most common practice in the AEC sector is to award the lowest cost bidder for a specific construction project the contract. For a general contractor to make a profit on the contract he has to fulfil the contract requirements at a cost lower than the project payment. The difference between the actual cost of fulfilling the contract and the received contracted sum is then the net margin on individual projects. The net income of the company as a whole is then simply the sum of the cumulative

profits from each project performed by the company in a given period less the companies fixed costs.

Assuming that the contracted amount represents 100% of the revenues received from the project the net margin can be found by subtracting each of the different cost factors. The costs of the GC during a construction project are typically classified into costs for self-performed work and cost of contracted work. The cost of self-performed work includes all costs for those parts of the project, which the contractor performs himself, such as design, labour costs and material, but it also covers fixed costs such as fees and project overhead. General contractors also typically outsource much of the work in the project to subcontractors. The cost of this work normally includes administration costs, labour costs, and material. Adding up all these cost factors like shown in Table 6 gives the net project margin of the GC. The table shows an example of the cost structure of a GC for a typical project within one type of construction services. The company may be involved in several different types of construction services, such as residential housing, industrial buildings, and large infrastructure projects. Each of these services is then likely to have a different distribution the cost elements.

	Net Income	**100%**
Self performed work	Design Cost	-7.00%
	Construction fee	-3.50%
	Project overhead	-7.50%
	Labour supervision	-4.90%
	Labour	-27.90%
Contracted work	Administration cost	-9.80%
	Direct labour	-12.80%
	Material	-19.20%
	Net Margin	**7.40%**

Table 6: Constructive Inc. project cost structure for industrial constructions

The estimation of the cash flows from each phase of the investment process are based on how the new capabilities enabled by the IT platform investment influence each of the factors in the cost structure for the different types of construction services, and how these changes affect the net project margin (Table 6). This process is repeated for each of the operating divisions in the firm that are identified as relevant to the new capability and the results are summed up for each period.

For example, a new information system may be expected to enable a reduction in project overhead by 0.5% and 0.2% reduction in administrative cost, on average when fully implemented. This translates into a 0.7% increase in the net project margin (pm) on each project for that particular type of services. The resulting cash flows are then derived by multiplying the net margin change (Δpm) with the company's market share (ms) times the current total market demand (D) for each type (i) of construction services the company offers.

$$\text{Net cash flows (CF)} = \sum_{i=1}^{n} \Delta pm_i \left(ms_i \times D_i \right) \tag{5.8}$$

A simplifying assumption in this model is that the variable costs of the platform investment are charged directly to each project, for example on fee bases or as a flat project based tax, and thereby reflected in the individual project area cost/revenue structure. Other benefits that are not captured directly in terms of changes in the cost structure of individual projects, such as changes in how the company is perceived as an innovator and technology leader (often classified as intangible benefits), are modelled and quantified through how they affect the companies market share (ms) in each area of the firms operating units. A successful acquisition of a new IT enabled capability may for example increase customer satisfaction, which will directly influence the company's ability to attract more projects in the future.

$$PV = \sum_{t=0}^{T} \frac{CF_t}{\left(1 + k\right)^t} \tag{5.9}$$

The present value of the investment programme is then derived using the PV formula (5.9), based on the cash flow analysis and using the companies risk adjusted discount rate.

5.3.2 Risk Analysis – consolidated approach through simulation

When considering the risk of individual investment projects the relevant risk is the systematic or, non-diversifiable risk (market risk). This risk is incorporated into the DCF model through the risk-adjusted discount rate. The same principle holds for the risk for individual stocks:

"The volatility of a stock price is a measure of how uncertain we are about future stock price movements. As volatility increases, the chance that the stock will do well or very poorly, increases. For the owner of a stock, these two outcomes tend to offset each other. However, this is not so for the owner of a call or put. The owner of a call benefits from price increases but has limited downside risk in the event of price decreases because the most the owner can lose is the price of the option. Similarly, the owner of a put benefits from price decreases, but has limited downside risk in the event of price increases. The values of both calls and puts therefore increase as volatility increases." (Hull 2003 p.168)

Therefore, when evaluating the NPV of a project the only relevant risk is the systematic risk. However when evaluating an *option on a risky asset*, the pertinent risk is the volatility of the rate of return on that underlying asset. This volatility is influenced both by systematic and unsystematic risks (project risks). Therefore, when performing the simulation of the project returns (for estimating the volatility), the stochastic properties of the variables in the models should reflect both those influences related to project specific events and market related impacts. The volatility measure therefore reflects the total risk of the project:

$$Total\ risk\ =\ Market\ risk\ +\ Project\ risk$$

The previous chapter discussed a number of different risk factors that can influence the outcome of IT platform investments. Identifying the relevant risks is an important first step in improving the analysis, but in order to incorporate then into the valuation the most important stochastic variables need to be recognised and their stochastic properties defined. While information about the stochastic properties of some of the important variables, e.g. the demand for various construction services, may be observable from market data[28], most of the private risks need to be estimated subjectively based on technical expertise, and experience[29].

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[28] Davis (1998) for example provides a framework for evaluating volatilities when the underlying asset is related to a traded commodity.
[29] E.g., Bräutigam suggests the use of diversified evaluation teams to identify and quantify investment risks (Bräutigam, Esche et al. 2003).
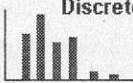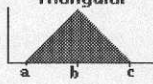
Parameter	Define the distribution	Possible sources of data
Technology Risk Implementation Risk	Discrete	Information about past projects as well as data from outside consultants and academic research may prove useful for deriving information about the distribution to these variables.
User Adoption	Triangular a b c Minimum = a % Most Likely = b% Maximum = c %	Scenario analysis based on data from similar projects, pilot projects and interviews with end users.
External adoption risk	Triangular a b c Minimum = a % Most Likely = b% Maximum = c %	Scenario analysis based on data from similar projects and possibly supported with interviews with key external stakeholders.
Demand for construction services	Lognormal μ σ Mean = μ Standard-Dev = σ	Observable from past market data, and detailed forecasts are available from a number of industry organisations, e.g. Reed Construction Data, FW-Dodge (USA) and Sveriges Byggindustrier (Sweden)

Table 7: Stochastic properties of the key variables affecting the future cash flows need to be defined

The methods introduced in Chapter 3, sensitivity analysis, scenario analysis and simulation are useful tools to identify and analyse key variables. Scenario analysis, for instance, is a useful tool to get information about the distribution of possible outcomes from the investment, depending on the context in which the platform is to be implemented. The impact of technology and implementation risk, on the value of the investment programme, can for example be assessed using scenario analysis based on information from internal experts, industry data, and consultants. The more effort that is put into the risk analysis the more reliable the data going into the evaluation model will be.

Estimating the volatility

The volatility of individual input parameters in an evaluation, is not the same as the volatility of the value of the project itself (Copeland and Antikarov 2001). The collective impact of the stochastic variables identified therefore needs to be

established in order to incorporate them into the evaluation. Valuing a project in a lattice framework becomes very complicated if the underlying value is driven by more than one source of uncertainty. Copeland and Antikarov (2000) suggest that in order to simplify the evaluation, multiple sources of uncertainty can be combined into a single source of uncertainty using computer simulations. The approach is based on the theorem that properly anticipated prices fluctuate randomly (Samuelson 1965; 1973)[30]. This entails that regardless of the pattern of benefits that a project is expected to generate; the changes in its present value will follow a random walk. This makes it possible to combine any number of uncertainties by using Monte Carlo simulation, and to produce an estimate of the present value of a project conditional on a set of random variables drawn from their underlying distributions (Copeland and Antikarov 2000).

The different sources of uncertainty can therefore be combined to determine the volatility of the project value through a Monte Carlo simulation of the discounted cash flow model. This can be done directly in a spreadsheet programme, or more easily using some simulation packages such as Crystal Ball[31]. A discounted cash flow analysis provides a single point estimate of the PV_t of the project at time t. However, having defined the stochastic properties of the stochastic variables in the DCF model, as well as possible covariance's between variables and time series properties, the present value of the project can be simulated numerous times in order to generate a distribution of possible present values.

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[30] Numerical examples and empirical testing of the applicability of this assertion are provided in Copeland and Antikarov (2001, p. 228-236)
[31] For an excellent guide on Monte Carlo simulations see, e.g. Mun (2004)
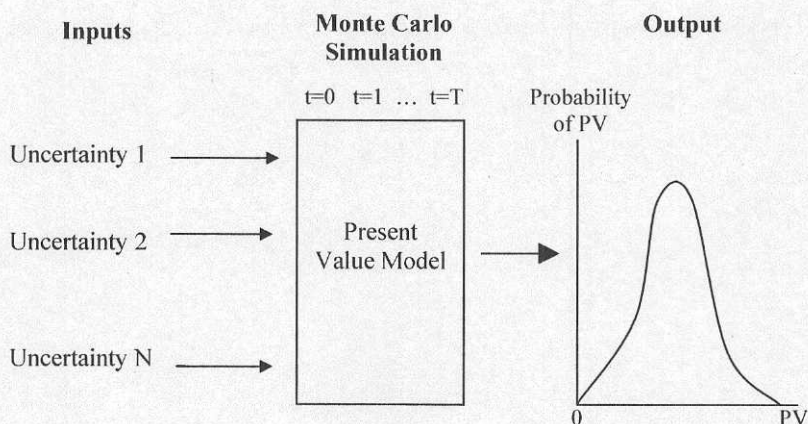
Figure 23: Generating a distribution of possible present values through Monte Carlo Simulation (from Copeland and Antikarov (2001, p. 245))

The information about the impact of the different uncertainties on the PV of the project, generated in the Monte Carlo simulation, needs to be formulated in terms of the volatility of the rate of return on the project. Equation 5.9 provides a formula for deriving the PV of a project at t = 0. Alternatively, the present value of a project at any time period (n) can be expressed as:

$$PV_n = \sum_{t=n}^{T} \frac{CF_t}{(1+k)^{t-n}} \quad \text{for n = 1, 2, ... T} \quad (5.10)$$

As suggested by Copeland and Antikarov (2001 p.246), the standard deviation of the percentage changes in the value of the project, from one time period to the next, can be measured through the following relationship:

$$PV_1 = PV_0 e^{\hat{r}} \quad (5.11)$$

Where $\hat{r}$ is the rate of return. Solving the equation for $\hat{r}$ yields:

$$\ln\left(\frac{PV_1}{PV_0}\right) = \hat{r} \quad (5.12)$$

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Where PV_0 is the simulated variable and equation 5.12 is a simple transformation that converts between consecutive random draws of present time values in the simulation. Based on all the values obtained for $\hat{r}$ through the simulation, the standard deviation of the rates of return can be calculated, providing a consolidated measure of the volatility of the project value:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}\left(\hat{r}_i - \bar{r}\right)^2}{N}}$$

Where $\bar{r}$ is the average rate of return and N is the total number of random draws in the simulation.

Traditional capital budgeting techniques are based on the assumption that the volatility of the return on the investment is constant over time. However, as emphasised in this thesis, the main advantage of staged investment strategy is the managerial flexibility it provides to react to new information that becomes available as the implementation progresses. This is one of the fundamental characteristics of IT platform investments as the platform provides options on future contingent investments. As the investment programme is made up of multiple related, but different projects, the standard deviation of the percent changes (i.e. the volatility) of the investment value is not likely to be constant throughout the investment process. Therefore, to capture the interdependence of the individual projects equation 5.12 needs to be adjusted to reflect the incremental volatility of the total investment programme as it progresses. Based on the relationship in equation 5.10 the rate of return can be re-written as:

$$\ln\left(\frac{PV_{T+1}}{PV_T}\right) = \hat{r}_T \qquad (5.13)$$

Where PV_T is the present value of the total incremental cash flows at time T (the time of the incremental investment), and PV_{T+1} is the present value of the total incremental cash-flows at time T+1. Through equation 5.13, it is therefore possible to measure the standard deviation of the percent changes in the value of the project at discrete points in time, i.e. when new investments are made that are likely to change the volatility of the project returns. The present value measures continue to include future cash flows from investments made at earlier stages in the investment

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process; however, the stochastic properties of the previous cash flows no longer have an impact on the volatility. For the multi-stage investment programme, the volatility is thus measured for the period between each of the contingent investments. Thus, for a platform investment (made at year 0) involving four contingent growth options at years 1, 2, 3, 4, the volatility needs to be calculated for each of the periods between the investment stages (σ_1, σ_2 σ_3 and σ_4). These volatilities are then used in deriving the value lattice, and for calculating the risk-neutral probabilities used to fold back the intermediate lattices, and the final option lattice.

5.3.3 Deriving the Value lattice

The analysis to this point has produced estimates for all the parameters required to solve for the investment value using the binomial option pricing technique. These variables are the value of the underlying asset (V), provided by the PV of the investment programme assuming a fixed investment strategy, the total investment costs at each stage (i) of the investment process (X_i), the time frame of each investment phase (T), the volatility of the investment return at each phase of the investment (σ), and the risk free interest (r) rate, which is assumed to be observable from the yield on government bonds for the corresponding time period.

The next step in deriving the value of the investment programme is to apply this information to describe the evolution of the project value using binomial lattices. As discussed in previous sections, a binomial value lattice is essentially a discrete simulation of the uncertainty influencing the value of the underlying asset. This type of binomial modelling was discussed in some detail in section 5.2, where the up and down movements in the lattice were calculated using equations 5.6 and 5.7. This general binomial evaluation approach is valid as long as the volatility of the underlying is constant over time. However, provided that the Monte Carlo simulation reveals changes in the volatility at different stages in the investment process, the equations for the up and down movements in the lattice need to be adjusted accordingly. Non-constant volatility further suggests that the branches in the binomial lattice are non-recombining. The left half of figure 20 illustrates a four step non-recombining lattice. The branches in the tree are non-recombining because at each step the volatility changes.
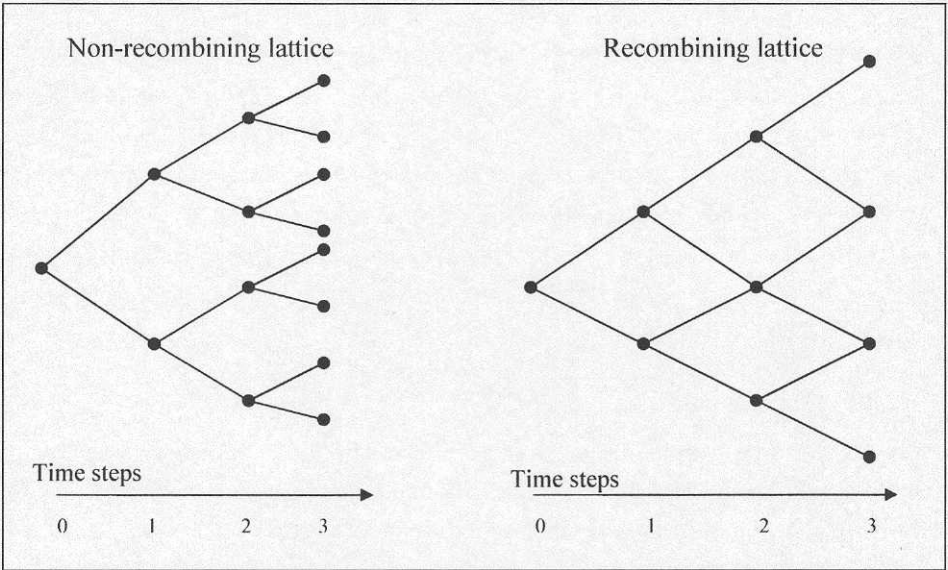
Figure 24: Example of Recombining and non-recombining lattices

The step size, i.e. the up and down movements are calculated in the same fashion using the relationship in the mentioned equations, except for one importance difference. In the non-recombining lattice the step size needs to be recalculated ever time the volatility changes. As a result the non-recombining lattice grows at a faster rate than in the constant volatility case, which complicates the analysis slightly.

In theory, new information is received continuously about the attributes of the project, thereby changing the volatility of the future return from the investment. In practice, however, it is impractical to model the effects of the changing risk characteristics continuously. A reasonable simplifying assumption is to assume that the value of the investment is reviewed at discrete points in time. In the model developed here, it is assumed that the volatility can change at distinct points in time, corresponding to the exercise dates of the embedded options. During the time period between these decision points, the uncertainty is assumed to be constant and the lattice therefore recombining. In practice, this means that the value lattice of a compound investment can be modelled as a combination of recombining and non-recombining lattices. This is illustrated in Figure 25, which shows the value lattice of a two-phase compound option with different volatilities.

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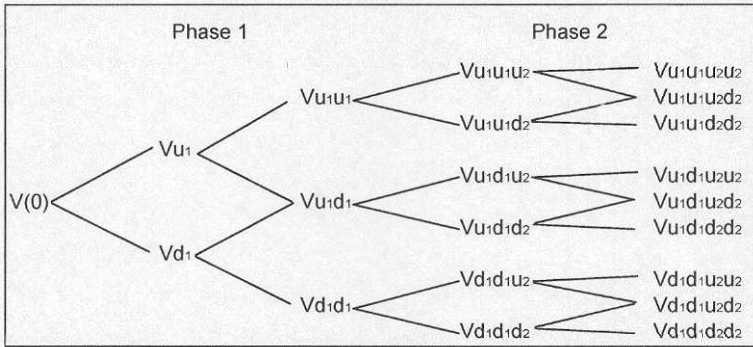
Figure 25: Two phase sequential compound option with changing volatility

This is a very simplified example but could represent a simple IT platform investment, where the platform entails a two-phase sequential compound option. Each of the two individual investment phases has different risk characteristics, which influence the value of the platform. Both phases in turn, take one year to complete and are modelled in two steps, i.e. every step represents 6 months. During each phase, the volatility is constant, and the lattice therefore recombining. The up and down movements for the first phase would be:

$$u_1 = e^{\sigma_1 \sqrt{1/2}} \text{ and } d_1 = e^{-\sigma_1 \sqrt{1/2}}$$

where σ_1 is the volatility during the first year. At the end of phase 1, however, the volatility changes to σ_2 and the up and down movements become:

$$u_2 = e^{\sigma_2 \sqrt{1/2}} \text{ and } d_2 = e^{-\sigma_2 \sqrt{1/2}}$$

5.3.4 Deriving the Option Lattices

The value lattice describes the development of the project value forward, from period 0 to period T. In the intermediate and option lattices, on the other hand, the value is calculated backwards from time T to time 0 with the decisions (flexibility) built into the value lattice. The complexity of the option lattice depends on the number and types of options embedded in the platform investment. This section explains the process for deriving the option lattices involving compound options, starting with the constant volatility assumption, and then describing the procedure for the more complex case with non-constant volatility.

