A REAL OPTIONS APPROACH FOR VALUATING INTERTEMPORAL INTERDEPENDENCIES WITHIN A VALUE-BASED IT PORTFOLIO MANAGEMENT – A RISK-RETURN PERSPECTIVE

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Abstract

Value-based IT portfolio management requires the consideration of intertemporal interdependencies that may exist among IT projects. Therefore, several papers suggest adopting the real options approach in order to include intertemporal interdependencies within the valuation of IT projects. However, this paper shows that the standard Black-Scholes model, which is often used for valuating real options, is not appropriate to correctly account for project-specific private risks due to its restrictive assumptions. Since this can have major impacts on the value of IT projects, we develop an approach – based on the Black-Scholes model – to consider private risks properly within project valuation. A comparison of the results of the standard Black-Scholes model used today and our approach finally reveals that the neglect of private risks results in a systematic underestimation of both risk and return of IT projects, which may lead to wrong investment decisions.

Keywords: Value-based IT portfolio management, intertemporal interdependencies, real options, Black-Scholes model, private risks

1 INTRODUCTION

Since firms with superior IT governance have at least 20 percent higher profits than firms with poor governance (Weill & Ross 2004), it is not surprising that in practice much effort is put towards implementing IT governance structures (IT Governance Institute 2008). Amongst others, companies seek to implement methods to plan and manage IT investments aligned with their business objectives. Since a lot of firms primarily seek to maximize shareholder value, they need to determine the value proposition of each IT investment considering its risk and return (IT Governance Institute 2008). But it is not sufficient to valuate each IT investment separately, because firms usually conduct several IT investments simultaneously or consecutively, which may cause the existence of interdependencies among these investments. Due to the fact that those interdependencies affect the value of a single investment, firms should rather implement methods to valuate the overall IT portfolio and make sure that interdependencies are considered correctly.

But as of today, only about half the firms are capable of measuring risk and return of their IT investments (IT Governance Institute 2008) and much less they are capable of accounting for interdependencies among multiple investments within a value-based IT portfolio management (ITPM). But interdependencies and conflicts among IT projects in particular are one of the primary reasons for budget over-spending, which affects about one third of all IT investments according to a study of CA Inc. (2007). Interdependencies also play a decisive role when investments in IT infrastructure (e. g. operating systems or core banking systems) are considered, which account for 31% of all IT investments (CIO Insight 2004). IT infrastructure investments are typically characterized by high cash out-flows and – if at all – only low direct cash in-flows. If firms valuate these investments without considering interdependencies, it is likely that they will be rejected from an economic perspective. Given that business objectives may require IT infrastructure investments (base projects) that provide an option to launch future value added projects (follow-up projects), the profits of the follow-up projects can be attributed to the base projects to some extent. Such intertemporal interdependencies are often modelled as real options. Research literature suggests adapting approaches from financial theory to the valuation of real options, but does not thoroughly verify the applicability of these approaches.

Therefore, this paper contributes to valuating IT base projects that contain intertemporal interdependencies with an advanced real options approach. After a discussion about the applicability of the Black-Scholes model (BSM) to the valuation of real options, we conclude that strict assumptions of the BSM prevent its application to a correct valuation of base projects, since project-specific risks (e. g. quality risks) that influence the value of possible follow-up projects cannot be considered. Hence, we extend the BSM in a way that it will be capable of valuating base projects correctly. Furthermore, we will show that the BSM – as it is used today for valuating base projects – underestimates the return of any base project as well as the associated risk due to the disregard of project-specific risks.

This paper is organized as follows: In chapter 2 we provide an overview of existing ITPM approaches. Thereby, we analyze how intertemporal interdependencies are considered today and question the applicability of the BSM to the valuation of IT projects that contain intertemporal interdependencies. In chapter 3, a model extending the BSM by a correct consideration of project-specific risks is proposed. The article concludes in chapter 4 with a recapitulation of the achieved results. Thereby, the limitations of the model as well as perspectives for further research are discussed. A real-world example will serve as running-example throughout the paper and underpin the relevance of our findings.

