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–
Accounting for strategic flexibility

By

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Evaluating IT Investments in Construction - Accounting for Strategic Flexibility

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Abstract

When investing in IT applications, Architecture/Engineering/Construction (AEC) managers do not only obtain direct benefits, such as immediate cost and time savings, but also the option of adding future applications to the original investment as the business and technical environment changes. Traditional discounted cash flow models do not account for managerial flexibility, whereas qualitative evaluation models require decision makers to agree upon an abstract measurement scale. Probabilistic models, such as real options and decision-analysis, explicitly model risks and therefore quantify the value of flexibility in monetary terms. A real option model links uncertainty to the value of an underlying traded asset and therefore produce an objective measure of the value of flexibility. The major limitation of this methodology is that its applicability is restricted to model risks that are external to the investing organization. We conducted a case study that investigated he value of adding a request for information (RFI) automation tool to a general contractor's enterprise resource planning (ERP) tool. The study showed the major risk to be the adoption rate of architects; and that there exists publicly traded software companies the stock prices of which can be to estimate this risk. As a result, it is possible to construct a real option model to measure the value of this flexibility. In another case study, a contractor considered investing in a pilot project to investigate the feasibility of company wide wireless inspection system. Since the risks are internal, a simpler decision

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analysis model is used instead of a real option model to evaluate the value of the pilot project in view of the information it is expected to generate. The results show that it is possible to quantify the value of managerial flexibility for IT investments in the AEC industry but that the proper method to use is contingent on the nature of the investment project.

Introduction

The evaluation and justification of IT investments constitute an important problem in all major industries. The costs and benefits associated with IT investments are uncertain and difficult to measure even in relatively stable environments such as an automobile plant. Numerous researchers (e.g., (Björk, 2001; Clark et al., 1999; Haymaker et al, 2000)) have shown that information technology can support and automate the activities required to complete a construction project. However, evaluating information technology investments that support the processes in this complex and changing supply chain becomes even more difficult than in other industries. Not only is the outcome of an investment contingent on the performance of the investing party's own organization; the attitudes, skills and execution of the external parties that are involved in a construction project are prerequisites for a favorable outcome. Based on interviews with AEC top managers, we identified user adoption as one of the major uncertainties in AEC IT investments. The extent to which it is possible to manage user adoption becomes even more limited when the adopting organization is not the same as the investing one.

One concept that has received obtained substantial attention from industry and researchers is the value of flexibility (Dos Santos, 1991, Kim and Sanders, 2002) to make further investments into the technology. An investment in information technology is likely to have not only direct benefits, but it also provides an avenue for future investments. In interviews with AEC decision-makers, we have found evidence that the value of future flexibility in view of future user adoption is important in at least two cases. First, pilot projects in the implementation stage can be considered as an option to test if the technology is useful before investing in a full-scale implementation. Another case in which AEC decision makers have stressed the importance of future flexibility is in the evaluation of software platforms such as an ERP system. Platform investments are long term and they can often be extended with a range of different applications. Today, investing in these applications may not be profitable but the situation may change throughout the lifetime of the software platform if, for example, the adoption rate of the external parties change. This paper introduces the concept of real options to assess the value of flexibility in IT investments.

This paper will first discuss different methodologies to evaluate IT investments and how they account for the notion of flexibility. Next we will discuss the use of a real option methodology to evaluate AEC IT investments by evaluating the option of adding a Request For Information (RFI) application to an ERP platform. A second example uses a decision analysis approach to evaluate the value of a pilot project to investigate the feasibility of implementing a wireless inspection application on a full-scale level within a large general contractor. The paper ends with a discussion that summarizes the conclusions from the two test cases, before identifying implications for industry practioners and identifying opportunities for further research.

Methodologies for Analyzing Flexibility IT Investments

There are several methodologies for evaluating IT investment. In this section, we provide an overview of alternative models, such as discounted cash flows and qualitative methods, which do not explicitly calculate the value of future strategic options. Next we discuss probabilistic models – real options and decision analysis – and discuss their applicability for evaluating flexibility in AEC IT Investments.

