Project Valuation using Real Options

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Swiss Federal Institute of Technology Zurich (ETHZ)
DMTEC Chair of Entrepreneurial Risks
and
Swiss Re

Supervisors:
Prof. Didier Sornette
Mr. David Petraitis - Swiss Re
Dr. Arnold Löw - Swiss Re

by
Thomas Ukelo Mbolo
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Abstract

Information technology (IT) investments in firms are subject to funding justification. Most of the time, only investments with positive net present value are considered, which leaves not much free room to upgrade systems and change IT equipment - which may not have a clear positive NPV. Further, the IT portfolio analysis used by managers does not allow them to consider the uncertainty embedded in the staged acquisition of new IT equipment. To receive the green light by the CFO, IT investments must bear the proof, that their introduction will increase the productivity of the company's key business drivers. Only under these circumstances will the funding for a new project be granted.

We present a methodological and detailed real options approach to value an IT migration project implemented through multi-stage investments. Management flexibility is captured within this framework by modelling a decision tree with embedded real option, and, furthermore, NPV and option value are simulated using a Monte Carlo model. Real options valuation results are discussed and illustrated with respect to implications on management decisions.

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1 Introduction

Information technology (IT) investments in firms are subject to funding justification. Most of the time, only investments with positive net present value are considered, which leaves not much free room to upgrade systems and change IT equipment - which may not have a clear positive NPV. Further, the IT portfolio analysis used by managers does not allow them to consider the uncertainty embedded in the staged acquisition of new IT equipment. To receive the green light by the CFO, IT investments must bear the proof, that their introduction will increase the productivity of business's key drivers. Only under these circumstances will the funding for a new project be granted.

In this thesis, we will use the real options approach to value the uncertainty embedded in IT investments, and more specifically on the migration of an IT platform within a specific division of the reinsurance company Swiss Re. The decision framework leading to the real options evaluation focuses on multi-stage real option. Starting from the base case of net present value calculation, we will then analyse the sources of uncertainty, value them and apply this information to the binomial tree approach. Finally, we will run a Monte Carlo simulation on the real option model to generate a distribution of the possible net present value and option value.

The thesis is organised as follows. The first introductory part explains what is an IT migration and gives an overview of the issues arising from such a project. The second part deals with the different methods to value a IT migration project. Starting with theoretical views over traditional discounted cash flow methodology, we continue with theory over decision tree analysis and real options. Financial options and real options are compared and their implications on managerial decision are defined. The third part, the core of the thesis, treats the valuation of the case study based on the appraisal method presented in part 2.

In part 4, we conduct sensitivity analysis on the results of part 3 and part 5 is the discussion with critiques to the approach and perspective for the future research.

1.1 Research problem and objectives

The aim of this thesis is to delve into the real options approach concerning multi-stage investment project and to quantify the IT migration case proposed by Swiss Re. Starting with a the net present value calculation, the real options approach developed here is thought to bring a methodological framework to value strategic investments. In order to provide managers with more accurate decision information, we will apply a Monte Carlo simulation and sensitivity analysis to mitigate uncertainty embedded within the calculation model. Real options valuation techniques should become a part of conventional management practice for project valuation at Swiss Re.

As the data and the real progress of the IT migration by Swiss Re are proprietary, we will not disclose any internal details on the case study but treat the global problematic of the case.

1.2 Strategy behind the case

> *Spanning across business domains, organizations are embracing new business paradigms. These include harnessing economies of scale, consolidation of applications to achieve leaner operations at lower total cost of ownership (TCO) and reduction of technology risks posed by shortage of legacy skills and obsolescence of technology. It also addresses increased application availability, improved agility to business changes, faster time to market products and enabling real-time availability of enterprise data. Customers also have other issues to*

> *worry about – a number of legacy hardware and software vendors have pulled out support for their platforms or have changed pricing norms while other vendors have upgraded their hardware and software platforms to contemporary versions. [25]*

The circumstances described above express the situation of Swiss Re when it has decided to embark upon a harmonisation of the corporate structure throughout the different locations worldwide. The harmonisation required the standardisation of some of the processes and this could be achieved to some extend through a redesign of the IT applications [2]. Harmonisation meant finding a technological common denominator to run the core applications. This could be done by redesigning IT application through migration.

> *What's more? Organizations possessing core, business-critical applications on legacy systems such as the mainframe cannot afford business disruptions of any kind, even if they decide to carry out migrations to other platforms. It is quite evident then, that such migration projects would need to be implemented with business continuity as an important consideration [25].*

1.2.1 What is Migration?

According to Prasun Mitra [25], migration reposes on the fact that the legacy applications are developed in out of date languages such as *Assembler, PL/I, Natural, Ideal and some flavors of Cobol would require to be migrated to more maintainable languages such as new Cobol versions, Visual Basic, C/C++ or Java.* And *depending on the languages and the program structures, many such language migrations are often called conversions. In many cases, applications are migrated across architectural boundaries to new technology architectures and* *platforms such as the widely accepted J2EE or Microsoft's .NET platforms*. Migrations concern day-to-day core business application to be transposed to the new platform without any interruption of any kind for the business continuity [25].

1.2.2 Business Imperatives, Business uncertainty and Migrations

Migration is driven by the necessity to reduce the maintenance costs and risks bound to the obsolescence of the application written a long time ago. Mitra [25] reports that *legacy insurance applications and products additionally suffer from the disadvantage of non-conformity to data and transaction standards. This makes them difficult to interface with partners or 'island' applications and systems or with newer technology, third-party applications*. Those applications were adapted and modified by new support staff over time to face new business imperatives. This succession of actualisations has rendered systems difficult to support, redesign and harmonise [25, 2].

Costs to run these applications are becoming too high and the continuity of maintenance is not optimally assured any more as the new programming languages on the market have naturally forced the new computer scientists to look away from the legacy languages: IT staff with specific knowledge becomes difficult to hire. Uncertainty about business evolution and low technological flexibility exposes business to risks. Kulatilaka and al. [21] declare that business uncertainty can be mitigated by the firm by *designing, implementing and managing the operating drivers*, so that information technology should not represent an obstacle.

The combined influence of these parameters - continuously modified applications, multiplication of island applications, rarefaction of IT staff with adequate knowledge - has made the system running the application very difficult to maintain, costly and inflexible toward increasing necessity to adapt to the market. Upgrades are not efficient any more and mainframe is ′dying′. Business risks are increasing because of the reduced adaptability of the system. Migration to a new platform and technology is then the solution to resolve most of these issues and contain the business risks linked to technology. The corporate transformation operated by Swiss Re relies on the technological harmonisation and standardisation of its data, and assures business efficiency [2].

1.2.3 Types of Migration

IT migrations have been studied by different researchers. Taudes and al. analysed, via a real-life case study, platform investment decision for a migration from SAP R2 to SAP R3 platform [30]. Cases of software development based on commercial off-the shelf or COSTS components treated with real options valuation approach are proposed by Erdogmus and al. [10, 11, 12, 13]. Jeffery and al. used real options for the case of data mart consolidation with re-hosting and re-architecting of the data marts into a new enterprise data warehouse [19].

Migration has become a reality for numerous mature firms nowadays and Prasun Mitra has listed four main types of migration:

Type of migration	Implication
Language Conversions	tool-based conversions of one language form to another – such as Cobol, PL/I, Natural, Mark IV or Assembler to Cobol, Cobol to Java, etc.
Database Migrations	migrating from non-relational databases such as IDMS, ADABAS, IMS, Datacom, Supra, System2000 etc to relational databases such as DB2, Oracle, SQL server etc.
Platforms Migrations	migrations of applications from one type of hardware and/or software platform (IBM MF, VAX, Unisys, Bull, Tandem etc) to another (such as Unix, Linux, Microsoft. Windows Server etc). These migrations can involve re-hosting, re-engineering or re-development. Migration across architectural boundaries such as IBM Mainframe to J2EE or .NET involves reverse engineering of the current applications, documentation, defining the target application architecture, design and development or forward engineering.
Migration to a "Product platform"	product implementation

Tab. 1: Classification of migration types according to Prasun Mitra.

Finally, he states: *Customers look for vendors who possess robust technology capability and relevant skills in the stated platforms in the first place. They also want the vendors to possess tool-sets that enable faster migration with predictable accuracy. Above all, customers need a proven migration methodology backed up by robust "Migration Management Processes"* [25].

1.3 Swiss Re's migration case

According to Mitra's classification, Swiss Re's present case concerns a platform migration as well as a language conversion with the key issues related to them. The migration project is designed as a multi-stage investment to assure an optimal implementation and review process during every phase. The project started in 2007 with the proof of concept. This time was principally allocated at evaluating the conformity and the robustness of the platform chosen, and the feasibility of the migration. The pilot phase, taking place in 2008, consists in implementing the migration process at small scale and running some tests of the applications on the new platform. Finally, 2009 will see the launch at full scale of the migration.

Beside the technological and business related benefits, the migration will allow substantial savings on the license costs. Furthermore, it is needless to say that the whole implementation must absolutely be performed without any interruption or obstruction to the actual business.

2 Project valuation: theoretical background

Project valuations are meant to help managers with making the good decision about investing in projects that account for the company's growth [6, 19, 21, 22, 27]. Today, to make decision management disposes of financial information based on traditional capital budgeting techniques that they simultaneously have to interpret with forecast analysis. Unfortunately, what is sure for today is not necessarily true tomorrow. And this is particularly true in the fast moving-world of IT and the subsequent investments that can be made into it. That's why many factors should be considered when making investment decision. Mark Jeffery [17] lists inexhaustively those factors as:

- *the assumptions underlying the costs of the project*
- *the assumptions underlying the potential benefits*
- *the ability to measure and quantify the costs and benefits*
- *the risk that the project will not be completed on time and on budget and will not deliver the expected benefits*
- *the strategic context of the firm; that is, does the project fit with the corporate strategy?*
- *the IT context of the project; that is, does the project align with the IT objectives of the firm, and now does it fit within the portfolio of all IT investments made by the firm?*

Taking into account those different factors can difficultly be done with conventional capital budgeting, where projects are evaluated using traditional discounted cash flow (DCF) spreadsheets. But the DCF technique contribution should remain the starting point of more accurate project evaluation.

2.1 DCF and Net Present Value

Discounted cash flow model (DCF) is the main approach to value project in traditional financial methodology. Probably because they are intuitive and straightforward to apply, DCF models are used by most companies.

Discounted Cash Flow valuation is based on the fact that 1 monetary unit today is worth more than 1 monetary unit tomorrow . That is, cash flows associated with a project, even if they occur in future period, can be discounted at time value money to express their values at present time - their present values. The interest rate at which the cash flows are discounted is also called rate of return and reflects the amount of risk associated with the cash flow [17]. For a series of cash flow CF_0, CF_1, CF_3...CF_n occurring at time t_0, t_1, t_2...t_n, the value of the cash flows, present value (PV), is given by their discounted sum:

$$PV = \frac{CF_0}{(1+r)^0} + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + ... + \frac{CF_n}{(1+r)^n}$$

where CF = cash flow, r = discount rate, and

$$Discount\ factor = \frac{1}{(1+r)}.$$

In order to compare projects that have different costs (investments amounts), it is useful to subtract the initial investment costs I from the present value, thus obtaining the net present value (NPV):

$$NPV = PV - I$$

If costs of the project are spread out over multiple of these cost time periods, then:

$$NPV = CF_0 - I_0 + \frac{(CF_1 - I_1)}{(1+r)^1} + \frac{(CF_2 - I_2)}{(1+r)^2} + \frac{(CF_3 - I_3)}{(1+r)^3} + .. + \frac{(CF_n - I_n)}{(1+r)^n} = \sum_{t=0}^{n} \frac{(CF_n - I_n)}{(1+r)^n}$$

Investments subtracted from the sum of all present value occurring in a project give the net present value (NPV). The net present value calculation is the most common approach to value large investments. A naive application of the net present value calculation states that if a project has a positive present value, it should then be undertaken. It will raise the value of the firm, which is the financial objective toward the shareholders of the company. The success and accuracy of DCF analysis is determined by the choice of concomitant discount rate. If chosen to high, the discount rate can lead to reject projects, as NPV will become negative. If chosen to low, projects might be accepted because they yield a positive NPV, which should not be positive.

