# The Uncertainty Decision-Making of ERP Investment

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**Abstract.** Investment in ERP projects has become a dominant part of IT investment of many enterprises. Traditional approaches used for such project evaluation are mainly based on Internal Rate of Return (IRR) and Net Present Value (NPV). However these approaches completely lack the ability to deal with the uncertainties in decision making process of the ERP investment. On the base of risk and uncertain analysis, this study employs a mathematical model to design an ERP decision analytical model based on real option. The model has accounted for the uncertainties and management flexibilities, it is more appropriate to evaluate ERP project investment in uncertainty.

**Keywords**: *ERP, Real option, Uncertainty decision-making, Investment, Risk*

## 1. INTRODUCTION

ERP investment projects involve a variety of risks and uncertainties, and the investment return is difficult to assess. Therefore, it is by no means easy to decide on the appropriate investment strategies for technology investment projects of such nature [1, 2]. Traditionally, project evaluation approaches such as internal rate of return (IRR) and net present value (NPV) are widely used to determine the appropriateness of an investment project. However, these traditional project evaluation approaches generally use expectations of future cash flows in calculating IRR or NPV and assume passive decision makers who do not dynamically respond to the changing investment environment [3]. Without recognizing the possibility that a proactive decision maker could exercise the managerial flexibilities and takes correct actions in response to the developing investment environment, such approaches are apparently inappropriate for valuating technology projects under uncertainty. On the other hand, the real-option approach overcomes the drawbacks of the traditional investment decision approaches, and provides a new approach for enterprises to carry through ERP project investment with managerial flexibility [4-6].

There are various reasons that explain the failures of investment decision making for ERP projects [7, 8]. One of the most critical ones can be attributed to the uncertainty of input cost and benefit of an ERP project [9]. Therefore, the evaluation

of the cost and benefit of IT project is a prerequisite to effectively solve decision making issues of ERP.

The valuation of real options is central to the decision making of an ERP investment project. Compared with the commonly used lattice simulation and finite difference method, stochastic programming is much more suitable for compound real option evaluation and thus a better approach to solving multistage decision making problems under uncertainty [10-12].

## 2. ANALYSIS OF ERP PROJECT RISK AND REAL OPTION OF INVESTMENT

### 2.1 Risk Analysis of ERP Project

According to the published reports on ERP implementations, it is found that firms are in general exposed to investment risks manifested by a high failure rate of ERP projects. These risks could be categorized into external and internal risks. The former types of risk include marketing risks, potential regulation risks, unpredictable risks and agent risks which could mainly derive from the uncertainties of demand of products in the future, government deregulation, and the emergence of inexpensive or more advanced technologies in the market. The internal risks consist of technology risks, management risks, resource risks and implementation risks. These risks are due to uncertainties arising from long-term investment capability of the firm (e.g. running out funds to complete the project), the internal competence in managing the new technology and the suitability of an ERP system to the business processes of a firm.

Traditional approaches to risk management aim at controlling either external or internal risk factors. Unfortunately, most risk factors are uncontrollable. Therefore, the effectiveness of these approaches is limited. Fortunately, the real-option approach could effectively solve the issues discussed above. There are numerous risks and uncertainties existing in the process of ERP investment. By maximizing the value of real options embedded in an ERP investment project, it is possible for decision makers to actively respond to unfavorable investment environment and take right actions to mitigate investment risks.

### 2.2 Real Options of ERP Investment

During the course of an ERP investment project, or even before the project is approved and commissioned, a technology manager will have a number of options open to him/her. Before committing any resource to the ERP project, he/she may decide on whether it is appropriate to kick start the project or adopt a wait-and-see approach. When the project has been rolled out, he/she still has to monitor the project continuously and decide on whether the project should still be confined to the pilot level, or to change the scale of investment (to expand or to withhold) or to abort it all

together (if the project turns out to be a failure). Within the framework of real options, the decision to take a particular option depends on a number of factors which are collectively represented as uncertainty. Therefore, the framework provides a kind of roadmap for the technology manager to make the appropriate investment decisions amidst uncertainties. The following options are some of the best known options and are considered to be pertained to ERP investment projects, which include the option to wait, the option to abandon, the option to change the project investment scale and the option to learn.

