Optimal Timing Decision on Information Technology Investment

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Abstract

Enterprise Resources Planning (ERP) investments not only yield potential future benefits, but also influence competitive performance. However, since ERP projects are costly and have high-failure rate, an evaluation tool is needed to assess and manage the risks of ERP implementation in order to improve the chances of success. Our study applies the Real Options theory to the evaluate ERP implementation, and quantify the strategic value of future opportunities. By taking into account managerial flexibility, managers can accurately evaluate IT projects under uncertainty, develop optimal investment strategies, and manage projects more efficiently. We use real world data to apply the Real Options theory to manage the context of risky ERP implementation. The main contribution of the paper is to provide a simplified, but insightful, illustration whereby managers and apply Real Options theory to their ERP projects and make strategic investment decisions under uncertainty in the context of high risk and costly IT investments.

Keywords: IT investment; Real options; Risk factor; Stochastic Model

1. Introduction

Investing in IT is an important strategy for enterprises to acquire competitive advantages and achieve good quality of service (QoS). ERP systems streamline business processes by creating an enterprise-wide transaction structure, which integrates the key functions of different departments within an integrated information system platform. ERP systems are therefore key strategic systems. According to statistics, ERP projects have become the largest, single investment in information system projects. For example, ERP implementation was the largest segment of U.S. companies’ applications budget throughout 2004 (Sumner,2000). Because ERP systems are complex pieces of software and entail high risks, many implementation projects that were difficult, lengthy and over budget were terminated before completion. Studies show that as many as three-quarters of past ERP projects were judged to be unsuccessful by firms that had implemented them (Bingi et al,1999). The significance and risks of ERP make it essential that companies focus on ways to manage its implementation.

However, companies do not make their ERP investment decisions based on strict financial quantification techniques. Most ERP project evaluations are conducted on a Net Present Value (NPV) basis; however, this traditional project valuation tool ignores the issue of uncertainty, and does not take managerial flexibility and various uncertainties into account (Trigeorgis,1995). Failure to consider the value of managerial flexibility means that the perceived benefits of a project are lower than the actual benefits, so managers are apt to reject, or prematurely cancel, projects that would in fact be economically viable (Keila et al, 1995). Moreover, NPV assumes that investments are reversible, and non-deferrable. In the real world, however, investments are irreversible, deferrable, and undertaken in conditions of uncertainty (Pindyck,1998).
Because incorrect evaluation may result in incorrect decisions and ineffective management of projects, an effective ERP project evaluation discipline that considers uncertainties is needed. Lacking such a discipline, inadequate ERP investment decisions may be made and cause huge losses. Previous studies in ERP have focused on the topics of ERP success, the interaction of ERP and organizations, and ERP system development, but few have discussed the strategic actions of ERP implementation from the Real Options perspective. Real Options theory is a risk-hedging approach and is especially suitable for projects that involve both a high level of uncertainty as well as opportunities to dispel that uncertainty when new information becomes available. Since ERP investment actually conceals enormous risks, managers must consider both technical and market uncertainties, respond to the changing environment, and take appropriate actions. All the characteristics make decision-making in the implementation of ERP projects contingent on as yet unknown future states. For these reasons, the Real Options approach is quite suitable for redefining decision making behavior via strategic thinking in the ERP evaluation stage. For example, it has the ability to evaluate wait and learn options and resolve the uncertainty inherent in investment decisions. The timing option generates additional value in terms of managerial flexibility, and enables managers to make decisions until the uncertainty factors are resolved.

This paper addresses the research questions: 1) In a costly and risky ERP implementation environment, when is the optimal time to invest? 2) How the value of managerial flexibility provided by an option changes the strategic actions? We endeavor to answer these questions in order to manage costly and time consuming ERP implementation efficiently.

2. The valuation methods

Traditional capital budget criteria, such as NPV, must be established at a specific point in time, but result in huge opportunity costs to make a now-or-never decision, neglecting the value of postponing the project. Decision-making based on such an incorrect project evaluation causes a company huge losses, whereas waiting for a period of time to obtain new information would be more advantageous. In addition to the disadvantages that make NPV inadequate for evaluation of a risky project, the way it handles such risks is also contentious. The NPV approach merely considers risk as a matter of appropriate discounting through a risk-premium item embedded in the approach. NPV asks for a higher adjusted discount rate for risks, resulting in a reduction in the total present value of projects. Uncertainties only provide a limited view of risk for managers facing uncertainty in projects; therefore, incorrect decisions are made based on inadequate evaluation criteria.