Although NPV calculation only contains the endogenous value of a strategic investment, it has to be considered carefully because it can be regarded as the first step leading toward real options valuation [27].

2.2 Decision Tree

DCF analysis assumes that the management will passively follow the evolution of a project without intervention. This can be corrected by using the decision tree analysis. Decision tree analysis allows one to model project outcomes and management intervention explicitly. To each node of a tree is associated a decision or an outcome and its resulting cash flows. This project representation allows taking into account the uncertainty in exploring different options leading to project fulfilment. The more uncertainty within the project, the more flexibility is produced by adding new paths or branches to the tree. Implicit assumptions made by managers when valuing a project become visible, and even if some managers refer to them in term of "intangible advantages", the flexibility contained in the tree is given by the real options. Disadvantage of this method is that a complex project will transform itself in a "forest" instead of a readable tree.

In a decision tree the different paths leading to project achievement represent future uncertainty which can be modelled by mean of a discrete decision tree of finite depth N, where N stands for the maximum of future time steps (e.g. months, years, etc) that we want to model. Looking at the nodes of the tree at depth k , give a view of all possible project state at this time. To each branch emanating from a node, we can associate a probability. The sum of the probability of the branches issued from one node is equal to 1[28]. The probability of realisation of one event can then be defined using the Bayesian probability or conditional probability. Looking at one particular node v, the probability that this state occurs, denoted $P(A)$, is the product of the probabilities of the branches from the root to node A. If the node A has a branch to node B, we denote the probability of node B conditional to node A as $P(B \mid A)$:

$$P(B \mid A) = \frac{P(A \cap B)}{P(B)}.$$

If X is a discrete random variable, conditional density of X given the event B is given by:

$$f(x \mid B) = P(X = x \mid B) = \frac{P(X = x, B)}{P(B)}$$

and the conditional expectation $E(X)$ is given by

$$E(X \mid B) = \sum_{x} x\, f(x \mid B)$$

In this framework, project phases are not considered as stand-alone steps leading to project achievement, but rather as a chain of interrelated processes with associated costs explicitly showing decisions to be made and their contributions to final project value. Decision tree analysis captures project uncertainty, linking implementation options with their possible outcomes.

2.3 Black-Scholes Formula

Options in finance are instruments which give the owner of the option the right to invest or not to invest, for a specified price, into the asset underlying the option. Options are strategic tools as they give a company the opportunity to grow and increase shareholders value. Decision about investing or not investing is made as uncertainty about the option's price resolve, the option expiration's time approaching. In their seminal work, Fisher Black and Myron Scholes proposed an elegant and simple solution to many useful option valuation problems. They valued the option price in a risk neutral world by calculating the expectation function of the random-walk-like evolution of the underlying asset price as a function of a Brownian motion. The geometric Brownian motion is described by:

$$dS_t = \mu S_t dt + \sigma S_t dW_t$$

where W_t is a Wiener process or Brownian motion, μ (the percentage drift) and σ(the percentage volatility) are constants.

The price of a call option in a risk-neutral world is obtained as:

$$Value\ of\ call\ option = [N(d_1) \times P] - [N(d_2) \times PV(EX)]$$

where

$$d_1 = \frac{\log\left(\frac{P}{PV(EX)}\right)}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$$

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

$N(d)$ = cumulative normal probability density function

EX = exercise price of option; $PV(EX)$ is calculated by discounting at the risk-free interest rate f_f

t = number of periods to exercise date

P = price of stock now

σ = standard deviation per period of (continuously compounded) rate of return

The principal assumption behind Black-Scholes model is that returns are of lognormal distribution; besides, there are a number of other assumptions which may lead to wrong results for critical cases.

2.4 The Link between Real Options and Finance

Financial options are instruments in capital investment and are traded on stock market, whereas real options refer to opportunities arising from strategic processes as for example whether to take the opportunity to expand or to invest in research and development. In contrast to financial options, real options cannot generally be traded as they have intrinsic value only for a certain party. Real options represent an important strategic dimension as they are at the core of strategic planning and investing under uncertainty [27]. Similarly to financial options, if the expected outcome generated by a real option is estimated as being not favourable, the real option is not exercised. Table 2, shows the correspondences between real options and financial option, in the case of the option to defer, as proposed by Smit and Trigeorgis. Deferment options are particularly important, when making an irreversible investment decision under uncertainty. Invested money can rarely be taken back in real life! With this example, Smit and Trigeorgis illustrate the fact that the *opportunity to invest in a project is like having a financial call option. In the real options case, the underlying asset is the present value of the cash flows from the completed operating project, V_t, while the exercise price is the necessary investment outlay (at time t), I_t.* Depending on market evolution, if later the situation becomes favourable and $V_t > I_t$,

INVESTMENT OPPORTUNITY	VARIABLE	CALL OPTION
Present value of expected cash flows	V	Stock price
Present value of investment outlays (cost of converting the investment opportunity into the option's underlying asset)	I	Exercise price of the option
Length of deferral time	T	Time to maturity
Time value money	r_f	Risk-free rate
Volatility of project's returns	σ^2	Variance of stock returns

Tab. 2: Correspondence table between financial options and real options in case of deferment

management can exercise the option by investing and project net present value becomes positive. In the opposite case where market development would be unfavourable, management will decide not to invest to cut further loss, thus losing only the amount spent to get the option.

Real options theory was developed to remedy the incapacity for traditional capital budgeting to capture strategic value of investments [28], and thus used the instruments brought by the financial option valuation to real and normally non-tradable assets.

2.5 Real options and managerial flexibilities

As mentioned before, options are the foundation of strategic planning as they constitute the opportunity to capture potential growth and mitigate losses. Unlike discounted cash flows approach, where a project has to be undertaken now and operated continuously, real options allow for flexibility. A proactive management may postpone a project, may be waiting for the conditions on the market to become more favourable. Management can also decide to abandon a project during its implementation to cut losses[27, 31]. Both examples reveal managerial flexibility, as management adopt the adequate behaviour toward the newly acquired information, some of the uncertainty having been resolved. The prevalent types of real options encountered are [6, 28, 27]:

- Option to defer (simple option)
- Growth option (compound option)
- Option to abandon
- Option to switch
- Option to expand
- Option to select the better of two or more alternatives

Managerial flexibility induces asymmetry in the probability distribution of NPV as management can limit the down-side risk of loss, but retain the upside potential for profit [27]. This asymmetry is not available in traditional capital budgeting, where NPV distribution must be symmetric as no adaptive behaviour is taken into account. Figure 1 shows the asymmetry induced in NPV by managerial flexibility to make decision upon resolved uncertainty. Flexibility introduces an augmented upside potential and limit the downside risks. The distribution is then skewed on the right. Finally, the profitability of a firm is dependant upon management to make the right decision.

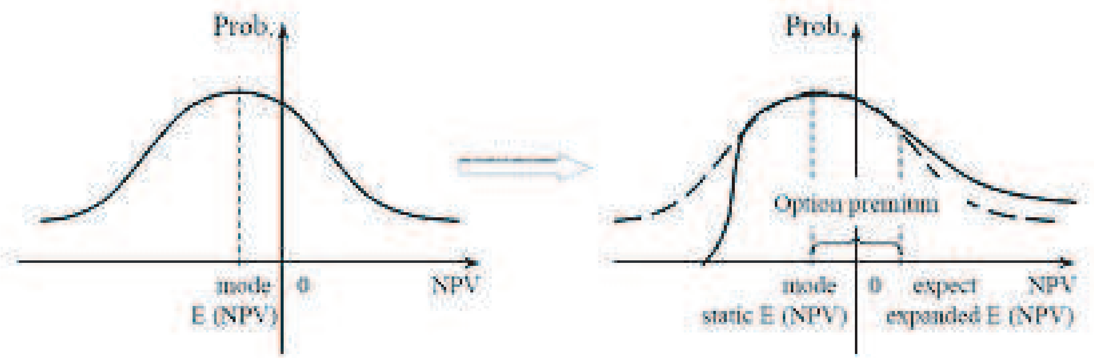

Fig. 1: Managerial flexibility introduces an asymmetry into the probability distribution of NPV (Trigeorgis, 1996)

Real options approach with embedded managerial flexibility has been accepted for its superiority compared to traditional capital budgeting or discounted cash flow analysis (DCF) [21, 23]. It allowed demonstrating the asymmetry introduced by managerial flexibility in the probability distribution of NPV [19]. In real world, realised cash flows differ most of the time from the expected cash flows forecasted with standard capital budgeting techniques. Real option valuations applied to these cases provide them with a realistic quantitative outcome.

Fichman stresses the fact that *organizations that evaluate investments according to the logic of real options but manage them according to the traditional principles will be falling out of the pan of systematic undervaluation and into the fire of systematic overvaluation* [15]. Real option valuation should therefore be accompanied by a series of measures to make sure that not only the project valuation form but also problem apprehension has changed.

2.6 Real options and It investments specificity

Also because investments in information technology (IT) have become an increasing part of firms' capital expenditure budget, real options methodology has been studied and used to optimise these investments. It is anyhow difficult to evaluate IT contribution to pursue the goals of a firm and investment justification have been thus studied using real option perspectives [1]. Erdogmus and al. have looked at the use of real options as strategic instrument in software development project as it is a way at quantifying the competitive advantage over the other actors in the field [10, 11, 12, 13]. Benaroch and al. have studied the type of option that should be recognised depending on the risks associated with the investment [3, 4]. Among others, Kauffman and al., Campbell, and Zhu and al. dealt with investment timing in information technology to quantify and optimise the return on investment [7, 20, 32].

Platform acquisitions or implementations valuation using real options approach methodology have been studied by Benaroch and al., Taudes and al., and Dai and al.. They all stress the importance at considering not only the immediate value brought by the new systems, but to also consider the 'leverage' enabled by those installations. Increased flexibility and cost advantage are seen as immediate value, whereas leverage is represented by the opportunity to capture growth by developing new applications that increase business value. In this case growth option represents the potential development of future applications [5, 9, 15, 29, 30]. The sequential or staged investments in information technology infrastructures has been analysed as well by Jeffery and al., Panayi and Trigeorgis, and Herath and Park. Sequential investment reveals a structure of compound option at the different investment stages and help management at justifying investment decision in project that would otherwise be considered as not viable [4, 24, 16].

It investment specificity arises from the fact that it is many times difficult to directly quantify its benefits. Costs reduction through reduction in license costs are easily apprehensible, but increased flexibility, growth opportunity, and diminution of business risks often cited as consequences of new IT infrastructures are difficult to evaluate [9, 14, 21]. Table 3 shows the correspondence between real options and the implication in the perspective of IT infrastructure investment. According to Dai and al. [9], the real option embedded within IT infrastructure is the opportunity to develop further application to adapt to the demand on the market.

