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Software Growth Options

by

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Abstract

In today's business environment characterized by global competition and buyers' markets, flexible response to changes in the environment is a key success factor for any firm. Consequently, there is increasing pressure for information systems to be easily adaptable to changing business processes. In this paper, we investigate ways of introducing this aspect of IS extendability into quantitative IT investment decision models via applying real options models. In particular, we discuss the usage of methods for evaluating sequential exchange options in order to obtain estimates for the value of software growth options, i.e. IS functions that are embedded in an IT platform and that can be employed once the particular base system is installed and their use is economically justified. On the basis of these models, we then investigate determinants of the value of software growth options and draw general conclusions with regard to decision making in the field of IT investment.

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Software Growth Options

1 Introduction

1.1 Motivation

In the design stage of an information system (IS), one often encounters functional requirements whose implementation is at that time not justified from a financial standpoint but which may become useful in the future. Examples of such situations are:

1. Suppose that currently a company does business only in its home country. However, if its business should expand abroad, the IS installed must be able to handle different languages and currencies, new methods of payments, etc.
2. Assume that a company produces several variants of a standard product. To use temporarily under-utilized resources, management decides to rent out machinery and personnel to other manufacturing companies on an hourly basis. If this kind of business is added to the current manufacturing process, a new type of order entailing different costing and scheduling must be supported by the firm's production planning and control system.
3. Market pressure to deliver customer-specific add-ons and modifications to standard products within a short time and at reasonable cost is on the rise. If the number and impact of such customer-specific orders increase, a company's production planning and control system must be able to efficiently support a variety of bills of materials and work schedules, e.g. via a bills of materials processor.
4. Instead of installing the latest release of SAP's mainframe system R/2, a firm considers the migration to the client/server version SAP R/3, as the new platform will permit the easy adoption of novel software technologies such as EDI, workflow management or document retrieval and archiving once these IS functions will be required.

Intuitively, a knowledgeable systems analyst will not neglect such possible requirements but take care that the existing IS can be easily enhanced in the directions indicated. Similarly, when judging the economic feasibility of an IS project or comparing alternative IS platforms for a given specification one should evaluate the benefits achieved from such possibly needed IS functions.

Capital budgeting offers quantitative methods for such evaluation tasks. A standard capital budgeting technique is the net present value rule. It is based on the net present value (NPV), calculated as the discounted sum of net benefits minus the investment cost, and states that an investment should be undertaken if its NPV is positive and that, if various independent investment alternatives are compared, the project with the highest NPV should be selected. Net benefit/period, investment cost and discount rate are assumed to be given as in other similar methods (see, e.g., [Trigeorgis3], p. 24 ff.).

Clearly, one can use the NPV method for evaluating the type of IS function presented above, if the future development is known for sure and the IS function's implementation date is fixed. Consider, for instance, the possibility of introducing EDI in example 4. If one assumes that the net benefit per electronic transaction is \$ 100[1] and that the quantity of possible electronic transactions rises from 500 by 100 per year due to an increasing number of possible partners, the NPV for an immediate implementation based on an 8% risk-free interest rate and a 10-year planning horizon is given by

$$NPV = \sum_{t=0}^{10} \frac{50,000 + 10,000t}{(1+0.08)^t} - I = \$712,373 - I. \qquad (1)$$

Thus, if the implementation cost I is less than \$ 712,373, the EDI function should be installed, otherwise not.

Now assume that the increase in net benefit/year is not known for sure, but that there is a probability of 0.45 that the number of electronic transactions decreases by 100, e.g., because the number of business partners using the same EDI format decreases. What value should we now consider for the EDI function? A natural choice would be an "expected NPV". In our case, this value is given by[2]

$$E(NPV) = V - I = \sum_{t=0}^{10} \frac{50,000 + 1,000t}{(1+0.1)^t} - I = \$386,264 - I \qquad (2)$$

as the stochastic process describing the development of the net benefit/period is a Random Walk and thus the cumulative change in period t, $t > 0$ follows a binomial

[1]The net benefit could be the difference between savings in inventory, transportation and document handling cost and the cost of an electronic procedure. We will deal in more detail with the issue of estimating the benefit of EDI in Section 2.2.

[2]According to the Capital Asset Pricing Model (CAPM), investors demand a risk premium for risky projects. The CAPM postulates that this risk premium is determined by the investment's systematic risk measured by its volatility relative to the market times the expected market risk premium given by the difference between the expected return from the market portfolio and the risk-free interest rate. For our example we assume a risk premium of 2% so that the appropriate discount rate is 10% (8% + 2%). For further details, see, e.g., [Trigeorgis3], p. 40 ff.

distribution with parameters $(nt, (p - q))$, n being the size of a move, p being the probability of an upward move and q the probability of a downward move.

Usually, the expected NPV is proposed to "save" the NPV formula for the case of investment under uncertainty. If in our case $I > \$386,264$, the expected NPV rule suggests that the implementation of EDI should not be considered. There we have implicitly assumed that EDI is implemented immediately. However, if possible, a reasonable decision maker would rather wait with the investment to see if developments are favourable. If, for instance, $I = 400,000$ and one waits whether $V = 80,000$ in period 4, a positive expected NPV of \$ 11,852 ($\sum_{t=4}^{10}(80,000 + 1,000t)/(1.1^t) - (400,000/1.08^4)$) is obtained.

In fact, the essence of "flexibility" is the ability to change the "configuration" of the asset obtained through investment in response to unknown future events instead of following a policy fixed at the beginning of the planning horizon. Therefore, formula (2) yields only a lower bound for the value of an investment alternative with embedded flexibility if configuration changes are made in an optimal way. In such a case, the expected present value V of a project depends on the policy of change chosen, and the actions taken depend on the development of the environment. Actually, for the IS functions described above the calculation in (2) will usually yield a negative expected NPV, as we assume that their "implementation at that time is not justified from a financial standpoint" and that the benefit of such an IS function lies in the possibility to implement it, if the environment develops in a certain way. Intuitively, a proper valuation method should therefore also give a positive value to IS functions present in an IS platform even if for the IS function the expected NPV is negative when calculated under the assumption that the IS function is to be implemented now.

In fact, the problems arising with the application of traditional capital budgeting methods in the IS field are not new. Based on an empirical survey of the usage of methods for capital budgeting in IS development, [Tam], for instance, finds that IT practicioners 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 rule. Consequently, simple, static models are often preferred to the net present value rule, and important project decisions are based rather on intuition, experience and rule of thumb than on quantitative analysis.