The function of the option lattice is to incorporate the options that have been identified in the evaluation framework and analyse what impact they will have on the value of the investment. Irrespective of the type of option being evaluated, the construction of the option lattice always starts with calculating the option value at the terminal (or end) nods of the value lattice as described in Figure 27. The lattice is then folded back using the risk neutral probability. When the option can be exercised early, i.e. an American stile option, the value at each nod is the maximum of exercising the option, or keeping it alive. Compound options further require that intermediate lattices be derived for each individual option. The procedure is similar in the case of simultaneous and sequential compound options. The intermediate value lattices evaluate each option contingent on the exercise of some other option. That is, the option with the longest time to expiration is evaluated first in the traditional manner based on the original value lattice. The option lattice of this option is then used as the value lattice for the second to last contingent option[32]. Specifically, the first option lattice becomes the value lattice on which the value of the second option is derived, and so fourth, until the value of the last option is determined which represents the total value of the investment with flexibility.

This is best explained with an example. Consider first an IT platform investment enabling the implementation of two applications in two years time. The platform itself generates no revenues as all direct benefits are expected to result from the implementation of the two applications. Both applications will have to be implemented simultaneously and can only be executed at the end of the two-year period, which is the lead-time needed to prepare the platform. The cost of the initial platform investment is MSEK 15. The cost of implementing each application is: MSEK 80 for application A, and MSEK 20 for application B. A simple DCF analysis, assuming that both applications will be implemented irrespective of the underlying conditions, showed the PV value of the investment to be MSEK 100. A Monte Carlo simulation further showed that the estimated annual volatility of the return on the investment is 25%, and as both investments are executed simultaneously it is identical for both applications (for expositional purposes the risk is now assumed to be constant, a more realistic example involving non-constant volatilities is presented in later in the text). The annual risk free rate is further found to be 10%. Using equation (5.6) and (5.7):

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[32] As defined previously in the text, a compound option is essentially an option which payoff is another option, which implies that the underlying asset of a compound option is also an option.

$$u = e^{0,25\sqrt{0,1/2}} = 1,1934 \quad \text{and} \quad d = e^{-0,1\sqrt{0,1/2}} = 0,838$$

Figure 26 shows how the binomial parameters have been used to construct a value lattice describing the payoff of the investment programme.
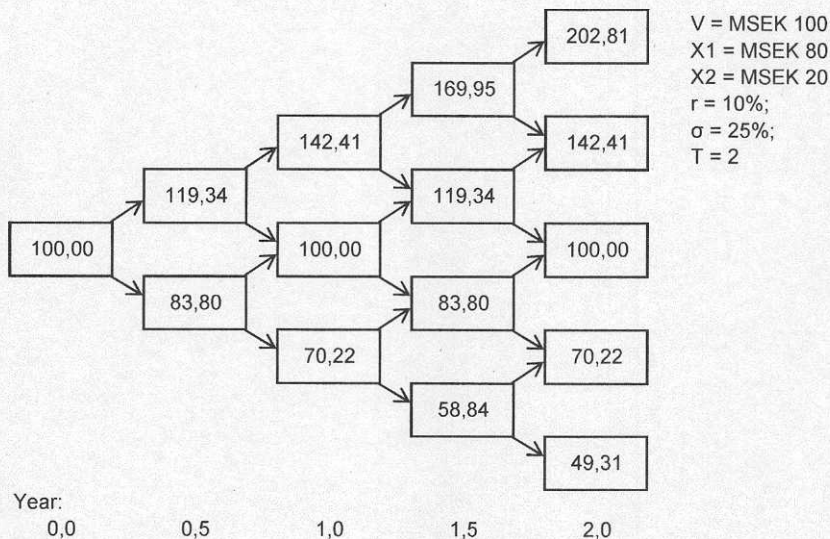
Figure 26: Value lattice of a two-phase compound option

The next step is to calculate the intermediate value lattice for the first option, which in this case is application A. As both applications are to be implemented simultaneously (i.e. a simultaneous compound option), either of the two options could therefore be evaluated first. The first option is valuated based on the value lattice using the risk neutral probability approach:

$$p = \frac{e^{(r\Delta t)} - d}{u - d} \quad \triangleright \quad \frac{e^{(0,1*0,5)} - 0,838}{1,193 - 0,838} = 0,6002, \text{ and } 1 - p = 1 - 0,6002 = 0,3998$$

Starting at the end of the lattice (the terminal nodes), the procedure involves using the profit maximising rule of taking the maximum of either exercising the option or letting it expire worthless. The terminal nod A in Figure 27, for instance, is maximum of exercising the option at the exercise cost 80 and receive the payoff, or not exercising and receive zero, i.e. Max [202,81-80; 0], or Max [122; 0] = 122. The value 202,81 is taken from the terminal nod far up to the right in the lattice in figure 26. The rest of the terminal nods are calculate in exactly the same manner. The

intermediate nods are calculated using the risk neutral probabilities and discounting using the risk free rate. Nod B in Figure 27, for example, is found by using the formula: $[(p * V_{up}) + (1 - p) V_{down})] e^{-r\Delta t}$, => $[(0,6002 * 62,4) + (0,3998*20)]e^{-0,05}$ =43,22
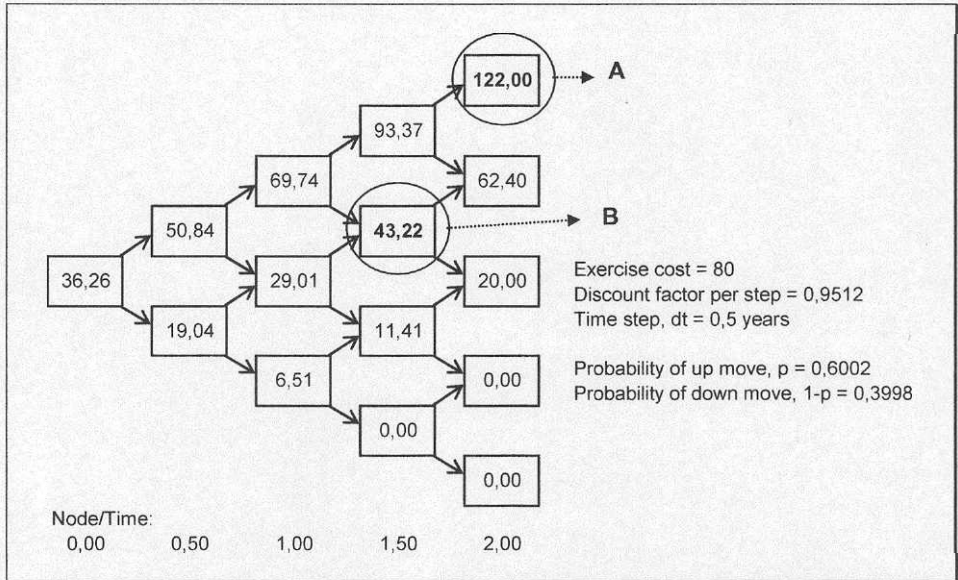
Figure 27: Intermediate value lattice for a compound option

Now the intermediate lattice is complete, the final option value lattice can be constructed using the intermediate lattice as the underlying value lattice. The procedure is identical to the one used to derive the intermediate lattice, that is one starts off by calculating the value of the terminal nodes, and then works backwards through the lattice using the risk neutral probability applying continuous discounting at each of the intermediate nods. The option value lattice for the second option with exercise price 20 is shown in Figure 28.
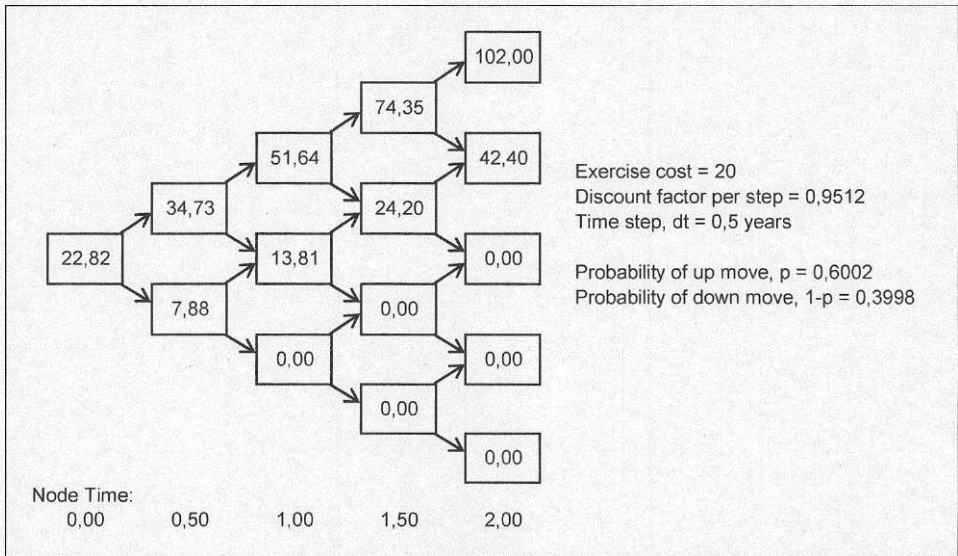
Figure 28: Option pricing lattice for a compound option

The option value lattice shows that the value of the compound options is MSEK 22.82. As cost of the initial platform investment is MSEK 15, the net present value of the investment programme becomes: MSEK 22,82 – MSEK 15 = MSEK 8,82 compared to the static NPV of MSEK -15.

The next example extends the analysis to include non-constant volatilities. Consider a Platform investment with two sequential growth options. The investment opportunity involves an initial platform investment that costs MSEK 6 to implement. In one-year time, the platform can be expanded to provide increased business capabilities at cost of MSEK 50, in present value terms. This investment will further enable an additional investment opportunity one year later, that will cost MSEK 70 to implement. The present value of the investment programme, assuming a fixed investment strategy, is found to be MSEK 100, and the present value of the combined investment costs is: MSEK 6 + 50 + 70 = MSEK 126. This gives a net present value of: 100-126 = MSEK -26. The investment thus has a negative NPV and would therefore, under the standard value maximising assumptions, not be implemented. The future payoff of the investment programme is, however, subject to significant uncertainty. A Monte Carlo simulation showed that the volatility of the return during the first phase is 30% and 20% during the period between the first and the second phase. The risk-free rate is 5% over the investment period. Based on this information a value lattice can be build that describes the evolution of the

investment value over time. All the evaluation variables and calculations are summarised in Table 8.

V_o: 100	σ_1: 30%	$u_1 = e^{0.3\sqrt{1/2}} = 1,236$	$p_1 = \dfrac{e^{(0,05*0,5)} - 0,809}{1,236 - 0,809} = 0,506$
$X_{0\ (year\ 0)}$: 6	σ_2: 20%	$d_1 = e^{-0.3\sqrt{1/2}} = 0,809$	$1-p_1 = 1 - 0,506 = 0,494$
$X_{1\ (year\ 1)}$: 50	r: 5%	$u_2 = e^{0.2\sqrt{1/2}} = 1,152$	$p_2 = \dfrac{e^{(0,05*0,5)} - 0,868}{1,152 - 0,868} = 0,554$
$X_{2\ (year\ 2)}$: 70	Δt: 0,5	$d_2 = e^{-0.2\sqrt{1/2}} = 0,868$	$1-p_2 = 1 - 0,554 = 0,446$

<div align="center">Table 8: Valuation variables and lattice parameters</div>

The valuation starts as before with deriving the value lattice. Beginning with the PV of the investment programme MSEK 100, the first two steps in the lattice are derived through the now familiar multiplication process using the u_1 and d_1 binomial parameters. At t=1, the volatility changes and the remaining steps in the lattice are derived using the second set of binomial parameters, u_2 and d_2.
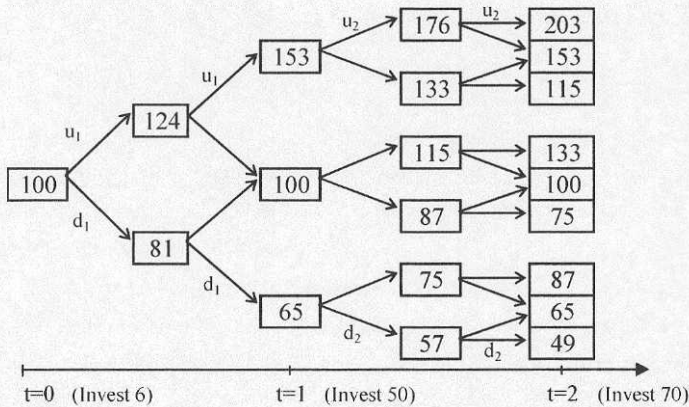
<div align="center">Figure 29: Value lattice describing the payoff of the investment programme</div>

The second step is to derive the first option lattice (shown in Figure 30), for the option with the last exercised date. The process is identical to the one described in the previous examples, except that now the risk neutral probabilities p_1 and p_2 are used in the first and second time periods respectively.
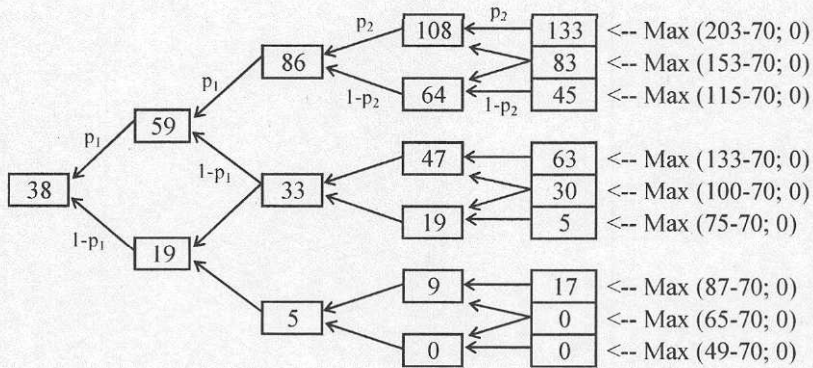
Figure 30: Intermediate option lattice

Finally, the value of the compound option can be calculated based on the intermediate option lattice. The exercise date of the first option was at t=1, so the construction of the final option lattice starts by applying the exercise rule on the values in the intermediate lattice, in the corresponding period.
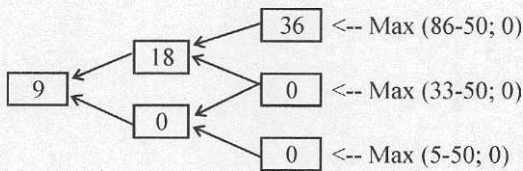
Figure 31: Final Option Lattice

From Figure 31, the value of the two contingent investment phases is found to be MSEK 9. The cost of the initial platform investment was estimated at MSEK 6, so the net present value of the investment programme is: MSEK 9 – MSEK 6 = MSEK 3, suggesting that this is a viable investment opportunity. The static NPV analysis, on the other hand, valued the investment programme at MSEK – 26. The value of the flexibility of being able to adjust the investment strategy (which is ignored in the static NPV) when new information becomes available can thus be calculated as: 3- (-26) = MSEK 29.

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CHAPTER 6   Application of the Analysis Model

Success is the ability to go from one failure to another with no loss of enthusiasm

Sir Winston Churchill (1874 - 1965)

6.1   Introduction

Chapter 6 presents a case study in which the evaluation framework and analysis model, developed in the thesis, are applied on a real-life case study. The goals of the case study are to demonstrate the application of the framework, and the mechanics of the analysis model on a real investment problem. The company in the study is Skanska, which is a large global construction company. The case involves an investment in an ERP system, and a number of related IT investment projects at Skanska. The chapter further compares the outcome of the analysis model to the results of a static Discounted Cash Flow (DCF) analysis. The application of the analysis framework illustrates how an investment in an ERP system can function as an IT platform for a number of subsequent future applications. The original project evaluations at Skanska were performed for each project separately, and at different points in time. Limited attention was therefore given to possible interdependencies, between individual projects, in the evaluation. The framework is used to identify and clarify the interdependencies between the projects. The analysis model is then applied to address the contingencies between the investments, and how they affect the *ex-ante* value of the ERP investment. The case study data is primarily collected through informal discussions with managers at Skanska's IT department, and from internal documents (e.g. project reports, PowerPoint presentations and Excel spreadsheets) used in the original project analysis at Skanska.

As described in Chapter 2, ERP is a software architecture that facilitates the flow of information between different functions within an organisation. This new breed of integrated management systems first emerged in the 1990's in the manufacturing sector and in 1998 total sales of ERP systems exceeded $10 billion (Hill 1999). The profitability of ERP investments however still remains a heavily debated topic (Ross 1999; Krasner 2000). Despite of the large investment costs involved with these investments several studies have shown that many companies do not evaluate the investment formally. Those companies that do calculate the return on their investment are however often disappointed. A survey of 69 companies conducted by the Meta Group found that the average cost of implementing an ERP system was $10.6 million and the average implementation time was 23 months. Furthermore, the net present value of the average investment was -$1.5 million over a six year period (Stein 1999 p.60).

The chapter starts with a short description of the case company and the background to the case. Next, using the framework developed in Chapter 4, the ERP investment is recognised as an IT platform investment and a number of contingent IT projects are identified and described. Based on this analysis, the platform investment together with the contingent IT projects is formalised as a contingent investment programme. The investment programme is then evaluated using the systematic process developed in Chapter 5. Specifically, each of the projects is initially evaluated using a standard DCF analysis. Important stochastic variables in the DCF model are then identified and their stochastic properties defined (the details of this analysis are presented in Appendix C). The value of the investment programme is then simulated in a Monte Carlo simulation. The simulation is used to calculate the volatility of the return on the investment programme at distinct points in time, corresponding to the start of each project. The binomial analysis model is then applied to derive the *ex-ante* value of the platform investment and the contingent IT investment programme. Finally, Chapter 6 concludes by comparing the results of the analysis model developed in the thesis with the results of the DCF analysis.

6.1.1 Background to the case study

Skanska was founded in 1887 and is now a leading global construction service and project development company[33]. Skanska has operations in over 30 countries and its

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[33] According to the Engineering News Record (www.enr.com) Skanska was the third largest global construction company in the world in 2003.

total revenues in 2003 were in the excess of SEK 133 billion. The company has approximately 53.000 employees worldwide, whereof 12.500 in Sweden. Skanska's services vary from small building contracts, to assuming the full responsibility for identifying and solving the customers' long-term needs for construction related services. Skanska's home markets are Sweden, USA, UK, Denmark, Finland, Norway, Poland, the Czech Republic, and Argentina. The company is a decentralised organisation in the sense that each home market operates with relative autonomy. The focus in this case study is on Skanska Sweden, which is the largest construction company in Sweden. The operations encompass a number of specialised subsidiaries, which focus mainly on housing and building construction and services related to road construction and civil engineering.

In 2001, Skanska Sweden[34] implemented an Oracle ERP System. The investment was at the time the single largest, non-construction related investment ever made by the company. An analysis, based on discussions with IT managers at Skanska and an examination of internal project documents, identified five other subsequent IT projects as related to the ERP system:

1. Electronic Invoicing involving manual scanning of incoming invoices
2. ERP System Upgrade
3. E-Business Project
4. Electronic Invoicing involving direct electronic delivery
5. Shared Service Centre

Prior to the ERP implementation, Skanska relied on an internally developed DOS-based legacy system. The system was becoming obsolete due to limited expandability potential and high maintenance costs. This was an expert system where end users worked with paper printouts and therefore had little direct contact with the system. The system architecture consisted of numerous different software applications, implemented independently at different departments in the organisation. Consequently, limited integration existed between the applications.