Non-probabilistic Models

In discounted cash flow (DCF) methods, investments are represented as a set of negative and positive cash flows. Discounting is used to enable the comparison of positive and negative 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 analysis, cash flows are discounted using an interest rate that accounts for the time value of money along with project risk. IRR, on the other hand, seeks to calculate the discount rate that equalize positive and negative cash flows. For an investment to be profitable in the two frameworks, the sum of the discounted cash flows should be positive in NPV, or the rate of return should be greater or equal to the company's discount rate. DCF methods are widely accepted and understood among industry decision-makers. However, they are ill suited for accounting for management flexibility (Dos Santos, 1991) in view of future events. One approach is to complement the NPV analysis with qualitative criteria that measure flexibility and other less tangible properties of an investment. Flexibility, for example, could be a measure grouped under the "future orientation" criteria in Van Grembergen's IT balanced scorecard (1998) or a separate benefit in an information economics (Benson and Parker, 1989) analysis. The disadvantage of qualitative models is that the output is an abstract number. The meaning of an NPV of $100,000 is intuitive to most decision-makers. However, knowing that a project's score is 42 out of a 100 in an information economics model requires an understanding of the model and the context before an investment can be evaluated. Scoring models are therefore better at comparing different investments and aligning them with the overall corporate strategy than as a means to put a value on a specific investment. Next we will see how probabilistic models, such as real option and decision analysis it is possible to quantify the value of flexibility in monetary terms.

Real Options

In order to incorporate the notion of future flexibility into a quantitative evaluation model for technology investments, Dos Santos (Dos Santos, 1991) and others (e.g., (Kambil et al., 1993; Benaroch and Kauffman, 1999) propose the use of an option model. The underlying rationale for the use of real options is that the basic flaw of a traditional NPV appraisal models is the inability to account for the value of active management. For an option model to be applicable, the investment should have characteristics similar to financial options. The holder of a call option retains the right to, at a future date, purchase a stock at a predetermined strike price. He or she can therefore wait and see whether the stock trades above this price before making the investment. Similarly, a contractor who has invested in a software platform, such as an ERP system, has the option to, at a future date, invest in applications that the platform supports. The value of the investment in the ERP system is then not only a function of the potential cost and time savings on the first couple of projects but also dependent on the increased flexibility associated with being able to swiftly move to a web-based platform if and when such a move is deemed to be appropriate.

Option pricing models can be either binomial or of the form of Black and Schole's (1973) now classic model for option pricing. Many authors have suggested the use of option pricing to evaluate IT investments. While real options literature also covers postponement (Benaroch and Kauffman, 1999)and abandonment options (Copeland and Keenan, 1998) most researchers have focused their attention on a third category of real options, growth options. Growth options include scaling up, switching up, or scooping up an investment to exploit a prior investment in a sequential investment (Kim and Sanders, 2002). Real options have been tested empirically to evaluate IT investments such as object-oriented middleware platforms (Dai et al., 2000), the deployment of Point of Sale Debit services (Benaroch, 2000), digital processing software (Taudes et al., 1999)and the evaluation of software platforms (Taudes et al., 1999). Within the AEC domain, researchers have proposed the use of real options in project evaluation (Ford et al., 2001) and material procurement (Ng and Björnsson, 2002).

Problems with real options include acquiring the data necessary to support the calculations (Jong et al., 1999), and their applicability requires a number of assumptions about the behavior of the different variables to be fulfilled. The most important requirement is the existence of an underlying traded asset to which it is possible to tie the outcome of the investment. Real options are therefore applicable when the risks are external to the party making the investment. Vendor risk and risks concerning adoption by external parties are examples of uncertainties for which there often exist related traded assets. It would, in contrast, be virtually impossible to come up with a market portfolio, which duplicated internal risks, such as technical implementation or internal user adoption. In the example below we use a binary real option methodology to evaluate an investment for which the primary risk is internal.