We think that one reason for this lack of appraisal of quantitative methods for evaluating IS investments is that traditional capital budgeting methods cannot adequately cope with the flexibility embedded in many investments in IS, as they are based on the assumption that either there is no flexibility or that the investment is reversible, i.e. that it can somehow be undone and the expenditures recovered should the environment turn out worse than anticipated (see, e.g., [Dixit,Pindyck], p.6). As the above examples show, in the case of IS there usually is the possibility to extend, modify, ... the system. Furthermore, investments in IS are largely irreversible: Investments in software development are sunk costs that cannot be retrieved, if the software turns out to be unusable in the future. Similarly, contracts concluded in this field are usually worded in such a way that the usage fees for standard software cannot be regained, if during usage the requirements of the IS change.

For this type of irreversible investment with flexibility, the "real options" literature ([Trigeorgis1]) proposes that the traditional NPV should be expanded to a "strategic NPV" defined as:

$$\text{Expanded (strategic) NPV} = \text{passive NPV of expected cash flows} + \text{value of options from active management} \quad (3)$$

In our application area, the first term refers to the difference between the discounted sum of net benefits generated by using the base configuration of the information system under study and its implementation cost, while the second term is the value of the possibility to introduce IS functions like those described at the beginning of this section when found beneficial. To valuate these possibilities, we use the similarity of flexible IS usage and financial options: Financial options offer the holder the right to buy, sell or exchange a financial asset under boundary conditions that, for instance, specify the period during which the right can be exercised or the relevant exercise price. Options need not be exercised. Real options, on the other hand, offer the owner of an asset with embedded flexibility the possibility — but not the obligation — of changing the asset's configuration, i.e. in our case by implementing additional IS functions.

1.2 Previous Work

Traditionally, real option models concentrate on flexibility in capital investments that produce or handle traded commodities like oil or copper[3], because in such a case the model's parameters can be easily determined[4]. However, in a recent paper Trigeorgis proposes the application of real option methods to "information technology or other platform investments" as a direction for future research (see [Trigeorgis1]), and a number of papers with applications in other areas have appeared[5].

The only paper using real options for valuing IS projects that is known to the author is by Dos Santos: in [DosSantos] he uses Margrabe's exchange option model (c.f. [Margrabe]) to determine the second term in (3) for an IS project using a novel technology for testing purposes. Dos Santos states that such a project generates the option to use the new technique for future projects in case it turns out useful,

[3] See, e.g., [Kemna] for the valuation of options embedded in investments for oil search and refinery and [Dixit,Pindyck] for the treatment of flexibilities in the operation of oil tankers and copper mines.

[4] The rationale for this argument will be given in Section 2.2.

[5] See, e.g., [Pennings,Lint] for the application of real option models for valuing R & D projects in electronics, [Nichols] for the use of real options in justifying R & D projects in pharmaceutics, and [Quigg] for the usage of real options to estimate the value of options embedded in the possession of real estate from observed land prices.

i.e. if it increases the NPV of future projects due to learning and experience. In his conclusion, Dos Santos writes: "The options pricing literature has developed a great deal over the past 15 years and numerous models have been developed for use in pricing different types of securities options. While this paper has showed how one such model can be used in evaluating new IT investments, the use of options pricing models to determine the value of other types of IT investments should be investigated. Such work will help put "justification" tools that can be used to handle a wide variety of problems into the hands of knowledgeable investment evaluators." Tam argues similarly: "In recent years there has been a growing interest in using the option pricing framework to incorporate the option to delay an investment decision. This approach has tremendous ramifications, because the option to offer new services and to enter new markets is contingent on the decision of the initial investment. Very often, the opportunity to expand or develop new products is described as strategic and having an intangible payoff in the IS literature. The availability of a formal model derived from option pricing theory will provide a valuable means to quantify opportunities in a more explicit way. " (see [Tam]).

1.3 Organization of the Paper

In Section 2, we start with a formal description of the type of IS flexibility studied and the usage of option pricing methodoloy for its valuation. As we demonstrate, the benefit of the implementation of a flexible IS platform can be viewed as consisting of the benefit of the base configuration chosen and the value of the "software growth options" embedded, i.e. the possibility to introduce new IS functions when found economically feasible. Subsequently, we deal with analytical models for the valuation of various types of software growth options to obtain an estimate of the second term in formula (3). There, we also present the implications of these methods for the dependence of the value of a software growth option on characteristics of the IS platform and the business environment. In Section 3, we discuss the relevance of software growth options for IS investment decision making; in Section 4, we summarize our findings and discuss further research topics in the area of software growth options.

2 Software Growth Options

2.1 The IS enhancement process

When checking the examples given in Section 1 for common elements, the following picture of flexible IS usage emerges (see also Figure 1):

- The implementation of a base configuration is started at time t_0. The implementation takes until time t_1, provides a particular passive NPV as given in

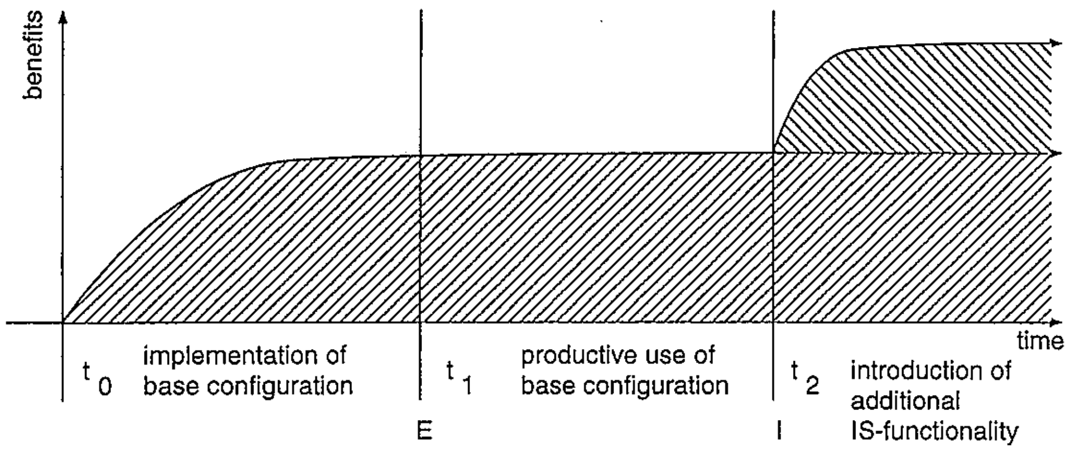

Figure 1: Software Growth Option

the first term of formula (3) and offers several software growth options[6], i.e. the possibility to invoke an IS function after time t_1. In the sequel, we will deal with valuing one software growth option and then return to the valuation of several software growth options in Section 2.5. In Figure 1, t_2 was chosen as a suitable time to implement the IS function under consideration.

