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HOW OPTION THINKING CAN IMPROVE SOFTWARE PLATFORM DECISIONS

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Abstract

In recent years, the use of option pricing models to support IT investment decisions has been proposed in the MIS literature. In this paper, we discuss the practical advantages of such techniques for the selection of a software platform. First, we argue that traditional quantitative approaches to a cost-benefit analysis give only a partial picture of such decision situations: 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". We then compare different valuation techniques for this task and discuss their respective advantages and drawbacks. The practical advantages of employing such models are demonstrated by describing a real-life case study where option pricing models were used for deciding whether to continue employing SAP R/2 or to switch to SAP R/3.

Keywords: Software Platform, Strategic IS Management, Real Options, Cost-Benefit Analysis, SAP R/3, Capital Budgeting

HOW OPTION THINKING CAN IMPROVE SOFTWARE PLATFORM DECISIONS

1. Introduction

Justifying Software Platform Investments

A software platform is a software package that enables the realization of application systems. Examples of software platforms are operating systems, database systems, CASE environments, workflow/workgroup systems and general-purpose, customizable application packages like an SAP R/3 or ORACLE Application. Together with the hardware and the organizational knowledge about planning, designing and operating application systems, the software platforms in use constitute a firm's information technology infrastructure (see, e.g., Weill 1993). According to Weill, the key distinguishing features of IT infrastructure are as follows:

1. Infrastructure is shared across most functional areas or business units.
2. Infrastructure is budgeted for and provided by the information systems function.
3. Infrastructure is a necessary investment that business units of functional areas are unlikely to make.
4. Infrastructure is typically large, long-term in nature and takes advantage of economies of scale[1].
5. Infrastructure is the enabling foundation for application systems that support the business processes.
6. Once in place, infrastructure is costly to change, in both financial and political terms.
7. The decision process differs from that for application systems. While for the latter investments the objective is to eliminate uncertainty as a part of the specification process, IT infrastructure projects must cope with the uncertainty of future needs. IT infrastructure investments require a decision as to how flexible, and thus tolerant of uncertainty, the infrastructure should be.

[1] Weill quotes estimates of 35% to 40% of total IT investment dedicated for IT infrastructure (Weill 1993)

More precisely, the characteristics 1, 3 and 5 suggest that one can view IT infrastructure as a bundle of functions that can serve as the basis of certain applications whose value changes over time. According to the characteristics 4 and 6, this bundle of enabling functions cannot be adjusted in the short run. However, within this framework, one can decide on the basket of applications to be developed, implemented and operated on the basis of the respective costs and benefits then observed. It is important to view the enabling technologies, i.e. the platform and applications separately : value is provided by the applications. One platform can enable several applications, while one application may necessitate several platforms. Clearly, the broader the range of possible application portfolios, the more flexible the IT infrastructure. However, here one is confronted with irreversibility: development and implementation costs are usually sunk in the sense that software development expenditures, license fees or expenditures for external consulting services cannot be retrieved when the environment changes and applications can no longer be used without alterations. The timing of the implementation of the single applications must therefore be well considered.

What methods of determining the value of IT infrastructure are used in practice and how satisfied are practitioners with such approaches? Weill investigates these questions by examining the justification rationales used for IT infrastructure investments by the chief information officers in five large, profit-seeking firms mostly active in the financial service sector. He finds that traditional methods of capital budgeting, such as the discounted cash flow/net present value (NPV) method, are not used as such[2]. A closer look at the assumptions that underlie the NPV and similar methods reveals why: the NPV method is easy to use for valuing a particular application that is to remain unchanged over a given period of time, but it is not clear how to deal with flexibility as regards the time when to implement an application or to stop using it or modifying it (characteristic 7). Due to this ability to react, the traditional expected NPV is a lower bound of the value of an application, as downward parts of the distribution are "cut off". In fact, even the possibility to implement an application whose current expected NPV is negative will have a positive value, since one can wait and face the implementation cost later on when the application's value is positive. One way to "save" the traditional NPV is to fix in advance a particular implementation policy and to calculate the expected NPV for the resulting application portfolio. Some firms in Weill's survey pursued such a strategy: in such firms "the IT department identifies a basket of business process applications that will aggregate enough benefits to justify the infrastructure investment" (Weill 1993). Similarly, (Hochstrasser 1994) states that the use of

[2] A similar finding is reported in (Tam 1992): in a survey of IT managers, Tam finds that IT practitioners have problems when determining model parameters like the time series of costs and revenues of an IS project, or the appropriate discount rate for the NPV model. Consequently, simple, static models are often preferred to the NPV model, and important project decisions are based rather on intuition, experience and rule of thumb than on quantitative analysis.

standard evaluation procedures for infrastructure is impossible due to the fact that applications for the new platform are still in early planning stages. Therefore, a 3 to 5 year medium-term business scenario should be evaluated and IT infrastructure should be designed to support this scenario. Clearly, such an approach is satisfactory in a stable environment, but it can be quite misleading in an uncertain environment characterized by a high upward potential and a downward risk that is limited by the possibility of corrective actions (i.e. refusal of implementation, stop of use or software change).