Decision Analysis

An alternative to the use of real options is to extend discounted cash flow models so as to incorporate flexibility(Jong et al., 1999). The likelihood of future events can be estimated by experts (IT managers) using subjective probabilities (Howard, 1984) or be based on historic data bout the outcome of past investments. The flexibility can be calculated using decision trees or dynamic programming (Bonini, 1977) techniques. Similarly, accounting for risk aversion also necessitates the estimation of the decision-maker's utility curve. Techniques such as probability wheels or having the user choose between hypothetical investment alternatives can be used to obtain these estimates. Spetzler (1968) argues that a company should base its utility curve on the preferences of top management, since they are the best suited to represent the company's risk policy. An alternative is to use the risk preferences of the owner's of the corporation. A diversified investor in a publicly traded company is likely to be risk neutral towards the investments made by any individual company in his or her portfolio. The key strength of the decision analysis methodology is that since decisions trees do not require the existence of an underlying proxy asset, it can be applied to internal, as well as external risks. Another advantage of decision analysis is its simplicity compared to more complex real option models, which are sometimes difficult for decision makers to interpret. Furthermore, the process of assessing the subjective probabilities can serve as a forum for involving the decision-makers in the evaluation process. The major problem of using decision analysis is associated with the difficulty in assessing the probabilities; for example, can an IT manager really assess the probability that an external party will adopt a proposed application? A resulting consequence is that the value of the project will depend on which expert is assigning the underlying probabilities. Similarly, it is often difficult to determine an undisputable corporate utility curve since it not only requires accepted estimates of the parameters that reflect risk preferences, but also makes it necessary to agree on what underlying function to use.

Evaluating Extension Options through a Binary Option Model

This section discusses the application of a binary option model to quantify the value of extending an Enterprise Resource Planning (ERP) system. We first present the investment case before comparing the results when evaluating using an NPV and a Real Options methodology, respectively.

Background

Enterprise Resource Planning is a software architecture that facilitates the flow of information between all functions within an organization, such as procurement, marketing and sales, product design and development, logistics, finance and human resources. The following case discussion is based on a recent investment decision facing a large California contractor who invested in an ERP system. The primary objective of the investment is to automate and support internal processes such as payroll, human recourses and accounting. In the future, the contractor is considering adding applications that enables the communication with external parties that are involved in a project. The contractor is choosing between two ERP systems (ERP Basic and ERP Sophisticated), both of which, according to the contractor's IT department, are sufficient to fulfill the primary need of supporting the internal processes. The vendor of ERP Basic charges $800,000 for the software license. Implementation costs, such as business process reengineering, programming, hardware and training costs amount to $4M dollar. The license for ERP Sophisticated is more expensive ($1.1M) while the implementation costs are the same. Both systems have an estimated life span of 10 years. The license for the more costly ERP Sophisticated covers not only the present needs but also includes usage of a suite of project management applications with which the contractor can integrate external partners such as architects owners and subcontractors. The license covers modules for:

- Request for Information (RFIs)
- Field Project Reports
- Request for Proposals (RFPs)
- Bid Invitations
- Document Archiving
- Project Payments

Unfortunately, user studies have shown that the external partners are not yet ready to adopt such systems. Only 12% of the architects, for example, are ready to move the RFI process online, which means that the contractor would only be able to use this application on 12% of its projects. The result is that none of the potential extensions that are included in the ERP Sophisticated license would bring about enough cost savings to justify the added implementation cost. At first sight, there is therefore no reason to choose the more expensive ERP Sophisticated over ERP Basic since the two systems will provide the same immediate functionality. However, top management feels that the adoption rate of their external partners may go up in the future, in which case the add-on investment becomes profitable. How should they value the options to extend into other applications in the future? Are these options worth the extra $300,000 that the ERP sophisticated license costs? Below, we will use a traditional NPV model, as well as a binomial option model, to estimate the value of one of these options: the option to invest in a Request for Information (RFI) process.

NPV Model

The implementation of the RFI Automation tool is estimated to cost $500,000. An in-depth study shows that automating the RFI process on all projects could lead to yearly cost savings of $850,000. The key problem is that the architects have so far been very adverse towards this idea since they perceive that it shifts the balance of power towards the general contractor. They argue that the decreased costs of issuing RFIs enables the general contractor to send more RFIs in order to put pressure on the architect. The contractor estimates that today only 12% of the Architects is willing to adopt an RFI automation system and the yearly cost savings are therefore only $102,000 ($850,000 * 12%)

A classical NPV calculation shows that implementing the RFI application is not profitable today

Investment (I): $500,000 (distributed over first four months)
Total possible yearly savings (TV): $850,000
Adoption rate in month j (AR(j)): 12%
Cash flow due to monthly cost savings (c_j) = (AR(j))*TV = $102,000
Discount Rate (r): 4.95% (10-years US Treasury Bond)
Time Horizon of Investment (N): 60 Months

$$\sum_{j=1}^{4}\frac{(I/4)}{(1+r)^{j}}+\sum_{j=4}^{N}\frac{(c_i)}{(1+r)^{j}} \qquad (1)$$

The result of the above equation is that the NPV of this investment is negative (-$75,600), and the value of the option to extend is therefore 0. For the investment to break even, the adoption rate has to equal at least 14.2%. However, management estimates that the architects' adoption rate is likely to change. If the adoption rate rises in the future, investing in the RFI application can be profitable. The problem is that this flexibility is difficult to account for using the traditional NPV model.