OPTION	CONCEPT APPLICATION TO IT RESOURCES
Option	The ability to develop business applications enabled by an IT infrastructure that enables a firm to effectively respond to demand changes in its marketplace
Underlying asset	The possible IT resources (e.g., business applications) that can be built upon a specific IT infrastructure
Value of the underlying asset	The business value of possible IT applications to improve the service or product offerings of a firm, leading to higher profitability
Market volatility	Demand uncertainty for product or service offerings made possible by follow on applications in the IT infrastructure; affects value of underlying asset
Exercise price	Expenditures associated with investment in follow-on IT applications
Option price	Expenditures associated with investing in a specific IT infrastructure
Time to expiration	Period of time from owning the IT infrastructure to when the follow-on IT investment opportunity runs out due to competition, regulation, technological advancement or demand changes, etc.

Tab. 3: Evaluation of IT infrastructure from a real options perspective.

3 Valuation of Swiss Re's real case based on the appraisal techniques of real options

Swiss Re's migration project consists in changing outdated IT platforms to new ones and accordingly updates the language of the applications running on the platform. The project is defined as a multi-stage project with strategic steps leading to the accomplishment of the whole project [4, 24]. The migration is of major importance to the concerned division; it will allow the transfer of the core applications onto the new platform. This migration will allow the development of further business driver applications, but this is beyond the scope of this appraisal. We will here concentrate exclusively on the project, which consists in the successive steps leading to the completion of the migration.

Project valuation is organised after a four-step approach proposed by Copeland and Antikarov [8]:

1. Compute base case model without flexibility
2. Model the uncertainty using event trees
3. Identify and incorporate managerial flexibility
4. Calculate real option value

Our static analysis of the base case starts with the proof of concept, which took place in 2007. This first stage required an investment in order to evaluate the feasibility of the whole project. The proof of concept sorted out the main issues of such implementation and defined the prerequisites allowing the completion: installation of new platforms, robustness of the new applications running on the platform and rewriting of the actual applications. The proof of concept is the zero state of our analysis and necessitated an investment of CHF 3.4 Mio. The proof of concept delivered a positive outcome, which lead to the decision of further investing in a pilot implementation. The costs of the pilot are estimated to be CHF 2.5 Mio and according to planning, the final stage of the project will further require an investment of CHF 2.2 Mio. Thus, project completion is based on a three stages resumed as:

1. The proof of concept in 2007
2. The pilot in 2008
3. The full scale implementation and launch in 2009

The benefits achieved through the migration project occur via costs containment. The benefits considered here are the IT licensing costs, which will be reduced by CHF 20 Mio per year for five years starting one year after project completion.

3.1 Base Case of Project Monaco - DCF analysis

The application of DCF analysis allows the segmentation of the different cash flows contained within the project. Based upon the project business case and using the formula for discounted cash flows:

$$PV = \frac{CF_0}{(1+r)^0} + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + ... + \frac{CF_n}{(1+r)^n}$$

$$CF = cashflow,\ r = discount\ rate$$

The discount rate, r, is internally determined in Swiss Re and yields 13%. Table 4 resumes the cash flows of the project detailed in the following calculation. The investments into the project are realised stage-wise. The first investment occurs in 2007 with the proof of concept. The present value of the first IT investment as for 2007:

$$I_{proof\,of\,concept} = \frac{CHF\,3.4Mio}{(1+13\%)^0} = CHF\,3.4Mio$$

The pilot stage requires an investment of CHF 2.5 Mio in 2008. This represents a present value of investment as for 2007 of:

$$I_{pilot} = \frac{CHF\,2.5Mio}{(1+13\%)^1} = CHF\,2.2Mio$$

The final investment to complete the project is allocated to the full scale launch with CHF 2.2 Mio in 2009. The present value of investment in full scale launch in 2009 as for 2007:

$$I_{full\,scale\,launch} = \frac{CHF\,2.2Mio}{(1+r13\%)} = CHF\,1.7Mio$$

Total investments into the project discounted as for 2007:

$$I = I_{proof\,of\,concept} + I_{pilot} + I_{full\,scale\,launch} = CHF\,7.3Mio$$

The expected benefits of 5 time CHF 20 Mio are expected from 2010 until 2014. The present value of the sum of the spread benefits as for 2007 is computed as:

$$PV = \frac{CHF\,20Mio}{(1+13\%)^3} + \frac{CHF\,20Mio}{(1+13\%)^4} + \frac{CHF\,20Mio}{(1+13\%)^5} + \frac{CHF\,20Mio}{(1+13\%)^6} + \frac{CHF\,20Mio}{(1+13\%)^7} = CHF\,55.1Mio$$

Finally, the Net Present Value of the project is given by the subtraction of the discounted investments costs to the sum of discounted benefits:

$$NPV_1 = PV - I = CHF\ 55.1 - CHF\ 7.3 = CHF\ 47.8Mio$$

	2007	2008	2009	2010..2014
Year	0	1	2	3...7
IT costs	CHF 3.4 Mio	CHF 2.5 Mio	CHF 2.2 Mio	
Benefits				CHF 20 Mio
Free Cash Flows	CHF 3.4 Mio	CHF 2.5 Mio	CHF 2.2 Mio	CHF 20 Mio
Discounted Free Cash Flows	CHF 3.4 Mio	CHF 2.2 Mio	CHF 1.7 Mio	CHF 55.1 Mio

Tab. 4: Discounted cash flows for migration project

NPV_1 represents the possibility of investing in three stages - 2007 for the proof of concept, 2008 for the pilot, and 2009 for the full scale launch - and to achieve the benefits for five successive years, starting one year after the completion of the migration project. This project is thought to be completed without delay and with all phases being finished in due time.

The management proposed also to value the possibility of delaying the migration project with a one year delay between the pilot and the full scale launch, leaving year 2009 without any tangible activity for the accomplishment of the project. This implies a delay in the last investment of CHF 2.2 Mio for the proof of concept and also a delay in the earned benefits. Applying the DCF for this second scenario encompassing full certainty, we have in Table 5 a resume of the detailed calculation:

	2007	2008	2009	2010	2011..2015
Year	0	1	2	3	4...8
IT costs	CHF 3.4 Mio	CHF 2.5 Mio		CHF 2.2 Mio	
Benefits					CHF 20 Mio
Free Cash Flows	CHF 3.4 Mio	CHF 2.5 Mio			CHF 20 Mio
Discounted Free Cash Flows	CHF 3.4 Mio	CHF 2.2 Mio		CHF 1.5 Mio	CHF 48.8 Mio

Tab. 5: Discounted cash flows for migration project in case of a one year delay in the implementation

Conducting the similar calculation as for the case above, without delay in the stage investment, we have a total investment value as for 2007 of:

$$I_2 = I_{proof\,of\,concept} + I_{pilot} + I_{full\,scale\,launch} = CHF\,3.4Mio + CHF\,2.2Mio + CHF\,1.5Mio = CHF\,7.1Mio$$

The present value of the benefits is also delayed by one year compared to the previous example, which means a PV value as for 2007 of the benefits starting in 2011 for 5 consecutive years of:

$$PV_2 = \frac{CHF\,20Mio}{(1+13\%)^4} + \frac{CHF\,20Mio}{(1+13\%)^5} + \frac{CHF\,20Mio}{(1+13\%)^6} + \frac{CHF\,20Mio}{(1+13\%)^7} + \frac{CHF\,20Mio}{(1+13\%)^8} = CHF\,48.8Mio$$

The value of the migration project with a one year break in the investment of the implementation has a net present value of:

$$NPV_2 = PV_2 - I_2 = CHF\,48.8Mio - CHF\,7.1Mio = CHF\,41.7Mio$$

This simple calculations based on the discounted cash flows methodology show that both scenarios have a positive present value due to the high benefits expected from the migration project. As stated above, the benefits are bound to costs saving on license costs and not on an increase in business capacity generating higher benefits. With DCF methodology calculation, we find that delaying the last stage of the project implementation by one year - NPV_2 - decreases the Net Present Value of the project by CHF 6.1 Mio.

However, in contrast to the assumptions of passive management admitted by DCF approach, managers are actively involved and adapt the strategy to the arising situation [18].

3.2 Modelling cash flows with a binomial process

The traditional NPV calculation does not take into consideration the uncertainties associated with the realisation of a project. The following calculation will captures the objective probability of success and failure of the different implementation steps needed to conduct the project, and render a more correct value for the whole implementation. This net present value calculation also called "naive" assumes that the project is conducted until the end without any option arising. This NPV will served as reference value for the option calculation project and Figure 2 shows the tree associated this base case.

NPV can be computed straightforward using the different probability of fulfilment for every event or stage. Figure 2 shows the binary tree with the objective probabilities. Those probabilities are based upon the management experience gained through previous similar projects. Dealing with that kind of implementation project, management can make good estimation about the success possibility. Thus, the probability of success of the project's first stage (p(PoC)), the proof of concept taking place in year 2007, is estimated to be 70%, which in that kind of binary tree approach leaves a

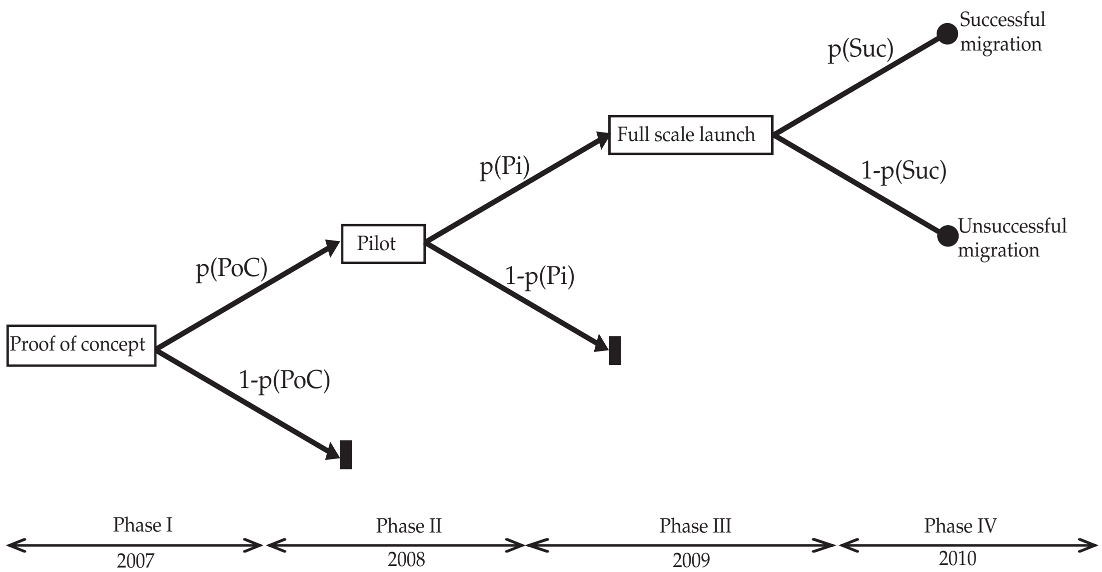

Fig. 2: Binomial tree with probability

rate of failure for the first stage equals to 1-70%, so 30%. The second stage, the implementation of the pilot phase, occurring in 2008, has a rate of success of 90% (p(Pi)). The last stage, happening during 2009, is the migration of the whole system onto the new platform. This launch at full scale has a success rate estimated to be 95% (p(Suc)). Bound to the possibility of unsuccessful implementation of the full scale launch, we have admitted that a salvage value could anyhow be perceived from the migration. This salvage value was estimated at being 10% of the benefits in case of success.