All the other justification rationales found in (Weill 1993) were rules of thumb such as “invest to keep up with the technology” or “invest if the competitors have been successful”. Clearly – contrary to the NPV method, such rules of thumb do not provide the decision maker with information about the impact of his decision on the firm’s value and can be manipulated easily to accommodate personal or departmental goals rather than yielding the best decision for the firm. Also, treating “flexibility” as an “intangible benefit” to be measured on a rank scale via cost-benefit analysis as suggested, e.g., by Buss in (Buss 1993) does not provide the basis for maximizing the firm’s value. Furthermore when applying cost-benefit analysis, one is confronted with a number of problematic assumptions made implicitly such as full substitutability of criteria and uniform ordinal scales. And there is plenty of room for political processes as the scores and weights of the single criteria must be found subjectively.

Previous Work on Option Valuation in IT

A recent stream of research wants to preserve the quantitative approach for valuing investments incorporating flexibility and is based on *real options* (for a survey, see, e.g., (Trigeorgis 1995)). (Trigeorgis 1996) states that the failure of the traditional NPV model derives mainly from ignoring the value of active management in adapting to changing market conditions and proposes to expand the traditional NPV by a value of options from active management or by simply attributing an option value to value projects where opportunities for adoption to a changing environment exist:

Expanded (strategic) NPV = **(Equ. 1)**

passive NPV of expected cash flows +
value of options from active management

The prerequisite for this new development in capital budgeting is the option-like characteristic of flexibility in real assets. Consider, for instance, a European call option: it offers its holder the right, but not the obligation, to buy at maturity the underlying share of stock for a specified strike price (see, e.g., (Copeland, Weston 1992, p. 240 ff.)). Similarly, an application which can be implemented at a specific software platform offers the firm the opportunity (but not the obligation) to obtain the benefits of the application (underlying) by investing a given implementation cost (strike price) at certain implementation decision points (maturity).

A number of researchers have written on the use of option models in IT investment decision making. The pioneering work by (Dos Santos 1991) employs Margrabe's exchange option model (Margrabe 1978) to value an IS project that uses a novel technology for testing purposes. He argues that such a project generates the option to use the new technique for future projects in case it turns out helpful, i.e. if it increases the NPV of future projects due to learning and experience. Similarly, Kambil et al. use Cox-Rubinstein´s (Cox, Rubinstein 1979) binomial option pricing model to determine whether a pilot project should be undertaken or not. As a real-world case they study the improvement of business processes via hand-held computers in a large profit-seeking city hospital. They demonstrate that while a NPV-based analysis of the whole project would suggest to abandon of the idea, the option value of a smaller pilot project exceeds its cost so that it should be undertaken (Kambil et al. 1993).

Both works only consider dependencies between a pilot project and a follow-up project. For a software platform, usually several options are relevant, additional investments to keep options alive and several alternative implementation dates of applications are possible. In analogy to Kester's „growth options" for firms (Kester 1984), Taudes investigates option models for evaluating „software growth options" which are formed by IS functions present in a software system that can be used in applications brought into operation at certain implementation decision points when found beneficial (Taudes 1998). This work thus lays the foundation for valuing software platforms. However, Taudes does not differentiate between IS functions and value generating applications. Furthermore, no real world case is provided.

(Benaroch and Kauffman 1998) investigate the problem of investment timing using the Black-Scholes and Cox-Rubinstein models in a real-world case study dealing with the development of Point-of-sale(POS) debit services by the Yankee 24 shared electronic banking network of New England. In such situations, the question is not whether an investment should be undertaken or which out of several alternatives should be chosen but when to exercise the option held, i.e. when to implement a particular IT solution. This necessitates a trade-off between the revenue lost by waiting and the possibility of a further increase in the system's value. Benaroch and Kauffman motivate the usage of option pricing methods whether the underlying asset is traded or not, arguing that the market will correct under-investing due to a wrong discounting rate with potential takeovers of the firm.

(Sullivan et al. 1997) and (Chalasani et al. 1998) argue that option models can provide a firmer foundation for software development decision-making heuristics. Using real options, they study the decision of whether software should be restructured to make it more flexible via information hiding (Sullivan et al. 1997) and to motivate software prototyping (Chalsani et al. 1998).

Organization of the Paper and Its Contribution to Research

This paper aims at further developing option models in such a way that they become part of the managerial practice when making software platform decisions. Its *main contribution* is the description of a *real-life case study* that demonstrates the usage of option valuation methods for deciding between a further usage of SAP R/2 and the introduction of SAP R/3. Furthermore, we discuss in detail the assumptions underlying the derivation of the value of an implementation opportunity. As regards the organization of the paper, we start with describing the methodology of option valuation of implementation opportunities in Chapter 2, and in Chapter 3 we present the above-mentioned case study. In the concluding Chapter 4, we summarize the present work and describe implications for MIS practice and research.