In an interview in CIO Sweden (2003, p.23-25), Skanska's IT manager explained that the company had started considering an ERP system in 1998 due to dissatisfaction with the existing IT systems, and problems with the accuracy in project prognoses. As a result, the management at Skanska initiated an internal pre

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[34] Hereafter referred to as Skanska in the text

study to evaluate the company's IT infrastructure and key business processes. The work was organised by a workgroup with people from different departments in the organisation. The study focused on analysing three topics: a) the state of current practice, b) the cost of current process and systems, and c) suggestions for ideal future practice. The initial work included a business process analysis using a formal Business Process Reengineering (BPR) model supplied by a major consulting firm, and a technical examination of the company's existing IT infrastructure. The work group focused on six main areas within the organisation:

1. Information Technology
2. Human Resources
3. Finance
4. Customer relations and Marketing
5. Procurement
6. Construction Management

The pre study also included group discussions and brainstorming sessions where the different departments identified their "ideal" system specifications. The overall objective of the study, which lasted 18 months, was to suggest ways to reduce administration costs, and provide better insight and control of costs down to the individual project level. The conclusion of the pre-study was that the key to transforming the firm's current capabilities was to consolidate disparate business units within the organisation through a single coherent computing environment and uniformed work routines. A fully integrated ERP system was identified as the main technology driver in this transformation. Together with an extensive reengineering of the companies business processes and streamlining of the organisational structure, this investment was expected to provide a platform for building additional IT related capabilities.

Based on discussions with IT managers at Skanska and an analysis of project documents, pertaining to the pre-study and a number of other IT projects at Skanska, this study found that four major areas for improvement had been identified prior to the ERP investment.

1. Skanska needed an integrated system to improve the construction project management. The construction project managers require constant access to accurate information about the present situation of the construction projects. This includes both information about the financial and the physical progress. Prior to the ERP

implementation, this work was organised using paper reports. The focus was primarily on cost control whereas access to information about the project revenues was limited. This often resulted in inaccurate project prognosis. The pre-study concluded that an on-line project based system would enable improved control, reporting, and analysis of projects.

2. The invoicing process needed to be improved. The different operating units within Skanska Sweden receive over 1.3 million invoices annually. The company estimated that the total cost of processing each incoming invoice was on average more than 100 SEK. Implementation of an electronic invoicing system, and standardisation the accounts payable processes was recognised as enabling substantial cost savings.

3. Procurement needed to be coordinated. Procurement is the largest cost factor in Skanska's operations, accounting for almost 70 percent of the annual turnover. At the time of the pre-study, procurement was to a large extent decentralised and individual project managers responsible for negotiating prices with suppliers. Skanska has gone from being a producing company to becoming principally a purchaser of material and services from subcontractors. The company produces ever less with their internal workforce, and increasingly more through subcontractors, which in turn take over the responsibility for purchasing the materials. In a six year period, the use of subcontractors increased from 45% to 65% and the material purchased by Skanska decreased from around 30% to 10%. Coordination of the purchasing process was very low and individual departments and project managers had opportunity to exchange information. Consequently, Skanska Sweden has over 30.000 active suppliers. As illustrated in Figure 32, Skanska establish that electronic project purchasing would enable the company to coordinate purchasing and develop closer relations with key suppliers.
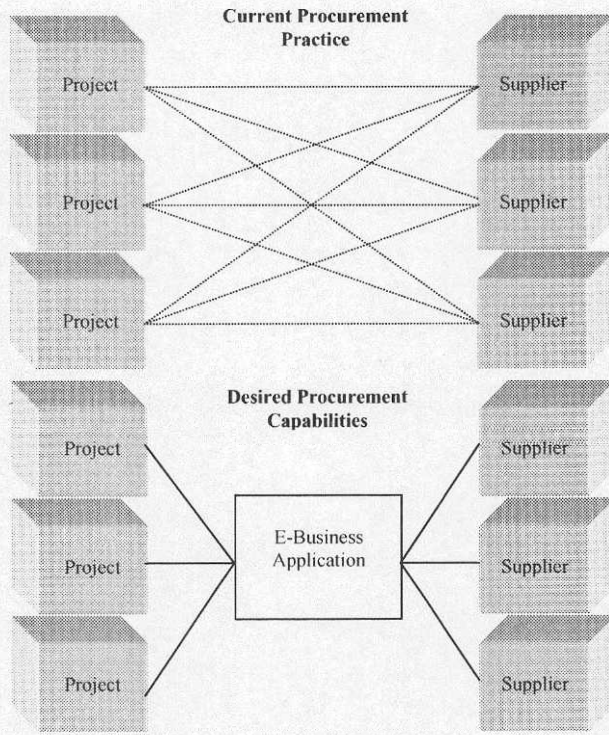
Figure 32: Planned transformation of the firm's procurement capabilities

Electronic purchasing or E-business capabilities essentially entail implementing an online IT application for establishing closer and more efficient relations with suppliers. This way the company can better take advantage of its size in the purchasing process. This type of manufacturer – supplier relationships have been around for over 30 years in the manufacturing industry using technologies such as Electronic Data Interchange (EDI). The nature of the construction industry with multiple time specific projects at dispersed locations, made this type of technical solutions essentially impossible or at least to costly to implement. It is first with the emergence of the Internet that this started to become a technologically viable option for construction companies.

4. Work routines and processes needed to be standardised. Skanska recognised that an important factor in deriving benefits from an integrated ERP system would be to standardise the administrative processes. This was expected to provide increased insight and better control of the organisation's costs and revenues, down to the individual construction project level. Many work processes involving administrative

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tasks were not standardised and spread out in the organisation. Different IT systems were being used at various business units for identical tasks. A single integrated application was found to enable important opportunities for reforming the administrative routines in the future.

Table 9 summarises a capability gap at Skanska prior to the ERP investment, based an analysis of internal project documents, and interviews with IT project managers.

Capabilities prior to the start of the investment programme	Desired capabilities
Financial, Project and Human Relations management is run in diverse expert systems. Employees work with paper printouts and data is re-entered many times in the system.	1. Fully integrated real time and on-line enterprise system where data is entered once at the source into the system.
Paper invoicing.	2. Electronic invoicing.
Decentralised project procurement using telephone, mail, and fax.	3. Coordinated electronic project procurement.
Diverse non-standardised administrative routines and processes.	4. Streamlined standardised work routines and processes.

Table 9: Skanska's capability gap prior to the ERP investment

Standard ERP systems are designed for highly structured organisations and stable business processes. Construction companies are extremely project-oriented organisations and therefore do not match that description well. Skanska's management never the less decided to focus the evaluation on standardised systems[35]. The objective was to use standard applications whenever possible. Consequently, many business processes and internal routines would need to be adjusted to fit the system. This limited the number and scope of applications possible to implement in a given time period. Skanska therefore decided to limit the initial ERP implementation to three main applications: Financial Management, Project Management, and Human Resource Management. However, before embarking on a full-scale implementation of an ERP system, Skanska decided first to evaluate the feasibility of the system in a limited pilot project. Assuming the successful implementation of the ERP system, additional applications would then

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[35] The management at Skanska had decided that the company was to become a leader amongst their competitors in the *application* of information technology. This entailed that the company should principally focus on implementing standardised systems rather than develop customised systems internally.

later be added to the system to provide additional capabilities. The ERP system was therefore intuitively seen as a necessary *platform* for the desired capabilities described in Table 9. Skanska however, evaluated each of these future projects separately, and independent of each other.

The analysis that follows focuses on the *ex ante* value of the ERP system, taking into consideration the value of options to add further applications in the future. It does not evaluate how much the investment has generated today. *In hindsight,* the different investment projects can now be seen as an investment programme with a sequence of investment decisions[36]. The initial decision (which in the analysis in Section 6.4 is assumed the only decision management has to commit to) is whether to execute the pilot project now or to reject the investment programme as a whole. Based on the outcome of the pilot project the decision maker is next faced with the decision whether to continue with the full-scale implementation of the ERP investment. Assuming the ERP system is implemented successfully, the company can then implement a number of additional applications. The implementation of the ERP platform therefore provides the firm with a series of contingent growth options in the form of new and extended applications. These growth options are however, sequentially interdependent. That is, investment Phase-2 cannot be executed until Phase-1 is completed, et cetera. *The investment programme should therefore be evaluated as a multi-stage compound option.*

The following sub-section describes the investment programme in more detail. The rest of the chapter is organised as follows. In line with the analysis model presented in Chapter 5, section 6.2 evaluates the ERP investment and each of the other contingent IT investment projects using a standard DCF analysis. Section 6.3 describes a risk analysis of the investment programme, involving a sensitivity analysis of the results of the DCF analysis and a Monte Carlo simulation of the volatility of the investment returns. Section 6.4 applies the binomial analysis model on the data collected to derive the *ex-ante* value of the investment programme. Finally, section 6.5 concludes with a discussion of the result of the analysis.

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[36] At the time of the ERP implementation, the investments following the ERP investment were not part of a formalised investment strategy at Skanska, but included in a vision developed under the pre-study. The detailed project evaluations and specific system selections where done at later periods following the ERP investment. The evaluation presented here is based on the assumption that most of the relevant information would have been available or obtainable at the time.

6.1.2 Defining the contingent investment programme

Based on the analysis above and a study of the individual project evaluations, the ERP investment, and the contingent future application projects are formalised into an investment programme, which is summarised in figure 33. T stands for the timing of each phase, i.e. T=0 denotes the year in which the ERP pilot project is executed, full scale implementation of the ERP system is planned to start the following year (T=1), et cetera.

Shared Service Center (SSC)	Phase 6 T=4
Electronic invoicing (EI-2)	Phase 5 T=4
E-business	Phase 4 T=3
ERP Upgrade	Phase 3 T=3
Electronic invoicing (EI-1)	Phase 2 T=2
ERP Platform	Phase 1 T=1
ERP pilot project	Phase 0 T=0
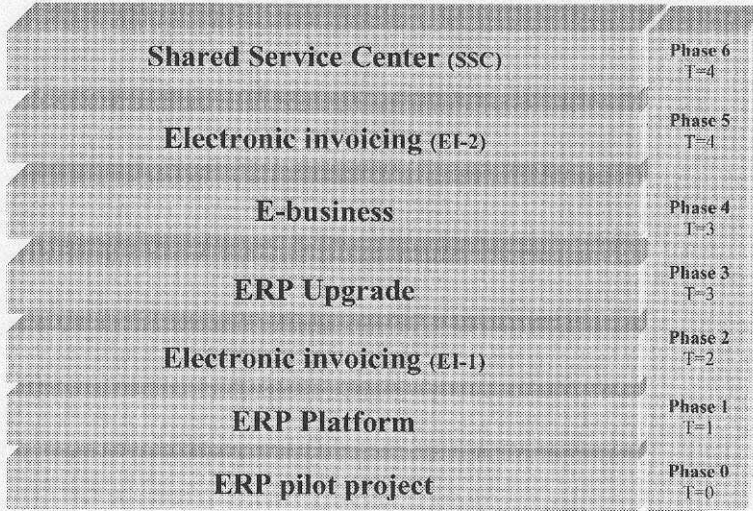
Figure 33: A stepwise process describing the investment programme

Phase 0 - ERP Pilot project.

After extensive work on documenting and analysing existing work process within the organisation along with designing detailed system specifications, a standard Oracle system solution called, the Oracle Business Suite was identified as the most feasible option. However, before deciding on a full-scale implementation a pilot project would be implemented to test the functionality and feasibility of the system. The pilot project will not produce direct benefits in terms of cash flows, but it will provide valuable information about the project risks involved with the system implementation. By implementing a pilot project, the company is therefore essentially exercising an option to defer the ERP investment for one year.

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Phase 1 - Full implementation of the ERP system.

Assuming a successful outcome of the pilot project the implementation of system could start in the year following the pilot project. The Oracle Business Suite is to be implemented with three main modules:

- Financial Management (FM)
- Project Management (PM)
- Human Resource Management (HRM)

The expected benefits of the investment are twofold. First, each of these modules provides the company with a given set of business capabilities that generate direct benefits, which can be measurable in terms of cash flows. Second, the individual application modules combined with the associated process reengineering provides the company a set of future growth options, which build on the applications in place and the possibility of integrating new applications into the ERP system.

Phase 2 - Electronic Invoicing (EI-1)

During the pre-study at Skanska, the project team considered the possibility of implementing part of the required systems to support the invoicing process together with the ERP system. This was however, later abandoned. The project would require extensive organisational change and standardisation of processes. The type of radical change needed takes time and resources. It was therefore decided that the desired capabilities would be attained in stages. The first stage would be that all incoming invoices be received centrally and scanned on arrival and then forwarded electronically for further processing. This requires the implementation of an additional Oracle system application in year 2, which can be fully integrated into the enterprise system. This capability would then be expanded in a later project to include scanning with automatic intelligent interpretation of the content of the invoice, and the possibility of receiving the invoices electronically direct from suppliers and subcontractors.

Phase 3 - ERP System Upgrade

ERP system vendors routinely release major system upgrades. This entails that support for previous versions is usually suspended few years after the new release. In order to extend the lifetime of the systems, companies are therefore forced to upgrade their systems regularly. This involves considerable costs for updating and testing the customised applications in the system. Considering that the system

version that Skanska wanted to implement had already been on the market for some time, it was evident that the system would need to go through a major upgrade in about three years time. This investment would be necessary to maintain the current system capabilities and enable additional future applications.

Phase 4 - E-business solutions

Coordinating the procurement in the construction projects was potentially the most valuable growth option enabled by the ERP system. This project would involve three types of investments: a) developing an effective purchasing strategy, b) reengineering the procurement processes, and c) implementing IT support tool. The IT support tool was in the form of an e-business application supplied by an external application service provider (ASP)[37], which *could* be fully integrated into the ERP system.

The new system would entail a radical change in the current practice. Not only would Skanska's project managers need to be persuaded to change their current practice, but the company's key suppliers would also need to actively participate in the implementation. Due to the large scope of the project, the application was therefore planned to be implemented gradually in individual regions and department. Specifically, the project would be implemented in five distinct stages, where subsequent stages would be made contingent on the successful completion of the previous stage. Each stage was estimated to take one year to complete and the earliest possible start would be in four years from the platform implementation. The E-business project is therefore, by itself a compound option embedded in another compound option (i.e. the investment programme).

Phase 5 - Electronic Invoicing; stage II (EI-2)

The second stage of the electronic invoicing project would start in 4 years from the initial platform investment. This project is essentially an embedded growth option that expands the previous project (EI-1) to include intelligent interpretation of the scanned invoices, and capacity to receive electronic invoices directly from

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[37] Skanska initially considered two main alternatives. Skanska could develop the required IT application internally the company could buy the required IT service and the necessary support from an external application service provider. The conclusion was that it would be both to costly and risky for Skanska to develop the application internally. An important risk factor was that the Skanska would not have sufficient internal IT competence to complete the development and implementation of the system, resulting in total project failure.

suppliers. The extended electronic invoicing application is a fully integrated application module from the ERP system vendor.

Phase 6 - Shared Service Centre (SSC)

The final stage in the investment programme would be to implement a Shared Service Centre (SSC). This project would not require large investments in IT applications, but rather focus on exploiting the infrastructure in place and streamlining the transformation of business process. This type of transformation is difficult to achieve directly with the implementation of the enterprise system and contingent applications, due to the enormous restrain on the company's resources during the transformation process. A further concern was that in the early stages of the investment programme, individual system applications involve timesaving elements that pertain only to part of the tasks performed by individual employees. This may not be sufficient to justify extensive task consolidation. However when an increasing number of tasks are affected by new applications, a point is reached when task consolidation becomes practical. The objective of the Shared Service Centre is thus to facilitate a consolidation and centralisation of administrative tasks currently being done at various levels in the organisation. The implementation of the Shared Service Centre is contingent on the successful completion of the second stage, of the Electronic Invoicing system, and can therefore start directly following its implementation.

6.2 Discounted Cash Flow Analysis

The NPV calculations are performed using the Discounted Cash Flow (DCF) approach[38]. The net cash flows are adjusted for depreciation, amortization, and changes in net working capital, in order to derive the annual *free cash flow* of each project. The free cash flows are then discounted to the present period using a risk-adjusted discount rate.

6.2.1 The Data

The data used for the financial analysis of the investment programme is primarily based on Skanska's internal Cost-Benefits analysis. The evaluation performed by Skanska applied a simple Payback method as the primary financial evaluation criteria. For the ERP project, the Electronic invoicing projects, and the Shared

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[38] To make the case as realistic as possible the original project data was used. The format of the data (the data was in some cases very aggregated) did however not make it possible to apply the cash flow model developed in chapter 6.

Service Centre, Skanska provided access to spreadsheet models with detailed cost-benefit calculations. Data on the other projects was more aggregated, with less information about how specific benefits were to be realised. The data was further complemented through discussions with members of the original project teams.

6.2.2 The ERP Investment

The implementation of the ERP platform was designed as a "Big-Bang", implying that all three modules would be implemented with full functionality in the whole organisation at once. Perhaps a more careful approach would have been a stepwise implementation of individual modules in the organisation or implementing all applications in the different department of the organisation gradually, or a combination of the two. As discussed in earlier chapters, a step wise investment strategy can have a significant effect on the *ex ante* value of the uncertain investments, as the managerial flexibility to adjust the investment strategy as uncertainty get resolved through the investment process, is potentially very valuable.

The estimated annual benefits of the respective modules, fully implemented and operational, are summarised in table 10. The benefits are based on an analysis of the processes affected by the system implementation.

	FM	HRM	PM	Σ
Direct benefits (MSEK)	0,40	7,78	5,70	*13,88*
Benefits requiring BPR (MSEK)	29,40	16,15	19,74	*65,29*
Total annual Benefits (MSEK)	29,80	23,93	25,44	**79,17**

Table 10: Estimation of the *annual benefits* assuming a fully operational system and realigned business processes, all numbers are in millions of SEK

Financial Management System (FM)
Assuming a fully functional system and successful process reengineering, the financial system is expected to enable almost 30 million SEK in benefits annually. The estimated benefits are based on:

- Reduced manual work and reduced time for executing tasks
- Registration of information is done at the source enabling aggregation of information up to top management level
- Simplified routines and better control

- Integration of the financial processes with the rest of the processes resulting in lower transaction costs

Human Resource System (HRM)

The implementation of the HRM module and reengineering of the personal processes is expected to enable annual savings of 24 million SEK. The estimated benefits are based on:

- Reduced manual work. Employees will, for example be required to register their own time sheet directly into the system.
- Effective system support with standardised processes enabling further process development and improvement

Project Management System (PM)

Effective system support and more effective processes in the construction projects were estimated to lead to annual cost reductions of roughly 25 Million SEK. The estimated benefits are based on:

- Effective system support where all information is accessible
- Frequent reporting leading to updated information being constantly accessible
- Data entry is done at the source
- Integrated information flow allowing for accumulation of information

The platform implementation is assumed to deliver full-anticipated business capabilities first in year 3. The original project evaluation at Skanska assumed full benefits immediately following the implementation. Considering the scope and complexity of the implementation, it is however unlikely that the system will deliver the anticipated benefits from day one. Furthermore, large part of the anticipated benefits involves extensive business process re-engineering and standardisation of inconsistent workflows. These changes will take time to implement as some end user resistance is to be expected.