- Depending on its nature, an IS function that forms a software growth option can be implemented at various times $t_2, t_3, \cdots$, ("implementation decision points") within a given planning horizon T. Bookkeeping systems, for instance, are usually put into operation only at the start of a new fiscal year. Another type of restriction may be the fact that other IS functions must be available. An MIS, for instance, can only be used if systems that deliver operating data are installed.

- The net benefit of an IS function that forms a software growth option in a particular period of a specified length is given by

$$P_t = N_t(p - c) - K \tag{4}$$

where N_t denotes the number of times the IS function is used during one period, p the benefit/usage, c the variable cost/usage and K the fixed cost per period. p and c are assumed to be given with $p > c$; N_t varies stochastically. p can be considered as cost savings and/or properly valued productivity gains, c as operating cost. K can be caused by periodic licensing fees and/or specialized supporting personnel that must be available regardless of the IS function's actual usage.

- There is a cost of invoking the IS function that is the basis of the software growth option. It can be composed of the (re)programming effort, licensing fees, cost of additional hardware, parameterizing effort, etc. The implementation cost can be fixed or vary stochastically, e.g. due to unknown price

[6]In example 4 of Section 1.1., for instance, we identified EDI, workflow management and document retrieval and archiving as software growth options present in R/3 but not in R/2.

reductions in the future[7]. In the case of deterministic implementation costs, we will denote them by F, otherwise by I.

- Additionally, there may be a cost E for providing in the base configuration the basis for a later use of the IS function to be decided upon at a given time. If E is not spent, the option to implement the IS function later is lost. An example could be the addition of functions to bookkeeping accounts with a view to using them when the cost accounting module is introduced.

2.2 Contingent Claims Analysis of Software Growth Options

One possibility to evaluate software growth options is to apply the option pricing theory developed for the valuation of contingent claims to securities and other traded assets. The goal of such a valuation is to value a claim to a security — or, more generally, to an "underlying asset" — as if it were traded in a frictionless market[8] where there are no transaction costs or taxes, no restrictions on short sales, where full use of proceeds is allowed, all shares of all securities are infinitely divisible and borrowing and lending at the same rate are unrestricted (see, e.g., [Trigeorgis3], p. 83). These assumptions are reasonable for financial options but need critical assessment in the case of real options. In particular, the following four questions must be dealt with when applying the option pricing theory to capital investment:

- What is the underlying asset and how is its value determined?
- What kind of stochastic process is reasonable for describing the development of the value, and how can its parameters be estimated?
- Can the "no arbitrage condition" used in deriving the value function of financial options be employed in the application area in question?
- Are closed-form analytical expressions for the value function available, and what kind of restrictions must be placed on the general situation described in Section 2.1 to permit their application?

For an option on a security the value of the underlying asset is the price of the security continuously determined via trading. The value of a particular IS function is the expected present value of the net benefits/period generated by its usage according to formula (4) and, thus, must be estimated by management. It is therefore much more ambigous than, e.g., a stock price.

[7]The case of an IS function present in the base configuration that can be changed to another IS function is also covered by this model, as in such a case the implementation cost can be seen as the sum of the (deterministic) implementation effort and the (stochastic) value of the IS function of the base configuration to be exchanged.

[8]This is consistent with using a risk-adjusted discount rate in an expected NPV calculation as done in formula (2).

Most option pricing formulas are based on the assumption that the value of the underlying asset follows a geometric Brownian motion. Hence, in our application context, one can assume that the net benefit per period P gained through the usage of an IS function follows a geometric Brownian motion, i.e.

$$dP = \alpha P dt + \sigma P dz, \tag{5}$$

where α is the drift parameter, σ the variance parameter and dz the increment of a Wiener process, that is $dz = \epsilon_t \sqrt{dt}$ where ϵ_t are serially uncorrelated, normally distributed random values with zero mean and unit standard deviation. In that case, the value of the IS function under study defined as the expected present value of the net benefits/period obtained through the IS function's usage is given by

$$V = E[\int_0^\infty P_t \exp^{-\mu t} dt] = \frac{P_0}{\mu - \alpha}, \tag{6}$$

i.e. V also follows a geometric Brownian motion. There, μ is the risk-adjusted discount rate and $\mu > \alpha$. Besides the fact that the value of an IS function is not continuously revised but rather at discrete times following the availability of new information to management, formula (5) implies that P is always greater than zero. Generally, this is only true if the fixed cost K in (4) can be neglected.

For traded assets, time series data about the development of V can be used to estimate α and σ[9]. For our area of application, subjective estimates by management based, e.g., on business process reengineering studies, experiences from similar projects, etc. must be used for parameter estimation. A suitable method for this task can be based on the fact that from (5) results that the percentage change of P follows a Brownian motion with drift, i.e. $dP/P = \alpha dt + \sigma dz$, so that the percentage change over any time interval Δt is normally distributed with the expected value $\alpha \Delta t$ and variance $\sigma^2 \Delta t$. Thus, in view of formula (4), management will have to answer two questions regarding the development of P to obtain parameter estimates:

- By what average percentage will the number of uses of the IS function under study grow in one period? The answer will provide an estimate for α.
- Below which value γ will the percentage change lie with a 95% probability? Due to the normal distribution, an estimate[10] for σ^2 will then be given by $((\gamma - \alpha)/2)^2$.

Critics of this method may argue that it is as undisciplined and unrepeatable as the less complex qualitative decision rules described in [Tam]. However, to counter

[9] However, also for financial options this can present a problem, as the stochastic process for V often is nonstationary.

[10] As we will see in the following sections, only an estimate for σ^2 will be required. However, an estimate for α is needed to estimate σ^2. Another method for estimating σ^2 for real options is described in [Nichols]: There, the observed volatility of biotechnology stocks is used as a proxy measure for the volatility of R & D projects in pharmaceutics.

this argument we would stress that only the dynamics of the development of the net benefit/period are estimated subjectively. These estimates can be subjected to checks for their plausibility as compared to other similar projects and, ex post, to the values actually observed. For instance, such an evaluation is not possible with an average "flexibility index" obtained from ordinally scaled judgments about this attribute (see, e.g., [Buss]). Furthermore, here "a rigorous option analysis will help management to identify the crucial variables and to see how the adoption and valuation decision are effected by risk, cash-flow projections, interest rates, and other important variables" (see [Sick], p. 4).