To overcome the disadvantages of NPV, the Real Options approach has been developed in the last two decades. A financial option is a contract whose value depends on certain variable underlying assets like stocks or interest rates. It allows an investor, by paying a sunk cost, to acquire the privilege to buy a stock at a fixed price if the stock price is favorable, but it does not obligate the option owner to buy the stock (if the price remains unfavorable). Black et al (1973) developed the option pricing theory, while Myers (1974) extended the financial option theory to real assets. Just as a financial option is a derivative of underlying financial assets, the Real Options value is determined by the underlying real assets. Many option-like characteristics can be found in ERP investments. For instance, the capability to delay ERP implementation is a "real option". This capability enables a company to implement ERP if the uncertainties are resolved favorably, but does not obligate the company to do so if the market is unattractive.
3. The Enterprise Resources Planning Case

Let us consider a scenario where Company A is a pharmacy company in Taiwan and is considering the implementation of an ERP system. The firm can implement ERP right away if the NPV approach reveals a positive NPV, or choose to defer the investment if there was no immediate competitive threat from an existing or potential competitor. Besides the cost of the various ERP modules, the estimated cost is NT$5,500,000, including the cost of software, training fees, consulting fees, workforce costs, and the costs for project rewards. After many meetings and preliminary studies, company A decides that all these modules should be implemented in one operation. Consider that the benefits depend on the unknown future state and are hard to estimate, the managers decide that the ERP investment can be postponed for a period of time in order to gain more knowledge about the uncertainties and the potential investment outcomes before committing to the entire investment. The project is expected to take two years. One year is to be spent on the requirements analysis and detailed feasibility study. Application design and application development is expected to take another one year. Investing in the requirements analysis and feasibility study can be considered similar to buying an option to invest in the design and application development project. The unsolved risks include:

1. Staff lacks needed technical skills
2. Uncooperative internal parties
3. The benefits adopting the ERP system must to be studied further
4. The introduction of a new superior implementation technology may render the application obsolete
5. The implementation technologies may be immature

There are some advantages for the firm to defer the ERP implementation for waiting would reveal additional information. The managers expect that by holding the option, they can be aware of activities or stages of the project where deferral is beneficial and scheduling them as late as possible. Examples include hardware procurement (delay may result in lower price), or some types of technical prototyping (delay may result in the availability of new technology). At the meantime, they can gather information in stages and delaying information gathering that may change and to resolve a more complete specification. Furthermore, deferring project may use the state-of-art new technology that may make it easy to obtain the desired technical performance of the system.

4. Modelling the ERP Case

We use the continuous-time stochastic process model developed by Dixit (1994) to model the ERP implementation. Compared to the Black-Scheles model, this model more specify the real case, while keeps its simplicity. The Black-Scheles model is a special case derived with the stochastic process, given some special boundary constraints. In the stochastic process model, variables that change over time can be described by a stochastic process. The cash flows of the project $V_t$ follow a process of geometric Brownian process, given by:

$$\frac{dV_t}{V_t} = \alpha \, dt + \sigma \, dz_t$$

(1)
The company implement ERP at the optimal time \( T^* \) with costs \( I \). The firm must decide whether to manufacture the product or not. At time \( t \) the firm decides to incur a cost \( K(t) \), in order to realize \( V \), the present value of the stream of uncertain future cash flows generated by this investment. \( V(t) \) represents the market value of a claim on the stream of net cash flows that arise from implementing ERP system subsequent to the discovery at time \( t \). It is recognized that if \( V^* > V(t) \), the firm decides not to implement now and keep waiting. The value to hold the defer option is \( V_0(C^*) \) and the value to execute the option is \( V_1(C^*) \) (See Figure 1).

![Figure 1. The threshold to implement ERP](image)

At the point, the option value equals \( \text{Max}(0, C_1^* - I) \), when the value of the option is below some threshold \( C^* \), its value equal 0. If it exceeds the threshold, the option value is \( C_1^* - I \). Whether the manager chooses to implement now or to wait to do so later, they aim to achieve the maximum of their benefits. Thus the criteria that whether the manager carries out to establish the ERP or not is according to the policy: If the project value is higher than the threshold, then chooses to implement right away. Counterwise, they choose to wait for a proper time to do. Formula 1 expression decision-making policy by the manager

\[
V_1(C) = \text{Max}(V_0(C), V_1(C))
\]

The firm knows the present value of future net cash flows of it implement ERP. However, the present value may be different of the ERP is implement in the future. \( \sigma_v \) is the volatility in future benefit, takes the future uncertainties into the evaluation model. \( \alpha_v \) is the is the constant drift rate of future benefit, and \( dz \) the increment of a Wiener process, i.e.,

\[
dz = \varepsilon \sqrt{t}
\]

where \( \varepsilon_t \) is \( N(0, 1) \) and \( E(\varepsilon_t) = 0 \), for \( t \neq s \).