2. Option Valuation of Implementation Opportunities

Clearly, the most important type of flexibility offered by a software platform is the ability to decide whether to implement an application or not in the future: often the decision to stop using an application does not yield substantial cost savings and/or is reversible. A change of an application can be viewed as the combined decision to abandon the old version and to implement the new one. We therefore study the valuation of "implementation opportunities" using a specialized version of (1) that considers the value of a software platform to be given as

Value of a software platform = **(Equ. 2)**

NPV of fixed application portfolio +
Option value of implementation opportunities

Option valuation starts out by developing a quantitative model of the underlying. In our case the underlying of an implementation opportunity is the stream of benefits that can be obtained by using the application under consideration. A number of different types of benefits of IT have been identified, common to most applications being that they decrease the cost for executing a particular set of business processes, either directly or by increasing productivity (see e.g. Hochstrasser, 1994). A simple model of this effect is

$$\boldsymbol{P_t = N_t \,.\, b} \qquad \textbf{(Equ. 3)}$$

where P_t is the benefit of the application at time t, N_t the number of times the activities supported by the application are performed in t, and b the savings in process cost obtained when the application under study is implemented.

Empirical support for such a model is provided, e.g., in (Mukhopadhyay et al. 1995) who study the benefits obtained by Chrysler by introducing EDI-based purchasing. They found that such an application saves time normally used for clerical work, such as document handling, and leads to cost savings in logistics. Furthermore, it turned out that the benefits/transaction as compared to a manual transaction are more or less fixed so that the total benefit is proportional to EDI penetration. When (3) is applied in such a case, N_t represents the number of supportable external transactions and is largely determined by the number of business partners that adopt a compatible technology. In the case of applications that support internal transactions, N_t will mostly depend on the development of the firm's sales.

Turning to the process of actively managing the application portfolio, we assume that IT management determines (3) at certain intervals ("implementation decision points") T and decides to implement the application under study when its value V_T, defined as the current value of the future stream of P_t, $t > T$, exceeds the total cost of ownership I[3]. I contains the cost of the implementation and the discounted sum of the operating cost. Typically, this will involve the costs of software development and customizing, additional hardware, user training, organizational changes, coordination with business partners, telecommunication, license fees, support personnel

[3] We thus assume that implementation opportunities correspond to European options. An alternative formulation could assume that IT management continuously observes V_t within an infinite time horizon and implements the application when the benefits foregone exceed I plus the value of the option for higher gains. We feel that our formulation is more natural as the determination of (3) can involve considerable cost, and often applications can only be implemented at certain times, e.g. at the beginning of a fiscal year.

etc. If there is no uncertainty regarding the development of P_t, one can determine V_T as the sum of P_t, $t > T$ discounted by the risk-less interest rate and then decide whether the application should be part of the application portfolio or not, i.e. the second term in (2) is not relevant. This changes when the development of P_t cannot be predicted with certainty: in that case, one prefers to let the insecure future unfold, to postpone the implementation decision until T and to know the present value of the implementation opportunity $max[V_T – I,0]$.

In the option pricing literature, it is customary to assume that V_t follows a geometric Brownian motion, i.e. $dV_t = V_t (\alpha dt + \sigma dW)$, where α is the drift parameter, σ the variance parameter and dW the increment of a Wiener process, i.e. $dW = \varepsilon_t \, dt^{-1/2}$, where ε_t are serially uncorrelated, normally distributed random values with zero mean and unit standard deviation. In our context this arises if N_t follows a geometric Brownian motion, b being constant[4], which implies that P_t and V_t defined as the expected discounted sum of the benefits P_t follow a geometric Brownian motion, too (see Appendix 1). α represents the rate at with the usage per period grows and σ is the standard deviation of the normally distributed percentage change of N_t. A straightforward estimator for this can thus be based on the fact that 95% of the probability mass of a normally distributed random variable is within the 2σ range.

Empirical support for the assumption of a geometric Brownian motion in our context is given by the fact that implementation opportunities typically involve applications that are based on novel software techniques whose adoption is uncertain and/or which are designed to support new fields of business of the organization. In both cases, N_t is governed by a product diffusion process. A number of empirical studies show that until saturation a geometric Brownian motion is a good descriptor of this phenomenon (see (Mahajan, Muller, Bass 1993) for a survey and (Pfeiffer 1992) for the modeling of the diffusion of EDI)[5].

Basically, there are two approaches for valuing projects represented by risky cash flow streams such as $max[V_T – I,0]$. Decision analysis constructs a decision tree that states the different relevant states and the subjective probabilities of their occurrence. Its aim is to determine the break-even buying price of the project using the firm's utility function to capture time and risk preferences (see, e.g., Smith, Nau 1995). The NPV model and option models aim at valuing a project as if it were traded on a perfect financial market, using the market to price the risk

[4] Clearly, there can also be uncertainty regarding b caused by incomplete information regarding the capability of the enabling technology at the time of implementation T, the quality of its implementation etc. We will return to this point later in this chapter.