A Binary Real Option Model

To model the value of the investment, we also used a binomial real options model (Ross et al., 1999). The underlying assumption is that each month the adoption rate AR either increases and decreases by a factor α_m. Let us assume that there exists an underlying asset which is a publicly traded asset, the value of which is closely related to AR. If the value of the project is a linear function of AR, the investment decision is then equivalent to investing in a proxy asset with a yearly standard deviation of $\alpha_{m.}$ Figure 1 shows a standard binomial adoption model to evaluate the investment where r is the risk-free interest rate. According to the binomial option model, if the value of the underlying asset is S(0) in month 0, then the value of the asset in month 1 will equal S(0) *)*(1+ α_y)/1+r with probability q and S(0) or S(0)*(1-α_y)/1+r with probability (1-q).

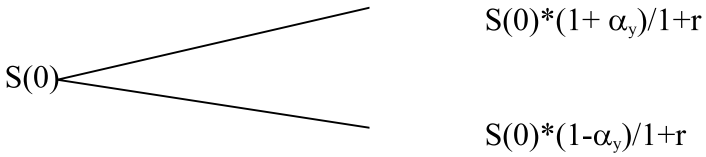

Figure 1 The Binomial decision model

In Figure 1, q is the risk neutral probability that makes the investor indifferent towards making the investment[3]. To find q, it is necessary to solve the equation:

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[3] It is important to note that q is not the actual probability that the asset will move up but the probability that makes the investor indifferent towards making the investment.

$$1= q*(1+ \alpha)/(1+r) +(1-q)(1- \alpha)/(1+r) \qquad (2)$$

Having obtained the risk neutral probability makes it possible to build an option model that estimates the value of investing in the RFI application. Each month, the architect's adoption rate will move up or down by the probability q. Or, in other words, the architect's adoption rate (AR(j+1)) in month j+1 will equal AR(j)*(1+ α) with probability q and AR(j)*(1 -α) with probability 1-q.

For the coming 5 years, the management team can, at the beginning of each month, decide whether they want to make the investment required to add an RFI application to the ERP system. They will then invest in the new RFI application if the current adoption rate is above a trigger rate (TR). The optimal Trigger Rate that maximizes the expected value of the adoption can be determined through simulation, as we will see below.

Given that the time horizon of the RFI is 5 years, investing in month i will then generate the cash flows as represented in Figure 1.

Month (j)	0	1	…	i-1	I	i+1	i+2	i+3	i+4	....	i+60	I+61	...	N
Cash Flows (c_j)	0	0	0	0	-I/4	-I/4	-I/4	-I/4	AR(j) *TS/ 12	AR(j) *TS/ 12	AR(j) *TS/ 12	0	0	0
AR=>TR	False	False	False	False	True									

Figure 2 Cash flows resulting from investing in the RFI application in month i.

If the contractor invests in the RFI application in month i, it will then incur negative cash flow during the first for months as it makes the investment (I). For the following 56 months, the company benefits will equal the total possible monthly (TS/12) cost savings multiplied by the architect adoption rate in month j (AR(j)).

Results from Simulation of a Binary Option Model

As mentioned above, the use of a real options model requires the existence of a traded asset that can function as proxy variable and enable the estimation of the standard deviation of the model (α). In this case, the key risk (the architects' adoption rate) is external to the investing organization and there exist assets that are subject to the same uncertainty. To estimate the yearly change in the architects' adoption rate (α) we used the stock price for 4 vendors of CAD systems for the first 24 months after the stock's initial public offering[4]. The companies were at that point fairly small; they only sold only a limited number of products, and architectural and engineering firms constituted the main target group for their applications. Table 1 shows the standard deviation for the monthly and yearly closing prices for the four stocks.