Returning to our EDI example, one can obtain empirical evidence regarding size and determinants of the benefits of EDI from [Mukhopadhyay,Kekre,Kalathur]. Mukhopadhyay et al. analyze the impact of EDI at Chrysler based on data collected at the plant level from nine assembly facilities during the period 1981-1990. They categorize the benefits detected into savings in:

- Inventory Holding Cost:
  due to increased accuracy of shipment information, buffer stocks can be decreased
- Obsolete Inventory Cost:
  for the same reason, write-offs of obsolete inventory can be reduced
- Transportation Cost:
  increased accuracy and long-term planning data permit a better usage of truck capacity
- Premium Freight:
  due to reduced shortages, the number of emergency deliveries can be lowered
- Document Handling Cost:
  due to electronic data interchange, a number of clerical tasks regarding data entry, document filing etc. can be saved

Mukhopadhyay et al. build econometric models, where theses variables are regressed against a measure of EDI penetration and several other factors like parts' variety and model changes to isolate the effect of EDI. In general, Mukhopadhyay et al. find a significant and approximately linear dependence of the different types of cost savings described above and EDI penetration. This lends credibility to formula (4). No data regarding the type of stochastic process that describes the growth of EDI penetration is given, but when looking at the growth path of other products that exhibit network economies of scale like the Internet, for instance, it is plausible that in the growth phase the development of the number of uses of the IS function is characterized by a constant average growth rate. Nevertheless, more empirical work dealing with this and the other above described assumptions of the geometric Brownian motion model is needed: for instance, while it seems plausible that there are unbounded deviations from the mean percentage change in both directions, empirical tests whether the normal distribution is a suitable model for the percentage change of P are necessary. Also the effects of the approximation of the real world discrete time process describing the development of P by the continous time geometric Brownian motion model should be investigated.

Differential equations describing the movement of the option value as a function of the value of the underlying asset can be derived on the basis of the "no arbitrage condition" which states that the value of an option must be set equal to the value of a replicating portfolio of a risk-free asset and the underlying asset that gives the same value as the option at the end of its exercise period, as otherwise risk-free profits — arbitrage opportunities — would be possible.

As in our case the underlying asset — the IS function under study or the right to use the particular IS function in the case of standard software — is not traded, this condition does not hold. However, it is possible to demonstrate that the results obtained via the no arbitrage condition also hold, if the value of the underlying asset is perfectly correlated with a traded "twin security" which can also be a possibly dynamic portfolio of traded assets. This condition is usually satisfied when flexibility is studied in assets producing standardized commodities like oil, minerals and agricultural products where risk concerns the commodity price. Hence, it is not surprising that early adoptions of real option models occurred in this field. The second phase of application is characterized by works like [Quigg] where well-traded but not as standardized products, such as real estate, represent the area of interest. According to [Sick], p. 4, the final area of adoption of real option models are investments in totally new products where no historic data is available and the construction of a perfect twin security is not possible. This will usually be the case in our field of application where at least part of the risk cannot be hedged via a combination of traded assets. Typically, the technical risk or the risk of user acceptance are "private" rather than "diversible" risks. In such situations, decision analysis is a proper valuation method, as it aims at determining the subjective value of the decision maker (see, e.g., [Smith,Nau]). In particular, [Smith,Nau] propose a combination of decision analysis and option valuation techniques so that the opportunities to hedge via buying and selling securities are incorporated when folding back the decision tree[11]. While such an approach is clearly suitable for a detailed analysis, we stick to the "market valuation" approach as an approximation for several reasons:

- As in our context the value of the underlying asset can only be approximated, there is no point in trying to be overly precise where the option value is concerned[12].
- For a software vendor, who has to decide which IS functions to offer in a future release and who has no information about the subjective preferences of his potential customers, it makes sense to get an idea of the "market value" of a software growth option.

[11] Using (naive) decision tree analysis with a constant discount rate for option valuation is not appropriate, as the risk of an option changes over time and with changing values of the underlying asset (see, e.g., [Kemna]).

[12] See, e.g., [Pennings,Lint] for a similar argument in the case of R & D projects in electronics.

- Closed-form analytical expressions permit a straightforward analysis of the sensitivity of the option value to variations in the parameters of the value function and may be familiar to the finance people who are in charge of project evaluation. Furthermore, with several judgments of γ, one can build a 95% confidence interval of σ^2 and, hence, of the option value.
- However, analytical formulas are only available for certain, simplified situations that do not cover all the options present in real life. Nevertheless, often only a lower bound for the value of a software growth option is needed. Consider our example of the decision between R/2 and the introduction of R/3. In such a case, the relevant question is: "Is the value of the software growth options embedded in R/3 high enough to justify the higher implementation cost?" Thus, only a lower bound for the option value of EDI, workflow management or document retrieval and archiving is needed.

2.3 Valuation as a Sequential European Exchange Option

Consider an IS function that forms a software growth option and assume that in Figure 1 there is only one implementation decision point: in t_1 the implementation of the base configuration is finished, and one can decide to spend preparation effort $E = qI$, $q \geq 0$, where I denotes a random implementation cost that follows a geometric Brownian motion to obtain the opportunity to implement the IS function in t_2. Clearly, until t_1 the usage of any IS function is not possible. Assume further that the IS function under study cannot be implemented before t_2, even if business development since t_0 implies a significant number of function usages, e.g. because the base configuration must be tested for a certain period of time and/or the IS function's invocation is tied to a particular date (e.g. to the end of a year).

In such a setting, the software growth option resembles a sequential (European[13]) exchange option, i.e. together with the benefits of the base configuration the user obtains the claim to the future net benefits of the usage of a particular IS function V (value of the underlying asset) via investing a certain amount $E = qI$ at t_1 and I (delivery asset) at time t_2 (exercise period). No "dividend payments", i.e. net benefits that the user of an implemented IS function obtains and the owner of an option on the IS function's implementation misses, are lost as the IS function cannot be used earlier.