2 LITERATURE SURVEY AND RESEARCH QUESTION

IT governance, which is defined as „*structure of relationships and processes to direct and control the enterprise in order to achieve the enterprise's goals by adding value while balancing risk versus return over IT and its processes*" (IT Governance Institute 2008), postulates value-based approaches to manage IT investments. This is in accordance with the definition of ITPM by Kaplan (2005), who refers to ITPM as a „*method for governing IT investments across the organization, and managing them for value*". According to these definitions firms have to valuate their IT investments as well as their overall IT portfolio under a risk-return perspective. Since existing interdependencies among IT investments can affect the value proposition of the investments (Santhanam & Kyparisis 1996), firms also have to consider them. These interdependencies can be categorized as follows:

- Intratemporal interdependencies:

  These interdependencies occur due to resource conflicts or structural bottlenecks (e. g. use of same processes or IT functionalities) in case that multiple IT projects are conducted at the same time.

- Intertemporal interdependencies:

  These interdependencies occur if IT projects serve as basis for potential follow-up projects.

As a result, value-based ITPM approaches require firms to focus on a risk-return perspective of their IT investments on the one hand, but also to consider inter- and intratemporal interdependencies among IT investments on the other hand.

2.1 Value-based ITPM: Status quo

Since value-based ITPM requires the quantification of both risk and return of IT investments, those approaches are also referred to as quantitative ITPM approaches. Verhoef (2005) for example uses the Net Present Value to valuate IT projects. He includes risk by introducing the "*weighted average cost of IT"* as discount factor, but he does not consider any interdependencies among IT investments , which makes this approach insufficient for a value-based ITPM due to the requirements mentioned above.

Santhanam & Kyparisis (1996), Butler et al. (1999), and Asundi & Kazman (2001) include intratemporal interdependencies among IT projects in their approaches. They use modern portfolio theory by Markowitz to aggregate IT projects to IT portfolios and intratemporal interdependencies are represented by correlations among IT projects. But these approaches still neglect intertemporal interdependencies, which leads to poor or incorrect valuations especially for infrastructure projects that are characterized by low or even none direct cash in-flows.

Bardhan & Bagchi & Sougstad (2004) in contrast focus on intertemporal interdependencies among IT projects. They assume that a firm has the right – but not the obligation – to conduct possible follow-up projects after the completion of a base project. This right is modelled as a real option.

2.2 Real Option Approaches for IT portfolio management

There exist many other approaches for IT portfolio management using real options theory. E. g. Benaroch (2002) suggests a real options approach called option based risk management (OBRiM) to mitigate risks of IT projects, which is empirically validated by Benaroch et al. (2006) and Hilhorst et al. (2008). But this approach is "not concerned with determining the monetary value that embedded options add to an investment" (Benaroch et al., 2006). Thus it is insufficient according to the requirements and concerns of this paper.

On the contrary, Taudes & Feurstein & Mild (2000), Benaroch & Kauffman (1999) and Fichman & Keil & Tiwana (2005) suggest the application of real options analysis (ROA) to the valuation of IT projects analogical to the approach of Bardhan & Bagchi & Sougstad (2004) and fulfil consequently the requirements of a value-based ITPM. All these approaches use the standard BSM or binomial trees to valuate existing real options.

But the application of valuation models like the BSM, which is adapted from financial options to real options theory, is heavily criticized due to its restrictive assumptions (Emery et al. 1978, Schwartz & Zozaya-Gorostiza 2003). Thus, the differences between financial and real options must be regarded properly, otherwise the application of the BSM to the valuation of intertemporal interdependencies can lead to skewed results. We therefore discuss the applicability of the BSM to the valuation of intertemporal interdependencies in the next chapter.

2.3 Applicability of the Black-Scholes model to the valuation of intertemporal interdependencies

The BSM is based on a riskless valuation of the option, whereby systematic risks are eliminated through a replicating portfolio consisting of the underlying and the option (Hull 2003). In order to be able to build this replicating portfolio and to continually hedge it during the runtime of the option, liquidity of the involved assets is a key requirement. But since real options usually cannot be traded and thus are illiquid (especially in the case of IT projects), the replicating portfolio cannot be built, which raises critics about the applicability of the BSM to the valuation of real options.[1]

Sick (2001) picks up this criticism and argues that the replicating portfolio does not necessarily have to consist of the option and its underlying per se. In fact, any liquid assets can be used for constructing the replicating portfolio, as long as they possess the same systematic risk. Therefore, trading real options is not necessary for a correct application of the BSM. Hence, the BSM can be used for the valuation of real options in case that the systematic risks can be replicated by tradable assets, which accordingly requires a complete market.