Taking into account the admitted objective probabilities and applying the discounted cash flow methodology to value the whole migration project as for 2007, NPV is calculated the following way:

$$NPV\ no\ flexibility = -PV_{Investment2007} - PV_{Investment2008} \times P(PoC) \\ - PV_{Investment2009} \times P(PoC) \times P(Pi) \\ + [PV_{Benefits} \times P(Suc) + PV_{Salvage} \times (1 - P(Suc))] \times (PoC) \times P(Pi)$$

where P(PoC) is the probability of success from the proof of concept, P(Pilot) is the probability of success of the pilot phase and P(Fsl) is the probability of success of the full scale launch.

$$PV_{Investment\,2007} = CHF\ 3.4Mio,$$

$$PV_{Investment\,2008} = \frac{CHF\ 2.5Mio}{1+13\%} = CHF\ 2.2Mio,$$

$$PV_{Investment\,2009} = \frac{CHF\ 2.2Mio}{(1+13\%)^2} = CHF\ 1.7Mio,$$

$$PV_{Benefits\,2010} = \frac{CHF\ 20Mio}{(1+13\%)^3} + \frac{CHF\ 20Mio}{(1+13\%)^4} + \frac{CHF\ 20Mio}{(1+13\%)^5} + \frac{CHF\ 20Mio}{(1+13\%)^6} \\ + \frac{CHF\ 20Mio}{(1+13\%)^7} = CHF\ 55.1Mio,$$

$$PV_{Salvage\,2010} = \frac{CHF\ 2Mio}{(1+13\%)^3} + \frac{CHF\ 2Mio}{(1+13\%)^4} + \frac{CHF\ 2Mio}{(1+13\%)^5} + \frac{CHF\ 2Mio}{(1+13\%)^6} \\ + \frac{CHF\ 2Mio}{(1+13\%)^7} = CHF\ 5.5Mio.$$

Now applying the formula defined above, the NPV without flexibility becomes:

$$\begin{aligned} PV\ no\ flexibility = CHF - 3.4Mio + CHF - 2.2Mio \times 0.7 \\ + CHF - 1.7Mio \times 0.7 \times 0.9 \\ + [(CHF\ 55.1Mio \times 0.95) + (CHF\ 5.5Mio \times 0.05)] \times 0.7 \times 0.9 \\ = CHF\ 27.2Mio \end{aligned}$$

So, considering the objective probability of realisation, we find the net present value of the project to be CHF 27.2 Mio which is by CHF 20.6 Mio smaller than the NPV found by the traditional NPV calculation (CHF 47.8 Mio). Traditional NPV calculation overestimates the value of the project by over 43 %! This could lead management to wrong conclusion. In this case net present value stays positive, but it is also possible that in other cases a positive NPV calculated the traditional way becomes actually negative, when computed with objective probabilities of realisation.

3.3 Uncertainty model using event trees

DCF analysis is based upon certainty of costs and benefits. This prerequisite of certainty never happens in organisation investing in new projects. Future is uncertain and the management should focus onto exploring the possible decisions, that have to be made in order to fulfil the project and the different possible outputs associated with the different decisions. Each decision takes into account recent resolution of uncertainty. Decisions are made based on the experience of the project owner, but they are most of the time implicit. The elaboration of an event tree allows one to explicit the possible paths conducting to project fulfilment. Most of the time, project are decomposed into phases, which necessitate stage investments. For the management, there is always the option to wait or to postpone an investment until uncertainty has been resolved. And the application of the event tree allows the visualisation of all the anticipated possibilities to achieve a project. Decision tree is a way for the representation of a project complexity.

The migration project is split in distinct phases, which all require a determined investment. The first phase, the proof of concept, the second phase, the pilot phase, and the finale stage, the full scale launch. To the different stages correspond budgeted investments and expected outcomes. But even to the best case scenarios alternative scenarios are needed. And this is the purpose of the decision tree to show and capture the uncertainty of the project.

Starting with the proof of concept, there are two possible outcomes: either the proof of concept is successful and favourable, or the proof of concept is unsuccessful. In both cases, decisions have to be made. In case of success, the management can decide to continue the project and start with the next phase or to delay the next phase to a more favourable time. In case of failure of the proof of concept, the management can either decide to conduct a new proof of concept or to abandon the project.

The next stage concerns the project pilot. And here again, depending on the outcome, the management can make decision either to keep on implementing the project or to delay any ongoing implementation or even to abandon the project. And the same decisions have to be made in case of failure of the pilot. The decision tree on Figure 3 captures all the stages, outcomes and decisions that have to be made until full migration is completed. Starting with this tree, management has to decide and concretely define all the possible and thinkable paths for their project. If no flexibility is admitted, the decision tree is reduced to the binomial tree from the previous section (cf. Figure 2).

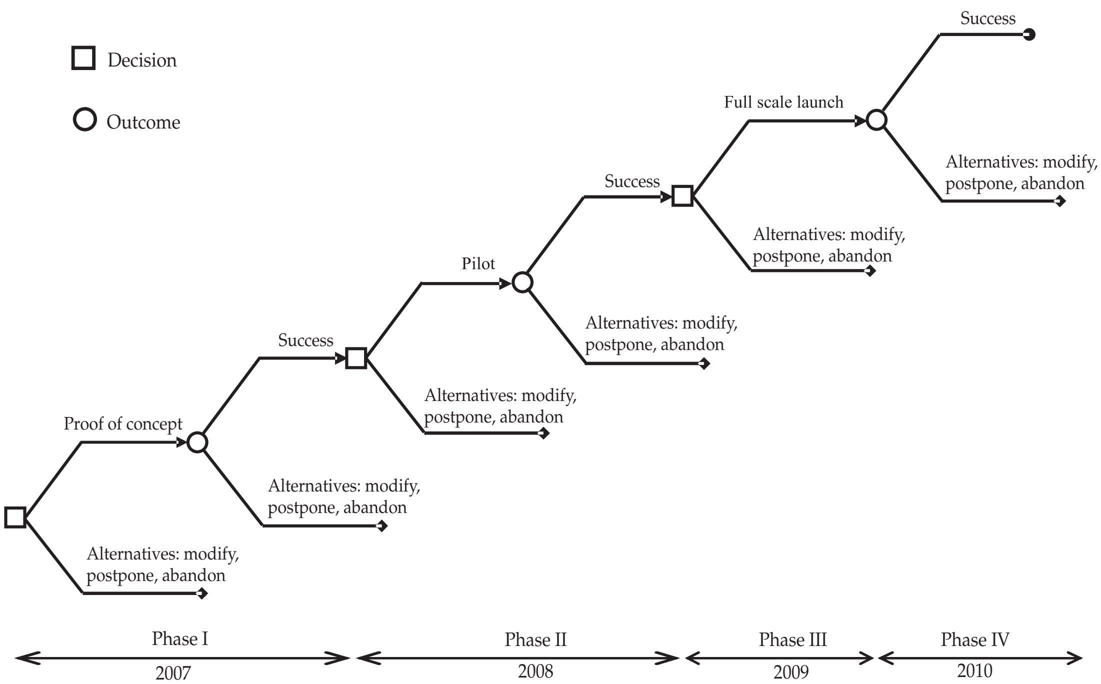

Fig. 3: Decision tree modelling uncertainty

3.4 Identify and incorporate managerial flexibilities

Assumptions and thinking made most of the time implicitly by managers can also be implemented within the decision tree. We saw that, based upon passed experience on similar projects, the project owner can estimate the percentage of success and failure at the difference phases constituting the migration. The proof of concept was estimated to have a successful outcome by 70%. This first milestone of the migration represents the opportunity to continue the project, or even if the outcome is successful to wait to resume the next stages of the problem. If the outcome of the proof of concept is a failure, the management decision is to abandon the project. This possibility to abandon reflects managerial flexibility.

Continuing the project implementation leads toward the second stage of the migration: the pilot, whose rate of success by implementation was estimated to be 90%. Once again, these percentages are based upon managers experience over passed project dealing with the same kind of uncertainty. In the present case, management has decided that a failure in the pilot stage would also lead to abandon the project. When successful at this point, management has chosen to either proceed with the next stage, with a percentage of 90%, or to delay the implementation of the project, with a probability of 10 %. This constitutes the option taken by the management to conduct this project.

For the third and final phase of the migration, the rate of success of this phase was estimated to be 95%. Management has confirmed that a failure at this stage would not lead to a total loss of the expected benefits, but rather to a salvage of some of the benefits. Salvage value has been evaluated at 10% of the benefits that would be achieved in case of success. The salvage value should be regarded as a negotiation power to lower costs of a new project with the contractor who promised a successful outcome.

The full success of the implementation allows to collect the full benefits. Once again benefits are costs containment benefits due to IT license reduction costs and are estimated at CHF 20 Mio per year for five years starting one year after project completion.

As mentioned, the option embedded inside this framework is the option for the management to wait after the pilot stage before continuing to implement the project. And this option can be valued by computing the net present value of the project, and comparing it to the net present value without flexibility.

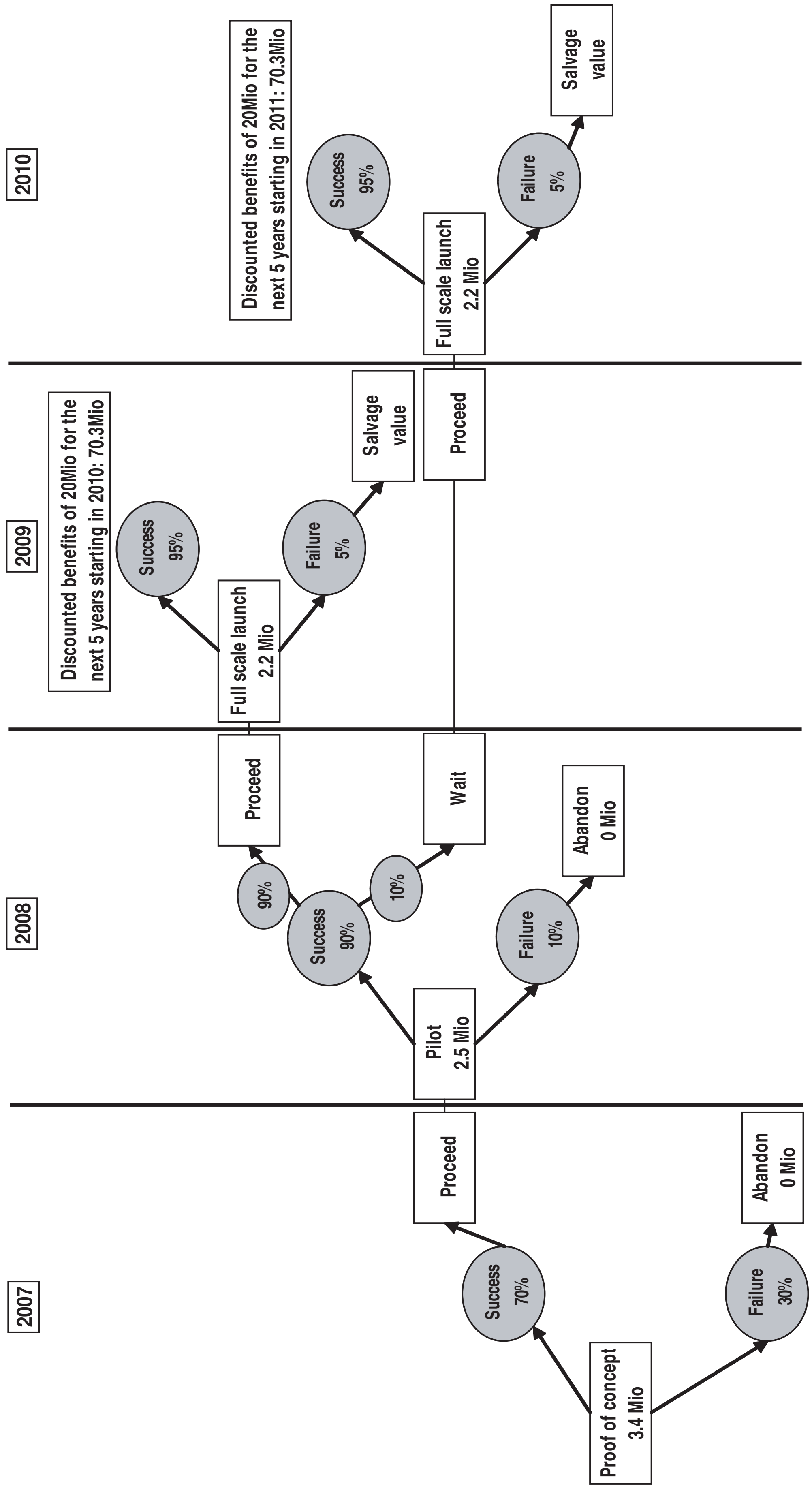

Fig. 4: Decision tree with objective probabilities including managerial flexibility.