Note that unlike NPV, the Real Options takes the future uncertainties into the evaluation model by adding up the \( \sigma_v \), i.e. the volatility in future benefit. Thus the value at the model depends on the timing and follows the lognormal distribution. Where the expected project value \( E(V_t) = V_0 e^{\alpha_v(t-t)} \), and the variance \( \text{Var}(V_t) = V_0^2 e^{2\alpha_v(t-t)} [e^{\sigma_v^2(t-t)} - 1] \). The PDE for the contingent claim is (See Dixit,1994)

\[
\frac{1}{2}\sigma^2 V^2 F'(V) + (\rho - \delta)VF'(V) - \rho F = 0
\]

(3)
Since we have the close-form solution for the PDE

$$\beta_i = \frac{1}{2} \frac{\rho - \delta}{\sigma^2} + \sqrt{\left(\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1$$

(4)

We can calculate the value for the project by

$$F = (V^* - I)\left(\frac{V}{V^*}\right)^{\beta_1} \quad \text{when } V < V^*$$

$$F = V - I \quad \text{when } V > V^*$$

(5) (6)

where F represents the value of the invest opportunity

$$V^* = \frac{\beta_1}{\beta_1 - 1} I$$

(7)

The manager estimates that by implementing the ERP system, the company can obtain competitive advantage by reducing headcount, improving cash management and achieving additional valuable management. The estimated cash flows of these benefits are estimated to be $10 million, $15 million, $20 million, $15 million, and $10 million in the next five years. The costs to implement the system need $65 million. According to the environment changes and the industrial competition, the firm evaluates the high risk ERP project and is willing to know the optimal time to adopt it. According to the traditional NPV analysis, the manager will adopt the ERP right away since it reveals a positive NPV i.e. $2.3 million. But what about the result conducted by the Real Options analysis? Since the project is undertaken under uncertainty, the project value varies at any time \(t\) to reflect the changes of the environment. We assume the volatility of future benefits, \(\sigma\), equals 5% by survey the average industry. The opportunity cost to wait, \(\delta\), to be 10%, representing the costs of delaying implementation of the ERP project due to the possible future market competition and estimate the \(\rho\) to be 4%.

5. **Numerical Analysis**

The NPV plot is a straight line with a exercise price $60 million with its slope -1. According to the parameters, we can work out the \(\beta_1\) to be 4.45 and \(V^*\) to be $77.4 million. Because the project benefits (net present value of the future cash flow $62.3 million) is less than the threshold ($77.4 million) \(V < V^*\) in Figure 1), the company delay the project. The \(V^*\) is actually a trigger that the company will change its strategy between the two alternatives (wait/adopt).The value of the project opportunity is $6.63 million. The value of the option to delay is thus $6.63million -$2.3 million (project value without managerial flexibility) = $4.32 million, nearly 7% of the total investment cost. That is the value of the managerial flexibility that the company have to take their strategic move.

According to formula (2), a higher \(\sigma\) means that there is more uncertain value to the project. Thus a firm will ask for more risk-premium to cover the project risks. A higher \(\sigma^\prime\)

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1 All figures are U.S. dollars
makes \( \beta_1 \) move closer to 1, leading a higher \( \frac{\beta_1}{\beta_1 - 1} \). Since \( V^* = \frac{\beta_1 - I}{\beta_1 - 1} \), \( \beta_1 \) stands for the multiple factor of invest that the company is willing to start the implementation under investment uncertainty. The more \( \delta \), the lower the \( \frac{\beta_1}{\beta_1 - 1} \) is, means that the firm is willing to execute the option cause the opportunity cost is high. The volatility plays an important role by affecting the size of the “option premium”. An increase in volatility increases total project value, while the associated opportunity cost, \( \delta \), go counter to the effect. The two important driving variables in the analysis are actually tradeoff in determining the project value. The volatility plays an important role by affecting the size of the “option premium”.

A throughout statistic parameter makes a more comprehensive understanding toward the individual factors. The greater uncertainty increases the value of a firm’s investment opportunities, but at the meantime, decrease the amount of actual investing. According to formula (2), a higher \( \sigma \) means that there is more uncertain value to the project. Thus a firm will ask for more risk-premium to cover the project risks.

Counterwise, the more \( \rho \), the more the \( \frac{\beta_1}{\beta_1 - 1} \) is, means that the firm is unwilling to execute the option. Because future project value is unknown, there is an opportunity cost to implement ERP project today. Hence the optimal investment rule is to invest when \( V \) is at least as large as a critical value \( V^* \) that exceeds \( I \). This is quite different from NPV rules. Thus critical strategic systems that are costly and high risk like ERP need to be evaluated carefully. The threshold of the timing is quite different and a wrong investment decision may be made based on the inadequate rule.

In the analysis we can see that the volatility \( \sigma \) plays an important role in Real Options decision making. Managers must understand the importance of the volatility. In future research, we may use Monte Carlo analysis to simulate the underlying asset value volatility because the lower CPU cost makes a complicated simulation feasible. To sum up, the Real Options approach enables managers to make correct decisions through managerial flexibility and efficient allocation of resources.

7. Conclusions & Managerial Implications

A Real Options perspective enables managers to consider uncertainty and how they might best react to it. It also offers management the flexibility to hedge risks until they are resolved. The managerial implications lie in that management can manage ERP investment to deliver the maximum value in terms of benefits to the business.

The results show that the Real Options approach places a positive value on management learning in ERP implementation and offers managers a brand new perspective on costly and risky information technology investment decision-making.

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