In a extensive survey of 163 organisations, which had implemented enterprise solutions, Davenport et al. (2002) found that only 36% of organisations manage to achieve their targeted benefits within one year of the implementation. Figure 34 shows that for 52% of the organisations it took up to 4 years to achieve the targeted benefits. Furthermore, 12% of the companies never achieved their targeted benefits.

ERP Solutions Benefits Achieved over Time

Targeted benefits achieved in 4 years or longer; 8%

Targeted benefits never achieved; 12%

Targeted benefits achieved within 1 year; 36%

Targeted benefits achieved within 2-4 years; 15%

Targeted benefits achieved within 1-2 years; 29%
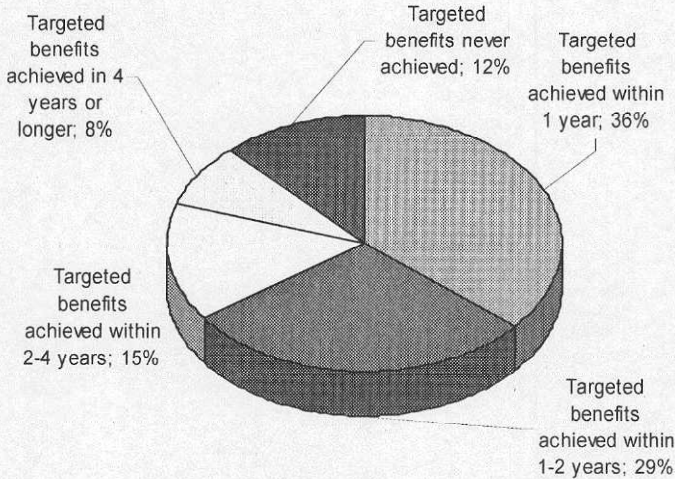
Figure 34: The extent of ERP benefits archived over time. Source: Davenport et al. (2002, p.9)

The calculations here are therefore adjusted moderately to reflect the historical difficulty in deriving benefits immediately after the implementation, and considering that Skanska had no prior experience with this type implementation. The DCF analysis as a result assumes that in the year of the implementation, 50% of the full benefits will be realised, and in the second year 75% of the benefits.

The investment costs include hardware, software licensing fees, and cost for customisations amounting to about SEK 200 million. The cost of the pilot project was further estimated to be SEK 8 million. User training was not included in the original project evaluation at Skanska. Additional data on these costs was therefore obtained though interviews with IT project managers. User training was to be organised internally so that first, 10 internal IT experts get external training on the system, they in turn train 300 internal instructors, which in turn teach 2.800 end-users. For this purpose, six permanent computer rooms need to be installed in four cities in Sweden. In total over 20.000 training days would be required. The cost calculations, summarised in Table 11 [39], further include the opportunity cost of the 2.800 non-productive employees during the training.

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[39] All the numbers in the tables are in MSEK

ERP Investment Costs	
Pilot project	8
Hardware/ software/ customisation /implementation	200
Education of internal IT experts	2
Direct training costs (material, facilities etc.)	20
Opportunity cost of non-productive employees during training	56
Total (MSEK):	**286**

Table 11: Evaluation of the ERP investment cost

ERP Investment	0	1	2	3	4	5
FM - Direct benefits		0,20	0,30	0,40	0,40	0,40
FM - Benefits requiring BPR		14,70	22,05	29,40	29,40	29,40
HR - Direct benefits		3,89	5,84	7,78	7,78	7,78
HR - Benefits requiring BPR		8,08	12,11	16,15	16,15	16,15
PM - Direct Benefits		2,85	4,28	5,70	5,70	5,70
PM - Benefits requiring BPR		9,87	14,81	19,74	19,74	19,74
Sum:		39,59	59,38	79,17	79,17	79,17
PV Annual Free Cash-Flows		**32,99**	**41,23**	**45,82**	**38,18**	**31,82**
PV Free Cash-Flows	190,03					
PV Investment costs	-286,4					
NPV	-96,37					

Table 12: DCF analysis of the ERP investment

Using a risk-adjusted discount rate of 20%[40] the DCF analysis shows a negative NPV of the investment of over 96 million SEK. Based on the analysis presented in Table 12 the platform investment, disregarding possible future follow up investments, should therefore be rejected. That is, _as a stand alone investment it is clear that the ERP system is not a financially viable investment._

6.2.3   Phase 2: Electronic Invoicing I

As illustrated in Figure 33, the Electronic Invoicing capability is to be implemented in two separate, but interdependent projects called EI-1 and EI-2. The first stage, involves scanning of all incoming invoices into electronic files. This practice will lead to a standardisation of the workflows involving the invoice processing. All invoices are then to be sent through the ERP system internally for further

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[40] Skanska generally applies a discount rate based on the firm's Weighted Average Cost of Capital (WAAC) which is determined on a project to project basis. No discounting was however performed in the original project evaluation. The discount rate here is subjectively chosen by the author based on discount rates used in similar studies. A risk adjusted discount rate of 20% is for example used by Taudes, Feurstein et al. (2000) in an analysis of an ERP upgrade investment.

processing. Skanska in Sweden receives on average around 1.3 million invoices annually. The system is therefore expected to enable substantial cost savings in terms of postage and handling. The project also involves standardisation of workflows, which is expected to result in increased efficiency and reduced risk of avoidable interest rate payments and fees, from late and incorrect payments. The first stage intentionally involves relatively simple technology applications, while the focus will be on adjusting the workflow to this new technology.

The first years following the ERP implementation, the IT personal is expected to be fully occupied with implementation issues surrounding the ERP system (including integration issues, system performance and getting the users to use the system correctly). Assuming the ERP system is implemented successfully, the EI-1 project can be implemented in year 2.

Phase 2 - Electronic Invoicing 1	0	2	3	4	5
Annual Free Cash-Flows		0,60	5,20	11,60	11,60
Investment Costs		-2,40	-1,30		
PV Investment Costs	-2,42				
PV Free Cash-Flows	13,68				
NPV	11,26				

Table 13: DCF analysis of the fist stage of the EI project

The DCF analysis for the EI 1 project is presented in Table 13. The project requires relatively low investment costs and the new capability is expected to deliver full benefits in the second year following the implementation. *The analysis shows a positive NPV of roughly SEK 11 million.*

6.2.4 Phase 3: ERP System Upgrade

The ERP investment analysis includes an annual cost for a standard service agreement with the ERP system provider. The service agreement entails that Skanska pays a fixed service fee, which includes support for the system and all system updates. Skanska does therefore not need to pay anything extra for the system update of the standard system. However, if the system is substantially customised, as was the case with the final configuration of the ERP system, the costs are potentially very high. The ERP system would however, initially be run on the company's existing Solaris machines, and at the time of eventual major system update, more cost efficient machines running in a Linux environment would replace these machines. The total cost of upgrading the system; including reconfiguration of

customised applications, testing, and implementation was estimated to be SEK 35 Million. The added benefits of the upgraded system together with the cost savings of replacing the outdated hardware were estimated to give a Payback on the investment in about 16 months in the initial calculations, or approximately within half the estimated lifetime of the system. These calculations are translated into a discounted cash flow analysis in Table 14.

ERP Upgrade	0	3	4	5	6
Annual Free Cash-Flows		28,00	14,00	7,00	3,50
Investment Costs		-35,00			
PV Investment Costs	-20,25				
PV Free Cash-Flows	26,93				
NPV	6,69				

Table 14: DCF analysis of the ERP system upgrade

The DCF analysis shows that the system upgrade would yield a positive NPV of 6,69 million SEK and would therefore be a profitable project.

6.2.5 Phase 4: The E-business project

There were two main objectives formalised for the E-business project:

- To continuously lower costs through grouping together all purchases to one point to be able to take advantage of the size of the company when buying from suppliers. (This part of the service could in principle be implemented independent of the platform investment but would then have a lower level of benefits)
- To have a fully integrated tool to support the whole process flow from the time a procurement need is identified until the final invoice is paid.

To maximise the potential benefits of the project, the implementation was planned to take place on a larger regional scale including several of the Nordic Countries. The implementation would however be done in stages starting with Skanska Sweden. Within each country, the service would be implemented gradually throughout different operating units and regions.

Focusing on ASP's rather than developing an internal system entailed that the project has relatively low fixed investment costs. The ASP's payment model is based on charging both the buying organisation and the suppliers connected to the service. In order to minimise the external user adoption risk Skanska decided to take

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on the costs from the supplier's side for the first two year. These additional costs are reflected in the DCF analysis presented in Table 16 below. Apart from the cost related to the service fees and for reconfiguring the standard application, extensive investment in user training would be required to make the project successful.

Approximately 4000 end-users would need to learn to use the new application. User training would be organised internally where 250 instructors would get two days intensive training on the system and would in turn provide a one-day training course for the end-users. Based in discussions with the IT project manger, the investment in user training is conservatively estimated to roughly 14.6 million SEK.

User Training	Number of employees	Cost per employee (T SEK)	Total (M SEK)
Training of Instructors[41]	250	4 000	1.00
Instructors opportunity cost of non-productive work days during their own training (2 days)	250 * 2	2 800	1. 40
Instructors opportunity cost of non-productive work days during end user training	375	2 800	1.05
Opportunity cost of non-productive employees during end user training	4 000	2 800	11.20
Total investment in user training:			14.65

Table 15: Evaluation of the cost of training for the e-business project

The implementation of the E-business capabilities would proceed in five distinct stages, starting in year 3. Table 16 shows the investment costs associated with each of the investment stages, and the expected benefits from each investment stage.

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[41] This includes cost of training material, training facilities, training fees and cost of travel and accommodation

Phase 4 – E-Business	0	3	4	5	6	7
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Utilize Frame agreements		8,00	17,00	40,00	55,00	63,00
Collaboration with Contractors			19,00	37,00	68,00	99,00
Support Project Purchasing				12,00	43,00	101,00
Improved Work Methods				12,00	22,00	35,00
Gross Benefits		8,00	36,00	101,00	188,00	298,00
Operating Costs		-8,95	-11,60	-16,70	-17,35	-17,45
Annual Free Cash-Flows		-0,95	24,40	84,30	170,65	280,55
PV Free Cash-Flows		-0,55	11,77	33,88	57,15	78,30
Investment Costs		-16,28	-18,93	-16,70	-17,35	-17,45
PV Investment Costs		-9,42	-9,13	-6,71	-5,81	-4,67
NPV	144,61					

Table 16: DCF analysis of the E-business project

The E-business project is clearly a very profitable project. The DCF analysis shows a positive NPV in the excess of 144 million SEK. *All the benefits of the project are however, not directly contingent on the ERP investment.* As the E-business capability is build up around an external ASP, much of the benefits are achievable without the ERP platform being in place. This specifically refers to the benefits derived from utilizing frame agreements and from closer collaboration with sub-contractors. The benefits anticipated from increased support with project purchasing and improved work methods are however directly contingent on the ERP system and the projects preceding E-business implementation. These benefits amount to 35% of the total net present value of the investment. Therefore, only roughly a third or *51.5 million* of the total NPV of the E-business project can be included in the value of the Platform investment programme.

6.2.6 Phase 5: Electronic Invoicing II

The second stage of the electronic invoicing project (EI-2) is to be implemented in year 4. The project involves that all incoming invoices arrive at Skanska electronically. The invoices are received either directly from suppliers, with the capacity to send electronic invoices, or through a service partner that transforms the paper invoices into electronic format with full content interpretation. The analysis is based on the assumption that 60% will arrive electronically direct from suppliers while 40% will be scanned manually with interpretation.

The system enabling this capability is an Oracle application that is fully integrated with the ERP system. The system can therefore not be implemented as a stand-alone system. Due to the integration of the systems, all changes in the electronic invoices

anywhere in the accounts receivable process will be reflected automatically in other applications in the ERP system, such as the project reporting and the account payable ledger. This entails that construction project managers get access to consolidated real-time information on all expenditures in the projects. Further benefits are expected to be derived from additional cost savings related to manual administration, postage and handling and document archiving.

Phase 5 – Electronic Invoicing 2	0	4	5	6	7
Free Cash-Flows		2,68	4,31	7,44	7,44
Investment Costs		-6,43			
PV Free Cash-Flows	7,59				
PV Investment Costs	-3,10				
NPV	**4,49**				

Table 17: DCF analysis of the second stage of the EI project

The investment costs are mainly related to user training, consultant services, licence fees and system configuration and customisation. The standard application will have to be substantially customised for Skanska to adopt it to the project-based environment. Up to 3000 end users will need to receive a half day of training on using the system. The same training model with internal trainers is to be used as in the previous projects. The DCF analysis of the project, summarised in Table 17, shows a *positive NPV of SEK 4.49 million*.

6.2.7 Phase 6: A Shared Service Centre

The Shared Service Centre (SSC) is planned to be a general business support centre for the different operating units in Skanska. The project will focus on rationalising the processes involving salary administration, finance and general administration. The project is contingent on the successful implementation of all the previous stages in the investment programme. Each of the previous stages will have some direct benefits in the form of cost savings and some limited rationalisation of the relevant processes. However, when all of the system applications are operational, centralising a number of remaining manual tasks into a common service centre within the company will allow for additional rationalisation. This is expected to generate value by increasing operational efficiency and improving the overall organizational effectiveness.

The service centre will not require large investments in specific system applications while substantial resources need to be invested organisational restructuring,

involving consolidation of offices and streamlining of the administrative processes. The anticipated benefits and associated investment costs of the project are summarised in Table 18.

Shared Service Centre	4	5	6	7
Central Cost savings	-0,01	3,09	3,09	3,09
Local Cost savings	21,07	33,77	33,77	33,77
Operating Expenses	-3,99	-5,78	-5,78	-5,78
Local phase out costs	-0,52	-0,32	-1,29	-1,29
Central phase out costs	-7,90	-4,76	0,00	0,00
Free Cash-Flows	8,65	26,00	29,79	29,79
Investment Costs	-11,01			
PV Free Cash-Flows	4,17	10,45	9,98	8,31
PV Investment Costs	-5,31			
NPV	27,60			

Table 18: DCF analysis of the Shared Service Centre project

The DCF analysis shows that this is a very attractive investment project. The project has a positive NPV in the excess of 27 million SEK.

6.2.8   Summary

Table 19 summarises the results of the DCF analysis of the investment programme.

		PV Free Cash flows	PV Investment costs	NPV	
Phase 1	ERP	190,03	-286,40	-96,37	MSEK
Phase 2	EI-1	13,68	-2,42	11,26	MSEK
Phase 3	ERP Upgrade	26,93	-20,25	6,69	MSEK
Phase 4	E-business (35%)	63,19	-12,58	50,61	MSEK
Phase 5	EI-2	7,59	-3,10	4,49	MSEK
Phase 6	SSC	32,91	-5,31	27,6	MSEK
	Total:	334,35	-330,06	4,29	MSEK

Table 19: Summary of the DCF Analysis

In total, the investment programme as a whole yields a positive net present value of SEK 4.29 million. Figure 35 depicts the development of the total value of the investment platform along with the contingent investment projects.

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Evolution of the Total Value of the Investment Programme

	32,99	74,64	139,45	199,59	262,91	296,56	334,35
-8,70							
	-286,40	-288,07	-312,37	-323,97	-326,32	-328,36	-330,06

Time in years

PV Cumlative Investment Costs   Cumulative PV of Benefits   NPV
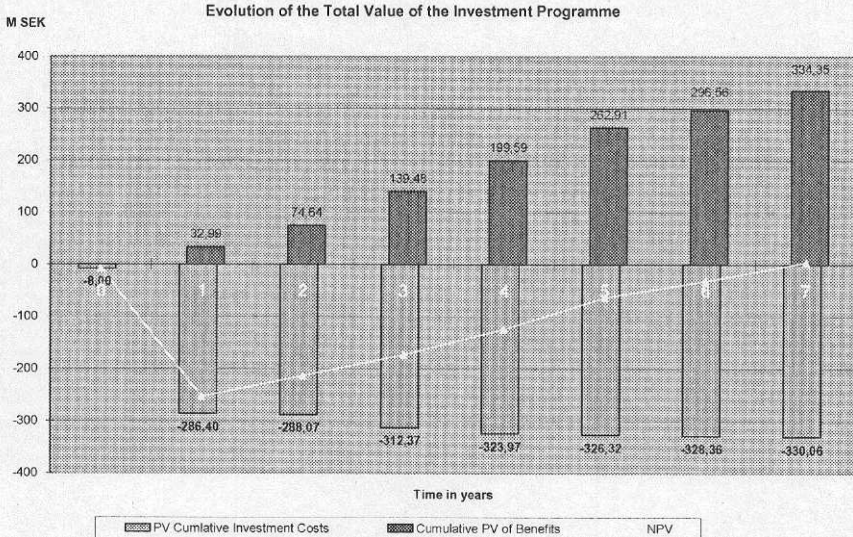
Figure 35: Evolution of the total present value of the investment programme

The graph shows that it is first seven years after the start of the investment programme that the investment breaks even. A straightforward interpretation of the NPV methodology would imply that the investment programme is profitable as it shows a positive NPV and, Skanska should therefore proceed with the ERP investment. In practice however, it is doubtful that many investment managers would approve an investment like this based purely on the business case presented to this point. The programme as a whole involves direct investment outlays in the excess of SEK 330 million. The investment in just the ERP platform, excluding the costs for the follow up projects, qualifies as the largest non-construction related investment ever made by Skanska. Although a relatively high risk-adjusted discount rate has been used in the analysis, the moderate NPV of the investment is not convincing. The anticipated benefits extend a long time into the future and in a volatile economic climate the business environment can change quickly, which could substantially change the outcome of the investment programme.

As discussed in the previous chapters the NPV approach is seriously flawed when it comes to evaluating interdependent investments. The methodology assumes a fixed investment strategy, while in reality the staged investment programme has a large degree of implicit managerial flexibility. This flexibility is valuable in responding to the uncertainty regarding the outcome of individual stages in the investment

process. The interdependency of the different projects contingent on the platform investment further entails that the underlying risks will change throughout the investment process. The application of the analysis model, developed in the thesis, on the contingent investment programme will therefore provide more insight into the true value of the platform investment. However, before the information generated in the DCF analysis can used in the binomial analysis model, the underlying risks need to be analysed.

6.3   Risk Analysis

No formal risk analysis concerning the financial outcome of the individual projects was performed in the original project evaluations at Skanska. Consequently, there was no direct data was available about specific risk factors. The risk analysis is therefore mainly based on the following sources:

- Inference from the original project data.
- Discussions with Skanska's IT managers
- Benchmark data from documented case studies.
- Industry data (statistical data from Statistiska centralbyrån (SCB) and Sveriges Byggindustrier).
- Accounting data (Skanska's annual reports).
- Secondary survey data.