Therefore, the application of the BSM implies that the underlying investments contain only systematic risks (market risks). This issue is also raised by Copeland & Antikarov (2003), who argue that with both financial and real options, risk - the uncertainty of the underlying - is assumed to be exogenous. This represents one major weakness of today’s application of the BSM to the valuation of real options, since there are also unsystematic risks inherent in every IT investment, which are referred to as “private risks” by Smith & Nau (1995). Those private risks or project-specific risks, like for instance deficient software quality, incorrect interpreted specifications, or problems with new technologies or frameworks, account for the major source of all risks concerning IT investments.

These risks cannot be considered within the replicating portfolio, since there are no liquid assets that perfectly replicate the private risks of the base project due to their uniqueness. As a result, the BSM cannot account for private risks and therefore neglects a major source of risks in the valuation of IT investments (Smith & Nau 1995).

In order to address this weakness, Smith & Nau (1995) suggest changing the assumption of a complete market into a partially complete market, which still provides liquid assets to account for market risks. Thus, the BSM can still be applied to the valuation of real options and does consider market risks, but private risks must be incorporated otherwise.

Irrespective of these facts, several articles apply the BSM to the valuation of real options without paying attention to its applicability and thus disregard the differences between financial and real options. Mason & Merton (1985) argue that although the underlying is not traded, firms rather seek to determine what the project cash flows would be worth if they were traded. A similar qualitative

[1] For a thorough explanation of the BSM see Hull (2003).

discussion, which eventually equates real options theory with financial options theory, can also be found in Benaroch & Kauffman (1999) and Taudes & Feurstein & Mild (2000).

In these articles the expected value of the cash in-flows (of the follow-up project in our case) usually serves as underlying of the option, since there is no observable market value (Schwartz & Zozaya-Gorostiza 2003). This expected underlying value contains the potential impacts of market and private risks. It can be determined by specifying scenarios and valuating them through a decision tree analysis. Possible deviations from the expected underlying value, which are caused by market risks as well as private risks, are oftentimes considered solely within the volatility of the BSM (cp. Bardhan & Bagchi & Sougstad 2004). But – as we have discussed above – this is not valid since only market risks can be hedged in a replicating portfolio of liquid assets. Taudes & Feurstein & Mild (2000) and Benaroch & Kauffman (1999) do not pick up the different risk types as a central theme in their articles. If we assume benevolently that the authors consider only market risks within the volatility of the BSM, their application would be consistent to the assumptions of the standard BSM. However, in this case they would completely disregard private risks in their valuation, which leads to skewed results because a significant part of IT project risks are neglected.

2.4 Research Question

Because of the major weakness of the standard BSM regarding the consideration of private risks, we will answer the question, how intertemporal interdependencies can be correctly valuated using the BSM within the scope of a value-based ITPM. Therefore, it is necessary to extend the BSM by a correct consideration of the impacts of private risks of the underlying (follow-up project) on the risk-return position of a base project.

But before answering this research question using our approach, we introduce a real world example to illustrate the relevance of this question. This example is taken from an IT Portfolio of a German retail bank, which invests a high binary million amount per year into IT projects. For reasons of confidence we changed the data proportional to the original values. The example will be continued throughout the paper.

A multi-channel retail bank wants to enhance its market position (relative market share) in distributing consumer credits. To reach this strategic objective, they want to increase the level of automation of their credit processes and enable a risk-adjusted pricing of consumer credits. Therefore, existing credit processes have to be redesigned, which requires the adaption of the IT landscape. First of all, their core banking backend-systems has to be changed. The costs for this infrastructure project are estimated at 2 million Euros. Furthermore, the investment into the backend-system does not generate any direct cash in-flows, which leads to the fact that it should be rejected from an economic perspective if the project is considered independently. But the bank decided to base their investment decision not solely on the NPV of this infrastructure project. The company rather considers this project to serve as a base project that provides the launch of future value adding project opportunities, which can be realized once the backend-systems are implemented successfully. Thereby, the company identifies a follow-up project that integrates the new credit-pricing into the existing retail frontends (i.e. in-store, online, and call-center) as a lucrative opportunity and decides to include this possible follow-up project within their investment decision. In contrast to the base project, the bank anticipates high cash in-flows from the follow-up project due to the involved launch of new credit products as well as savings on human resources due to the automation of credit processes. In order to integrate this possible follow-up project into the investment decision, the company wants to use the real options approach to evaluate the base project with the follow-up project being an option to expand.