[5] Note that even though the geometric Brownian motion is a continuous-time model, it is not necessary to continuously measure the potential benefits of implementation opportunities. Rather, this has to be done only when deciding to implement the application under study. One can imagine that there are always events influencing N_t.

involved. The NPV method achieves this by using a discount rate μ that equals the equilibrium expected rate of return on securities equivalent in risk to the project being valued. Usually, the Capital Asset Pricing Model (CAPM) is employed to determine μ as the sum of the risk-less interest rate r and a risk premium given as the market price of risk, i.e. the difference between the return of the market portfolio and *r*, and the correlation of the cash flow stream with the market portfolio (the project's systematic risk "beta").

When employing the NPV paradigm in our case, one could calculate the NPV of an application that can be implemented at *T* and decide whether it should be included in the application portfolio or permanently excluded depending on whether

$$\begin{aligned} NPV_1 &= e^{(-\mu.T)}.(E(V_t)-I) \succ 0 \\ NPV_1 &= e^{(-\mu.T)}.(V_0.e^{(\alpha.T)}-I) \\ V_0 &= N_0.b/(\mu-\alpha) \end{aligned} \qquad \textbf{(Equ. 4)}$$

Keeping this decision open until *T* generates an implementation opportunity. Continuing with the same line of reasoning, its value is given as

$$NPV_2 = e^{(-\mu.T)}.E(\max[V_T - I, 0]) \qquad \textbf{(Equ. 5)}$$

On the basis of some algebra - provided in Appendix 2 - , one finds:

$$\begin{aligned} NPV_2 &= e^{-\mu T}.(V_0.e^{\alpha T}.N(d_1)-I.N(d_2)) \\ d_1 &= \frac{1}{\sigma\sqrt{T}}\left(\ln\left(\frac{V_0}{I}\right)+\left(\alpha+\frac{1}{2}\sigma^2\right)T\right) \\ d_2 &= d_1-\sigma\sqrt{T} \end{aligned} \qquad \textbf{(Equ. 6)}$$

where N(.) denotes the cumulative standard normal distribution function. Clearly, the value of the extended NPV will always exceed the ordinary NPV since we have introduced the possibility not to invest in the project after observing the state of the world at time *T*. This difference will increase with increasing variance. Thus, while the value of the underlying will decrease with growing systematic risk, the value of the corresponding option increases with increasing uncertainty. The problem with this approach is that μ in (6) has to be different from that in (4), as the correlation of V_t with the market portfolio is different from the correlation of $max[V_T - I,0]$. In fact, if V_t has a constant μ, the expected rate of return for $max[V_T - I,0]$ will not be constant, but it rather will fluctuate with movements of V_t and time, among other factors (see, e.g., Trigeorgis, 1996, p. 391).

An alternative approach that avoids such complications is based on the assumption that perfect financial markets are arbitrage-free in the sense that no investor can make a profit without taking some risk or expending some capital. Such gains could be made if an option were priced differently than a portfolio consisting of the underlying and a risk-less security with the amounts being continuously adjusted so that the value of the portfolio replicates the value of the option. This consideration can be made the starting point of valuing $max[V_T - I,0]$. As shown in Appendix 3, this results in the Nobel prize winning Black-Scholes formula:

$$F_0 = V_0 N(d_1) - Ie^{-rT} N(d_2) \quad \textbf{(Equ. 7)}$$

where

$$d_1 = \frac{1}{\sigma\sqrt{T}}\left(\ln\left(\frac{V_0}{I}\right) + \left(r + \frac{1}{2}\sigma^2\right)T\right)$$
$$d_2 = d_1 - \sigma\sqrt{T}$$

Though structurally quite similar to (4), (7) contains less parameters that are easier to determine, i.e. α is absent and r appears instead of μ. In our case, the underlying is not traded. To be able to use (7), one thus assumes that there exists a “twin security” as a continuously adjusted portfolio of traded securities that perfectly replicates V_t. This is not unproblematic, as IT projects often also show idiosyncratic risks such as the technical risk regarding the feasibility of the enabling technology in the proposed area of application or an organizational risk in that the organizational changes required cannot be achieved due to resistance by the staff. It is implausible that such risks are priced by the financial market. We feel that such aspects mainly influence the determination of *b* in (3), while the “public risk” manifested in the development of N_t can be hedged due to the fact that financial markets determine security prices for the firm evaluating a software platform and firms that supply enabling technologies based on published sales figures which in turn determine the number of internal and external transactions that can be supported by the application under study. Thus, an option value calculated via (7) based on a pessimistic estimate of *b* that covers the private risks involved can serve as a lower bound of the value of an implementation opportunity (see Smith, Nau, 1995 for the formal argument). In fact, such a conservative lower bound is sufficient for our application of option pricing theory, as we do not want to determine the price of options we write but find out, which of several software platforms has the highest value.

In fact, (7) will also be a lower bound if several alternative implementation decision points T are possible. In this case, the implementation opportunity resembles to a European call option with several exercise periods. (Trigeorgis, 1993) uses numeric methods to determine the value of such "compound options" and finds that in such a case the error made by using (7) with the earliest implementation decision time is small as the different options compounded are very similar and all further options are killed once an option is exercised. Nevertheless, one also has to expect that, due to the costly and approximate determination of the underlying (3), an error will be made when actually hedging with a portfolio that is only correlated with $max[V_T - I,0]$ instead of a perfect replication. Intuitively, this error can be significant if the correlation is low. Further research in real options should address this subject.