3.4.1 Calculation of real option using objective probability and managerial flexibility

Applying the conventional option calculation to the resulting decision tree from the previous section, we can compute the option value at the different stages of the migration project. To do this, we work the different paths backward, from the expected final outcomes - ending either in 2009 or 2010 - up to the time zero of the tree, which is 2007. Figure 5 shows the decision lattice and the probabilities associated. Further calculation refers to the nodes and probabilities given in this tree.

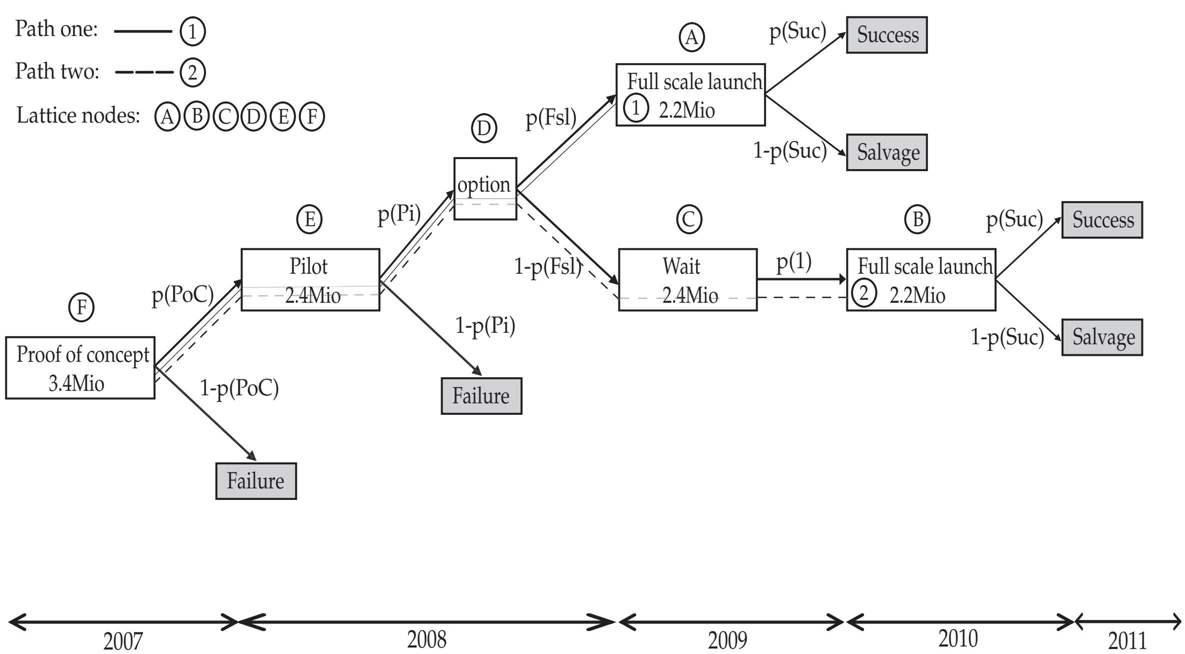

Fig. 5: Decision lattice used for real option computation. p(Suc) refers to probability of success for the whole migration; p(Fsl) refers to probability to proceed with of full scale launch; p(Pi) refers to probability of success associated with the pilot; p(PoC) refers to the probability of success of the proof of concept's stage. p(PoC) = 0.7, p(Pi) = 0.9, p(Fsl) = 0.9, p(Suc) = 0.95.

Following the lattice and starting from the end of the branches, going one year backward implicates to discount the cash flow by the discount rate. For each node of the diagram tree, all branches emanating from one node enter the calculation, as they represent management's possible decision. Thus, going backwards to node A on path number one - shown in Figure 5 -, which leads to a launch at full scale for the migration project in 2009, we have:

- in case of success, the value of the expected aggregate benefits of CHF 20 Mio per year from 2010 until 2014. Using the discounted cash flow methodology, we find that the value of the aggregate benefits in case of success as of 2010 is:

$$CF_{success} = \frac{CHF\,20Mio}{(1+13\%)^0} + \frac{CHF\,20Mio}{(1+13\%)^1} + \frac{CHF\,20Mio}{(1+13\%)^2} + \frac{CHF\,20Mio}{(1+13\%)^3} + \frac{CHF\,20Mio}{(1+13\%)^4} = CHF\,79.4Mio$$

- in case of failure at full scale launch, the value of aggregate salvage - determined as one tenth of the successful outcome - as of 2010 becomes:

$$CF_{salvage} = CHF\,7.9Mio$$

Going backwards on path number one from 2010 to 2009, we use the objective probability and discount the cash flows to compute the value at node A. Value at A equals the weighted discounted cash flows from 2010 minus the investment value in 2009. Net Cash Flow in A is:

$$NCF_A = \frac{0.95 \times CHF\,79.4Mio}{(1+13\%)} + \frac{0.05 \times CHF\,7.9Mio}{(1+13\%)} - CHF\,2.2Mio = CHF\,65Mio$$

Going backwards to node B on path number two, which leads to full scale launch for the migration project in 2010, we have:

- in case of success: the value of the expected aggregate benefits of CHF 20 Mio per year from 2011 until 2015, as for 2011 leads to the exact calculation and results as for path number one:

$$CF_{success\ 2011} = CHF\,79.4Mio$$

- in case of failure: the value of the expected aggregate salvage from 2011 until 2015 is exactly the same as for path number one with:

$$CF_{salvage} = CHF\,7.9Mio$$

Going backwards on path number two from 2011 to 2010, using the same methodology as before, the value of the net cash flow at node B becomes:

$$NCF_B = \frac{0.95 \times CHF\,79.4Mio}{(1+13\%)} + \frac{0.05 \times CHF\,7.9Mio}{(1+13\%)} - CHF\,2.2Mio = CHF\,65Mio$$

Those values are exactly the same for both paths. This makes sense as we computed these net cash flows with the value of aggregate benefits starting one year after migration completion. Node A and node B represent exactly the same situation, and thus same results are expected.

Going backwards on path number two from 2010 to 2009, we have to discount the cash flow NCF_B. Thus we have a net cash flow at node C:

$$NCF_C = \frac{CHF\,65Mio}{(1+13\%)} = CHF\,57.5Mio$$

Going backwards from 2009 to 2008, and using the respective objective probabilities, we find a net cash flow at node D computed as:

$$NCF_D = \left[\frac{NCF_A \times 0.9}{(1+13\%)} + \frac{NCF_C \times 0.1}{(1+13\%)}\right] = CHF\,56.9Mio$$

Still in 2008, at node E net cash flow becomes:

$$\begin{aligned} NCF_E &= [(NCF_D \times 0.9) + (CHF\,0 \times 0.1)] - Investment_{pilot} \\ &= [(CHF\,56.9 \times 0.9) + CHF\,0] - CHF\,2.5Mio = CHF\,48.7Mio \end{aligned}$$

Finally working back to 2007, the net present value for the whole project (node F) - with the embedded option to wait for one year after completion of the pilot phase is given by:

$$\begin{aligned} NPV &= \left[\frac{(NCF_E \times 0.7) + (CHF\,0 \times 0.3)}{(1+13\%)}\right] - Investment_{proof\ of\ concept} \\ &= \frac{CHF\,48.7Mio \times 0.7}{(1+13\%)} - CHF\,3.4Mio = CHF\,26.8Mio \end{aligned}$$

The net present value for the whole migration project, containing the option of delaying the full scale launch stage implementation after completion of project pilot is CHF 26.8 Mio. This allows the valuation for the option to wait for one year. The option to defer is the difference between the net present value of the project with the option valued here as CHF 26.8 Mio and the net present value calculated for the case where no flexibility is available - result from part 3.2 - CHF 27.1 Mio. We find an option value of

$$Option\ value = CHF\,26.8Mio - CHF\,27.2Mio = CHF - 0.4Mio$$

In this case, the option to wait yields a loss of CHF 0.4 Mio, which is explainable this way: managerial flexibility encountered within this framework allows one to postpone the last stage of the project for one year. This implies a deferment in the discounted benefits by one year, so lesser benefits as all other things remain unchanged.

Under these circumstances, flexibility to defer did not allow resolving uncertainty and go for expected higher benefits as it is often the case, but simply to expect the same benefits but with one year delay. Thus, having an option value which is negative makes totally sense in this specific case.

3.5 Real options analysis with embedded volatility - Monte Carlo simulation

The option based calculation is a valuable tool and allow making decision on objective figures, which take into consideration the different possible paths leading to the full project realisation. But up to this point, the option analysis is based upon objective probability given by the management and estimated on previous similar projects. At every stage of the implementation outcomes are probabilistic and depend on endogenous factors, but there is uncertainty bound to exogenous factors as well. This exogenous uncertainty is the volatility within the option analysis, and it comes from the different cash flows. Investment cash flows are subject to volatility. Numbers given in the business case are expected values, best estimations but there are prone to correction. The net present value calculation details the different cash flows (cf. Appendix A.1).

In agreement with the management, we admitted that the first entry in the DCF analysis, the costs of the IT staff, is subject to uncertainty. Defining the range of uncertainty for these costs can be done by looking at the effective costs of project - costs calculation after project fulfilment - from internal historical data. According to management, theses costs can fluctuate by about 10%. This 10% volatility is defined as constant over the time horizon of three or four years, depending on the path conducting to the full scale launch for the migration project (cf. Figure 4). This assumption - of constant volatility over time - does not totally match the reality of assets' price evolution as no inflation is taken into consideration; never the less it gives a simplistic but good estimation to model the stochastic behaviour of the real option. The next entry in the DCF calculation, the costs occurring from contractors, is also subject to a steady volatility of 10 % over the same time horizon as before. The costs of the Swiss Re IT staff and the contractor costs are variable because they depend on the issues arising during the project and the ways to solve these issues during the implementation. A project stage can take more or less work time than estimated and accordingly influence the project's total cost.

Benefits of the project are the results of contract agreement with the contractor's firm. As they contribute to the highest part of the present value, their fluctuation is from major importance. To better capture the incidence of these high benefits on the net present value and specifically on the option's value, we establish that the benefits exhibit also a volatility of 10%, constant over the time horizon of five year, starting the year after full migration completion. To capture the uncertainty linked to the cash flows is the most sensible issue of the real options analysis.