The value of such a sequential exchange option is derived in [Carr] as

$$F_C(V, I, q, t_1, t_2, \sigma^2, \sigma_I^2, \rho_{VI}, r) = \qquad (7)$$
$$VB(d_1(\frac{Rexp^{rt_1}}{R^*}, t_1), d_1(Rexp^{rt_2}, t_2)) -$$

[13]An American type of option can be exercised at any time during its exercise period, while for a European one this is only possible at the end of the exercise period.

$$Iexp^{-rt_2}B(d_2(\frac{Rexp^{rt_1}}{R^*},t_1),d_2(Rexp^{rt_2},t_2)) -$$
$$qIexp^{-rt_1}N(d_2(\frac{Rexp^{rt_1}}{R^*},t_1))$$

where

V - value of the IS function under study, expected present value of net benefits of usage

I - cost of implementing the IS function under study, $R = V/I$

q - fraction of I needed for implementation preparation

t_1 - decision time for implementation preparation (start of productive use)

R^* - value of R above which the (simple) exchange option should be acquired at t_1 obtained by solving $F_M(V, I, t_2 - t_1, \sigma^2, \sigma_I^2, \rho_{VI}, r) - E = 0$ for R, where F_M is given by Margrabe's exchange option formula in equation (8) below

t_2 - implementation decision time

σ^2 - instantaneous variance of V

σ_I^2 - instantaneous variance of I

ρ_{VI} - correlation between V and I

$N(.)$ - cumulative standard normal distribution function

$B(.,.)$ - bivariate cumulative standard normal distribution function with correlation coefficient $\sqrt{t_1/t_2}$

$d_1(\theta,\tau) = (ln\theta + \frac{1}{2}\omega^2\tau)/(\omega\sqrt{\tau})$

$d_2(\theta,\tau) = d_1(\theta,\tau) - \omega\sqrt{\tau}$

$\omega^2 = \sigma^2 + \sigma_I^2 - 2\sigma\sigma_I\rho_{VI}$, instantaneous variance of R

r - risk-free interest rate.

From (7) the following sensitivity results can be derived (see [Carr]): other factors being constant, the value of a software growth option is higher,

- the higher the present value of net benefits V,
- the lower the implementation cost I,
- the lower q,
- the longer the option is held (t_1, t_2),

- the higher the variance of R (ω^2),
- the higher the risk-free interest rate r and
- the lower the correlation ρ_{VI}.

The first three results are obvious. The reason for an option value increasing in its exercise period and variance is that in such a case the chance of an increase in value rises, while the downward risk is limited by the possibility of not exercising the option. As the implementation cost must be paid only when the IS function is activated, it constitutes a risk-free loan which earns a dividend r as long as it is not spent. Furthermore, the greater the correlation between V and I, the less likely it is that V will exceed I in t_2 and thus the lower the option value.

If there is no effort for implementation preparation, q vanishes and (7) is reduced to Margrabe's exchange option (see [Margrabe]):

$$F_M(V, I, t_2, \sigma^2, \sigma_I^2, \rho_{VI}, r) = VN(d_1(Rexp^{rt_2}, t_2)) - Iexp^{-rt_2}N(d_2(Rexp^{rt_2}, t_2)) \quad (8)$$

[DosSantos][14] proposed this model to quantify the value of the experience and know-how gained via a first-step pilot project for subsequent projects, i.e. in addition to the NPV directly attributable to the pilot project, the value of the option on further projects using the same technology is to be taken into account when deciding whether to undertake the pilot project.

If the implementation cost is also deterministic, the well-known call option model according to Black-Scholes emerges:

$$F_B(V, F, t_2, r, \sigma^2) = VN(d_1(\frac{V}{Fexp^{-rt_2}}, t_2)) - Fexp^{-rt_2}N(d_2(\frac{V}{Fexp^{-rt_2}}, t_2)) \quad (9)$$

If the implementation cost is deterministic but a deterministic effort for implementation preparation remains, Geske's formula for a compound option ([Geske]) is obtained:

$$\begin{aligned} &F_G(V, F, E, t_1, t_2, r, \sigma^2) = \qquad (10) \\ &VB(d_1(\frac{V}{V*exp^{-rt_1}}, t_1), d_1(\frac{V}{Fexp^{-rt_2}}, t_2)) - \\ &Fexp^{-rt_2}B(d_2(\frac{V}{V*exp^{-rt_1}}, t_1), d_2(\frac{V}{Fexp^{-rt_2}}, t_2)) - \\ &Eexp^{-rt_1}N(d_2(\frac{V}{V*exp^{-rt_1}}, t_1)) \end{aligned}$$

[14] Contrary to Dos Santos, we assume that the money needed for the implementation in t_2 can be invested in a risk-free way to earn a dividend r in order to be able to make a fair comparison between the different option models presented.

where V^* is the value of V above which the call option should be acquired at t_1 obtained by solving $F_B(V, F, t_2 - t_1, r, \sigma^2) - E = 0$ for V, where F_B is given by Black-Scholes' formula in equation (9) above.

Let us now apply this model to the option to implement EDI as given as example 4 in Section 1. There, we will make the following assumptions:

- The net savings per transaction done via EDI are \$ 100 and the current usage level is 500 transactions per year. Fixed costs are negligible. Thus, the net benefit/period is \$ 50,000.
- The number of EDI transactions rises by 10% a year on the average and the percentage change will lie below $0.1 + \sqrt{0.4}$ with a 95 % probability so that $\sigma^2 = 20\%$. Besides this basic scenario, alternative calculations for $\sigma^2 = 10\%$ and $\sigma^2 = 30\%$ are done.
- The time needed for the installation of the base configuration is 1 year (t_1). t_1 also serves as decision time for the preparation of the implementation. The implementation decision point is year 3 ($t_2 = 3$). Besides, alternative calculations for $t_2 = 1$ and $t_2 = 3$ will be done.
- The risk-free interest rate is 8%. The appropriate risk-adjusted rate of return is assumed to be 20%, so that according to formula (6) the current value of the EDI function is given as $V_0 = 50,000/(0.2 - 0.1) = \$500,000$.
- Estimates for the implementation effort are \$ 500,000, \$ 750,000, \$ 1,000,000, respectively. For (7) and (10) a cost of 10% of I (F) is required if implementation is prepared at t_1. $I_0(F)$ will then be lowered by that amount to be able to make a fair comparison between the various types of software growth options.
- For (7) and (8) we use the same values for σ^2 and σ_I^2 and calculate (7) and (8) for correlation coefficients of 0.5, 0 and -0.5 in the case of $t_2 = 2$, $t_2 = 3$ and $t_2 = 4$, respectively.