3. Case Study – Continuing with R/2 or Switching to R/3

Models (4) – (7) have been applied in a real-life software platform decision. The project was carried out at a medium-sized manufacturing company in the automobile and arms industry with about 1500 employees in several facilities. The company is a long-term SAP R/2 user on a traditional mainframe with mostly terminals and a few PCs connected. The modules in use covered book-keeping, cost-accounting, material management and production planning and control. The firms decision problem was to decide whether the R/2 platform should be upgraded and used in coming years or whether it should be abandoned in favor of R/3. At the beginning of the decision making process, the different stake holders were in total disagreement on this subject: the users were satisfied with the functionality of the current system and did not wish a risky and time-consuming transition, especially as the company was forced to undergo severe cost-cutting measures. The IT department, on the other hand, argued that SAP R/3 was the technologically superior platform that would allow them to better meet future demands. The CFO wished the advantages possibly gained to be quantified. He was unable to assess the value of having a "technologically better" software platform and was afraid that IT just wanted a new, expensive toy. Also, he had to justify the investment vis-à-vis the owners of the company who viewed IT not as a core competence of the company but rather as a necessary tool whose costs had to be kept low.

To start with, a comparison of traditional NPVs based on the company-wide risk-adjusted discount rate of $\mu=20\%$ prescribed for IT projects was done. The result of this analysis is shown in Table 1[6]:

Investment cost (R/3)	
Server cost	200.000
Desktop cost	225.000
Training effort (IT department)	90.851
Training effort (other)	615.319
Platform adoption	576.667
License cost	150.000
Maintenance	45.000
Total	1.857.837

[6] While the reasoning and the way of determining the parameters resembles to those used in the practical example, the figures given are modified for privacy reasons.

Benefits	PV
Server maintenance	200.000
Operating effort	335.398
User productivity	906.000
Total	1.441.398
Net present value	-$416.500

Table 1 Cost-benefit analysis of SAP R/3

The rationale given for the above entries was as follows:

- The cost of hardware, software and training were obtained by comparing different external offers.
- For the staff a two-month external training was assumed involving explicit costs of SAP and UNIX courses and opportunity cost for non-productive staff during the training session.
- Training cost for other employees were calculated in the same way assuming a one-week external training which only would cover the direct use of SAP R/3.
- The platform adoption cost was obtained by comparing the offer from an external consultant with internal estimates and checking it against published SAP case stories.
- Benefits regarding the server cost result from ending the operation of the former mainframe.
- In contrast to this operation, no more operator night shifts will be required with the new system so that one employee less will be needed at the IT-department.
- During the first 2 years, the IT department would be fully occupied with realizing a stable implementation on the new platform of the current application portfolio so that no fixed plans for installing further applications were made. Thus, for the users no productivity gains except those due to a more intuitive and user-oriented interface could be attributed to R/3. The increase in user productivity hence was calculated assuming a 2% time saving effect over a period of 10 years which should be reached 2 years after implementation on account of the learning and training time needed. Presuming an annual salary of $80,000, this leads to savings of $120,000 after the first year of operation and of $240,000 after the second year.

On the basis of Table 1, R/3 should have been rejected, the investment has a negative NPV of about $420,000. Nevertheless, the CFO felt that this traditional analysis neglected the IT department's argument concerning the possibility to implement novel applications, i.e. that the consideration of the second term in (2) would change the ranking of the competing software platforms.

When applying option thinking to such a situation, the first step to be taken is the identification of new enabling functions provided by the SAP R/3 software platform versus R/2 and to decide which applications based on these functions might be beneficial within a reasonable time horizon. This step is of great practical value as it leads to an objective and structured way of discussing such projects. It can be accomplished by comparing the existing platform specifications plus the known future functions with the firm's information needs. In our case study, the users and the IT department were informed about the possibilities offered by an EDI interface, by workflow and document management systems and by the Internet as a tool for doing business. Subsequently, in a brainstorming session a number of novel applications were discussed that could be implemented after the 2-year stabilization phase, provided the transaction volume would then be sufficient. The implementation opportunities found were:

- EDI-based purchasing
- EDI-based invoicing
- Workflow for sales
- Engineering document handling
- World wide web based e-commerce system

For each of these implementation opportunities, the parameters for calculating the option values were estimated. The following questions had to be answered:

- How many tasks could the firm support with this type of application today? (N_0)
- What does the firm gain when supporting a task in such a way? (b)
- By what percentage will this number (gain) rise by the end of one year? (α)
- In which range will that percentage then lie ? (σ)
- When can the application be technically implemented at the earliest? (T)
- What is the total cost of ownership? (I)

The results are presented in Table 2:

Implementation opportunity	***b***	N_0	α	σ	***T***	***I***
EDI-based purchasing	100	100	8%	35%	4	$50.000
EDI-based invoicing	100	100	7%	30%	2	$200.000
Workflow for sales	70	150	5%	45%	4	$100.000
Engineering document handling	90	300	7%	35%	3	$300.000
World wide web based e-commerce system	150	250	15%	80%	5	$1,500.000

Table 2 Data for option valuation

For the EDI-based components, N_0 was found by checking the number of orders per year sent to customers and suppliers who already had a suitable EDI interface. Workflow for sales N_0 was obtained by analyzing the number of documents handled in a typical sales transaction multiplied by the number of transactions per year. Similarly, N_0 for the engineering document handling application was estimated. N_0 for the world wide web application was found by asking customers in an empirical survey whether they would be willing to order their products via the Internet.