Table 1 Standard deviation of closing prices for the first 24 months after IPO for the stock for software companies that target architects and design firms

	Standard Deviation of Closing prices at the end of each month (α_m)	Corresponding Standard Variation on yearly basis (α_y) ($=\sqrt{12}*\alpha_m$)
Stock 1	13.0%	45%
Stock 2	0.9%	3%
Stock 3	42.1%	146%
Stock 4	4.4%	15%

For each adoption rate, the simulation model tested a wide range of trigger rates to determine the one that maximized return of the investment. For each pair of adoption and trigger rates, the simulation model computed the average payoff from 10,000 scenarios. Figures 1 and 2 show two typical scenarios for a yearly variation of an adoption rate of 15.4 % (the median for the four stocks) and a trigger rate of 20%. In Figure 1 the adoption rate reaches the trigger rate of 20% in month 49. The company then makes the investment and therefore incurs negative cash flows for four months before benefiting from cost savings for the next 56 months. The net present value of the investment is in this case $375,200.

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[4] The stocks of the four companies are traded at four different exchanges. The reason why we chose to use data for the first 24 months only was that one of the stocks had only been traded for 27 months.

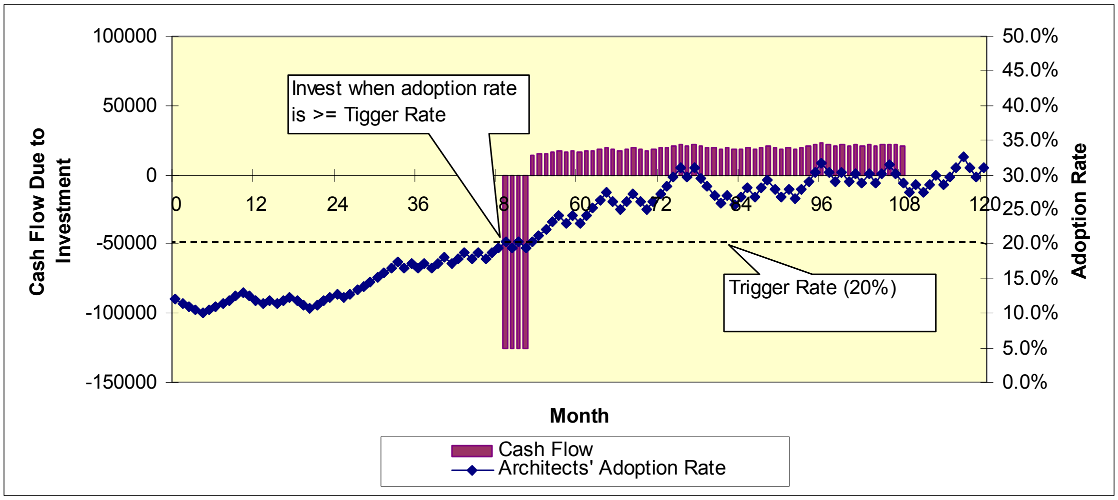

Figure 3 Scenario in which the investment is made. In month 49, the adoption rate reaches the trigger rate of 25%. The net present value of the investment in this scenario is $375,200.

Figure 2, on the other hand, illustrates a scenario where the trigger rate is never reached. The investment is therefore never made and the NPV of the scenario is 0.