3 CONSIDERATION OF PRIVATE RISKS WITHIN THE VALUATION OF INTERTEMPORAL INTERDEPENDENCIES

To illustrate our model and the impact of private risks on the risk-return position of a base project, we firstly have to introduce some notations and assumptions.

3.1 Notations and Assumptions

A firm has to decide, whether it invests in an IT project (base project) at time $t = 0$ with a runtime of T periods. This base project creates the technical requirements for a possible follow-up project. In case of conducting the base project, the firm can decide in $t = T$ whether it invests in the follow-up project or not. This can be interpreted as an intertemporal interdependency and thus be modelled as a real option (option to expand) on the follow-up project. Because the focus of this paper is the correct valuation of the real option using the BSM, we state the following simplistic assumption:

(*A1*) The direct cash flows and thus the isolated Net Present Value (*NPV*) of the base project (without considering the impacts of the follow-up project) are known and fixed.

In order to valuate the real option under a risk-return perspective we have to consider the risks concerning the follow-up project. During the runtime of the base project two major types of risk exist which cause uncertainty regarding the cash in-flows of the follow-up project. The first type of risk can be described as market risks, which – as we mentioned earlier – can be considered by the volatility of the standard BSM. Examples for market risks are uncertainties regarding economic conditions like the prime rate or the demand since they are subject to fluctuations. The second type of risk – private risks – cannot be considered in the standard BSM as discussed above. It results from uncertainties regarding the implementation quality of the base project. Some examples of those uncertainties are:

- Uncertainty regarding the requirements of the base project: At the beginning of the base project it is not conceivable whether the functional or technical specifications describe the requirements unambiguously. Missing functionalities due to missing or incomplete functional specifications will limit the amount of possible subsequent applications.
- Uncertainty regarding the replacement of legacy systems: If (poor documented) legacy systems have to be replaced, unpredictable side effects can occur and reduce the scope of available functionalities.
- Uncertainty regarding the product quality: Irrespective of the uncertainties mentioned before, the implementation itself can be inaccurate. If too many critical mistakes are made during the implementation, it is likely that the scope of available functionalities is reduced.

These uncertainties can be responsible for providing an insufficient amount of functionalities at time $t = T$. The fact that the cash in-flows of the follow-up project (underlying of the real option) depend on the implementation quality of the base project leads to our second assumption:

(*A2*) At time $t = 0$, there is a known functional connection between the achieved implementation quality of the base project at time $t = T$ and the cash in-flows of the follow-up project. The present value of the cash in-flows of the follow-up project at time $t = 0$ is represented by the non-negative random variable $\widetilde{S}_0$ with its known corresponding density function *f(s)*.[2]

[2] $\widetilde{S}_0$ can also be a discrete random variable with probability mass function *f(s)*.

Function $f(s)$ represents the potential impacts of the private risks on the present value of the cash in-flows of the follow-up project.

Since the follow-up project will be conducted by an IT services provider and is already contractually fixed in $t = 0$, the cash out-flows of the follow-up project can be considered as independent of market and private risks, which leads to the following assumption:

(*A3*) The present value of the cash out-flows X_0 of the follow-up project is known and fixed at time $t = 0$.

This paper focuses on the correct consideration of private risks during the runtime of the base project, which affect the cash in-flows of a follow-up project. Therefore we abstract away from the existence of risks during the runtime of the follow-up project with the following assumption.

(*A4*) The present value of the cash in-flows of the follow-up project is known and fixed at time $t = T$ (depending on the implementation quality of the base project).

On the basis of these assumptions we will discuss the impacts of private risks on the risk–return position of the real option and consequently on the base project in the next chapter. Therefore, we compare the results of the standard ROA with our approach.[3]

3.2 Impacts of private risks on the risk-return position of the base project

According to standard ROA, the extended net present value (*ENPV*) denotes the return of the base project. It consists of the isolated net present value of the base project (*NPV*) and the value of the option (C_0) to extend the base project with a follow-up project (Trigeorgis 1996). In order to calculate C_0 the value of the underlying is required. But since the underlying is not traded on a market, the expected value of the underlying ($E(\widetilde{S}_0)$[4]) is often being used instead (Schwartz & Zozaya-Gorostiza 2003). Bardhan & Bagchi & Sougstad (2004) therefore approximate $E(\widetilde{S}_0)$ by conducting a scenario analysis. According to the BSM function $c(s)$, which is described in appendix A-2, the value of the option (C_0) then equals $c[E(\widetilde{S}_0)]$ according to our notation. As a result, the return of the base project calculated with the standard BSM can be obtained through the following equation:

$$ENPV = NPV + C_0 = NPV + c[E(\widetilde{S}_0)] \quad (1)$$

According to this approach the value of the option depends on the risk, but it still can be calculated deterministically, because all risks are hedged by the replicating portfolio. But note that equation (1) is only valid in case of a complete market, where only market risks exist, which can be replicated by traded securities, and private risks do not. But in a partially complete market private risks have to be considered separately.