# 3. INVESTMENT APPROACHES TO ERP PROJECTS

## 3.1 Investment Strategy of ERP Project

An enterprise might choose to achieve a complete as opposed to a partial implementation at the beginning of an ERP implementation project. Two possible investment strategies have been identified and given as follows:

**Strategy S-1**
Purchase the complete, integrated ERP system from a leading ERP solution provider. A comprehensive suite of major modules are available to support business functions (finance, production, human resource, market and sales). This is followed by the project rollout whose tasks include process analysis and design, implementation tasks including system configuration, installation of software components, customization, development of interfaces, training, etc.
**Strategy S-2A**
Select the minimum system configuration to provide a software solution for major function departments in an enterprise;
**Strategy S-2B**
Enhance the system capabilities by including other application components for use by other departments; design and develop interface software (which is used to connect application programs) and perform overall system integration (Figure 1).
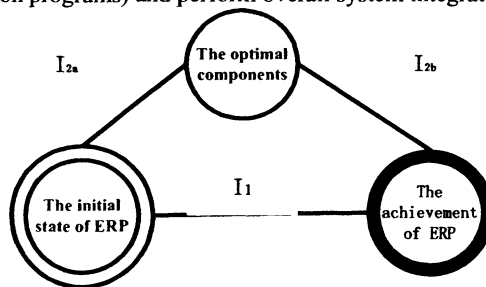


**Figure 1. Investment Strategies of an ERP Project**

Suppose that the investment decisions for an ERP project will be made over a multiple-period time horizon from period 1 to $T$, the decision maker is assumed to possess managerial flexibilities or options with respect to investment timing and scale at each decision making period or investment evaluation stage $t \in \{1,...,T\}$. In the selection of an appropriate investment strategy, two assumptions are made:

- Assumption 1: at each decision evaluation period $t \in \{1,...,T\}$, the decision maker can randomly select either strategy S-1 or S-2, or can choose to wait and invest until more information is gathered or uncertainties are resolved.
- Assumption 2: once the decision maker selects investment strategy S-2A, investment strategy S-2B must be selected before the investment valuation terminated at period $T$.

### 3.2 Investment Process Analysis of an ERP Project

An enterprise has the opportunity to input certain expense ( $I$ ) for the implementation of an ERP system in ERP project investment. The cost of investment is determinate but the future change of $I$ is uncertain on every time point $t \in \{1,...,T\}$ in decision period $T$.

$\tau$ is the period starting from the project inception when the investment is made to the point in which the project has formally resulted in income for the enterprise. Let the capital investment for the ERP project be $I(t)$ at time point $t$. The initial investment $I(0)$ but $I(t)$ is uncertain for $t > 1$. $\tau$ periods after the initial investment the enterprise begins to receive income $C$ in various forms until the end of system lifecycle $T^*$. However, the enterprise can also delay its investment by choosing to bide time because of the uncertainties that arise from the ERP investment cost and on the possible incomes that could be attained. So, there exists an option to wait in the investment project. The time-dimensional analyses of two major investment strategies are shown as Figure 2 and Figure 3 respectively:
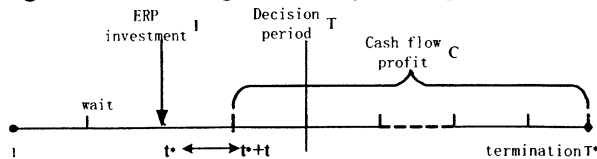


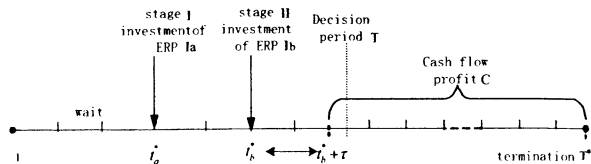Figure 2. Time-Dimensional Analysis of Investment Strategy S-1