Table 1 gives a survey of the values of the EDI growth option thus resulting. There, both the values for I_0 (F) and the option values are given in percentages of V_0. The overall picture emerging is quite surprising: Even though the implementation of EDI currently is not justified due to a non-positive expected NPV, up to 71% (!)[15] of the discounted sum of net benefits possible due to EDI usage, i.e. $0.71 \times 500,000 = \$355,000$, can be added to the NPV of net benefits generated by using the base configuration, because there is the possibility to invoke EDI in period 4 if $V_4 > I_4$. With regard to the influence of model parameters, the values calculated follow the sensitivity results given above: the later the implementation decision, the higher the volatility, and the lower the implementation cost, the higher the value of a software growth option. In general, only for rather short-lived implementation opportunities

[15]This happens in the case of Margrabe's exchange option for parameter values $V_0 = I_0$, $t_2 = 4$, $\sigma^2 = 30\%$ and $\rho = -0.5$.

Table 1: Value of EDI growth option

	$t_2 = 2$			$t_2 = 3$			$t_2 = 4$		
Black-Scholes' formula									
σ^2/F	100%	150%	200%	100%	150%	200%	100%	150%	200%
10%	0.26	0.09	0.03	0.32	0.16	0.08	0.38	0.22	0.13
20%	0.31	0.16	0.09	0.39	0.26	0.16	0.45	0.32	0.23
30%	0.36	0.22	0.14	0.44	0.31	0.23	0.51	0.39	0.31
Margrabe's formula									
	$t_2 = 2$, $\rho = 0.5$			$t_2 = 3$, $\rho = 0$			$t_2 = 4$, $\rho = -0.5$		
σ^2/I_0	100%	150%	200%	100%	150%	200%	100%	150%	200%
10%	0.26	0.09	0.03	0.39	0.25	0.16	0.51	0.39	0.31
20%	0.31	0.16	0.09	0.49	0.37	0.29	0.63	0.54	0.48
30%	0.36	0.22	0.14	0.56	0.46	0.38	0.71	0.64	0.59
Geske's formula, $t_1 = 1$,									
	$t_2 = 2$			$t_2 = 3$			$t_2 = 4$		
σ^2/F	100%	150%	200%	100%	150%	200%	100%	150%	200%
10%	0.22	0.06	0.01	0.28	0.09	0.03	0.33	0.14	0.05
20%	0.28	0.12	0.05	0.34	0.18	0.09	0.40	0.23	0.13
30%	0.32	0.17	0.09	0.39	0.24	0.14	0.45	0.30	0.20
Carr's formula, $t_1 = 1$									
	$t_2 = 2$, $\rho = 0.5$			$t_2 = 3$, $\rho = 0$			$t_2 = 4$, $\rho = -0.5$		
σ^2/I_0	100%	150%	200%	100%	150%	200%	100%	150%	200%
10%	0.22	0.06	0.01	0.34	0.18	0.09	0.45	0.30	0.20
20%	0.28	0.12	0.05	0.43	0.29	0.20	0.56	0.45	0.36
30%	0.32	0.17	0.09	0.50	0.37	0.29	0.64	0.54	0.47

in stable environments that at the time of deciding which base configuration to implement are highly unprofitable (e.g. in the case of $t_2 = 2$, $\sigma^2 = 0.1$ and $I_0 = 2V_0$) the neglectance of software growth options seems justified when calculating the NPV for IS usage.

As can be seen from the first 12 rows of Table 1, Margrabe's exchange option generates a higher value for a software growth option than the standard call option. While the values for these two option types are the same if $\rho = 0.5$, in which case $\omega^2 = \sigma^2$ according to our assumptions, the exchange option turns out to be significantly more valuable, the larger the implementation decision time and the more negative the correlation between V and I. Furthermore, an exchange option's value turns out to be less sensitive to changes in I_0: While the value of a call option drops from 0.51 to 0.31 by 39% if F is doubled in the case of $t_2 = 4$ and $\sigma^2 = 0.3$, the corresponding value of an exchange option only falls by 17% (from 0.71 to 0.59) if the implementation cost is negatively correlated with the value of EDI. In this case, \$295,000 can still be added to the passive NPV of the base configuration, even though the current implementation cost has risen from \$500,000 to \$1.000,000. We feel that in our area of application situations of the latter type will be frequent in view of falling implementation costs caused by economies of scale of software development, network economies of scale or learning effects.

The positive effect of randomness of implementation cost can also be inferred by comparing the values obtained for Geske's and Carr's formulas given in the second half of Table 1. Again they are the same for $\rho = 0.5$, but then Carr's formula yields higher values. In general, the values obtained are lower than those resulting from the respective model without implementation preparation effort due to the need to spend E earlier. In addition to the values given in Table 1, information regarding the critical values R^* and V^* is obtained for these models. For instance, if for a compound option $\sigma^2 = 0.1$ and $F = \$900,000$ an implementation at $t_2 = 4$ should be considered only if the ratio of the value of EDI to the implementation cost is larger than 0.68 in t_1. In such a case, the \$100,000 preparation effort should be spent. This bound drops to 0.49 in the case of a sequential exchange option with the same parameter values and $\rho = -0.5$.

The option pricing methods so far presented are based on the assumption that there is only one possible moment t_2 when the IS function under consideration can be invoked. In practice, though, there are often several opportunities to introduce a new IS function. With a six year planning horizon, e.g., there are five chances to implement a cost accounting system module, if the installation of the base configuration takes one year and the application of the cost accounting function can be started only at the beginning of a fiscal year. Furthermore, in that case the benefit lost by waiting for another opportunity has to be taken into account, i.e. after t_2 the option becomes American.

As in Section 2.2. we argued that often only an approximate lower bound is interesting, one approach to this issue is to use formulas (7) - (10) as lower bounds for the value of an option with several exercise periods[16]. The error due to such an approximation is discussed in [Trigeorgis2]. The general result of this line of research is that the value of a combined option is the more additive in the values of the options combined, the more different their type, the more similar their exercise periods and the more different their exercise price. Moreover, the combined option value is more additive, if the exercise of one option does not preclude that of another one. None of these conditions is met in our case. Generally, a software growth option is composed of several exchange options which have very similar exercise prices and different exercise periods and where the exercise of the first option "kills" all following ones, i.e. once the IS function at the base of the software growth option is used, it cannot be used again. Thus, we feel that a good strategy for obtaining a conservative approximation for the value of a software growth option is to use formulas (7) - (10) at the earliest implementation date possible[17].