Bardhan & Bagchi & Sougstad (2004), for instance, consider private risks within their scenario analysis for the calculation of $E(\widetilde{S}_0)$. They include the deviation of the underlying value within the volatility of the BSM. But unfortunately, this approach cannot account for private risks since only market risks can be considered within the BSM (cp. chapter 2). Other approaches neglect the impacts of private risks completely (e. g. Benaroch & Kauffman 1999), which leads to wrong investment decisions if a value-based valuation takes place.

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[3] The notation used in this paper is summarized in appendix A-1.

[4] Even though the standard ROA does not explicitly account for $\widetilde{S}_0$, we denote the expected value of the underlying as $E(\widetilde{S}_0)$ according to our notation, as it provides an intuitive description as well as a better comparison of the two approaches.

In order to correctly account for private risks, we first consider the present value of the cash in-flows of the follow-up project being a non-negative random variable $\widetilde{S}_0$ due to its uncertainty according to (*A2*). Since the corresponding and known density function *f(s)* denotes the different realizations of $\widetilde{S}_0$ (s^*), we can picture all possible impacts of the private risks on the cash in-flows of the follow-up project.

In a next step we need to find out how this uncertainty of the underlying affects the option value. Therefore, we need to focus on the functional connection (in our case the BSM function *c(s)*) between the underlying and the option value. As the BSM function cannot handle private risks, an option value has to be generated for every possible realization s^*. Since every option value $c(s^*)$ has the same cumulated probability as its corresponding underlying value s^*, we obtain $\int_0^{c(s^*)} g(c)dc = \int_0^{s^*} f(s)ds$ for all $s^* > 0$, and thus we can sufficiently approximate the density function *g(c)* of the option value $\widetilde{C}_0$, which is also a random variable. According to this transformation we now know the different impacts of the private risks on the option value. Finally, we have to add the option value $\widetilde{C}_0$ to the net present value of the base project (*NPV*) to get the extended net present value of the base project ($E\widetilde{NPV}$), which is consequently represented by a random variable:

(2) $$E\widetilde{NPV} = NPV + \widetilde{C}_0 = NPV + c(\widetilde{S}_0)$$

At the time when the decision about the base project is made ($t = 0$) we only know the approximated density function *g(c)* of the option value and thus the probability for every possible option value, but we do not know the actual realization in $t = T$. In order to account for this uncertainty caused by private risks, we will use the expected option value ($E(\widetilde{C}_0)$) to calculate the expected extended net present value of the base project ($E(E\widetilde{NPV})$), since it includes all possible realizations of the option value that are caused by private risks. By doing so, $E(E\widetilde{NPV})$ represents the return of the investment decision and can be obtained by the following equation:

(3) $$E(E\widetilde{NPV}) = NPV + E(\widetilde{C}_0) = NPV + E[c(\widetilde{S}_0)]$$

In order to compare the return of the base project obtained by our approach (equation (3)) with the standard BSM (equation (1)), we need to go into a more detailed analysis of the BSM function. In case of call options the first and second derivative (i. e. the greeks "delta" and "gamma") of the BSM function are positive (Hull 2003), thus we know that the BSM function is strictly monotonically increasing and strictly convex. Therefore, Jensen's inequality, as is denoted in equation (4), becomes valid:

(4) $$E(c(\widetilde{S}_0)) \geq c[E(\widetilde{S}_0)]$$

Since the BSM function is strictly convex, Jensen's inequality can be rewritten in our case as $E(c(\widetilde{S}_0)) > c[E(\widetilde{S}_0)]$, which implies:

(5) $$E(E\widetilde{NPV}) = NPV + E[c(\widetilde{S}_0)] > NPV + c[E(\widetilde{S}_0)] = ENPV\,.$$

This leads to our first result:

(R1): The expected value of the real option and therefore the return of the base project are underestimated if the standard BSM (equation (1)) is used to valuate intertemporal interdependencies.