Figure 3. Time-Dimensional Analysis of Investment Strategy S-2

Assume that income are uncertain, the decision to wait for a certain period before making the investment would seem to be a better approach. If the value of any ERP assets decreases by the time, that will justify this decision to wait until the right timing. However, the lifecycles of ERP systems are becoming shorter and shorter with the advent and development of new technologies, waiting means the enterprise is gradually losing out on new technology initiatives, thus reducing its capability to enhance its revenue and some other less tangible benefits. Therefore, these two factors must be jointly considered in order to make the optimal decision.

# 4. THE ANALYSIS OF UNCERTAINTY – INVESTMENT BENEFITS

The benefits derived from an ERP project are the fundamental considerations in the investment decision process. Compared with other types of capital investment projects, it is difficult to assess the costs and benefits of an ERP investment project due to the tremendous uncertainty that might occur during the project lifecycle. Since the valuation of such a project within the real-option framework involves a trade-off between these uncertain quantities, some appropriate approaches for their evaluation are required. This section will be devoted to the discussion on those pertained to benefits.

The benefits that are derived from an ERP project can be categorized either as tangible or intangible. The former includes the reduction of production cost and inventory expenses, and increased productivity. On the other hand, the intangible types of benefit consist of improving product quality, reducing lead time, increasing the flexibility of firms, and promoting corporation image, among others. Unfortunately, such intangible benefits of ERP are difficult to assess and as a result, most valuation approaches are incapable of addressing these benefits. Also, the large uncertainty associated with such intangible benefits in technology projects makes their assessment even more difficult. However, for valuating an ERP project, this aspect is clearly a very important factor to consider. If the intangible benefits are ignored, any similar initiative for productivity improvement will probably receive a similar, negative valuation. On the other hand, tangible benefits that can be derived from an ERP project also contain significant uncertainties. It is apparently that, in today's competitive environment, no certain future demand and hence income can be guaranteed.

## 4.1 Assessment of Tangible Benefits under Uncertainty

Given $G^t$ to be the total demand of an enterprise's product in the market in year $t$, it is commonly observed that $G^t$ is a process of production pervasion [13]. Geometric Brownian motion (GBM) is therefore appropriate for describing such a process because the tangible profit for an enterprise will become uncertain after the

implementation of ERP. With this assumption, the differential coefficient of $G'$ is given as

$$dG' = \alpha G' dt + \sigma G' dW \qquad (1)$$

$\ln(G')$ follows a simple Brownian motion with drift because the demand is non-negative. Thus,

$$dg' = (\alpha - \frac{1}{2}\sigma^2)dt + \sigma dW, \quad t \in \{1,...,T\}, \qquad g' = \ln G' \qquad (2)$$

where $\alpha$ is the growth rate of income accrued during the project lifecycle. $\alpha$ can be positive or negative. $\sigma C dW$ represents the stochastic deviation of $C$.

With the assumption of risk neutrality, the change of cash flow $C$ can be described by Eq. (1) and (2) and the uncertainty of demand

$$dC = (\alpha - \eta_c)Cdt + \sigma CdW^* = \alpha^* Cdt + \sigma CdW^* \qquad (3)$$

where $\eta_c$ is the risk premium of uncertainty of cash flow, and $dW^*$ is the increment of Gauss-Wiener process that is linked with the entire economic activity with the assumption of risk neutrality.

So, the income with uncertainty can be deduced from Eq. (3),

$$V(C',t) = E_Q[\int_{t+\tau}^{T^*} C(\tau)e^{-r_f\tau}d\tau] = -\frac{C'}{r_f - \alpha^*}[e^{-(r_f-\alpha^*)\tau} - e^{-(r_f-\alpha^*)(T^*-t)}] \qquad (4)$$

Eq. (4) represents the tangible benefits that the ERP project would bring to the enterprise when the investment decision for the ERP software system is made at the decision point $t$, see table 1.