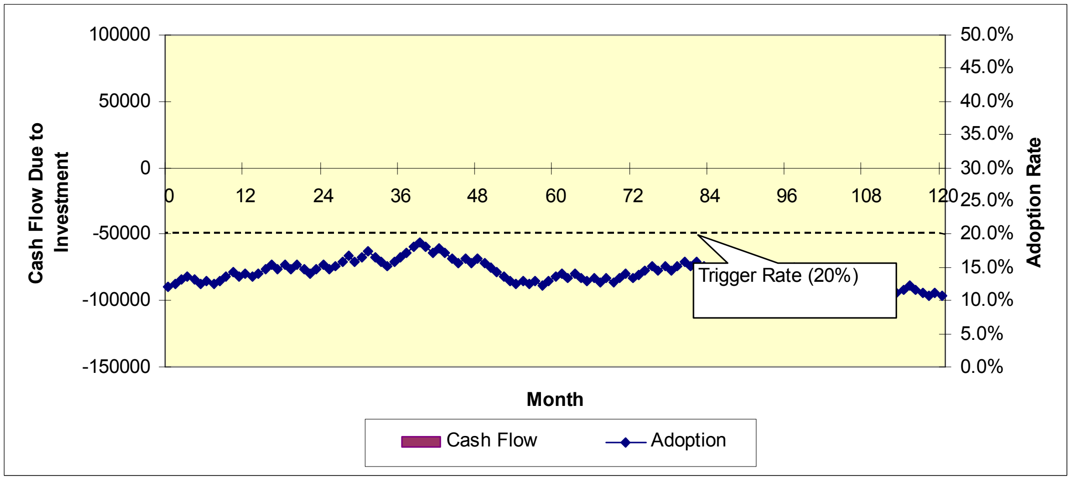

Figure 4 Scenario in which the investment is not made. The adoption rate never reaches the trigger rate of 20% and the net present value of the investment is $0.

Table 2 shows the average payoff each level for different variations of the adoption rate along with the associated optimal trigger rate.

Table 2 Results from simulation of binomial option model. The diagram shows the best trigger rate and expected NPF for each of the simulated variation of the adoption rate.

Yearly Variation of adoption rate (α_y)	**Best Trigger Rate**	**Expected NPV**
Min (3.1%)	14.5%	$57,579
1st Quartile (10.3%)	16%	$65,694
Median (15.4%)	17%	$78,087
Mean (45%)	25%	$160,986
3rd Quartile (50.0%)	26%	$164,680
Max (146%)	68%	$14,403

As we can see, the option has a significant value in all almost all of the cases. In particular, the Median and Mean of the variation generate a value of $78,100 and $164, 700. The simulations show that the option to invest in the RFI application has a value even if the change in the adoption rate is very small (3.1%). As expected, the higher the variation, the higher the value of the adoption. However, for very high variation the value is limited to the fact that there is an upper limit to the adoption rate (100%) and thus also to the maximum savings generated by the investment. Another anticipated result is that the higher the variation of the adoption rate, the higher is the appropriate trigger rate. In the model with the smallest variation (3.1%), it is fairly unlikely that the adoption rate will reach 14.5% only to fall below the break-even rate of 14.2% soon enough to make the investment unprofitable.

This model does not account for learning and network effects. As the technology is learned, both individually and at the organizational level, more processes can be speeded up or eliminated. The total cost savings of the investment could thus exceed the maximum level that is reached in a linear model when 100% of the architects adopt the technology. It has also been shown that network effects may reinforce the rate of adoption of new technologies (Saloner and Shephard, 1995). One could, for example, argue that it would be unlikely that the adoption rate reaches 60% in month 32 only to then decline to 25% in the following months.

Evaluating a Pilot Project using Decision Analysis

The following case is based on a real investment facing a large US general contractor. It investigates the applicability of using a decision analysis framework to measure the value of a pilot project.

Background

The general contractor is considering investing in a wireless system that can be installed on Palm Pilots or Pocket PCs to facilitate inspection by providing instantaneous access to checklists and reference manuals. Data can be shared in real time between companies and departments. The potential benefits from this investment do not only include improved risk management due to reduced errors and rework, but also include the possibility of enforcing best practice throughout the company. Implementing the application, full-scale and company-wide, costs $1000,000 and will take six months. According to an investigation by the IT department, the investment will thereafter, if successful, generate yearly cost savings of an estimated $600,000 for 5 years. The investigation also identified two major risks involved in the project. First, there is a technical risk involved in migrating the data from the old off-line system to the new application. The IT managers estimate that there is a 75% chance of successfully undertaking the data migration. Second, if the technical implementation is successful, there is also a user adoption risk. Based on earlier implementation projects, the management estimates that there is a 50% chance that the users will adopt the technology. If the technical implementation is unsuccessful, or if the users fail to adopt the technology the project will be abandoned and generate no cost savings. Using the same discount rate (4.95%) as in the previous scenario, the net present value model results in -$85,000. The project is therefore not profitable at this stage. However, to find out more about the feasibility of the wireless project, the IT department also considered undertaking a pilot project. By testing the technology on a single project, the IT managers hope to obtain better information about the risks associated with user adoption and technical implementation. The cost of the pilot project is $20,000, and it has no direct benefits except for better information about the profitability of the larger project. How can the IT managers evaluate the value of the pilot study?