The uncertainties contained in the cash flows yielding a probabilistic distribution, they can feed a Monte Carlo model: a stochastic method to simulate the cash flows fluctuation. The Monte Carlo simulation consists in creating artificial futures of the real option model by generating thousands and even hundreds of thousands of sample paths of outcomes and analysis their prevalent characteristics. Monte Carlo techniques allow us to produce an estimate of the present value of a project conditional on the set of random variables drawn form their underlying distribution. Rather than looking at the NPV as a unique estimator, like in the previous section, we now use the random variations to produce thousands of possible NPV. The NPV based on the draw of a set of random variables is registered and the process is repeated thousand of times, so that we do not obtain a most likely estimate but a range of distribution. The use of this tool is widely spread in financial modelling due to its adaptability to every situation, where deterministic algorithms are used.

The domain of possible inputs has been defined as we have determined which cash flows are affected by uncertainty and we also estimated their respective volatility. Additionally, as most of the time in finance, we admit a lognormal distribution for all the variables of the model. Lognormal distribution is applicable when the quantity of interest must be positive. The probability density function of the lognormal distribution is defined as:

$$y = f\left(y \mid \mu, \sigma\right) = \frac{1}{x \cdot \sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$$

for x > 0, where μ and σ^2 are the mean and variance of the variable logarithm in the corresponding normal distribution. μ and σ satisfy the following equations

$$m = e^{\left(\mu + \frac{\sigma^2}{2}\right)}$$

$$s^2 = e^{\left(2\mu + 2\sigma^2\right)} - e^{\left(2\mu + \sigma^2\right)}$$

where, m and s are the mean and the standard deviation of the lognormal distribution.

So given m and s, the μ and σ can be obtained as:

$$\mu = \frac{1}{2} \cdot \log\left(\frac{m^2}{1 + \frac{s^2}{m^2}}\right)$$

$$\sigma = \sqrt{\log\left(1 + \frac{s^2}{m^2}\right)}$$

We use now the lognormal distribution for all the defined variables and generate possible sample paths by running the Monte Carlo simulation. The most important assumption underlying the model is that variables are independent. This, because of the difficulty to estimate their reciprocal influence but also for simplicity. The program MATLAB from Mathworks International has been used to run the computational algorithm, where 50'000 trials have been generated and registered. Figure 6 shows the net present value and option's value, lognormally distributed.

The 50'000 states generated allow for the calculation of a good estimation of mean and standard deviation for the net present value and option value distribution. The 10 % volatility on the respective variables produce a net present value for the whole migration project of CHF 26.8 Mio with a standard deviation of CHF 1.5 Mio. The option value to wait one more year before earning the benefits is of CHF - 370'00 with a standard deviation of CHF 17'000 (cf. Table 3). The kurtosis of both net present value and option value distribution are very close to 3. The kurtosis is an indirect interpreter of the variance of the values. A higher kurtosis means a bigger part of the variance comes from value in the extreme ends of the distribution. A normal distribution has a kurtosis of 3. In this case the kurtosis very close to 3 means that the distributions can very well be approximated by a normal distribution function. The skewness is an indicator of the asymmetry of the probability distribution. A positive skew indicates that the long tail is on the right side of the distribution and a negative skew indicates a long tail on the left side of the distribution. We have here a slightly positive skew for the NPV distribution and a slightly negative skew for the option value distribution, as both distribution are very close to a normal distribution. Mean NPV and mean option value stay naturally the same as in the case of real option calculation without volatility, but embedding volatility within the model provide us with a range for the possible NPV and option value.

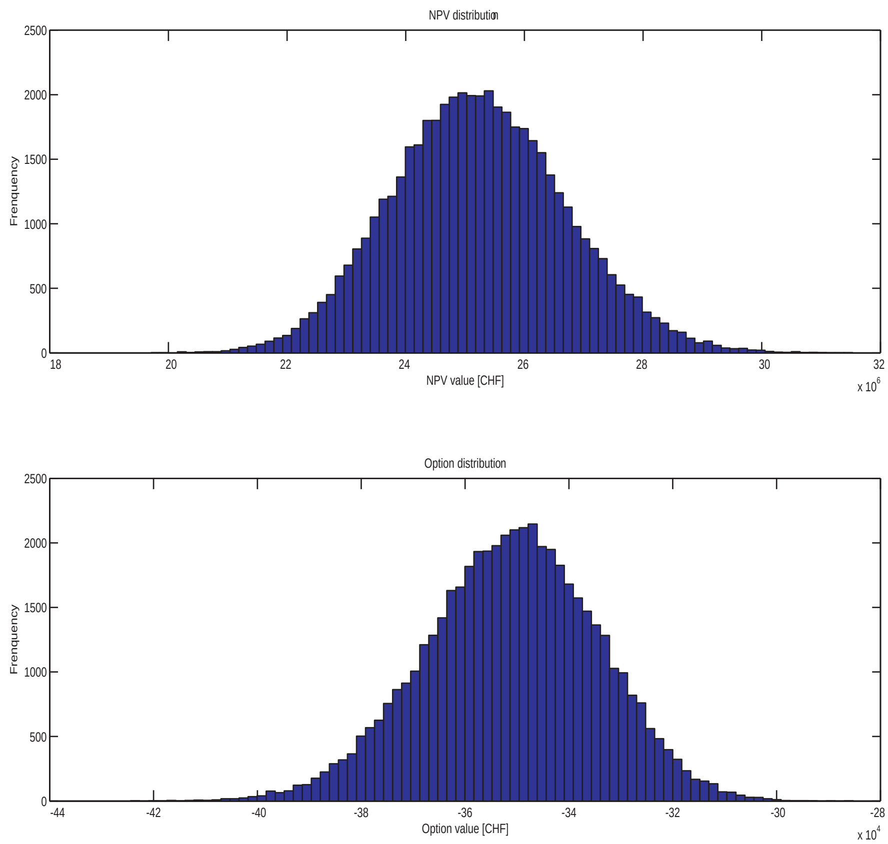

Fig. 6: Graph of NPV and option value distribution after Monte Carlo simulation with 50'000 trials and assuming 10 % volatility.

	NPV distribution	Option value distribution
Number of trials	50'000	50'000
Mean	CHF 26,762,000	- CHF 369,000
Standard deviation	CHF 1,520,00	CHF 17,000
Volatility	0.06	0.05
Kurtosis	3.02	3.07
Skewness	0.13	-0.14

Tab. 6: NPV distribution results after Monte Carlo simulation with 50'000 trials and assuming 10 % volatility.

The cumulative distribution function of a value x, F(x) defined as:

$$F(x) = P(X \leq x) = \int_{-\inf}^{x} f(t)dt$$

is the probability to observe a particular outcome less than or equal to x . If f is a probability density function for the random variable X, the associated cumulative distribution function is F. The cumulative distribution function has two theoretical properties:

- The cumulative distribution function ranges from 0 to 1.
- If y > x, then the cumulative distribution function of y is greater than or equal to the cumulative distribution function of x.

The cumulative distribution function allows defining confidence intervals for the net present value and the option value, which is of great interest when evaluating the costs or the benefits of an investment. The cumulative distribution functions (cdf) of the net present value and option value allow us to evaluate the first and the ninth percentile, which defined an 80% confidence interval. Thanks to the cumulative distribution function, we find that there is 80 % of chance that the NPV finds itself within the interval

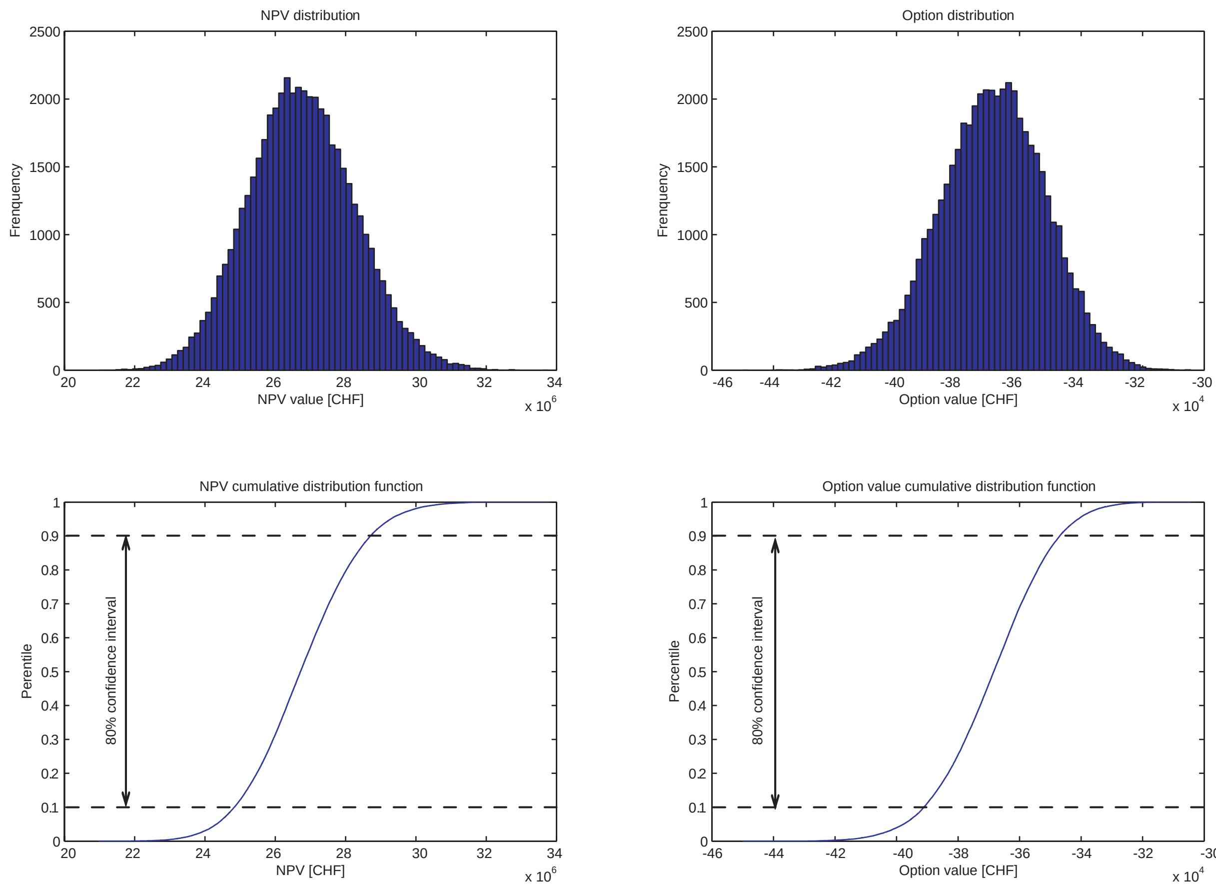

Fig. 7: NPV and option value distribution and their associated cumulative distribution function (cdf). cdf allows for the determination of confidence intervals.

CHF 24.8 Mio to CHF 28.7 Mio, and the option value has an 80 % chance to find itself between CHF -391'000 and CHF -346'000.

To summarise, the application of the Monte Carlo simulation using random independent variables produces a distribution of potential outcomes for the net present value and for the option value. Looking at the cumulative distribution of these two results, we can forecast confidence intervals, which assure the likelihood for the NPV and option value to find themselves within this interval. Instead of having only one estimation for the net present value and one estimation for option value, we now have confidence interval for those estimations. In this case, we can see that the option value remains negative over the whole interval, which means that the option of waiting for one more year decreases the value of the NPV. There is no way for management to use flexibility and make decision that would lead to a positive option value. But management can still handle to mitigate the losses. However, the option value represents only 1.4 % of the project value. According to those findings, two interpretations are possible. The first one could be to conduct the migration project without delay up to the end because money is discounted at a discount rate of 13 %. The second interpretation could state that the project could be implemented with one year delay for the last stage, as waiting for one year is worth only 1.4 % of the net present value.