For the EDI components estimates for α and σ were obtained by checking the customers' and suppliers' past rate of adopting EDI and verified by asking them about their EDI-related IT plans. Then, different scenarios regarding the adoption were created and the variance was computed using the percentile estimation for the normal distribution. For the workflow and document handling components we contacted Corporate Planning to obtain different scenarios regarding the development of the firm's sales. Here, the growth rate and variance obtained, directly applied to the number of internal transactions in sales and development, as each sale triggered a constant average number of internal process steps. Estimates for the web components α and σ were gathered using market research data of the growth rate of e-commerce systems.

The savings in logistics and productivity gains per usage *b* where calculated by valuing a cautious estimate of the time gained via accompanying business process reengineering multiplied by average salaries. This leads to a conservative estimation. A more accurate estimation could be done by using hedonic wage models (see Sassone 1987).

The next step was the calculation of the current value V_0 of the applications described above.

Implementation opportunity	$N_t.b$	V_0
EDI-based purchasing	1000	95000
EDI-based invoicing	1000	87000
Workflow for sales	10500	79000
Engineering document handling	27000	235000
World wide web based e-commerce system	37500	880000

Table 3 Current value of applications

Based on the values above, the 3 different methods for the valuation of these applications developed in the previous chapter were compared: NPV_1 analysis (4), an extended version of NPV analysis, where the possibility not to install the applications is taken into account, denoted as NPV_2 (6) and the option value based on the Black-Scholes formula to value an European call option (7). The different results based on r = 6% are shown in Table 4:

Implementation opportunity	NPV_1	NPV_2	Black-Scholes	$\Delta NPV_2/BS$
EDI-based purchasing	38000	39200	57400	46%
EDI-based invoicing	0	900	1000	11%
Workflow for sales	0	15400	27200	77%
Engineering document handling	0	37400	50200	34%
World wide web based e-commerce system	110000	470000	514000	9%
Σ	148000	562900	649800	16%

Table 4 Comparison of NPV_1, NPV_2 and Black-Scholes option values

To understand the differences, recall the implicitly underlying assumptions for each of the three methods. The NPV method assumes an implementation of the application at time *T*, obtaining the benefits and paying investment cost *I*, regardless of the observed realization of V_T. It should be noticed that these assumptions do not coincide with the real setting, because an application will not be implement when it turned out to be not profitable at time *T*. Only EDI-based purchasing and the world wide web based e-commerce system show a positive value. However, the NPV of both applications of $148.000 is not sufficient to justify the implementation of R/3. In contrast, both other evaluation methods show positive values for all implementation opportunities. The total values of \$562.900 and \$649.800 respectively exceed the negative passive NPV based on a fixed application portfolio of the R/3 platform and lead to a quantitative justification of the decision to switch the platform. Table 4 also indicates that although NPV_2 and the Black-Scholes formula are based on different assumptions, they show a difference of only 16% which increases the credibility of the result. Incidentally, note that it is possible to sum the values of different implementation opportunities to obtain the second term in (2) only if the respective applications can be implemented independently from each other, i.e. if it is not the case that one application can be implemented only if another one is already in use. In our opinion, in practice this is usually the case within a reasonable planning horizon, as it is very hard to get reliable estimates for (3) for applications whose implementation has to be decided upon in the distant future and whose feasibility is contingent on other applications which perhaps will not be implemented.

In addition to the calculations described, sensitivity analysis has been applied in order to get an idea of the effect of changing parameters on the value of an implementation opportunity. An example of such an analysis for the EDI-based purchasing application is described in Table 5.

	T=3			*T*=4			*T*=5			*T*=6		
	NPV	NPV_2	BS	NPV	NPV_2	BS	NPV	NPV	BS	NPV	NPV_2	BS
σ=15%	40300	40300	52900	38200	38200	55300	36000	36000	57600	33700	33700	59700
σ=25%	40300	40400	53200	38200	38400	55800	36000	36200	58200	33700	33900	60400
σ=35%	40300	41100	54500	38200	39200	57400	36000	37100	60100	33700	34800	62500
σ=45%	40300	42500	56500	38200	40600	59900	36000	38500	62900	33700	36100	65500
σ=55%	40300	44100	59000	38200	42300	62800	36000	40100	66000	33700	37700	68900

Table 5 Different Scenarios for the implementation opportunity EDI-based purchasing

One can see from Table 5 that both NPV_2 and Option values increase with a rise in uncertainty, while NPV stays constant. If μ would be corrected for a higher σ, the NPV would even decrease. The increasing values reflect the higher upside potential while downside risk does not lower the value due to freedom of choice in implementing the application under consideration. Similarly, a change in the number of periods until the application can be implemented lowers the NPV of the application as the time value of money decreases. Options value increase due to the fact that the more periods are considered, the higher the upward potential while downward risk is limited.