Calculating Option Value through Decision Analysis

In this example, we will evaluate the pilot study as an option to make the larger investment at a later stage. In this case, the risks are internal to the company and it is therefore not possible to base the value of the option on some underlying proxy variable.

Instead, a decision analysis methodology is used to obtain the managers' subjective estimates of the different probabilities. The managers estimate four different probabilities:

1. The probability for the pilot study to succeed technically is estimated to 0.8
2. Given that the pilot study is a technical success, the success rate for the large project increases to 0.8.
3. Given technical success, the probability that the pilot users will successfully adopt the application is 0.6.
4. Given that the pilot users adopt the application, the probability of successful user adoption (given technical success) for the large-scale project is 0.7.

Equitation 3 below shows a typical utility curve (Howard, 1970) that is used to reflect the corporation's risk preferences. In the equation, x is an amount in USD and γ is the risk aversion coefficient. This function not only adheres to the delta property, which makes the valuation of an investment independent of the corporation's current assets, the function also has the convenient property that u(0) equals 0.

$$u(x) = \frac{1 - e^{-\gamma x}}{1 - e^{-\gamma}} \tag{3}$$

Based on the CEO's evaluation of hypothetical investment cases, it was possible to estimate γ to equal $1.20 * 10^{-7}$.

Results

Figure X illustrates the estimation of the value of the option if seen as an option to invest in the full-scale project. Knowing the outcome of the pilot project improves the estimates of the probabilities of successful technical implementation (P(T)) and user adoption (P(U)), respectively. The contractor can then decide to exercise the option of investing in the full-scale project only if the expected net present value (ENPV) is positive. As expected, this will only be the case if the pilot project was a success both from a technical and a user perspective. The expected utility is positive (259,800), while in the two other scenarios the contractor is better off not investing and thus obtaining an expected utility of 0. As a result, the expected utility of the pilot project equals $116,900 (0.75*0.6* 259,800), which corresponds to a certain equivalent of $117,800. Given that the cost of the pilot project was only $20,000, the investment is profitable. If the contractor were perfectly neutral, the expected net present value of the pilot would instead equal $154,700.

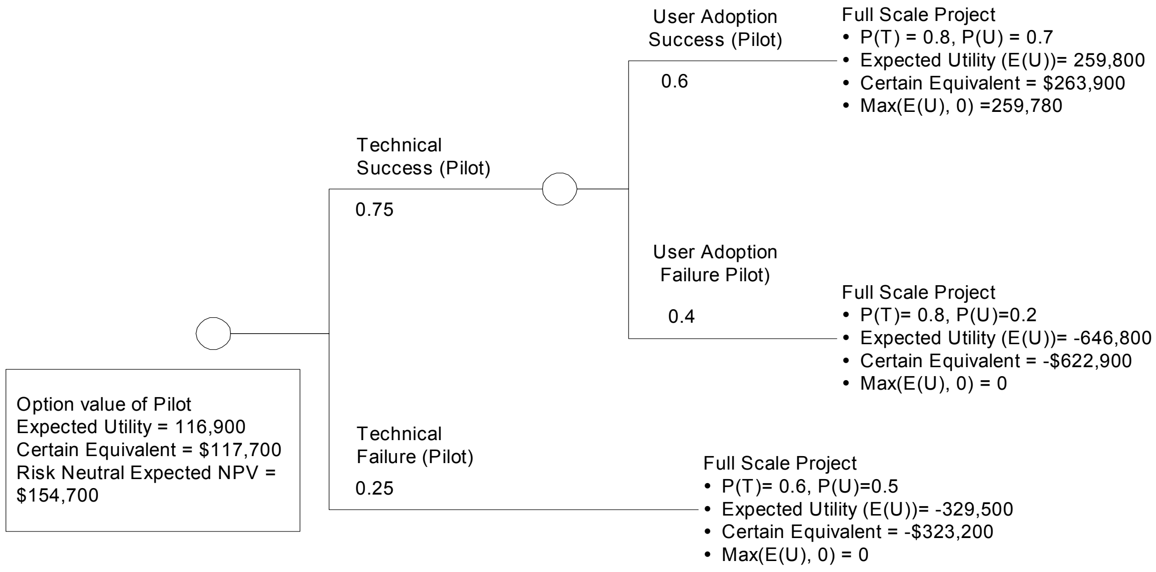

Figure 5 Calculation of the option value of the pilot project. Based on the outcome of the pilot project, the contractor will obtain better estimates of the probabilities of successful technical implementation (P(T)) and user adoption (P(U)), respectively. The contractor can then decide to exercise the option of investing in the full-scale project only if the expected utility (E(U)) is positive. The resulting estimate of the value of the pilot project equals $117,700.