The return of the option derived by both, the standard BSM (equation (1)) and our approach (equation (3)), are pictured in Figure 1. It further shows the density function of the underlying *f(s)* and the density function of the real option *g(c)*, as well as their functional connection through the BSM function *c(s)*.

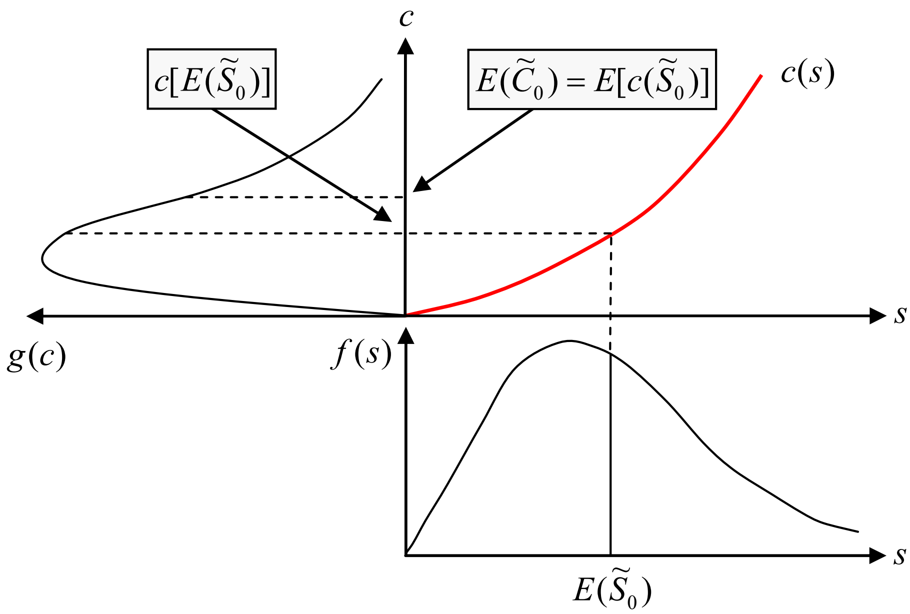

Figure 1 – Impacts of the private risks on the option value

Figure 1 also visualizes the consequence of Jensen's inequality: The density function *g(c)* results from a compression of *f(s)*, which is stronger for small values than it is for larger ones due the convexity of the BSM function *c(s)* (The skewness of *g(c)* is greater than the skewness of *f(s)*). This leads to the fact that the cumulated probability for $E(\widetilde{C}_0)$ is greater than the cumulated probability for $E(\widetilde{S}_0)$. But since the cumulated probability for $s^* = E(\widetilde{S}_0)$ equals the cumulated probability for $c(s^*) = c[E(\widetilde{S}_0)]$, $E(\widetilde{C}_0)$ must be greater than $c[E(\widetilde{S}_0)]$.

The bank decides to evaluate the possible follow-up project (option to expand) with the BSM, which created some challenges due to the collection of the data. Although the costs of the follow-up project, the risk-free rate, and the runtime of the base project could be estimated easily, the estimation of the discounted cash in-flows of the follow-up project (underlying of the option) seemed to be a major challenge, because they are based on the sale of new credit products. In order to address the uncertain success of the project, a scenario analysis (consisting of a worst-case, most-likely, and best-case scenario) was conducted (cp. Table 2) that should cover possible outcomes. By doing so, the bank derived an expected value of the discounted cash in-flows in the amount of 5.7 million Euros. Furthermore, the estimation of the volatility of the discounted cash in-flows were another major challenge: Since the volatility can only account for market risks, the bank used the volatility of a credit derivative index, because it was believed that this volatility represents all relevant risks of the credit markets.

An overview of the estimated values of the parameters needed for the BSM is provided below:

Expected Present Value of Cash in-flows ($E(\tilde{S}_0)$)	Costs (X_0)	Risk-free rate (r)	Runtime (T)	Volatility (s)
5.7 mio. Euros	4 mio. Euros	5%	1 year	40%

Table 1. BSM Parameters[5]

According to the standard BSM the option value obtained by the bank was 2.05 million Euros ($c[E(\tilde{S}_0)]$). Since the option value outweighs the negative NPV, the consideration of the intertemporal interdependency resulted in a positive value for the investment decision.