### Table 1. Definitions of Variables in Eq. (4)

| | |
|---|---|
| $C'$ : | $G' \bullet p$ |
| $E_Q$ : | Measure of risk neutrality |
| $\alpha^*$ : | $\alpha - 1/2\sigma^2$ |
| $r_f$ : | Risk-free interest rates |
| $p$ : | Net profit of unit product |

## 4.2 Assessment of Intangible Benefits under Uncertainty

The intangible benefits derived from ERP are, by their nature, difficult to assess. Especially, such benefits vary widely and are very hard to assess quantitatively. This study will adopt the model of Kalafut and Low [14] as the basis for assessing the enterprise intangible benefits. Based on this model, a fuzzy assessment method will

be developed in this study to evaluate the intangible benefits derived from an ERP system implementation.

The net profits $D^t$ in time t brought to an enterprise due to the ERP project are related to market demand of product $G^t$. Therefore, it is also uncertain.

$$D^t = G^t \bullet p \tag{5}$$

$p$ is net profit of unit product. Similar to the calculating process of tangible benefit $V(C^t,t)$, the enterprise's total net profit value $V(D^t,t)$ within years of applying ERP system can be calculated by using

$$V(D^t,t) = -\frac{D}{r_f - \alpha^*}[e^{-(r_f - \alpha^*)\tau} - e^{-(r_f - \alpha^*)(T^*-t)}] \tag{6}$$

Total intangible profit cash flow of ERP
= $\delta$ ×the total net profit of enterprise in the lifecycle of ERP system.
= $\delta \times V(D^t,t)$ (7)

# 5. CASE STUDY

Datang Telecom (CDMA) was founded in April 1993 to deal in the high-tech businesses. The company mainly engages in product R&D, production, sales and service in the field of telecom and information. In order to solve the management problem, enhance the management level, and achieve the long-run development strategy programming, the company decided to adopt SAP's advanced ERP management information system. The project period was from 1999 to 2002. This case study represents a retrospective analysis of the project valuation process using the proposed framework based on real options.

## 5.1 The Decision Model

Cost information provided by Datang Telecom is given as follows. The sunk costs due to the project are given in Table 2.

Table 2. Value of ERP Sunk Cost

| Decision point | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $I_1$ | 586 | 556 | 540 | 530 |
| $I_{2a}$ | 397 | 385 | 375 | 368 |
| $I_{2b}$ | 159 | 142 | 136 | 129 |

Also, according to the market forecast, the volatility rate $\sigma$ is taken to be 0.3 and $b$ =30 Yuan/Line (unit product saved cost) and $p$ =100 Yuan/Line (unit product net profit) from data provided by the company.

In terms of prediction for VCI by ERP implementation experts, $\delta$ in this case is 10%.The value of consultancy, training and other expenses are:

$$K_0^1 = 2.33 \text{ Million(yuan)}\quad G_0^1 = 663.5 \text{ K Lines}$$

$$\mu_k = \ln 2.62,\ \rho_k = 0.0012,\ \sigma_k = \ln 0.5$$

$$\gamma = 5\%,\ E = 200K(Yuan)/year;\ v_1 = 1.2,\ v_2 = 1.6$$

$$L = 902K(Yuan),\ \alpha^* = 0.52,\ r_f = 0.82,$$

$$P_1 = 823K(Yuan),\ P_{2a} = 432K(Yuan),\ P_{2b} = 341K(Yuan)$$

The constraint of expense budget:

$$I = 12000K(Yuan),\ I' = 8000K(Yuan)$$

Set the initial feasible portfolio 1 of decision variables to be {1,0,0,0,0,0,0,0,0,0,0,0}, the sub-problems and the corresponding deterministic programs can be solved (**NB.** the model is developed in Visual C++ using the solver ILOG). Since the results obtained from solving these deterministic programs are unbounded, constraints will be added to the main problem. Then, by using the ILOGHybrid20 package, the main problem of the 0-1 integer program can be solved. After 5 iterations, portfolio 8, {0,0,0,0,1,0,0,0,1,0,0,0}, is substituted into the sub-problem. The result obtained for this portfolio is $S_{max} = 2425.6$ K (Yuan). According to this portfolio, the decision maker did not invest in the first year but adopted S-2A in the second year due to the uncertainty of income and consultancy expense. S-2B was then implemented in the third year. The maximum of the NPV of the ERP investment project with real options was 2425.6K Yuan.

## 5.2 Solving $NPV_{static}$

The static NPV is obtained based on the following information, see table 3.

**Table 3. The Definitions of Variables of Static NPV**

| | |
|---|---|
| $NPV_{static}$ | The NPV that is to adopt investment strategy S-1 and invest immediately without considering the flexibility of ERP investment at period $t = 1$. |
| $V$ | The net cash flow of total profit that the implementation of ERP that would bring to the enterprise. It is estimated by the expert team of the ERP project. $V$ =9,895K (Yuan) |
| $M$ | NPV of the operation and maintenance total expense from ERP system go-live to the end of the ERP project = 9x200K(Yuan) |

| $I_a$ | Total cost required by employing S-2A = Consultant cost + software cost + project cost |
|---|---|
| $I_l$ | =7,860K (Yuan) |
| $\gamma$ | Risk-free rate = 0.05 |
| $\tau$ | The time required for the implementation of the ERP system if S-1 is adopted = 1 (year) |

$$NPV_{static} = \frac{V}{(1+r)} - \frac{I_1}{(1+r)} - \frac{M}{(1+r)^2}$$
$$= 942.4 - 748.5 - 163.2 = 307 \text{ K (Yuan)}$$

The total ROV of ERP project investment was:

$$ROV = \max\left(NPV_{option} - NPV_{static}, 0\right) = 2118K \text{ (Yuan)}$$

It is obvious that the NPV of investing portfolio 8 is larger than that of adopting S-1 at period $t = 1$. The reason is that the value of managerial flexibilities are explicitly considered in portfolio 8, including the value of real options such as the option of waiting, option to learn, option to abandon and option to change the project investment scale are used in project investment.

# 6. CONCLUSION AND FINDINGS

## 6.1 A Comparative Study of the Real-Option Approach and the Traditional NPV Method

Under the real option framework, the compound real options are considered. These include the option to learn and the option derived from the flexibility of decision-making management and the uncertainty of benefit and cost in ERP project investment. Also, the model employs investment portfolio 8, which will enable the firm to achieve the maximum NPV including the real options of the project. Therefore, the optimal investment strategy, portfolio 8, should be selected. In contrast, the traditional financial evaluation method will take no account of the uncertainty and value of real options in the project investment, and the value of NPV is negative. Consequently, the firm will miss the optimal opportunity of investment.

## 6.2 Findings and Significance of the Research

For the analysis of ERP investment strategy, the approach used in this paper, the decision-making model of stochastic programming, counts in the intangible benefit

after ERP project go-live in quantity, and takes uncertainty of consultant expense of investment cost into consideration, which will make the decision-making model more in accordance to real investment environment. In previous studies on the valuation of ERP investment projects, few authors have considered the intangible benefits that could be derived from the ERP system.   However, the motivation for such investments is due more to the potential value that could be created as a result of the introduction of the advanced management approaches and information systems. Unfortunately, such intangible benefits are known to be difficult to assess.   In traditional financial valuation methods, due to a lack of an effective quantitative approach for the assessment of intangible benefits - the benefits of ERP usually have not been given a more rigorous evaluation and will lead to overrating or undervaluing of the benefits of ERP for the firm.  With the option values added to the static NPV, the real-option framework will provide a basis for better approaches for valuating technology investment projects.

## ACKNOWLEDGEMENTS

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