2.4 Valuation as a Pseudo-American Exchange Option

Another approach to approximately value a software growth option with several alternative implementation decision points is to assume that the IS function under consideration can be implemented at any time within a given planning horizon T and to use the approximation via pseudo-American exchange options derived in [Carr]. A pseudo-American option assumes a constant dividend yield and that the option can be exercised at fixed exercise times $t_1, t_2, \cdots, t_n$ within planning horizon T. If the option can be exercised only at T, its value is given as a European exchange option with dividend δ ([Carr]):

$$F_{A1}(V, I, T, \sigma^2, \sigma_I^2, \rho_{VI}, r, \delta) = \\ V exp^{-\delta T} N(d_1(R exp^{-(\delta - r)T}, T)) - I exp^{-rT} N(d_2(R exp^{-(\delta-r)T}, T)) \quad (11)$$

If the option can only be exercised at $T/2$ or T, its value is given as ([Carr]):

$$F_{A2}(V, I, T, \sigma^2, \sigma_I^2, \rho_{VI}, r, \delta) = \\ V exp^{-\delta T} B(-d_1(\frac{R exp^{-(\delta-r)T/2}}{Q^*}, T/2), d_1(R exp^{-(\delta-r)T}, T)) - \quad (12)$$

[16] Another possibility is to use numerical methods (see, e.g., [Geske,Shastri]). However, this could prevent managers from accepting real option models. On this point [Kemna] recalls his experience with the application of real option models at Shell International Petroleum Company: "For practical purposes we cannot afford to come up with complicated option techniques that can only be priced with black-box computer programs."

[17] In fact, the problem with multiple exercise periods is quite frequent in a real options setting, as there often is no fixed contract that exactly specifies the option's boundary conditions as in the case of financial options. [Kemna] advocates that one should use the shortest possible exercise period, as otherwise competitors could obtain the same option, enter the market and, thus, lower the option's value.

$$Iexp^{rT}B(-d_2(\frac{Rexp^{-(\delta-r)T/2}}{Q^*},T/2),d_2(Rexp^{-(\delta-r)T},T))+$$
$$Vexp^{-\delta T/2}N(d_1(\frac{Rexp^{-(\delta-r)T/2}}{Q^*},T/2))-$$
$$Iexp^{-rT/2}N(d_2(\frac{Rexp^{-(\delta-r)T/2}}{Q^*},T/2))$$

where Q^* is the value of R above which the exchange option with exercise date T should be acquired at $T/2$ obtained by solving $F_{A1}(V,I,T/2,\sigma^2,\sigma_I^2,\rho_{VI},r,\delta)-V+I=0$ for R, where F_{A1} is given by the European exchange option with dividend formula in equation (11) and the correlation coefficient in $B(.,.)$ is $-\sqrt{0.5}$.

The expression for an arbitrary number of implementation decision points derived in [Carr] involves expressions in normal distributions up to the order of n and, thus, is rather difficult to evaluate. However, [Carr] gives the following approximation for the case $n\rightarrow\infty$:

$$F_A\approx F_{A1}+\frac{1}{3}(F_{A2}-F_{A1}) \qquad (13)$$

Table 2 is a collection of the values so obtained for the approximation via a pseudo-American exchange option for our example with planning horizon $T=6$ and $\rho=0$. As discussed in Section 2.3., in that example $\mu=0.2$ and $\alpha=0.1$ so that $\delta=0.1$, i.e. in the first period, 0.1 . \$ 500.000 = \$ 50.000 can be obtained as the "dividend" for making 100 transactions via EDI, which is lost if one waits with the implementation of EDI until the next implementation decision point. Alternative computations are done for $T=5$, $\delta=0.18$, $\rho=0.5$ and $T=7$, $\delta=0.02$, $\rho=-0.5$.

Table 2: Value of EDI growth option as pseudo-American exchange option

	$T=5$, $\delta=0.18$, $\rho=0.5$			$T=6$, $\delta=0.1$, $\rho=0$			$T=7$, $\delta=0.02$, $\rho=-0.5$		
σ^2/I_0	100%	150%	200%	100%	150%	200%	100%	150%	200%
10%	0.06	0.02	0.01	0.11	0.07	0.04	0.15	0.10	0.08
20%	0.15	0.09	0.06	0.31	0.25	0.22	0.53	0.48	0.44
30%	0.54	0.46	0.41	0.66	0.61	0.57	0.73	0.70	0.66

When comparing Table 2 with the entries for Margrabe's exchange option in Table 1, we find that the estimate here obtained is lower for higher dividends, but higher if the difference between the risk-adjusted discount rate and average growth rate is small and the planning horizon is long. In addition to this information the values computed for Q^* indicate whether the IS function should be implemented at a particular implementation decision point or not. For instance, if R exceeds 1.09 at $T/2=2.5$ in the case of $T=5$, $\delta=0.18$, $\rho=0.5$ and $V_0=I_0$, it is better to implement the function to start collecting the dividend than to wait further. Due to the lower dividend, longer exercise time and higher correlation this bound increases to 4.16 if $T=7$, $\delta=0.02$, $\rho=-0.5$ for the decision point $T/2=3.5$.

2.5 The Value of IS Flexibility

Typically, an IS platform will embed several software growth options: In example 4 of Section 1, SAP R/3 provides for the flexible implementation of EDI, workflow management and document retrieval and archiving. If the exercise of one software growth option does not influence the value of the other software growth options embedded, the value of IS flexibility as defined in the second term of formula (3) can be calculated as the sum of the values of the individual software growth options. An example of the violation of this property is a cost accounting system needing as its basis a bookkeeping system, where the latter is not implemented as a part of the base configuration but forms a software growth option of its own. If the aim is to find a conservative approximation for the value of IS flexibility, we propose to neglect software growth options that depend on the prior implementation of IS functions also forming a software growth option and to deal only with independent software growth options.

In fact, we feel that within a reasonable planning horizon such "second-order interactions" are seldom, as the basic IS functions will all be implemented as a part of the base configuration and the time horizon for the implementation of IS functions, that depend on IS functions forming a software growth option, usually lies outside the usual planning horizon of, say, 10 years. Furthermore, reliable estimates for the parameters in formula (5) for IS functions, whose practical relevance lies several years ahead and whose implications for improving business processes currently are not well understood, seem very hard to obtain.

A theoretical rationale for our approach is the "diminishing marginal option effect" described in [Trigeorgis2] who states that the additional value of another embedded option decreases with the number of options present, so that "although a few particular options may have been neglected ... the valuation as it is may still represent a close approximation to the true value, especially if the options that were included were selected so as to minimize their overlapping" ([Trigeorgis2]).

3 Implications of Software Growth Options for IS Investment Decisions

3.1 Selecting a Strategic IS Platform

The NPV rule states that an IS project that yields a negative NPV should not be undertaken. According to formula (3), a negative "passive" NPV can be outweighted by the value of the options embedded. Furthermore, the addition of the second term in formula (3) can change the ranking obtained via the "passive" NPVs when comparing alternative IS platforms.