(a) $ENPV = -2\ mio.\ Euros + 2.05\ mio.\ Euros = 0.05\ mio.\ Euros$

In the following, this result will be compared to the result the bank would have achieved if they had considered private risks correctly. According to our approach, the different scenarios represent the private risks, and thus an option value has to be determined for each scenario. Based on the resulting realizations of the option values the expected value of the real option has to be derived by summerizing the realizations weighted with their adherent probabilities.

Scenario:	Present Value of Cash in-flows	Expected Present Value of the cash in-flows	Option value	Expected value of the option
best-case	8 mio. Euros	5.70 mio. Euros	4.22 mio. Euros	2.26 mio. Euros
most-likely	6 mio. Euros		2.31 mio. Euros	
worst-case	3 mio. Euros		0.23 mio. Euros	

Table 2. Scenario Analysis and Option Valuation

As we can see from Table 2, the expected option value calculated with our approach equals 2.26 million Euros. This leads to the following equation:

(a') $E(\widetilde{ENPV}) = -2\ mio.\ Euros + 2.26\ mio.\ Euros = 0.26\ mio.\ Euros$

Illustrated by this real world example we can state, that considering private risks correctly can lead to a fundamental increase of the return of the base project (in this case by approx. 420 %).

The standard ROA approach also suggests that the value of the option ($C_0 = c[E(\tilde{S}_0)]$) is riskless, which means the resulting value of the base project (*ENPV*) is a fix return on the investment. Thus, no consideration of further risks concerning the investment decision is required. Our approach enables the consideration of private risks, which are the major source for uncertainty regarding IT projects. Hence, we modeled the value of the option as a random variable ($\tilde{C}_0 = c(\tilde{S}_0)$), which means the value of the base project is also a random variable ($\widetilde{ENPV}$) with its expected value $E(\widetilde{ENPV})$. This expected value represents the return on the base project. But the possible deviations of $\widetilde{ENPV}$ and so the private risk must be included in the investment decision about the base project. This leads to our second result:

[5] The number for the volatility was adapted from Wigan (2006).

(R2): Private risks are neglected if the standard BSM (equation (1)) is used to valuate intertemporal interdependencies within an IT project. According to our approach, the consideration of private risks leads to an uncertain value of the option and consequently of the base project, which must be taken care of in the investment decision.

3.3 Consequences for the investment decision

Because of the uncertainty of the value of the base project resulting from private risks, the return or expected extended net present value is not sufficient for a risk-return integrated valuation within the scope of a value-based ITPM. Hence, it is necessary to balance risk versus return of the investment decision in order to get a thorough result. Therefore, the deviation of the project value resulting from our approach has to be opposed to the higher return in comparison to the standard BSM to get a risk adjusted value of the base project. The impact of this uncertainty on the risk adjusted value (value proposition), which results from private risks, heavily depends on the risk attitude of the decision maker.

If the decision maker is risk neutral or risk seeking, our approach leads to a higher value proposition for the base project compared to the standard ROA. This results from the increase of the return on the investment, which is shown in equation (4). However, if companies put efforts towards identifying and considering risks, they are aware of risk. Through this risk awareness and the consequent risk management such companies can be assumed to be risk averse. In this case, the consideration of the private risks within a risk-return integrated base project valuation will lower the return on the investment. In this case, the value of the base project can be lower than using the standard ROA, depending on the degree of risk aversion – which symbolizes the perception of the weight of private risks – and the specific utility function that the decision maker chooses in order to integrate risk and return.

Using the standard BSM, the bank based its investment decision on one deterministic value for the ENPV (cf. equation (a)) and thus neglected the existence of private risks. Based on this positive ENPV the bank decided to conduct the project.

But, according to our approach, the Bank should have considered private risks separately and carefully balanced their decision dependent on their risk attitude. As the bank also suffers from the subprime crisis, the company is currently risk averse. Therefore, a monetary valuation of the private risks regarding the degree of risk aversion would have been required. Based on such a risk valuation, the bank could have also rejected the base project, if the private risks had been assigned according to the degree of risk aversion with a monetary value greater than 0.26 million Euros. This would have led to the fact that the risk adjusted value of the base project is negative – although a higher return was realized compared to the result of the standard BSM.

Finally, we can state that the valuation of the intertemporal interdependencies with the BSM, as it is done today, can lead to false estimations and therefore to wrong investment decisions due to the neglect of the impacts of private risks on the risk-return position of the investment.