Let us thus summarize the main implications of option thinking in the case presented: Even though the initial set of applications run under SAP R/3 was the same as the one so far used under SAP R/2, the additional opportunities to introduce applications based on EDI, workflow management, document management and e-commerce justified the introduction of SAP R/3. This convinced both the CFO and the users that switching to SAP R/3 was a good idea as the higher implementation cost could be related to higher future benefits, and the additional value provided by SAP R/3 could be plausibly and objectively explained.

In particular, the following advantages of the options based method could be observed:

- The method discussed stresses that software platforms derive a substantial part of their benefits from implementation opportunities. It conforms to Weill´s characteristic 7 of IT infrastructure: in contrast to NPV analysis, the higher uncertainty of possible future implementation possibilities is not punished, but it is recognized that a higher uncertainty leads to higher potential benefits while possible unfavorable developments do not entail losses due a given flexibility.
- Determining the value of these implementation possibilities provides a clear structure for determining the value of “long-run potential” in the decision process. It also gives users a concrete idea of what applications they can expect from a particular alternative.
- Unlike flexibility indices or similar measures which cannot be directly related to implementation costs, the result is measured along the same scale as such costs. A clear method for deriving the value of a software platform from the basic assumptions is shown.
- Plausibility can be checked objectively: data like N_0 or b are given, growth rates and variances can be checked against experiences made with other projects and/or results published in the literature.

4. Implications and Conclusions

In this paper, we have presented a methodology for valuing implementation opportunities provided by a software platform and demonstrated the advantages of applying this method to support the selection of such a platform. Using a real-life case study concerned with the decision of whether to continue using SAP R/2 or switching to SAP R/3, we have shown that this approach can lead to a better-structured decision process, to an improved integration of users and to a more objective and controllable way of arriving at a decision.

The *implications of this work for MIS practice* are as follows:

- When adopting a software platform, IT management should carefully consider the future applications possible and discuss their potential value and its determinants with the potential users instead of presenting arguments to which future users cannot relate.
- The IT department should quantify the value of the opportunities thus obtained to allow a financially oriented management a direct comparison with the total cost of ownership of the various platform alternatives.

As the results here presented are based only on a few cases, it is clearly too early to view our statements as generally acceptable - a number of questions still remain open and research in this direction would certainly represent a fruitful area of investigation. From the authors' point of view, the following issues appear to be particularly interesting:

- the empirical investigation of the assumptions made by option valuation models, especially those concerning the statistical properties and the possibilities of hedging;
- the investigation of real-life software platform decisions so as to find out whether IT managers use option thinking in a qualitative way and/or what approximations/proxies for the option value are employed;
- the estimation of option values present in software platforms using methods developed in (Quigg 1993) for the estimation of the value of the option to develop land.

Mathematical Appendix

Appendix 1

The derivations shown here can all be found in standard textbooks in finance. We compile them in order to be self-contained. At first, we show that the expected discounted sum of benefits per period V_t follows a geometric Brownian motion. The profit P_t is given by the product of the number of usages N_t of the software application times a constant benefit per usage b:

$$P_t = b.N_t$$
$$dP_t = P_t.(\alpha.dt + \sigma dW_t)$$

The expected discounted sum of benefits V_t is defined as:

$$V_t = E_t\left[\int_t^\infty e^{-\mu.(s-t)} P_s ds\right] =$$
$$= \int_t^\infty e^{-\mu.(s-t)} E_t[P_s] ds =$$
$$= P_t.\int_t^\infty e^{-\mu.(s-t)} e^{\alpha.(s-t)} ds =$$
$$= P_t.e^{t(\mu-\alpha)}.\int_t^\infty e^{s.(\alpha-\mu)} ds =$$
$$= \frac{P_t}{\mu-\alpha}$$

Appendix 2

We derive an explicit formula for the extended NPV_2. We compute $E(\max(V_T - I;0)$. We can write

$$V_T = V_0 . e^{\tilde{\alpha}.T+\sigma.\sqrt{T}.z}$$

where $\tilde{\alpha} = \alpha - \frac{\sigma^2}{2}$ and z is a standardized normal variable.