The probabilistic distribution of the accepted parameters feeding the real option model provide us with a robust valuation of NPV and option value. But what would happen if some of the variables would be subject to changes. How would the net present value of the project and the option value behave? To find an answer to these questions will help the managers to choose between the two interpretations mentioned above.

4 Scenario analysis

In the previous section, the real option model for Monte Carlo simulation has been run under different assumptions:

- a constant discount rate of 13% unchanged over the 4 years of implementation and the five consecutive years, when the benefits are effectively achieved.
- no inflation over the whole project duration.
- the objective probability are fixed.

If we now consider the objective probabilities, their values are given by the management but should however be tested against possible other probable scenarios where the probability might diverge from the base case. Taking into consideration the what-if hypothesis allows to look at the sensitivity of some of the parameters with respect to the net present value and option value calculation.

4.1 Objective probability sensitivity

Firstly, we look at the case where we would consider the probability leading to a successful full scale launch (cf. Figure 5, P(Suc)) to be very optimistic. What would happen if instead of having a 95 % chance of success at this stage, we would consider a 75 % chance of succeeding at this stage?

All other things being equal and varying the probability of success for the full scale launch (P(Suc)) to 75% instead of 95%, we find a net present value for the migration project of CHF 20.6 Mio and an option value of CHF -297'000, when running the Monte Carlo simulation on the real options model with this new parametrisation (Figure 8). The 80 % confidence intervals given by the first and ninth percentile are, for the net present value, of CHF 19 Mio to CHF 22.2 Mio, and for the option value of CHF -315’000 to CHF -279’000 (Figure 8). Comparing the mean values found here with the case admitted by the management, where the probability of full scale launch is 95% instead of the 75% chosen for the sensitivity analysis, we find that the NPV for the project migration falls from CHF 26.8 Mio to CHF 20.6 Mio, which represents a difference of CHF 6.2 Mio or 23%. Thus a 20 % decrease in the probability of success at full scale launch induces a 23% decrease of the NPV.

The option value, as the migration project exhibit less benefits, inversely increases as it is negative. Its original value CHF - 370’000 goes up to CHF - 297’000. This represents a difference of CHF 73’000. So the probability of success at full scale launch (P(Suc)) has a high impact on the project NPV and a lesser impact on the absolute option value, as this one is much smaller than the net present value (cf. Appendix A.2)

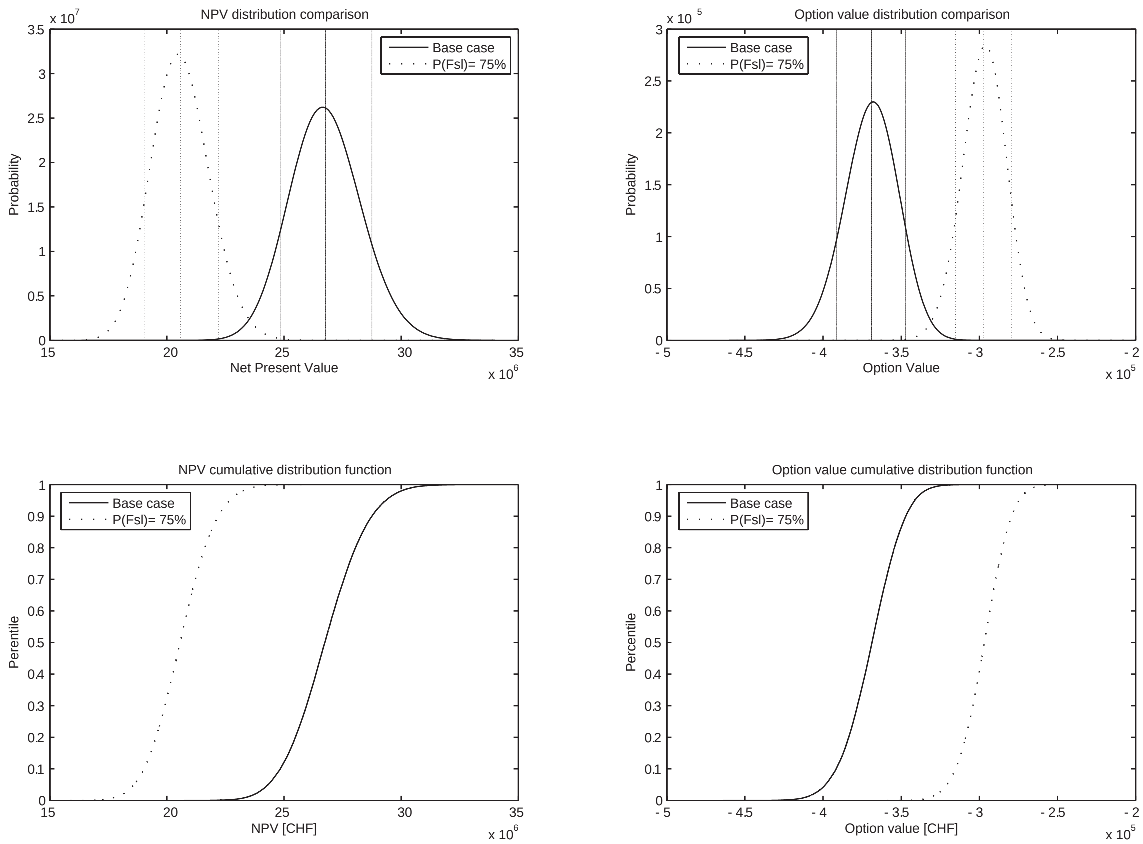

Fig. 8: Sensitivity analysis on NPV and option value distribution - comparison graphs. The objective probability of success for the full scale launch is set to 75% instead of the 95% chosen by the management. The upper graphs show overplots for the distributions with mean value and the 80 % confidence intervals - base case and case where objective probability of success for the full scale launch is set to 75% instead of the 95% (dotted line) . The lower graphs show overplots of the cumulative distribution function with the first and ninth percentile for NPV and option value.

We could now admit that instead of being fixed to one value, the probability of full scale launch could be uniformly distributed around 95 % plus minus 5 %. Running the Monte Carlo simulation under this assumption, all other things being equal, we have for the net present value a mean of

CHF 26.8 Mio. Figure 9 shows the NPV and option value distribution for the base case and the sensitivity case. NPV remains constant as in the case without probabilistic distribution of the objective probability for success at full scale launch, and the option value also remains the same with CHF - 369’000. However, the confidence intervals have changed. These results are expected as the mean value of the probability success by full launch is the same as in the base case, the difference now is that this probability is uniformly distributed. The cumulative distribution function allows to determine the 80 % confidence intervals, which are respectively CHF 24.5 Mio to CHF 29.1 Mio for the NPV, and CHF -395’350 to CHF -343’442 for the option value. As before, the mean values remain the same as in the base case, and confidence interval boundaries are wider apart. The upper value of the 80 % of the NPV is now CHF 29.1 Mio against CHF 28.7 Mio before, and the lower boundary is CHF 24.5 Mio against CHF 24.8 Mio in the base case (cf. Appendix A.2).

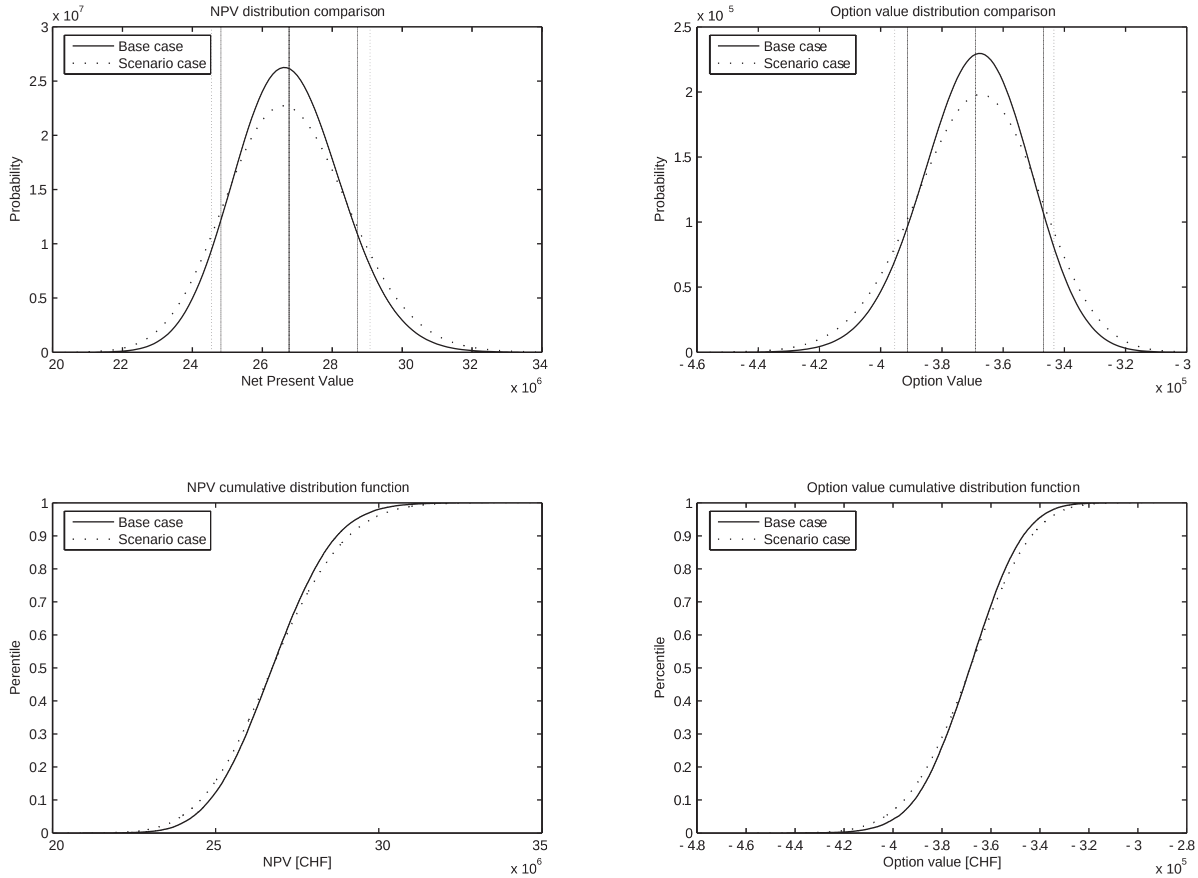

Fig. 9: Sensitivity analysis on NPV and option value distribution - comparison graphs. The objective probability of success for the full scale launch is set to be uniformly distributed centred at 95%. The upper graphs show overplots for the distributions with mean value and the 80 % confidence intervals - base case and case where objective probability of success for the full scale launch is uniformly distributed centred at 95% (dotted line) . The lower graphs show overplots of the cumulative distribution function with the first and ninth percentile for NPV and option value.

The estimate for objective probability of success for the full scale launch has a significant influence over the net present value and option value calculation. When set to 75 % instead of the original 95 %, NPV decreases by more than CHF 6 Mio. If we admit that the estimate given by the project owner, although conservative but truthful, we find that a uniform distribution around the given value has only a slight influence on the confidence intervals.