It is also interesting to estimate the value of "clairvoyance", or the value of the pilot, if the outcome of the pilot project were perfectly correlated with the outcome of the full-scale project. If the contractor at the completion of the pilot project know with perfect certainty whether the full-scale project would be a success from both a technical and user adoption perspective, the expected value of the option would equal $485,200 at the start of the pilot project. This number serves as an upper limit of the estimated option value in this type of scenario.

Discussion

This article demonstrates the applicability of using real option evaluation models to assess the value of flexibility in two different types of IT investment scenarios. In the first scenario, the risk is external and can be linked to an underlying asset that is publicly traded. As a result, it is possible to use a real option model to determine the value of future flexibility. The main benefit is that this approach estimates a 'fair' market value, which is independent of any one decision maker's estimates of risk preferences and subjective probabilities. Nonetheless, it is important to involve the decision makers in order to determine cost savings and the relationship between the proxy variable and the outcome of the investment. In the scenario of the pilot project, the uncertainties were internal to the contractor making the investment. As a result, a real option approach was not applicable since there existed no proxy variable. A decision analysis tree could, on the other hand, model the value of conducting the pilot project to obtain improved information before deciding whether to go ahead with the full scale project. In Table 1, we summarize the two methodologies in terms of key strengths and key weaknesses in an AEC IT investment setting.

Table 3 Comparison of the applicability Real Option and Decision Analysis to evaluate IT investments in AEC.

	Real Options	**Decision Analysis**
Method to estimate underlying uncertainty	Volatility of underlying traded proxy asset	Decision-maker's estimate of subjective probabilities Outcome of past investments
Key Strength	Calculates 'fair' market value	Applicable to internal as well as external sources of risk
Key Problem	Only applicable to external sources of risk	Difficulty in assigning correct probabilities
Uncertainty to which methodology is appropriate	Vendor failure, External user adoption	Technical Implementation, Internal User adoption

This paper has important implications for industry practioners. The two scenarios illustrate the importance of incorporating flexibility when evaluating risky AEC IT investments. We also provide a methodology to apply a binary real options model to estimate the value of extending software platforms. Given that the choice of software platform is a major long-term investment for most contractors, it may be well worth considering devoting some additional effort to conducting a real option analysis. For smaller investments such as pilot projects, and in situations where the risks are private, the use of the simpler decision analysis method is likely to be the preferred alternative. Finally, this research points out that it is possible to quantify future flexibility, which facilitates the communication of its importance to top managers in AEC. An IT manager may intuitively understand the value of flexibility but find it difficult to emphasize importance vis-à-vis costs and direct benefits. The use of, for example, a binary option model, can make the value of long-term strategic investment can be made more explicit.

This work also opens several avenues to further research. The existence of a traded asset makes it possible for an investing company to hedge investments in the stock market. In the RFI scenario, the contractor could reduce uncertainty by shorting (borrowing in order to sell) stock of a provider of RFI automation software. An alternative would be to reduce the vendor risk by shorting stock of the provider of the ERP system. The optimization of risks and financing options have been subject of studies in other areas (Smith and Nau, 1995), and it would be interesting to investigate this concept's applicability to an AEC IT portfolio.

In addition, this paper discusses two scenarios where the risks are either internal or external. In situations where there exists internal as well as external risks, Smith and Lau (1995) have shown that it is possible to combine a binomial real options model with a decision analytical approach. Using a decision analysis methodology, the decision maker estimates the certain equivalent of the private risk, which will then constitute the possible outcomes in the binary model. The evaluation of this approach's applicability also in an AEC IT investment setting therefore constitutes another opportunity for further research.

In an industry that in the recent years have seen the rise and fall of a number of potential technologies, the underlying uncertainty of IT investments gives rise to threats but also to opportunities. A company that carefully manages its portfolio of IT projects in view of future contingences, as well as strategic actions, can therefore gain critical competitive advantages while at the same time avoiding serious pitfalls.

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