The objective of the risk analysis is to estimate the volatility of the return on the investment programme as defined in Section 5.3.2. However, first the underlying risks in each individual project need to be identified. The risk analysis therefore starts with a sensitivity analysis of the results from the DCF analysis, where key variables are identified using Tornado charts. Next, the properties of the stochastic variables identified and possible interdependencies are defined in a Monte Carlo simulation for each of the projects. Finally, the cumulative value of the investment programme is simulated by combining the DCF models of the individual projects, and defining the return relationship (which is the simulated variable) for the periods corresponding to the planned start of each project. The Monte Carlo simulation thus provides multiple measures of volatility (assuming the volatility in not constant) which are used in the binomial evaluation model in Section 6.4.

6.3.1 Identifying the underlying risks

A large body of literature has focused exclusively on the implementation of ERP systems. In a recent survey of 117 organisations that had implemented ERP systems, 40% of organisations reported that within 12 months after completing the implementation they had failed to realise the anticipated business benefits, and 20% of the respondents had abandoned the projects completely (Dudley, Gelman et al. 2001). The survey further showed that in those cases where the benefits were achieved it took 6 months longer than expected and, in 75% of the cases there was a severe drop in productivity following the implementation. The respondents further indicated that assimilating the business processes to the system specifications was a much greater concern than issues related to the technical integration of the system itself. The implementation costs were reported to be 25% over budget on average, and the cost of supporting the system following the year of the implementation was on average 20% higher than anticipated (ibid).

In Chapter 5, two main types of uncertainty are defined. On one hand, there is project specific risk that is typically driven by uncertainty surrounding technical issues during the implementation, system performance, user adoption and the alignment of the system with the organisation structure and business processes. On the other hand, there is general market related uncertainty driven by changes in total demand for construction services. To incorporate the effects of the different sources of uncertainty on the value of the investment, a Monte Carlo simulation is used to derive a consolidated measure of volatility of the project return. However, before the outcome of the investment programme can be simulated, the key uncertain variables need to be identified. The first step in the risk analysis is therefore to identify the key drivers behind the success of the project. Those drivers are the variables that need to be simulated. An effective method for this purpose is to perform a sensitivity analysis of the main input variables in the DCF model. The approach adopted here is the so-called "Tornado Analysis". That is a static sensitivity analysis on each of the input variables in a specified model, where individual variables are iteratively varied within a pre-specified range, e.g. plus/minus 10%, while the all of the other parameters are held constant. The results are then tabulated and graphed in a descending order of importance. This analysis can thus be used to identify the main stochastic variables. A sensitivity analysis is performed on each of the DCF models in section 6.2.

The sensitivity analysis starts with the ERP project. The tornado chart for the ERP platform is presented in Figure 36. All underlying parameters in the aggregated DCF are included in the analysis. The graph however, only shows the ten parameters that had the greatest impact on the NPV result. Each parameter was tested within a range of +/- 20 %.

NPV ERP Platform

	0,00
Investment Cost	-334,08 ... -222,72
Discount Rate	0,24 ... 0,16
FM (T=3)	23,52 ... 35,28
Level of 3rd year Benefits	60% ... 90%
PM (T=3)	15,79 ... 23,69
Level of 2nd year benefits	40% ... 60%
HR (T=3)	12,92 ... 19,38
FM (T=4)	23,52 ... 35,28
PM (T=4)	15,79 ... 23,69
Preperation costs	-9,60 ... -6,40
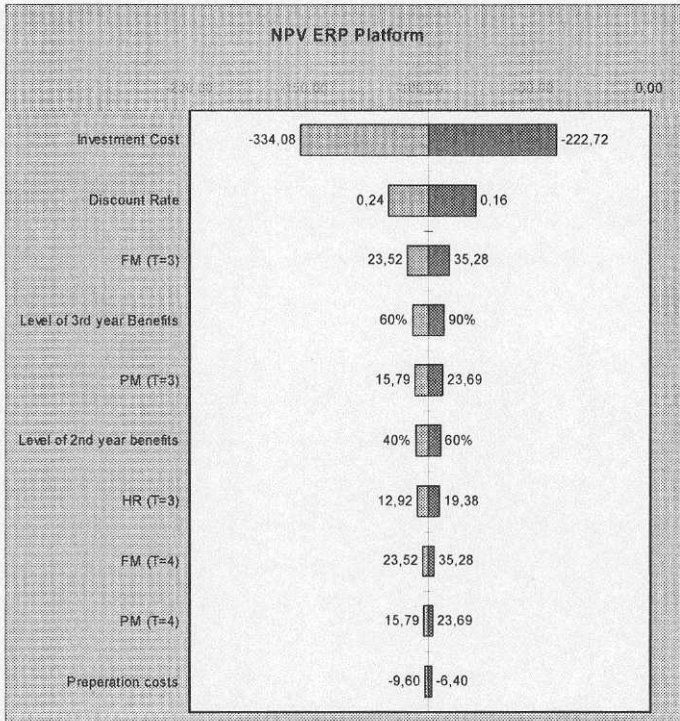
Figure 36: A Tornado Chart for the ERP platform analysis

The variable that has the single largest impact on the NPV of the ERP platform is the investment cost. The scope of the impact within the testing range is roughly 114 million SEK. Unsurprisingly the discount rate also has a substantial impact on the outcome of the evaluation from -70 million SEK on the up side to approximately -107 million SEK on the down side. Other variables have a somewhat lesser impact on the NPV ranging from 19 million to just under 4 million SEK. The analysis further shows that no single variable has a large enough impact to push the NPV of the investment over the breakeven threshold. The results of the tornado analysis for the other projects are presented in Appendix C.

6.3.2 Defining the stochastic variables

The Monte Carlo simulation focuses on the key stochastic parameters identified in the tornado analysis. The simulation, which is build directly into the DCF model, involves two main tasks. The first task is to define the distribution of the stochastic parameters in the model and, the second task is to identify and delineate possible correlations between the stochastic variables. Although it is difficult to predict exactly the relationship between the impacts of the individual stochastic variables, it is obvious that in many cases they are correlated. Mun (2004 p.113) argues that "as a rule of thumb, even when no good measures of correlation exist whether through lack of data or exact approximations, if the a priori expectations require a correlation, one should be included. The most commonly used rule of thumb is to include a -0.75, -0.5, -0.25, 0.0, 0.25, 0.5, 0.75 correlation for significant negative correlation, high negative correlation, mild negative correlation, no correlation, mild positive correlation, high positive correlation and significant positive correlation variables, respectively".

Each of the stochastic variables needs to be examined carefully and the underlying source of uncertainty identified. The key assumptions for the simulation of the ERP investment are discussed in this section. Details on the other investment stages are presented in Appendix C.

The benefits of the ERP system are twofold. First, there are direct benefits that are derived from cost savings directly attributable to the different system applications. This includes for example reduced mailing, paper and printing costs, wage administration and interest rate costs. Given that the system is implemented successfully (which is uncertain), these benefits are subject to low level of uncertainty but may fluctuate slightly from year to year depending on number and scale of ongoing projects. Second, there are indirect benefits, which are realised through the process-reengineering programme associated with the implementation. This category stands for bulk of the benefits or roughly 82% of the total annual benefits (cf. Table 10). The main part of these benefits concerns timesaving in key processes that run both centralised in the organisation, and decentralised in individual construction projects. The main uncertainty factors involve the accuracy of the estimated amount of savings achieved per unit of time, and the level of user adoption. The expected benefits were estimated by Skanska through a process analysis of the affected business processes.

Based on an analysis of the underlying parameters, the annual benefits derived from each of the three applications are assumed to follow a normal distribution with 25% standard deviation. The standard deviation is further assumed to increase by 5% from the third year onwards reflecting a widening confidence band. Benefits derived from the individual applications are assumed highly correlated (+0,5) through time, and significantly correlated internally (+0,75). That is, a high level of benefits achieved from one application, is likely to be associated with high level of benefits in the other applications, and vice versa. Note that the normal distribution allows the stochastic variable to take a negative value. This is justifiable here as negative net benefits can occur due to exceptional situations where the system may potentially cause large business disruption costs.

The standard deviations are derived from a separate simulation based on a detailed DCF model of the annual benefits of the individual applications. This simulation modelled both the effect of market uncertainty and technical risk on the expected benefits. Total market demand for construction services is assumed to follow a lognormal distribution with an annual standard deviation of 30%. The volatility estimate is based on quarterly data from SCB on the total number of building permits in terms of gross volume of floor area granted in Sweden, including both residential and non-residential housing. As the expected benefits are almost exclusively based on cost savings, the expected return on the investment is assumed relatively unaffected by the price volatility of construction services.

In the DCF analysis 50% of the full benefits are assumed to be achieved in the year of the implementation and 75% in the year following the implementation. The sensitivity analysis showed that these variables, i.e. the level of benefits achieved, have a great impact on the value investment. These assumptions are related to the *expected end-users acceptance* of the new system applications and *the success of the BPR*. Skanska realised that that it would take time for people to accept the new way of working with the system. At first, using the new system would therefore not be obligatory. That means that the employees are able to continue to work with paper printouts from the system rather than directly in the system. With time, however, stricter incentives to use the system are to be implemented progressively. It is therefore difficult to predict precisely the user adoption rate. Skanska can therefore influence the adoption rate to some extent by means of direct incentives, and through the level of resources devoted to user training. Furthermore, should the BPR progress better than expected, benefits will accumulate at a faster rate and equally, should the effort on the BPR be unsuccessful, it will take a longer time to

achieve the targeted benefits. Published case stories on ERP implementations also indicate that organisations must even be prepared for a potential drop in productivity immediately following the implementation, due to a steep learning curve in mastering the new applications (Stein 1999, p.60). It is difficult to determine a particular distribution of the rate at which the full potential of the system capabilities materialise. The levels of targeted benefits for the third and fourth years, is therefore assigned a uniform distribution with +/- 20% of the expected value.

Once the properties of the key stochastic variables have been defined, the project value can be simulated in a Monte Carlo simulation.
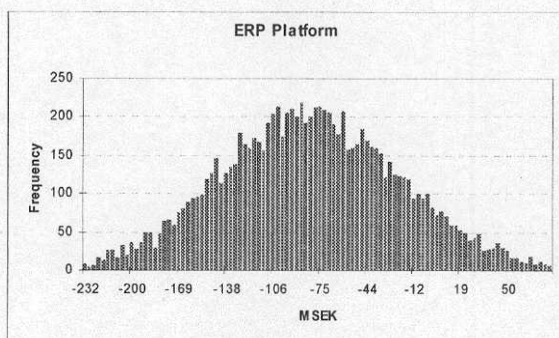
Figure 37: Frequency chart showing the distribution of the NPV of the ERP investment

Figure 37 shows the frequency chart from a 10.000 trials simulation of the NPV of the ERP investment using the assumptions defined above. The spread of the distribution is considerably wide. The mean and median of the distribution are close to the expected value from the static DCF analysis of SEK -90,43 million. The standard deviation is 62 million, which by mathematical convention implies that there is a 95,4% probability that the NPV of the investment will fall between SEK -214 and +34 million. It also implies that there is less than a 10% probability that the investment will yield a positive NPV as a stand-alone project.

This analysis is repeated for each of the projects in the investment programme. The details of the analysis are presented in Appendix C. Figure 38 shows the frequency and cumulative distribution of the simulation for the whole investment programme.
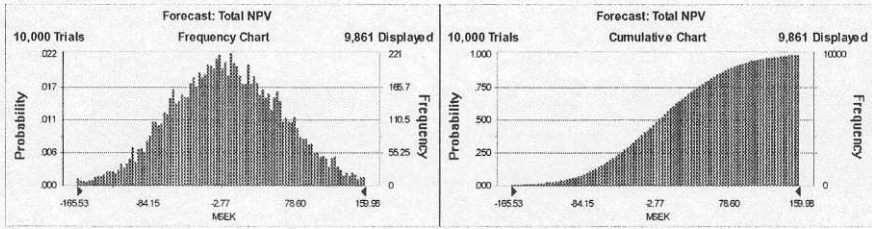
Figure 38: Simulation results for the whole investment programme

The simulation shows that there is approximately a 50% probability that the investment programme will have a negative return, assuming that Skanska will follow a fixed investment strategy.

6.3.3 Deriving the volatility of the rate of return

The forecast variable used to measure the volatility for the real options model is defined through the following relationship (described in Chapter 5):

$$\ln\left(\frac{PV_1}{PV_0}\right) = \hat{r}$$

Where r is the simulated variable which's standard deviation measures the volatility of the return on the investment. The equation is a simple transformation that converts between consecutive random draws of present time values in the simulation and the standard deviation of the rate of return, namely the volatility of the project value. To determine of the volatility of the return of the individual projects in the investment programme the simulation is first performed on each of the individual projects. The results are summarised in Table 20.

	ERP	EI-1	ERP upgrade	EI-2	SSC	E-business
Trials	9996	10000	10000	10000	10000	10000
Mean	0,09	0,14	-0,77	-0,11	0,18	0,13
Median	0,15	0,15	-0,74	-0,08	0,18	0,14
Standard Deviation	**0,37**	**0,19**	**0,26**	**0,26**	**0,32**	**0,34**
Variance	0,13	0,04	0,07	0,07	0,10	0,11

Table 20: Simulation statistics, assuming independent projects

The standard deviation of the rate of return of individual project is shown in bold. The simulation statistics show the varying degrees of risks in individual projects. As was to be expected, the ERP investment has the highest risk, or 37% volatility, while the first stage of the electronic invoicing project has the lowest individual risk, or only 19% volatility. What this simulation does not capture however, is the interdependence of the individual projects when analysing the investment programme as a whole. Therefore, the simulation is repeated, measuring only the incremental volatility of the total investment programme as it progresses. This is done using the same relationship as before, but now on the total incremental cash flows of the investment programme by combining the individual DCF models.

$$\ln\left(\frac{PV_{T+1}}{PV_T}\right) = \hat{r}_T$$

Where PV_T is the present value of the total incremental cash flows derived from time T (the time of the incremental investment), and PV_{T+1} is the present value of the total incremental cash-flows at time T+1.

	ERP	EI-1	ERP upgrade	EI-2	SSC	E-business (Uncorrelated)
Trials	9997	10000	10000	10000	10000	10000
Mean	0,09	-0,48	-0,39	-0,60	-0,10	0,13
Median	0,15	-0,43	-0,35	-0,55	-0,10	0,14
Standard Deviation	**0,37**	**0,32**	**0,31**	**0,28**	**0,25**	**0,34**
Variance	0,14	0,10	0,09	0,08	0,06	0,11

Table 21: Simulation statistics, assuming interdependent projects

This changes the results considerably as the volatility of the investment programme now decreases throughout the staged implementation. Note that the E-business project is not included in the incremental cash flow analysis. The study previously established that a large part of the benefits of the project could be achieved independent of the investment programme. However, 35% of the project value is directly dependent on the platform investment, and the projects leading up to the E-business implementation. The project value is therefore modelled as a nested compound option in the investment programme. This implies that the underling asset value develops independently of the investment programme. The value of the E-business project will therefore be evaluated in a separate lattice in the following section.

6.4 Real Options Analysis

The platform investment programme involves four embedded growth options *EI-1 and 2, the ERP upgrade and the SSC project*, and one nested growth option, *the E-business project*. The difference between these two types of growth options is that the embedded options are all subject to the volatility of the same underlying asset while the underlying vale of the nested growth option develops independent of the volatility of the investment programme. It is therefore necessary to first value the nested growth option before the total value of the investment programme can be estimated. The value of E-business project (i.e. the value of option to invest in the project) is then integrated into the valuation of the investment programme at the corresponding period.

6.4.1 Evaluation of the E-business project

The E-business project is to be implemented in five distinct stages over a five-year period. The successful completion of each individual stage provides an option to proceed with the next one. The project is therefore evaluated as a sequential compound option. As there were no other projects identified as directly affecting the project development, the volatility is assumed constant throughout the investment process. This entails that the binomial lattices are recombining. The input parameters required for the valuation are summarised in Table 22. The underlying asset value, derived from the DCF analysis in section 6.2, is the PV of the whole project at *year three* (excluding investment costs), corresponding to the start of the first stage (T=3). The volatility was derived in the previous section (cf. Table 21), and the risk-free rate, 5 percent is annual the return on a five year government bond. The investment costs for the individual investment stages are also derived from the DCF analysis, discounted to year 3.

Asset value	Volatility	Risk free rate	$e^{0.05}$
311.98	34%	5%	0.9512
$u = e^{0.34\sqrt{1/1}}$	$d = e^{-0.34\sqrt{1/1}}$	$p = \dfrac{e^{(0.05)} - 1.405}{1.405 - 0.7118}$	$1 - p = 1 - 0.49$
1.4049	0.7118	0.4898	0.5102
Investment costs stage 1 (X_1)	Investment costs stage 2 (X_2)	Investment costs stage 3 (X_3)	Investment costs stage 4 (X_4)	Investment costs stage 5 (X_5)
8.45	11.60	16.70	6.62	5.70

Table 22: Input parameters for the evaluation of the E-business project

Following the model in Chapter 5, the valuation starts with the underlying value lattice. The value lattice is derived forward, where the first step in the lattice is the PV of the project derived from the DCF evaluation. Table 23 shows all the lattices used to evaluate the E-business project.

Each step in the value lattice shows the *up (u)* and *down (d)* movements in the project value based on the volatility of the underlying asset. The first two steps are for example:

$$311.98 * 1.4049 \text{ (u)} = 438.31 \text{ and } 311.98 * 0.7118 \text{ (d)} = 222.06$$

Value Lattice	t=4	t=5	t=6	t=7	t=8
311.98	438.31	615.80	865.17	1215.52	**1707.75**
	222.06	311.98	438.31	615.80	865.17
		158.05	222.06	311.98	438.31
			112.50	158.05	222.06
				80.07	112.50
					56.99

Lattice 1	X₅=5.70				
307.54	433.65	610.90	860.02	**1210.10**	**1702.05**
	217.39	307.07	433.16	610.39	859.48
		153.15	216.90	306.56	432.61
			107.34	152.63	216.36
				74.65	106.80
					51.30

$Lattice\ 1 \quad X_5=5.70$

$Lattice\ 2 \quad X_4=6.62$

Lattice 2	X₄= 6.62				
302.12	427.95	604.91	853.72	1203.48
	211.69	301.08	426.86	603.76
		147.16	210.60	299.93
			101.04	146.01
				68.03

Lattice 3	X₃= 16.70			
287.74	412.84	589.02	837.02
	196.58	285.20	410.16
		131.27	193.90
			84.34

Lattice 4	X₂ = 11.60		
277.25	401.80	577.42
	185.55	273.60
		119.67

Lattice 5	X₁=8.45	
269.210	393.35
	177.10

Combined Lattice					
269.21	393.35	577.42	837.02	1203.48	1702.05
	177.10	273.60	410.16	603.76	859.48
		119.67	193.90	299.93	432.61
			84.34	146.01	216.36
				68.03	106.80
					51.30

Table 23: Evaluation lattices for the E-business project

The first of the intermediate lattices, lattice 1 values the longest-term option, or the last step in the staged implementation. Contrary to the value lattice, the intermediate lattices are derived backwards, starting with the terminal values in the last column. These values are obtained through the value maximisation of exercising the option versus letting it expire worthless. For example, the investment cost for the last implementation stage in year 5 is SEK 5.7 million so the value in the top right cell

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in lattice 1 is Max (1707.75 (this is the value in the top right corner of the value lattice) – 5.7; 0) = 1702.5. Each of the end values in the lattice is derived in the same way. The lattice is then folded back applying backward induction using the risk neutral probability approach. For example, the value in the top row in the second to last column is calculated:

$$1.210,10 = [(p * V_{up}) + (1 - p) V_{down})] e^{-r\Delta t}$$
$$\Rightarrow 1210,10 = (0.4898 * 1702,05 + 0.5102 * 859,48) * 0.9512$$

This same procedure is applied all the way back to the first step in the lattice. This process is repeated for each stage of the investment process, where the preceding option lattice becomes the underlying lattice for the actual investment stage.