4 CONCLUSION

In this paper we propose an approach to consider intertemporal interdependencies within a value-based IT portfolio management. Therefore we analyzed current approaches of valuating intertemporal interdependencies among IT projects. Since intertemporal interdependencies are usually modelled as real options and valuated with the BSM, which is adapted from financial options theory, we examined the applicability of the BSM to real options. Through this examination we revealed that the BSM is only able to consider market risks, but not to consider existing private risks of IT projects. Since private risks mostly preponderate in case of IT projects, we developed an approach based on the BSM that allows the consideration of private risks and thus provides a correct valuation of intertemporal interdependencies. The main findings in this paper are that today's real option approaches based on the BSM underestimate the risk as well as the return of IT projects systematically. Hence, the application of the standard BSM can lead to false investment decisions.

4.1 Limitations

But there are still limitations that come along with the introduced model.

E. g. the assumption of fixed cash in-flows of the follow-up project at time $t = T$ (*A4*) leads to a neglect of any risks that can occur during the follow-up project. As software is usually developed in sequent releases which contain intertemporal dependent projects and in order to provide a thorough assessment of all risks involved in the IT portfolio, the consideration of follow-up project risks would further increase the results of this approach.

Another limitation comes along with assumption *(A2),* where we assume, that the cash inflows of the follow-up project depend only on the implementation quality of the base project at time $t = T$. But there may exit different other aspects which influence the cash inflows of a follow-up project. These aspects cannot be considered within our approach.

Furthermore, we are not able to calculate a concrete risk adjusted value of the base project, since we do not model the risk attitude and the risk itself by a specific risk measure.

4.2 Further Research

In order to overcome these limitations further research is required. To cope with the last mentioned limitation, we want to extend this paper by developing and introducing a decision model. Therefore, private risks need to be quantified by an adequate risk measure in a first step. Since firms usually focus on downside risks, the lower partial moment (LPM) can serve as an adequate risk measure. Otherwise, if firms also want to take the upside chances of a base project into account, a symmetric risk measure like the standard deviation can be chosen. Once a risk measure is selected, a preference function will be introduced that accounts for the investor's risk preference. Founded preference functions for different risk measures can be found in decision theory literature.

Since firms not only conduct projects consecutively but also parallel at the same time, further research is needed to additionally consider intratemporal interdependencies among projects. The approach suggested by Santhanam & Kyparisis (1996) can serve as a fundament for this extension.

Further research is also needed regarding the consideration of multiple real options within an IT project and their impact on its risk and return. Smit and Trigeorgis (2006) already propose an approach to manage a portfolio of real options, on which our further analysis can be based. On the one hand, compound options, i. e. options on options, which occur if a follow-up project again serves as basis for another follow-up project, can be considered. On the other hand, the impacts of either deferral options or abandonment options on the risk-return position of IT projects deserve a more detailed analysis.

Appendix:

A-1: Notation:

Symbol	Definition
t	Point of time: $t = 0$: Investment decision about the base project $t = T$: Completion of the base project
NPV	Net Present Value of the base project without considering the intertemporal interdependency
$c(s)$	BSM function to valuate call options
X_0	Present value of the cash out-flows of the follow-up project at time $t = 0$
$\tilde{S}_0$	Present value of the cash in-flows of the follow-up project at time $t = 0$ (random variable)
s^*	Realization of $\tilde{S}_0$ at time $t = T$
C_0	Option value of the mean of $\tilde{S}_0$ ($c(E(\tilde{S}_0))$)
$\tilde{C}_0$	Uncertain value of the option to extend the base project by the follow-up project at time $t = 0$ (random variable)
$ENPV$	Value of the base project including the intertemporal interdependency
$E\tilde{N}PV$	Uncertain value of the base project including the intertemporal interdependency (random variable)
$f(s)$	Density function of $\tilde{S}_0$
$g(c)$	Density function of $\tilde{C}_0$

Table 1. Notation

A-2: BSM function:

Black & Scholes (1973) define the BSM function $c(s)$ as follows:

$$c(s) = sN(d_1) - Xe^{-rT}N(d_2)$$

$$with\ d_1 = \frac{\ln\frac{s}{X} + (r + 0{,}5\sigma^2)T}{\sigma\sqrt{T}}$$

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

where s = value of the underlying

r = risk-free rate

$N(\cdot)$ = value of the standard normal distribution function at $(\cdot)$

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