The expectation value becomes

$$\int_{z_0}^{\infty} \frac{1}{\sqrt{2\pi}} \left(V_0 . e^{\tilde{\alpha}.T+\sigma.\sqrt{T}.z} - I\right) e^{-\frac{z^2}{2}} dz =$$

$$= \frac{1}{\sqrt{2\pi}} \int_{z_0}^{\infty} \left(V_0 . e^{\tilde{\alpha}.T+\sigma.\sqrt{T}.z}\right) e^{-\frac{z^2}{2}} dz - \frac{I}{\sqrt{2\pi}} \int_{z_0}^{\infty} e^{-\frac{z^2}{2}} dz$$

with the lower bound of the integral

$$z_0 = \frac{\ln(\frac{I}{V_0}) - \tilde{\alpha}.T}{\sigma\sqrt{T}}$$

In the first term of the expectation value we complete the square in the exponent to obtain

$$\frac{V_0 . e^{\tilde{\alpha}.T}}{\sqrt{2\pi}} \int_{z_0}^{\infty} \left(e^{\sigma.\sqrt{T}.z}\right) e^{-\frac{z^2}{2}} dz =$$

$$= \frac{V_0 . e^{\alpha.T}}{\sqrt{2\pi}} \int_{z_0}^{\infty} e^{\frac{1}{2}\left(z-\sigma\sqrt{T}\right)^2} dz =$$

$$= V_0 . e^{\alpha.T} . N(-z_0 + \sigma\sqrt{T})$$

where N(.) denotes the cumulative standard normal distribution.
The second term can be written in terms of the standard normal distribution $I.N(-z_0)$.

Finally, the extended NPV is given by

$$NPV_2 = e^{-\mu T} . (V_0 . e^{\alpha T} . N(d_1) - I.N(d_2))$$

$$d_1 = \frac{1}{\sigma\sqrt{T}} \left(\ln\left(\frac{V_0}{I}\right) + \left(\alpha + \frac{1}{2}\sigma^2\right) T \right)$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

Appendix 3

The derivation follows the binomial approach to the Black-Scholes formula developed in (Cox, Ross, Rubinstein 1979) as contained in standard textbooks on finance such as (Copeland, Weston 1992, p. 240 ff.) or (Hull 1997, p. 217 ff.). However, instead of using a hedge portfolio consisting of one share of stock and a number of call options sold short, we start by constructing a replicating portfolio that consists of risk-less securities and twin securities (Smith, Nau 1995).

First, let us look only at an implementation possibility that must be decided upon in 1 period of time. Assume that *V* can go up by a certain percentage *u* and go down by a certain percentage *d* in that period where $u > 1+r > 1$ and $d < 1 < 1+r$. Also, assume that there is a portfolio of securities that is perfectly correlated to *V* (the twin security) and whose current value is *W*. Furthermore, there shall be a risk-less security that pays *(1+r)* per unit after 1 period, where *r* is the risk-free interest rate. Then, the portfolio that exactly replicates the payoffs of the implementation possibility under study must satisfy the following set of equations:

$$n(1+r) + mW_u = U$$
$$n(1+r) + mW_d = D$$

where *n (m)* is the number of risk-less securities (twin securities) and $U = max[0, Vu-I]$ and $D = max[0, Vd-I]$, i.e. the values of the option to implement the application under study in the two possible cases, respectively.
From this we deduct that the portfolio must consist of $n = \frac{D_u - D_d}{(1+r)(u-d)}$ risk-less securities and $m = \frac{U-D}{W(u-d)}$ twin securities so that its value is given by

$$F_0 = n + mW = \frac{D_u - U_d + (U-D)(1+r)}{(u-d)(1+r)}$$

This formula can also be obtained by solving

$$\frac{W_u q + (1-q)W_d}{(1+r)} = W$$

for the risk-neutral probability *q* to obtain $q = \frac{(1+r)-d}{(u-d)}$ and by calculating the expected option value via

$$F_0 = \frac{Uq + D(1-q)}{(1+r)}$$

Let us now consider several periods. In that case, the option values after *T* periods are the expression of the type $max[0,u^n d^{T-n} V_0 - I]$, where *n* is the number of upward movements in *T* trials with the constant probability *q*. Thus, the probability of each payoff is given by the binomial distribution $B(n|T,p) = \frac{T!}{(T-n)!n!} p^n (1-p)^{T-n}$ and the expected option value after *T* periods is given as

$$F_0 = \sum_{n=0}^{T} \frac{B(n|T,p)\max(0,u^n d^{T-n} V_0 - I}{(1+r)^T}$$

Summing only those option values that have no less than *h* jumps so that they are positive and separating terms, this equals

$$F_0 = V_0 \left[\frac{\sum_{n=h}^{T} B(n|T,p)(u^n d^{T-n} V_0 - I)}{(1+r)^T} - I(1+r)^{-T} \sum_{n=h}^{T} B(n|T,p) \right]$$

As (Cox, Ross, Rubinstein 1979) show, this results in the Black-Scholes formula

$$F_0 = V_0 N(d_1) - Ie^{-rT} N(d_2)$$

where

$$d_1 = \frac{\ln(\frac{V}{I}) + rT)}{sT^{0.5}} + 0.5sT^{0.5}$$
$$d_2 = d_1 - sT^{0.5}$$

when the length of a time period becomes infinitesimally small and $u = e^{s(\frac{t}{n})^{0.5}}$ and $d = e^{-s(\frac{t}{n})^{0.5}}$ d.

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