Lattice 5 is the last evaluation lattice and returns the total value of the staged investment project. The first step in lattice 5 shows that the total value of the E-business project is *SEK 269.10 million*. The final lattice in the table shows the combined lattice for all the staged investment process. Recall, however, that only 35% of the project value is attributable to the platform investment. That is the value of the nested compound option at year 3 is: 269.10 * 0,35 = **SEK 94.22 million**

6.4.2 *Creating the value lattice for the investment programme*

Now all the input variables for the final binomial valuation model have been estimated and the total value of the investment programme can derived. The input variables are summarised in Table 24 and the binomial parameters are calculated in Table 25.

Annual risk-free rate			5.00%
PV of the underlying			271
Number of steps per year (Δt)			1
$e^{-r\Delta t}$			0.9512
X_1 (ERP)	278.40	σ_1	0.37
X_2 (EI-1)	3.70	σ_2	0.32
X_3 (ERP upgrade)	35.00	σ_3	0.28
X_4 (EI-2)	6.43	σ_4	0.25
X_5 (SSC)	11.01		

Table 24: Input parameters for the platform evaluation

Each year is modelled in one-step in the lattices. Increasing the granularity of the model, by devising each step into smaller periods will result in more precision; however, for easier graphical representation only one-step is used in the analysis that follows.

$u_i = e^{\sigma_i \sqrt{T/n}}$		$d_i = e^{-\sigma_i \sqrt{T/n}}$		$p_i = \dfrac{e^{(r\Delta t)} - d_i}{u_i - d_i}$			
u_1	1.4477	d_1	0.6907	p_1	0.4763	1-p_1	0.5237
u_2	1.3771	d_2	0.7261	p_2	0.4994	1-p_2	0.5006
u_3	1.3231	d_3	0.7558	p_3	0.5208	1-p_3	0.4792
u_4	1.2840	d_4	0.7788	p_4	0.5393	1-p_4	0.4607

<div align="center">Table 25: Calculated parameter values for the evaluation lattices</div>

The value lattice is created using the same procedure as in the E-business project evaluation. The only difference now is that the volatility is not constant throughout the whole investment period. From time 0 through time period 2 the volatility is constant at 0.37 (σ_1), from the end of period 2 through 3 it is 0.32 (σ_2), from the end of period 3 through 4 it is 0.28 (σ_3) and finally, from 4 through 5 it is 0.25 (σ_4). Consequently, the lattice is a combination of recombining and none recombining lattices, and grows at a faster rate than in the E-business project evaluation. The evaluation process is, however, the same.

The value lattice starts with the present value of the total investment programme, excluding the E-business project. Based on the calculations presented in Table 25 the up and down steps in the value lattice can be calculated as follows: u_1 * V_0 and d_1* V_0, where V_0 is the value of the underlying asset at time 0. Similarly in period two, the values in the lattice are $(u_1)^2$ * V_0, $u_1 d_1$* V_0, and $(d_1)^2$ * V_0. In period 3, the two value from the top row of the lattice are found by multiplying V_2*u_2 and V_2*d_2 respectively. The same procedure applies for period 4 and 5 using the parameters from Table 25.

0	1	2	3	4	5
271,16	392,57	568,34	782,67	1 035,58	1 329,71
	187,30	271,16	412,70	591,53	806,51
		129,37	373,42	546,05	759,54
			196,90	311,91	460,69
			178,17	494,09	701,15
			93,95	282,23	425,27
				260,53	400,50
				148,82	242,92
				235,74	634,42
				134,65	384,80
				124,30	362,39
				71,00	219,80
					334,53
					202,90
					191,08
					115,90
					302,69
					183,59
					172,90
					104,87
					159,61
					96,81
					91,17
					55,30

Figure 39: Event lattice describing the evolution of the value of the investment programme

The shaded areas in the diagram are merely for illustrative purposes, in order to show how each branch in the value lattice expands.

6.4.3 Deriving the total value of the investment programme

At each stage of the investment programme, the company can decide whether to proceed with the next phase or abandon further implementation. As all the investment stages are contingent on each other, implementing phase II is not possible unless phase I is completed, phase III is not possible without completing phase II and so on. The investment is therefore evaluated as a sequential compound option where each phase is essentially an option to proceed to the next phase.

The option valuation is performed in five steps, where each step corresponds to the individual investment stages. As a result, five different option lattices need to be constructed. The evaluation starts with the longest-term option based on the event tree, and then the second longest option is evaluated based on the first option lattice and so on until the first investment stage, which derives the total value of the investment program. The end values in each of the intermediate value lattices are based on the maximum of either continuing to the next phase of the investment program or abandoning further investments.

The final project in the investment programme is the Shared Service Centre. The project can be implemented immediately following the start of the EI-2 project or at any time up to the end of year 5. This gives an implementation window of one year.

The project is therefore modelled as an American compound option which can be exercised at anytime during this period. In practice, however, given the low granularity of the model, this means that there are two implementation opportunities, at the end of year 4 and 5 respectively. The process of deriving the lattice is in principle the same, except that now, at year 4 the possibility of an early exercise of the option needs to be considered. Starting from the back of the lattice in year 5, the terminal values are the determined by the maximisation of exercising the option or letting it expire worthless. This equals: Max $(V_5 - X_5; 0)$, where V_5 is observed from the value lattice derived before. This procedure is performed to derive the last column in the lattice. In year 4, the values are derived based on the maximum of exercising the option early or waiting. The exercise rule is:

$$\text{Max} \left(\text{Max} (V_4 - X_5; 0); ((p_4 * C_5^{up}) + (1 - p_4 * C_5^{down})) * e^{-0,05}) \right)$$

Where C_5 stands for the up and down states of the value of the (call) option derived from the last column in the lattice. That is, the maximum of early exercise at year 4, which is the maximum of the value derived from the value lattice from year 4 and zero, or the value of keeping the option alive which is derived using the risk-neutral probabilities and discounting using the risk free interest rate. The analysis showed that it was never optimal to exercise early in year 4.

0	1	2	3	4	5
262,59	383,56	558,86	772,71	1 025,10	1 318,70
	178,29	261,69	402,74	581,06	795,50
		119,90	363,46	535,58	748,53
			186,94	301,44	449,68
			168,20	483,62	690,14
			83,98	271,75	414,26
				250,06	389,49
				138,34	231,91
				225,26	623,41
				124,18	373,79
				113,83	351,38
				60,53	208,79
					323,52
					191,89
					180,07
					104,89
					291,68
					172,58
					161,89
					93,86
					148,60
					85,80
					80,16
					44,29

Figure 40: Intermediate Option lattice for the SSC project

The second to last stage in the investment programme is the EI-2 project, which can be implemented at the cost of SEK 6,43 million (X_4). This project is assumed to have a fixed window for implementation in year 4, following the ERP upgrade. The project is therefore modelled as a European type call option with a fixed expiration date. Year 4 is also the time in which the first stage of the E-business project is planned to start. The value of the E-business option is therefore added to the terminal values of the underlying value lattice, which in this case is the option lattice for the SSC project. The lattice is then derived in the traditional manner, taking the maximum of values from exercising the option or letting it expire worthless.

$$\text{Max } [C_4 + \text{Value of E-business option} - X_4 \text{], or}$$
$$\text{Max } [(1.025,10 + 94,22) - 6,43; 0]$$

The rest of the lattice is then derived backwards to time 0, using the relevant risk neutral probabilities for each period, and discounting with the risk free rate.

0	1	2	3	4
334,47	459,12	638,30	856,22	1 112,90
	253,85	341,12	486,25	668,85
		199,34	446,97	623,37
			270,45	389,23
			251,72	571,41
			167,49	359,55
				337,85
				226,14
				313,06
				211,98
				201,62
				148,32

Figure 41: Option lattice for the EI-2 project

In year 3 the plan is to implement the ERP upgrade project. The lattice is derived like before, working backwards from the last column, taking the maxim of the value from either implementing the project or letting the option expire, and then using the risk neutral probabilities and discounting to fold the lattice back to period 0.

0	1	2	3
304,34	427,45	605,01	821,22
	222,18	307,83	451,25
		166,04	411,97
			235,45
			216,72
			132,49

Figure 42: ERP system upgrade

The next step is to evaluate the EI-1 project which is to be implemented in year 3. The lattice is derived by taking the maximum of exercising the project at the cost of SEK 3,7 million (X_2) or abandoning further implementation. The lattice is then folded back using the risk neutral probabilities.

0	1	2
300,99	423,93	601,31
	218,66	304,13
		162,34

Figure 43: Option lattice for the EI-1 project

The final lattice involves the decision whether or not to invest in the ERP project in year 1 or not. The exercise rule is the same as before, maximum value from either exercising the project or letting the option expire.

0	1
65,93	145,53
	0,00

Max [423,93 – 278,4; 0] = 145,53
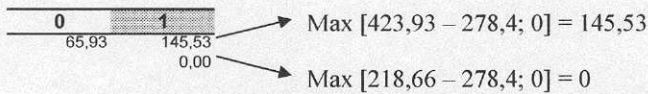
Max [218,66 – 278,4; 0] = 0

Figure 44: Final option lattice

It is interesting to note here that depending on how the uncertainty evolves in the first time period, it is only optimal to go ahead with the ERP investment should the up state occur, while should the down state occur the investment programme should be abandoned and the company should not invest in the initial ERP platform.

The final value at time zero is then derived using the risk neutral probabilities:
$$(0,4763 * 145,53 + 0,5237 * 0) * e^{-0,05} = 65,93$$

The analysis has now shown that the total value of the investment programme at time 0 is SEK 65.93 million. Subtracting the cost of the pilot project of SEK 8 million (see table 11), the net value of the platform investment and the contingent investment programme is:

MSEK 65,96 (total value of the contingent investment programme) – MSEK 8 (cost of the pilot investment) = SEK 57,96 million

The evaluation therefore shows that, although the ERP system by itself is not a profitable investment, it does provide a number of valuable growth options that fully justify the initial investment expenses.

6.5 Discussion

The value derived from the Real Options analysis is considerably higher than the results obtained from the simple DCF analysis. Although the DCF analysis showed that the investment programme as a whole was marginally acceptable, the ROA returns a much more decisive result of roughly MSEK 58 million. However, the real options analysis also shows that the profitability of the investment is contingent on the outcome of the pilot project. That is, should the pilot project show a favourable development of the total value of the investment programme the company should proceed with the platform investment. While on the other hand should the pilot project reveal serious implementation problems, further implementation of the current configuration of the investment programme should be abandoned.

This outcome underscores both the principle advantage, and one of the main drawbacks of the Real Options approach. When evaluating financial options, the value of the underlying asset is continuously observable. This is however, rarely the case when dealing with project evaluation. It is therefore important that the pilot project be designed so that it will reveal as much information as possible about the potential outcome of a fully implemented enterprise system. The most important type of information that can be obtained during the pilot stage is about the technical risks that influence the implementation of the new system capabilities. This includes for instance, information about potential integration issues, information about end user acceptance, performance of the system, and how well the system supports the new work processes. Information about the demand for construction services, i.e. the number of new projects and order bookings received, will also accumulate during the pilot project. Under active management of the investment programme, new information is valuable as it changes the expected value of the investment. Should the company, however, pursue a fixed investment strategy, as the DCF approach presumes, new information is of no value.

What the results of the ROV further suggest is that the development of the value of the investment programme during the first stage is decisive for profitability of the investment programme as a whole. This implies that the management should perhaps reconsider the "big bang" implementation strategy of the ERP platform in favour of a more cautious staged implementation plan. It may thus be worthwhile to give up part of the anticipated cash flows in the first two years, and even take on additional implementation costs (for example additional testing and more user

training), in order to secure a technologically successful implementation of the enterprise system.
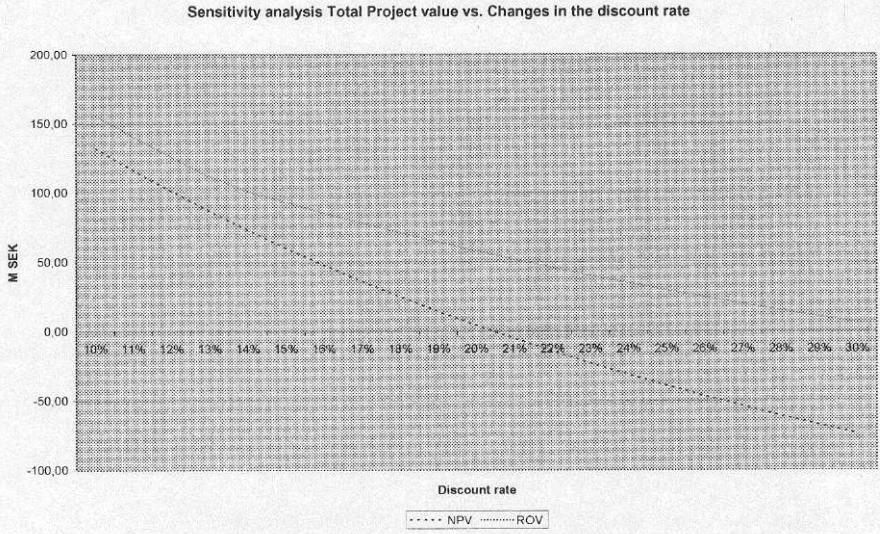

Figure 45: Sensitivity analysis showing the effect of changes in the discount rate on the results of the NPV and ROV analysis

A sensitivity analysis of the discount rate in both of the models shows a distinct difference in the two methodologies. A low discount rate gives a high positive NPV of the total investment programme and the two models produce similar results. However, Figure 45 shows that as the discount rate increases and the NPV decreases, flexibility becomes more important and the two methods provide very different results. In contrast with the NPV analysis, the ROV shows that the value of the investment is not a straight line, but asymptotically decreases to zero when the discount rate is increased. Although the option valuation shows a positive ex ante value, the project may still end up making a loss. However, by making future contingent investments conditional on new information on both external market conditions and the outcome of previous investment stages, the company is able significantly limit the downside risk.

CHAPTER 7 Conclusions

Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.

Sir Winston Churchill (1874 - 1965)

7.1 Reprise of the research objectives

The purpose of this study is to identify, analyse, and develop means to evaluate interdependent IT investments related to platform investments in the context of the AEC industry. The purpose is addressed in three research objectives:

- The first objective is to formulate a conceptual analysis framework to identify IT platform investments, and to formalise the evaluation with regard to the problems presented by this type of investment decisions with special relevance to the AEC industry environment.
- The second objective is to analyse and compare existing methods for evaluating independent and interdependent IT investments and to develop an evaluation model for deriving the value of IT Platform investments.
- The third and final objective is to test the framework and evaluation model empirically in a real industry case study.

The first two objectives have been addressed in Chapters 2 through 5. In Chapter 2, the current IT investment evaluation practice in the AEC sector was analysed through an interview study. The study focused on identifying the type of methodologies being applied, the types of costs and benefits included in the evaluation, and the major potential risk factors that affect the investment outcome. Furthermore, an effort was made to distinguish between different types of IT investments, in order to identify distinct analysis requirements tied to the *size* and

scope of the IT investments. In Chapter 3, a number of different methods used in IT investment evaluation were explored for potential applicability on IT platform investments. Next, in Chapter 4, a theoretical and conceptual framework was developed with the focus on addressing the specific challenges presented by IT platform investments (cf. section 1.5). The conceptual framework provided an approach to identify potential platform investments and to perform the evaluation with regards to possible contingent future investments. In Chapter 5, a four-step evaluation approach has been developed for IT platform investments. This approach is essentially a composite methodology that incorporates Discounted Cash Flow analysis, Monte Carlo simulation and a binomial option pricing model. A single measure of volatility was introduced providing means to quantify the effect of multiple uncertainties affecting the value of the IT platform. This consolidated volatility measure combines the different sources of uncertainty pertaining to the investment programme through the Monte Carlo simulation. Next, a binomial lattice model is formulated to derive the total value of the platform investment and potential contingent future investments. Finally, in Chapter 6, the evaluation framework and analysis model are applied on a number of interrelated IT projects at a major construction firm, and the results compared to those obtained through the traditional static DCF analysis.

7.2 Conclusions

When analysing the characteristics of large-scale IT investment projects, it quickly emerged that individual IT projects often entail important platform properties in terms of enabling related future investments to be implemented later on. Furthermore, the study observed that these types of investments are typically analysed as independent investment projects in construction firms. The interview study found that IT projects are seldom subject to rigorous financial evaluation prior to implementation. Generally, only simple capital budgeting methods were applied in the evaluation, such as the "Payback method" and simple "ROI calculations". It is now generally recognised that this type of methods are ill suited for capturing many of the subtle benefits generated by IT investments (cf. Chapter 3). A number of the interviewees implied that due to the limitations of the formalised methods, they were often circumvented by managers and important investment decisions instead based on other non-formalised methods, or purely on the managers' intuition. This is not a unique scenario in the AEC sector as many studies have shown similar practice in organisations in other industries (cf. Chapter 2). However, what makes this fact a more important issue in construction firms is that these

informal decisions apply predominantly to those investments that are made centrally in the organisations. However, in project dominated construction firms, a large part of the capital investments are made at the individual construction project level. Consequently, the responsibility for many of the firms IT investments often rests on individual construction project managers. They are in turn responsible for the profitability of their projects, and therefore hesitant to commit resources to investments in unproven information technology applications.