[DosSantos] points out that one reason why an IS project with negative passive NPV should be pursued is to gain experience. The models presented in Section 2 indicate that there are other classes of IS projects with substantial option values, too. In particular, we feel that the evaluation of software growth options is important for investments in novel IS platforms as, according to [Buss], for such IS projects "the intangible benefits can be more important than the tangible ones. This is particularly true, for example, in the case of information processing software projects such as the conversion of operating systems, the design of data networks, and the creation of databases for multiple applications."

An example of this type of IS project is the SAP R/2 - R/3 decision described in Section 1, example 4, where the new platform offers opportunities for implementing EDI, workflow management and document retrieval and archiving. To illustrate the importance of software growth options for such decisions, let us assume that the extension of the base configuration by these IS functions can be described by an exchange option where for EDI the assumptions made in Section 2.3 with $t_2 = 4$ and $\rho = -0.5$, $\sigma^2 = 20\%$ and $I_0 = \$1.000.000$ hold, for workflow management $t_2 = 4$ $N_0 = 100$, $p - c = \$200$, $\alpha = 15\%$, $V_0 = 20,000/(0.2 - 0.15) = \$400,000$, $\sigma^2 = 30\%$, $\rho = -0.5$ and $I_0 = \$600,000$, and for document retrieval and archiving $t_2 = 3$ $N_0 = 1,000$, $p - c = \$100$, $\alpha = 10\%$, $V_0 = 100,000/(0.2 - 0.1) = \$1.000,000$, $\sigma^2 = 10\%$, $\rho = 0$ and $I_0 = 1,5V_0$. In that case, the implementation of SAP R/3 can cost up to $0.48 \times 500,000 + 0.64 \times 400,000 + 0.25 \times 1.000,000 = \$746,000$ more than continuing to use SAP R/2 (see Table 1 for the respective option values).

3.2 Justifying Strategic IS Investments

The importance of software growth options for strategic information systems (see [Neumann]) is shown by the fact that, typically, the rationale of such systems is "the eroding status quo", i.e. in the current business environment they are not economically justified, but if the conditions change, e.g. due to deregulation or the entrance of new competitors, they can bring many benefits. As, e.g., [Kester] points out, in such situations it is important to act early, as the value of growth options can significantly decline the more obvious their value becomes to competitors who then may decide to exercise the option themselves and, thus, lower the option's value. Hence, valuable opportunities are lost if the second term in formula (3) is undervalued or neglected. Given the increasing volatility of the business environment and the strong dependence of the value of software growth options on the variance (see Section 2.2), we feel that considerations like those described in Section 2 are of increasing importance for IS management.

3.3 Another Argument in Support of General Standard Software

We feel that another IS investment where software growth options play an important role is the decision to either use general standard software or software specifically designed for an industry. Often, the effort for implementing a general standard software package like SAP R/3 will be higher than that for software designed for customized industry. However, usually a more general platform will contain more software growth options, as it is based on the requirements and know-how of a much wider user base. For instance, the IS functions mentioned in examples 1 to 3 in Section 1 may be present in a general standard software solution, but not in software tailored to an industry's particular interests (examples 2 and 3) or in software developed to cover business transactions in the home country only (example 1). Valued via the methods described in Section 2, such software growth options will increase the "strategic" NPV of the general standard software alternative and can make it the platform selected even if its passive NPV is lower.

Assume, for instance, that both a general standard software solution's base configuration and software designed for business in the home country only meet the requirements to cover the current business processes (see example 1 of Section 1). Due to a higher effort for the parameterization, the cost for implementing the general standard software is \$ 1,000,000,–, while for the second type of software mentioned, that does not cover business with foreign countries, it amounts to \$ 900,000,–. If the number of transactions with foreign business partners is assumed to grow from 200 by 15% a year with $\sigma^2 = 30\%$ and $p - c = \$100$, the current value of this IS function is given by $V_0 = 200{,}000/(0.2 - 0.15) = \$400{,}000$. If the IS function is to be activated in 2 years, if the cost of a detailed analysis of the relevant business processes in question, of activating the appropriate parameters and of training the users concerned is \$ 360,000, and \$ 40,000 constitute the preparation effort in period 1, it is advisable to choose the more general platform as in that case the value of the software growth option is $0.32 \times 400{,}000 = \$128{,}000$ (see Table 1, Geske's formula for $t_1 = 1$, $t_2 = 2$, $\sigma^2 = 30\%$, $F = V_0$). This example shows that the implementation of general standard software can be economically indicated even if adopting the base configuration to meet the same requirements is more expensive than using an alternative with a lower number of functions.

3.4 Software Engineering for Adaptability

When IS users start to use formula (3) to evaluate IS platforms, also IS vendors must consider possibilities to obtain the highest possible value for the software growth options embedded in their systems. This clearly means to abandon programming according to customers' specifications in favour of offering adaptable standard software packages. The design of such systems must take into account the findings described in Section 2: There must be a chance for the IS functions implemented as software growth options to be used in the near future (i.e. N_t will grow fast, p is sufficiently high and c sufficiently low) and their implementation must be easily performed (i.e. I_0 (F) and E must be low). To support the process of selecting IS functions that can offer software growth options, it is paramount to keep in close contact with the users and to observe new developments, as "adaptivity is not a generic quality of a software system as a whole: Software systems are adaptable in specific, designated ways, if at all. Therefore, the adaptability must not only be explicitly engineered into the software, it must be engineered into the software in places where it will do the most good to the business. " (see [Fayad,Cline]).

4 Conclusions

In this paper, we proposed the use of option pricing formulas to obtain an estimate for the value of flexibility of an IS platform. After describing an abstract version of the process of IS enhancement, we discussed the various assumptions of the option pricing models and the limitations of the real options approach in the context of IS investments. Then we introduced option pricing formulas for the valuation of various types of software growth options and studied the dependence of the value of a software growth option on parameters describing the IS platform and the business development. Finally, we dealt with the implications of software growth options for investments in IS platforms, strategic information systems and software engineering.

Further empirical work will be required to gain more insight into the various assumptions made and into their validity. E.g., which are suitable stochastic processes for modelling the development of the net benefits obtained from IS usage? What kinds of risk arise and what hedging strategies are feasible? With regard to theoretical work, we feel that a closer study of the combination of decision analysis and option pricing described in [Smith,Nau] and the development of models for the mixture of European and American exchange options would be interesting in our application context.

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