Like in other industries, sophisticated IT applications are certainly found at central levels of construction companies. However, the application of IT on the construction sites is limited. Individual construction project managers are likely to be less willing to make costly IT investment decisions based purely on their gut instinct, than IT managers operating centrally in the organisation are. The inability of the current evaluation methodologies to capture the full impact of IT investments is therefore perhaps a contributing factor in the low-tech reputation often associated with construction firms. Whether or not this is the case, it is evident that in general IT applications are increasingly becoming more integrated into essentially every level of organisations today. The level of integration between information systems, process and organisation structure is also increasing. Greater interdependence between individual IT investment projects can be seen as an inevitable consequence of this development. Therefore, the study emphasises the importance of considering the *interdependence* between different IT initiatives. IT projects should not be analysed in isolation when there is an evidence to suggest that an investment is related to other planned or ongoing investment projects. When an IT investment is identified as having a strategic value in the sense of enabling further investments in the future, it should be treated as a *platform investment*. By investing in an IT platform, a firm is essentially acquiring *options* on future investment opportunities. This type of investment may yield a low return when considered in isolation. However, doing so ignores the full value of the investment. *The individual investments should instead be seen as links in a chain of a multi-stage investment programme.* The study shows that the structure of IT platforms, and the subsequent contingent investments, intuitively and analytically, mirrors that of options.

IT investment is not a new phenomenon, neither AEC or in other industries. This raises the question of why to devote the present thesis for emphasising the importance of IT platform evaluation now. Explanations are found in exploring the fact that information technology development is a fast changing. The needs of

organisations and industries also change, while at the same time the role and function of IT within organisations develops. In the early stages of the computerisation era the characteristics of IT investments where quite different from that of today. The size of the investment cost and the complexity of the applications are several orders of magnitude larger now than those of the 1970s. Initially the computer's operating systems and application software were integrated into closed systems, generally designed for very specific purposes (Cash, McFarlan et al. 1992). This was a way to optimise the "limited" computing power available at the time. The computer companies developed and sold both hardware and software. This provided them the attractive advantage that their customers essentially became stuck with the system they selected. If newer and better software applications became available from another vendor it was difficult to change systems. This involved that the company would need to abandon the whole current system, including both hardware and software. Therefore the choice of the system vendor was very critical as a company would in principle be stuck with the vendor for many years to come (Wikforss 2003). This may have been acceptable for large companies in industries with a good control over the whole design, production, marketing and sales process. However, the multiplicity of stakeholders involved in the complex and temporary supply-chain in each construction project made this type of solutions unattainable for the project dominated AEC industry. For extensive computerisation of the AEC sector, all the actors would have had to invest in the same system.

Today this situation has been reversed. Software applications are now generally independent of the type of hardware they run on. Large enterprise systems are becoming increasingly modular, allowing applications from multiple vendors to be run on a single operating platform. The Internet has further opened up immense opportunities for AEC organisations. Webb-based systems allow for increased application integration and easy access through simple computer terminals. It is therefore perhaps first now that it is realistic to talk about extensive computerisation of the AEC sector. The increased flexibilities in constructing IT capabilities have introduced a new and important dimension in to the evaluation of this type of investments. That is, the objective of an evaluation is no longer limited to choosing between different system vendors (providing a fixed set of capabilities) but has to include the value of the flexibilities offered by different systems and implementation strategies. The evaluation further needs to capture the internal

interdependencies between different IT applications, and interdependencies between IT and the processes in which it is applied to create business capabilities.

The Real Options methodology developed in this thesis provides a formal framework for analysing the strategic value and managerial flexibilities in IT platform investments. However, how does management intuition measure up against the outcome of this type of formal valuations? This study offers no conclusive answer to this question. Several studies have attempted to test empirically the advantages of Real Options Analysis. Howell and Jägle (1997) studied how managers, intuitively or otherwise, value real growth options and compared the responses to the results from the Black and Scholes model (1973). This was a laboratory study involving 82 practising managers in nine leading companies representing various industries in the UK. The results showed that the managers valued the investments involving growth options unpredictably presenting both significant over and under valuations[42]. On average the respondents overvalued the investment cases by 78% compared to the theoretical option value obtained by the Black and Scholes model[43]. More recently, Miller and Shapira (2004) found evidence indicating specific biases affecting subjective valuations of options. They however found that both buyers and sellers price options below their expected values, and that the buyers' prices were consistently below the sellers' prices. They further argue that the evaluation of compound option investments may be additionally complicated as they may be subject to behavioural phenomena such as myopia (Miller 2002) and escalation of commitment (Staw 1981; Zardkoohi 2004).

Miller and Shapira (2004 p.281) point out an interesting paradox. One the one hand, there is substantial evidence that managers and organisations are ill equipped to handle Real Options decisions intuitively (Busby and Pitts 1997; Howell and Jägle 1997) and that they typically do not use formalised option pricing techniques for this type of evaluations (Graham and Harvey 2001). One the other hand, they argue that strategic decisions under uncertainty appear to conform to some general expectations based on real option theory (Kogut 1991; Folta 1998; Folta and Miller 2002). The authors suggest that the resolution of this paradox is likely to be that despite managers' biases, their strategic investment decisions can loosely conform

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[42] A survey by Busby and Pitts (1997) even found that some managers view real options embedded in their projects as undesirable as they may reduce organisational commitment to a the project.

[43] Pike (1997) however suggests that the large variation in the valuations obtained in the study could be attributed to faults in the research design, and thus possibly reduces the validity of the findings.

to normative real options models. In an recent interview study with 34 companies in seven different industries, Triantis and Borison (2001) found that the Real Options Approach to valuing real investments has established a solid, although limited, foothold in the corporate world in the USA. The study identifies three main corporate uses of real options: as a strategic way of thinking, as an analytical valuation tool, and as an organisation wide process for evaluating, monitoring, and managing capital investments. Companies in industries where large risky investments are common, such as in the oil and gas industry and life sciences, were further found to be most interested in the Real Options Approach.

7.3 Summary of Main Contributions

The research described in this study has been a multi-disciplinary effort. The study has incorporated insights from operations management, corporate governance, engineering, finance, and information system management. The scientific and practical contribution of the research is similarly divided into several domains. This section highlights some of the main contributions of the study.

1. *This study presents an improved framework for identifying and analysing IT platform investments.*

The initial aim of the research project, leading up to the thesis, was to develop means to improve upon the current practice of IT evaluation in the AEC industry. An interesting problem was identified related to a certain type of IT projects. Specifically, investments that involve only limited direct benefits that are not sufficient to justify the investments, using the traditional capital budgeting methods. These investments however have important implications in terms of enabling other potentially valuable applications to be implemented later on. The first step in towards improving the valuation of this type of investments is therefore to formally recognise these distinct characteristics. Even without the application of the analysis model, the framework adds rigor to the evaluation. The framework provides an approach to explicitly formalise management's intuition regarding the value of strategic and managerial flexibility.

2. *The study develops an improved analysis model to evaluate IT platform investments*

The methodology provides a basis for quantifying the strategic value of IT investments in monetary terms without abandoning well-understood financial principles. The model captures the interdependencies between contingent

investments and incorporates the effect of uncertainty into the evaluation. It further does not exclude the possibility of using any of the other subjective methodologies described in Chapter 3, to support the decision making process. A consistent application of the methodology developed in this thesis on a list of potential IT platform investments will at minimum result in a relative ranking of mutually exclusive investment projects. This despite one may question the significance of the absolute accuracy of the number derived as an output of the evaluation model.

3. *The application of the analysis model shows that the value of IT platform investments are considerably higher than traditional DCF analysis suggest*

The application of the analysis model in Chapter 6 confirms that IT platform investments are difficult to justify as stand-alone investments. In order to realise the full benefits of these investments the evaluation needs to take into consideration the value of the future opportunities enabled by the platform. The evaluation framework and analysis model developed in the thesis, further presents a legitimate basis for demonstrating that the value of IT platform investments is often significantly more valuable than traditional evaluation methods indicate. The evaluation methodology using option based models results in increased estimates of the value of the investments because it better expresses the interdependence and complementary contribution of the different operating drivers making up the platform investments. An important difference between the standard DCF methods and the Real options approach is in how they deal with risk. According to standard financial principles, higher risk calls for higher required rates of return, i.e. investors need to be compensated for taking on risks. However, when there is flexibility to react to uncertain events, the Real Options framework implies that investments with higher risk can be worth more than otherwise identical investments involving lower risk.

4. *The framework provides a broader perspective of IT investments and an improved decision making framework for AEC firms*

The framework presents a realistic approach to define IT Platform Investments in terms of their capacity to generate business capabilities. The focus is therefore not limited to the technology itself but on the combination of technology, business process design and the organisational restructuring necessary to generate the desired capability. The framework developed in the thesis extends, and demonstrates the practical application of previous conceptual work by Kogut and Zander (1992), Kulatilaka et al. (1996), Kogut and Kulatilaka (2001) and others.

By providing a comparable monetary metric the results of the analysis can now be compared fairly with other capital investment alternatives throughout the firm. IT platform investments are option intensive investments. It is therefore likely that this type of investments will benefit from the possibility of a comparison with other short term and perhaps less risky firm wide investments alternatives. Consequently, the framework and analysis model show promise for improving the perception of long term IT Platform investments in AEC firms, in addition to providing an improved tool for managing the IT investment process.

5. Increased understanding of the evaluation of IT in AEC

The interview study in Chapter 2 provides a contribution to the existing literature on the evaluation IT investments in AEC organisations. The study offers new insight into what type of methodologies are being applied in this type of organisations and thus contributes towards an increased understanding of the application of IT in construction.

6. The study has contributed to the development and application of the Real Options Approach

This thesis also contributes to the field of real options pricing. First, a binomial option pricing technique is developed to evaluate multiple compound options with changing volatilities through a combination of non-recombining and recombining lattices. This approach extends the previous models that have been applied to this type of investments but have assumed a constant volatility throughout the option lifetime. To this date, there are still relatively few examples of the application of options pricing model on real investment cases. Therefore the application of the analysis model on the platform investment at Skanska is by it self an important contribution to the existing literature.

7.4 Suggestions for further research

All research faces limitations that create potential opportunities for future extensions and improvement. One major limitation of this work is that it focuses almost exclusively on the financial side of IT investment evaluation. Monetary-based assessments of IT investments are a central and necessary part of the information required for making well-informed investment decisions. Arguably however, they may not always be sufficient to ensure a multi-faceted understanding of IT enabled capabilities. Multi-criteria assessments, for example, offer an additional perspective, an analysis that goes beyond some of the existing

capabilities of purely monetary evaluation. An interesting extension of the research could therefore be to integrate this type of methods into the framework presented here.

As the analysis framework suggests the evaluation and implementation of IT platform is a dynamic process, requiring active management of the investment programme after the initial investments have been made. The study therefore leaves room for improvement through further integration of the financial evaluation into the IT project management area. There are obvious benefits to both the financial evaluation side and the IT project governance side from closer integration. Information generated through the IT management process can for example, provide an improved and more formalised channel of information about project risks into the financial model. On the other hand, the evaluation framework presented here provides project managers with a valid structure for managing the different stages in the implementation process in terms of expanding, delaying or abandoning additional stages.

Platform investments inevitably suggest a longer time horizon than is to be expected for an isolated investment IT project. An extend time period will consequently increase the risk of pre-emption or other competitive reaction from competitors, potentially reducing the expected value of the investment programme. The evaluation model should therefore be extended to more explicitly model the potential effects of this on the ex-ante investment value. This could for example be done by incorporating important insights from Game-Theory into the Real Options model. Some work has already been done in this area (see, e.g. a collection of articles in Smit and Trigeorgis (2004b)) but this has manly involved simple investment scenarios in duopoly environments. Therefore, it would be interesting to explore the possibility to extend this type of analysis to include the actions of multiple stakeholders in the AEC environment and apply the results on a real investment case. The project driven and multi stakeholder AEC industry makes this type of analysis even more interesting than, for example, similar investments in other industries. The need for different stakeholders to cooperate in temporary construction projects suggests that competitor reactions are likely to have positive, as well as negative impacts on the value of IT investments of the individual companies. The more efficiently and effectively the different actors can exchange information in the construction projects, the lower the total cost of the project can

be expected to be. This raises some interesting Game Theoretic implications of sharing the cost and benefits of IT investment between the different stakeholders.

The application of Option Pricing techniques on real investments is not without controversy. The analysis model relies on some strong assumption about the value of the underlying asset such as the Marketed Asset Disclaimer assumption. For this type of analysis to gain general industry acceptance, more empirical testing of this assumption is needed.

Appendix A: Interview guide

No formalised questionnaire was used in the interviews (in the interview study presented in Chapter 2) however; a prepared interview guide was used to ensure that the predetermined scope of the interview was covered. The following topics were in included in the interview guide.

How?

> What is the decision process?
> What methodologies are applied if any?
> To what extent is the process formalized?
> How would AEC decision-makers measure/quantify costs and benefits?
> Before the investment is made?
> After the investment has been put in place?
> What are the next steps if the investment takes place?
> Will there be a pilot study or full scale implementation?
> Is there any post-evaluation of the performance of the investment?

What?

> Criteria are important when evaluating the investment?
> Costs
> Benefits
> Risks

Who?

> Who are involved in the decision?
> Who Finances the investment?
> How do contractors share costs and benefits with other project stake-holders?

Appendix B: Describing Investment Risk

Risk-Handling methods can essentially be devised into two groups. The first group incorporates techniques that are principally aimed at describing the risks of given investment scenarios while the second group aims to incorporate the investor's perception of the project's uncertain outcomes within the net present value model (Pike and Neale 1996). This section briefly introduces some of the statistical methods used to describe risks.

Most of the risk measurement techniques which summarised in the Table 26 were initially applied in the context of financial securities evaluation but are now also widely used in other investment or project evaluation. The fundamental difference between asset pricing (pricing of securities) and project evaluation is that in asset pricing the investor has little or non control of the value of the asset, where as in project evaluation, the investor (decision maker) has the opportunity (flexibility) to affect the value of the project after the investment has been made.

Expected value	$E(X) = \sum_{i=1}^{N} P_i x_i$	Extends over all possible values (x_i) of a random variable X and returns the mean
Variance	$\sigma^2 = \sum_{i=1}^{N} P_i (X_i - \overline{X})^2$	Expected value of the squared discrepancy about the mean is called the variance
Standard deviation	$\sigma = \sqrt{\sum_{i=1}^{N} P_i (X_i - \overline{X})^2}$	Is the positive square root of the variance and measures the dispersion from the mean
Coefficient of Variation	$CV = \dfrac{\sigma}{E(X)}$	Calculated by dividing the standard deviation by the expected value
Covariance	$\sigma_{ab} = \sum_{i=1}^{N} P_i (X_{ia} - \overline{X}_a) * (X_{ib} - \overline{X}_b)$	A measure of the degree to which returns on two risky assets move in tandem
Beta β	$\beta = \left(\dfrac{\sigma_{aM}}{\sigma_M} \right)^2$	Beta is a measure of the relative volatility of a asset to the market or another portfolio of assets
Volatility	$= \sqrt{\dfrac{1}{n-1} \sum_{i=1}^{N} (X_i - \overline{X})^2}$	Measures of the tendency of the value of a risky asset to rise or fall within a given period of time

Table 26: Overview of common risk measurement techniques

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The statistical expression *expected value* is traditionally used in investment evaluation as expected monetary value. Given a choice among alternative actions, the expected monetary value criterion dictates the choice of the action with the highest expected monetary value. In the case of sequential decision-making, the use of the expected monetary value criterion is often applied in association with decision trees. The decision tree is basically a map of a decision process that involves a series of choice alternatives with outcomes that are subject to risk. Using simple expected values when evaluating complex investments is flawed because it fails to consider the full range of possible outcomes that might occur.

Variance and standard deviation
Finance was transformed with the publication of the Markowitz (1952) article on Portfolio Selection. He was first to observe that the portfolio with maximum expected return is not necessarily the one with minimum variance. He showed that there is a rate at which the investor can gain expected return by taking on variance, or reduce variance by giving up expected return. Later Tobin (1958) develop an method to identify efficient portfolios for individual investors, consisting of a risk less asset (cash or treasury bills) and a risky asset that are independent of the proportion of the investment balance. This made it possible to describe the investor's decisions as if there was a single non-cash asset.

Coefficient of Variation (CV) is a standardised measure of risk per unit of return and is often used to compare investments off different scales. The general rule is that the lower the CV, the lower is the relative degree of risk of the individual investment projects.

Covariance measures the degree to which returns on two risky assets move together. A positive covariance means that asset returns move together; a negative covariance means returns vary inversely. This measurement of risk is particularly important when considering a portfolio of different investments with different risk characteristics.

Beta is a risk measure typically used in a portfolio context to measure how the price or value of an individual security or asset moves with a wider portfolio, often the whole market or specific industry indexes. Beta is calculated using regression analysis. In the securities markets a beta of 1 indicates that the security's price will move with the market. A beta greater than 1 indicates that the security's price will

be more volatile than the market; while a beta less than 1 means that it will be less volatile than the market.

Volatility is statistical measure used to describe the tendency of the value of a security, market or investment project to rise or fall within a given period of time. Volatility is normally calculated by using variance or annualized standard deviation of the price or return.

Appendix C. Risk Analysis

This appendix presents the details of the risk analysis in Chapter 6.

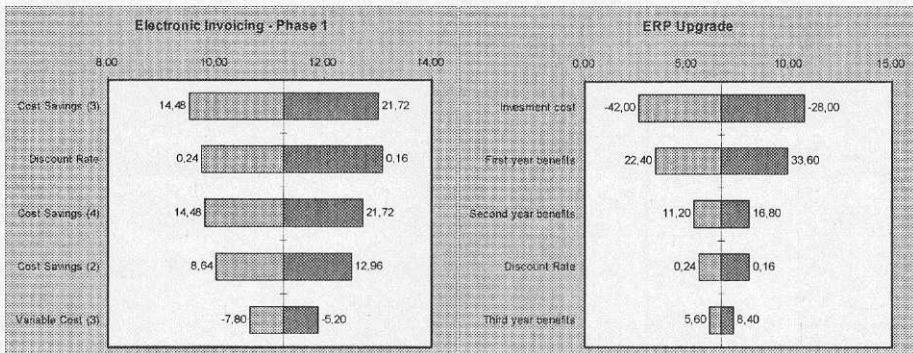*Identifying the underlying risks*

Figure 46: A Tornado chart for the EI-1 project and the ERP upgrade

The Tornado chart for the first stage of the electronic invoicing project shows a large variation of the NPV from a number of the input variables. The estimated costs savings three years from the implementation have the largest impact on the outcome of the project. The discount rate is the second most influential variable in the model, followed by the estimated net cost savings in the forth and third year from the project start.

The sensitivity analysis of the ERP upgrade investment further showed substantial variation in the NPV of the project from small variations from a number of key variables. The investment cost and the first year benefits are markedly most influential on the profitability of the project. The top five ranking variables in the analysis are presented in Figure 46.

For projects further on in the future, the relative impact of the risk adjusted discount rate increases. For instance, in the second stage of the electronic invoicing project, a 20% change up or down in the discount rate can mean a difference between a NPV

of roughly 3.5 million SEK or a NPV of close to 6 million SEK, which is over a 70% difference.

The profitability of the shared service centre is also most sensitive to the discount rate. The variation of the five most influential variables in the model has a relatively small impact on the total project value. The SSC project also has a high NPV in relation to the investment costs involved and it therefore appears to have a relatively low risk of returning a loss, given that the previous projects in the investment programme have been implemented successfully.
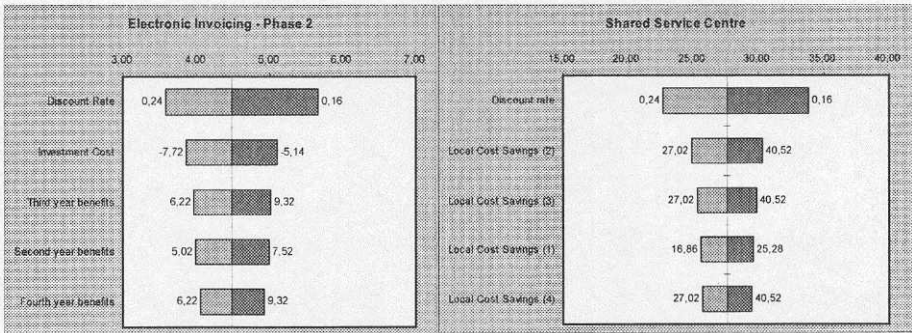

Figure 47: Tornado chart for the Shared Service Centre and the EI-2 project

The E-business project is clearly the single most attractive stage in the investment programme. The capabilities involved can be achieved at a relatively low cost, while the upside potential is large. This is further reflected in the sensitivity analysis as the investment cost does not rank among top 20 most influential parameters in the model. The E-business capabilities are planned to be implemented in stages throughout different divisions in the organisation, so that in the forth year full capacity is reached. This is clearly reflected in the tornado diagram where the four most influential variables are the total annual benefits in a reverse order. Note that the sensitivity analysis is performed on the total project value while only 35% of the net outcome of the project is directly related to the platform investment.
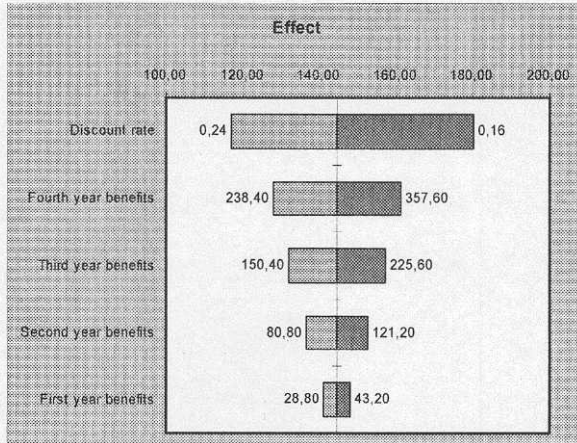
Figure 48: Tornado chart for the E-business project

The sensitivity analysis has provided essential information about the most influential parameters in the evaluation model. These are the key parameters that will be used in the Monte Carlo simulation, with two exceptions. One important result was that variations in the discount rate and the investment costs ranked high in many of the individual projects. Later, in the simulation and the real options model however, both these variables are assumed constant. The simulation focuses on analysing the effects of the stochastic cash flows on the return on the investment. This is however not to imply that investment costs can realistically be assumed to be known with certainty. Especially in the case of IT investments, this is usually far from the truth. Stochastic investment costs can be included in the real options model (CITE) but this would result in a much more complex model and significantly reduce the intuitiveness of the model. The analysis model therefore assumes constant investment costs; however, the analysis results are tested with relation to their sensitivity to variations in the investment costs.

The risk-adjusted discount rate will also be assumed constant in the simulation. The NPV approach presumes that the discount rates must be known and non-stochastic, that is they must evolve deterministically over time (For a detailed discussion on this see for example: Trigeorgis 1998 p. 38-50).
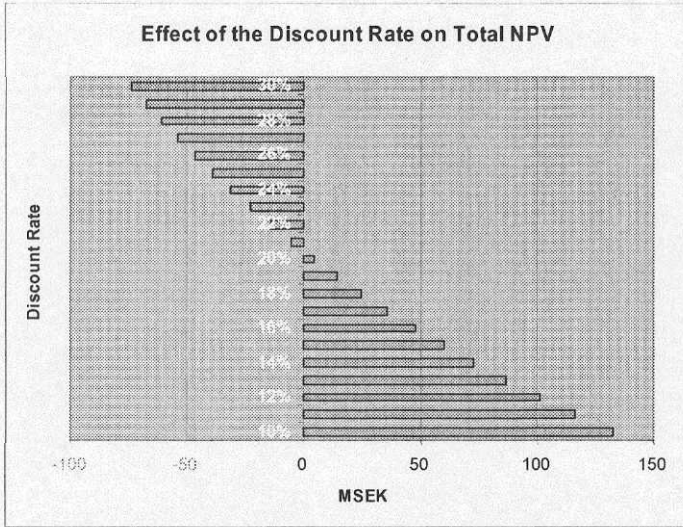
Figure 49: Sensitivity analysis of the discount rate in the DCF analysis

Figure 49 shows the result of a simple sensitivity analysis of the NPV of the whole investment programme in relation to the discount rate. The analysis shows that small variations in the discount rate have a major impact on the result of the analysis. A single percent increase can thus mean the difference between a positive or negative NPV of the investment and thereby changing the accept/reject decision.

Defining the stochastic variables

Electronic Invoicing – Phase I

The estimated annual cost savings are assumed to follow a normal distribution starting with a 10% standard deviation and an increasing confidence band of 5% year each passing year. The estimated benefits each year are further assumed to be highly correlated (+0.5), that is, a high level of benefits one year are more likely to be followed by high level of benefits the following year. The variable costs (consisting of operating expenses and cost for scanning) are assumed to follow a normal distribution that is truncated at max three standard deviations on the upside potential, i.e. the costs can never be negative. The cost variables are further assumed to be significantly negatively correlated (-0.75) with the anticipated benefits, that is, the higher the benefits from the applications, the higher the variable costs. This is because most of the variable costs are directly related to the use of the applications; this includes for example the unit cost of scanning individual documents. Figure 50 shows the distribution of the NPV of the EI-1 project based on 10.000 trials.
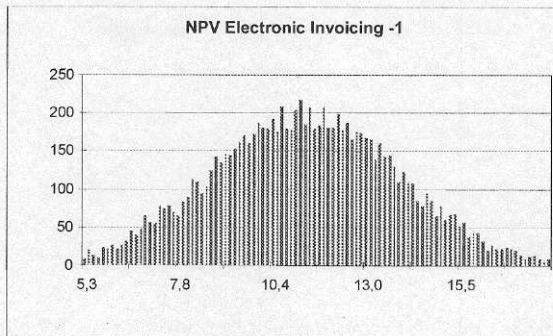
Figure 50: Frequency chart for the EI-1 project

ERP system upgrade

The annual benefits are estimated primarily based on cost savings from replacing old hardware, which will require less support and maintenance. The net benefits are however also subject to costs of integrating customised applications. These costs are subject to the outcome of potential integration issues and are the principle source of uncertainty regarding the net annual benefits. It is problematical to fit a specific distribution to these potential benefits. One widely used approach in this kind of situations is to define the properties of the stochastic variables in terms of potential implementation scenarios. The simulation therefore assumes a simple triangular distribution of the annual net benefits based on the expected outcome of three scenarios, the expected value where the implementation goes according to plan, high cost scenario (15 % lower net benefits) and lower than expected costs resulting in 15% higher net benefits. Each of the variables is fitted with this distribution and the variables assumed to be significantly positively (+0.9) correlated through time.
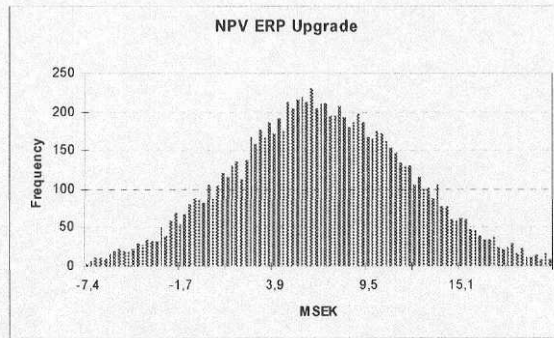
Figure 51: Probability distribution of the NPV of the ERP upgrade

E-business project

It is not an easy task to define the distribution of key variables for an investment that is to take place several years from now. Evaluations are however typically based on assumptions, and it is the level of confidence behind these assumptions, combined with all available data on the volatility of external variables that are the key roadmap in defining the stochastic properties of the parameters used in the DCF evaluation.

The anticipated benefits in the E-business project are to a large extent based on the premise of larger purchasing volumes for lower prices which leads to two important sources of uncertainty, a) uncertainty regarding the volume size, and b) uncertainty regarding the level of price reduction achieved. Further, to be able to achieve economies of scale the company needs to attract a sufficient number of suppliers willing to sign up to the service. This risk is somewhat mitigated through Skanska's strategic decision to assume the suppliers costs for the service during the first two years.

At the time of the initial ERP project evaluation, a major research programme focusing on the current and potential application of IT in the construction sector was underway. This programme, financed equally by the industry and the government, was a combined effort involving all the major actors in the Swedish AEC industry and a number of academic researchers. One project focused specifically on plans for implementing electronic trading in the sector. The results of the study showed that companies in the industry generally agreed that there were immense potential benefits from implementing e-business solutions (Sedig 2000 p.42). Most of the

responding companies indicated however that they would prefer to wait and see how the technological solutions would develop in the near future, before deciding to invest in this type of capabilities. The main risks identified were uncertainties regarding the practical functionality of technology and the potential cost. Furthermore, the study that was based on interviews with over 270 actors on the market, gave relatively detailed information about the attitudes of both general contractors and potential suppliers towards participating in this type of service. This type of information is very useful in defining the confidence level around the parameters used in the evaluation.

The net benefits, which include cost savings derived from frame agreements and support for project purchasing, benefits from increased collaboration with contractors and improved work methods, are therefore assumed stochastic with a log normal distribution, with a 25% standard deviation and a 5% increasing confidence band each year. The stochastic properties of the annual operating costs, including the internal administration and service fees are defined based on triangular distribution reflecting a low cost scenario (-15% of the base case), most likely scenario and a high cost scenario (+15% of the base case). The annual benefits are assumed to be significantly positively correlated through time and significantly negatively correlated with operating costs.
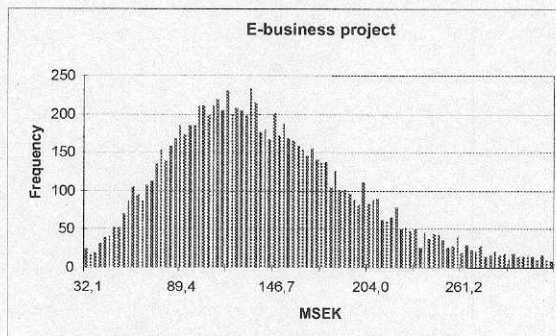

Figure 52: Probability distribution of the NPV of the E-business project

Figure 52 shows the frequency chart from 10.000 simulation trials using the assumptions above. The net present values are approximately log normally distributed with a median value of SEK 135 million and a standard deviation of SEK 63 million.

Electronic Invoicing – Phase II

For the second stage of the electronic invoicing project, the net annual benefits were assigned a truncated normal distribution with a 15% standard deviation and a 5% increasing confidence band. The annual benefits are further assumed to have a significant positive correlation (+0.75) through time. The annual operating costs are relatively negligible and are therefore assumed constant.
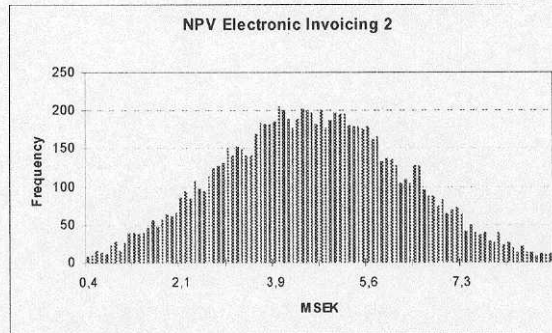

NPV Electronic Invoicing 2

Figure 53: Frequency chart showing the distribution of the NPV of the EI-2 project

The results of the 10.000 simulation trials of the NPV of the EI-2 project are shown in Figure 53. The analysis showed a zero percent possibility of a negative net present value and limited up side potential of roughly SEK 10 million.

Shared Service Centre (SSC)

The sensitivity analysis identified the annual local cost savings as the single most important variable in the DCF analysis. These benefits are mostly dependent of the successful execution of the process reengineering associated with the project implementation. Considering the relatively low operating costs associated with these actions the benefits can rationally be assumed never to be negative. It is therefore reasonable to suppose these stochastic benefits to follow a log normal distribution. The uncertainty regarding process adjustment is slightly lower at this stage of the investment process in view of the experience that should have accumulated through the previous implementation stages. However, much of the rationalisation is to take place decentralised in the organisation which entails an increased element of uncertainty. Therefore the variables are assigned a 20% standard deviation and a 5% increasing confidence band. The annual central cost savings are more controllable and are therefore assigned a simple triangular distribution with the nominal expected scenario and +/- 10% in the high/low

scenarios. The annual operating expenses and central phase out costs are assumed to follow a normal distribution which is truncated at two standard deviations on the upside to eliminate the possibility of non-negative costs. The variable costs are further assumed to be significant negative correlation with the stochastic benefits to reflect that high level of implementation is likely to be linked with higher costs. Figure 54 shows the frequency distribution of the NPV of the SSC project from 10.000 simulation trials.
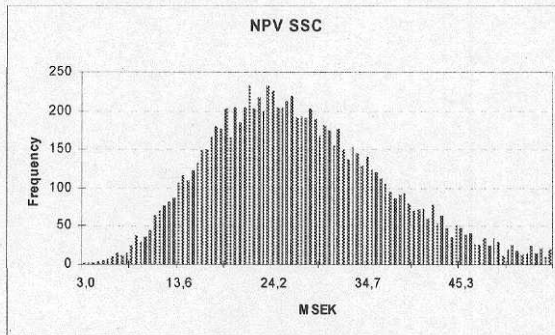

Figure 54: Frequency chart showing the distribution of the NPV of the SSC project

Appendix D: Acronyms

AEC	Architecture, Engineering and Construction
APT	Arbitrage Pricing Theory
ASP	Application Service Provider
BPR	Business Process Reengineering
CAD	Computer Aided Design
CAPM	Capital Asset Pricing Model
CE	Certainty Equivalent
CEC	Certainty Equivalent Coefficient
CIO	Chief Information Officer
DCF	Discounted Cash Flow
ERP	Enterprise Resource Planning
Ex ante	Beforehand (Latin)
Ex post	After the fact (Latin)
FM	Financial Management
GC	General Contractor
HRM	Human Resource Management
IRR	Internal Rate of Return
NPV	Net Present Value
MSEK	Million Swedish Kronor
PV	Present Value
PM	Project Management
ROA	Real Options Approach
ROI	Return on Investment
ROV	Real Options Valuation
WACC	Weighted Average Cost of Capital

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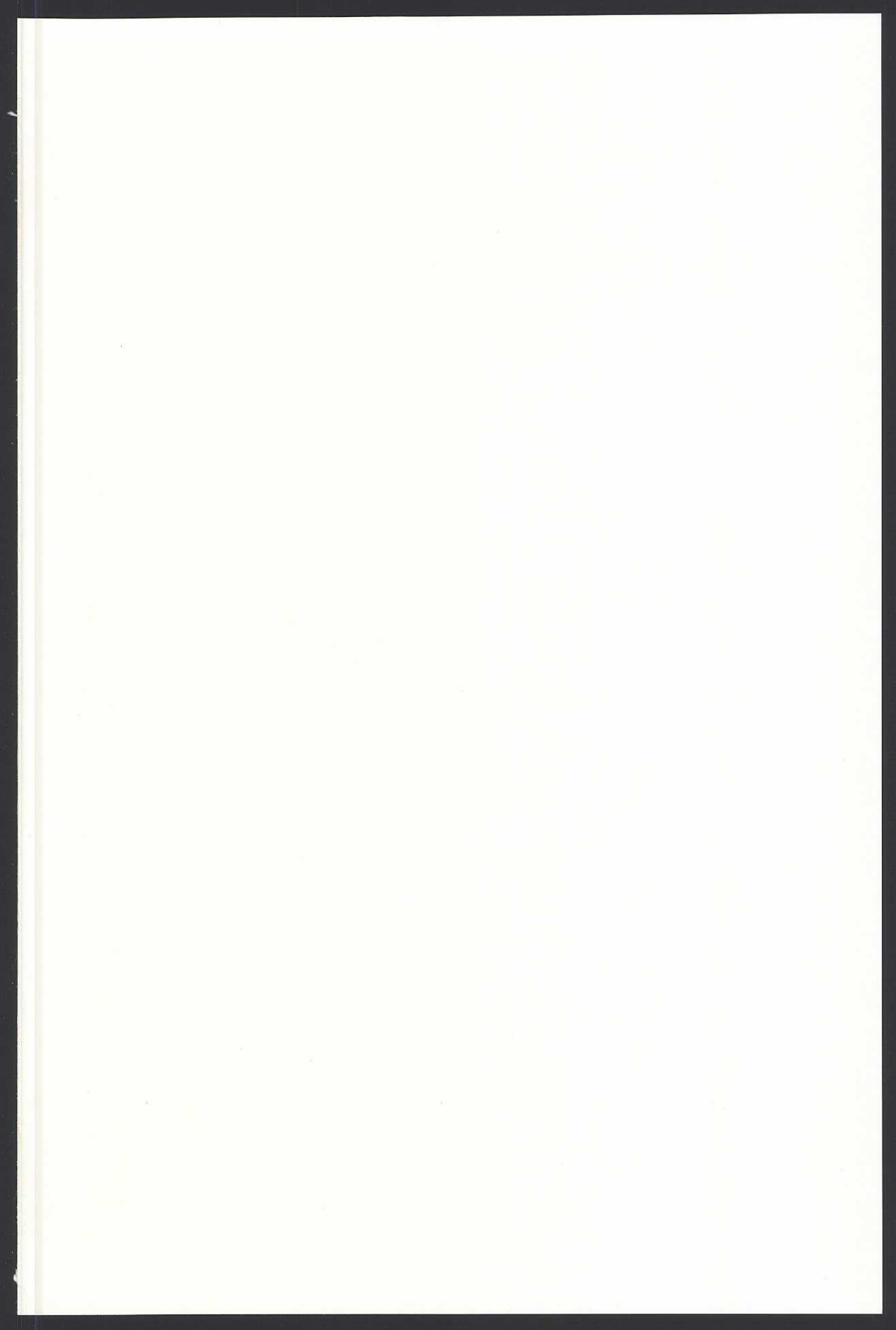
This thesis develops a structured evaluation framework and a comprehensive Real Options analysis model for evaluating IT platform investments. Many IT investments have platform properties in the sense that they are essential requirements for further technology investments. IT Platform investments however, often do not generate sufficient benefits to be justified as standalone investments. These investments may nevertheless be shown to be profitable when contingent future investments are included in the analysis. The traditional capital budgeting methods are nevertheless not suitable for capturing the full benefits, risk and costs of IT platform investments.