4.2 Benefits volatility sensitivity

An important assumption in the base model is that benefits are independent from year to year and that their volatility stays constant at 10 %. What would happen if solely the benefits, which occur for the highest part in the net present value, could vary from 10 to 20 %. It is reasonable to delve into this what-if analysis as the benefits contain more uncertainty as the other cash flows, their proceeds being delivered not before than 4 years after the project's start.

To apply the Monte Carlo simulation for this case, we increase the benefits volatility stepwise by 2 % from 10 to 20 % and obtain so a distribution for each respective case. Figure 10 shows the comparison for two particular cases: the results for the base case, where 10 % volatility is assumed, and the case with 20 % volatility. We find the 80 % confidence intervals for the NPV and the option value to be CHF 23 Mio to CHF 30.7 Mio and CHF - 415'000 to CHF -326'000, respectively for the 20 % volatility case. The results for the intermediate values - 12%, 14%, 16%, 18% - are not represented in figure 10, but their distributions are comprised between the two boundary values, in the case of NPV and option value. Detailed results can be found in the Appendix A.3.

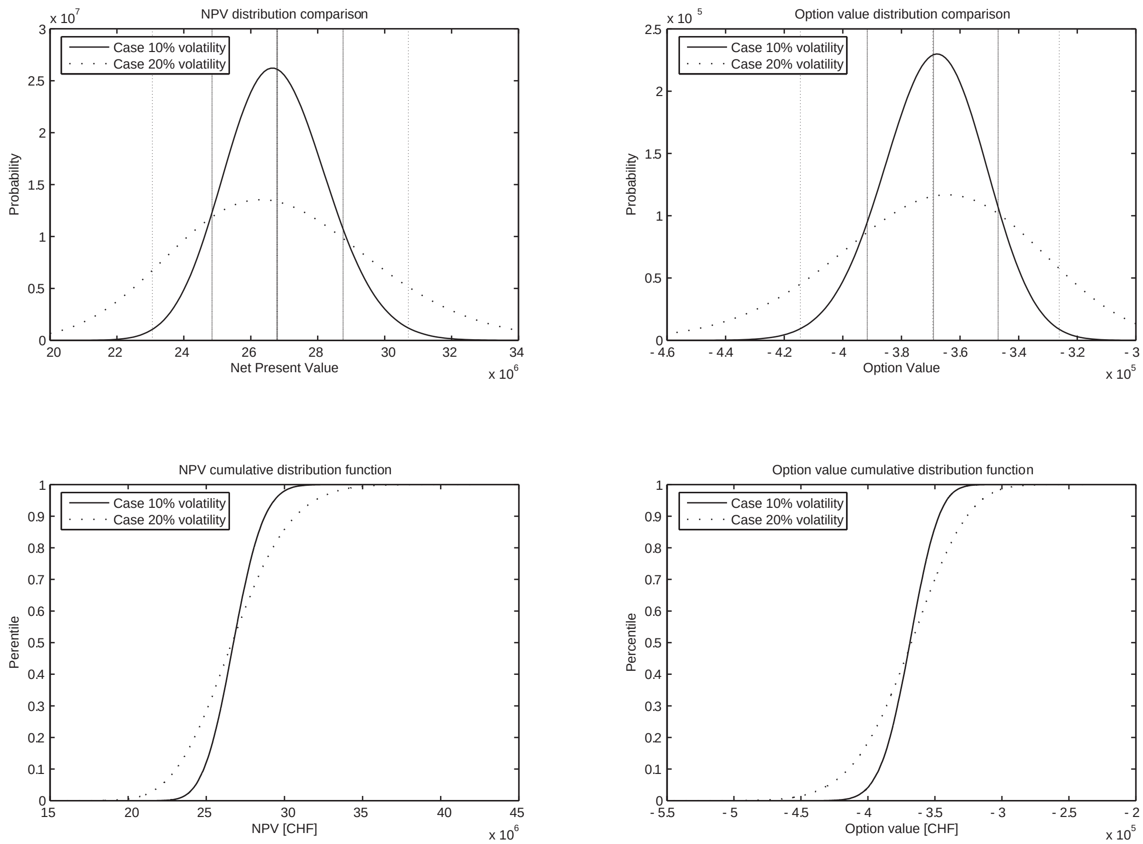

Fig. 10: Sensitivity analysis on NPV and option value distribution - comparison graphs. Benefits volatility is increased from 10% to 20 %. The upper graphs show overplots for the distributions with mean value and the 80 % confidence intervals - base case (benefits at 10 % volatility) and case where the benefits have 20 % volatility (dotted line) . The lower graphs show overplots of the cumulative distribution function with the first and ninth percentile for NPV and option value.

An increased volatility of the benefits has a significant influence over the confidence intervals of the net present value and the option value. Depending on the estimated benefits volatility, management can expect to capture upside value for NPV and limit the downside of the option value.

4.3 Growth scenario

The growth scenario is widely encountered in the field of real options valuation because many times, investments allow for a potential growth of the firm business drivers. And in those cases, many times, the decision to postpone a stage in the implementation provides the management with more information about the future and help him to follow the path which leads to a higher growth through the implementation.

This scenario is thought to evaluate the net present value and the option price in case of a growth of the benefits, when the full scale launch is delayed by one year. An example for this scenario case could be that a new technology has been developed but will not be available on the market before one year. As a change into this new IT technology is almost compulsory, the decision to delay the implementation by one year would make it possible for the management to directly acquire the latest technology and avoid further costs for technology switching. Schwartz and Zozaya-Gorostiza have computed the stochastic cost function that shows the rapid decrease in the costs of some IT assets. They found that it becomes many times attractive to wait for cost to be lower [26]. This finding could comfort management to delay the project. And compared to the base case, these cost avoidance opportunities would constitute a growth in the benefits.

In this scenario, we explore the influence of a benefits growth on the net present value and on the option value. We assume a discrete growth of the benefits of 2 % between 10% and 20 %, all other things staying as in the base case. For each increment, we run the Monte Carlo simulation and obtain the correspondant NPV and option value. Figure 11 shows the distribution and cumulative distribution functions of NPV and option value for the two extreme cases: base case where there is 0 % growth and the case where 20 % growth is assumed.

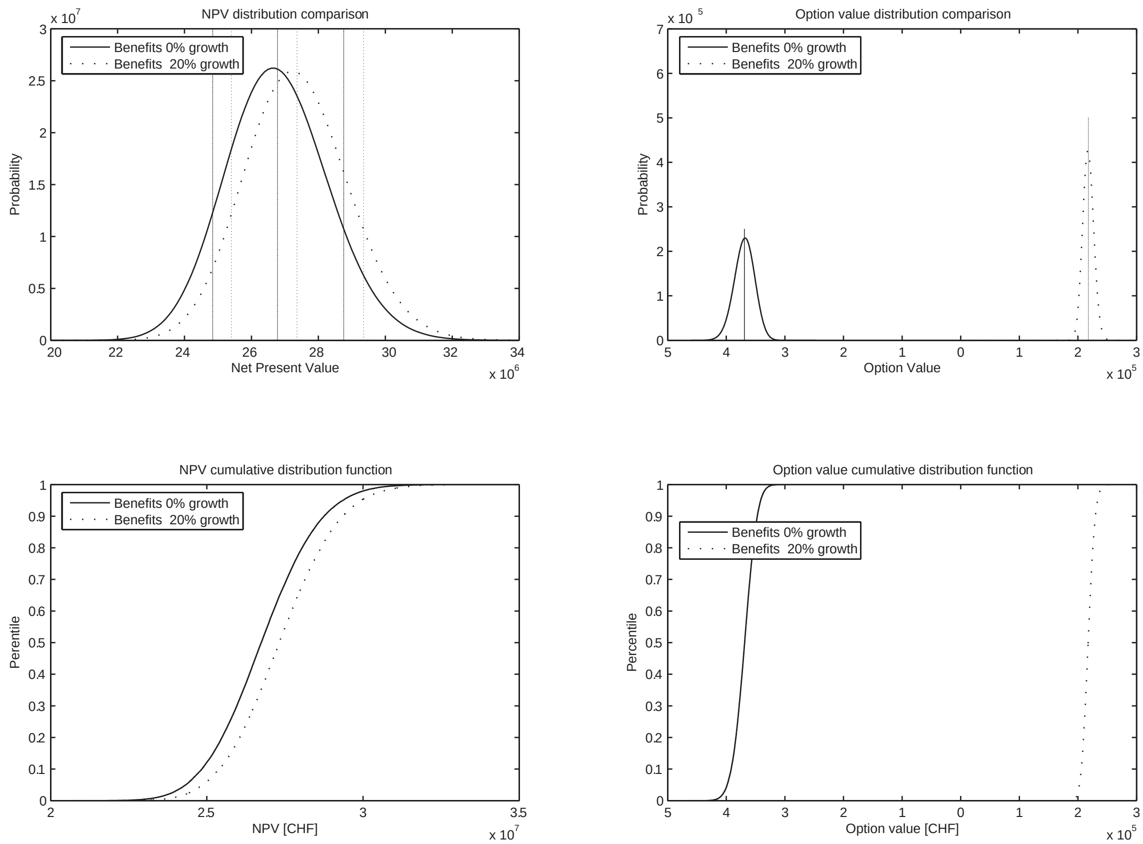

Fig. 11: Sensitivity analysis on NPV and option value distribution - comparison graphs for growth scenario. In case of project postponement, benefits increase from 10% to 20 %, compared to base case. The upper graphs show overplots for the distributions with mean value and the 80 % confidence intervals - base case (no growth) and case where the benefits have a 20 % growth(dotted line) . The lower graphs show overplots of the cumulative distribution function with the first and ninth percentile for NPV and option value.

In the case of a 20 % growth of the benefits if the implementation is delayed, we obtain a net present value of CHF 27.4 Mio and an positive option value of CHF 218’00 with 80 % confidence intervals of CHF 25.4 Mio to CHF 29.3 Mio and CHF 206’000 of CHF 230’000 respectively, when running the Monte Carlo simulation. We find under these assumptions a positive value for the option value. In the case of a 20 % expected growth, deferring the last stage of the implementation results in favourable decision as this option is calculated to be CHF 218'000. Compared to the base case where no growth is expected, this represents a positive earning of CHF 218'000 - CHF -370'000 = CHF 588'000. Detailed value can be found in the Appendix A.4.

5 Discussion

The case study about IT migration proposed by Swiss Re allows the application of different financial techniques to calculate the net present value of the project.

The first technique, broadly used in the field of finance is the discounted cash flow calculation. This method based on the discount rate gives a net present value of CHF 47.8 Mio. This value is computed straightforward on the basis of expected investments and expected benefits, but these quantities are assumed to be exact.

The second technique of calculation is based upon the objective probability of realisation at the different stages of the project. This approach proposes to take into consideration the probability of success and failure of the different phases and build a decision tree incorporating the different management strategy; but once again it assumes that the estimates for the objective probability are correct. The decision tree is an efficient way to apprehend strategic decisions by sketching the possible paths leading to migration fulfilment, also considering alternatives - or options - to the straightforward path conducting to project achievement. In this case, considering the different objective probabilities on the tree diagram (cf. Figure 5), the investments and benefits at every project stage, we find a net present value for the project of CHF 26.8 Mio. This net present value is much smaller than the one found through discounted cash flows methodology (CHF 47.8 Mio) but captures the uncertainty embedded within the project, even though objective probabilities are estimations made by the project owner upon his experience gathered from previous similar project.

Decision tree analysis gives the possibility to value the option to defer the project by one year. We found a value for this option of CHF -0.4 Mio. This negative option value can help management to make decision about the path to follow to fulfil the migration. There are two possible interpretations: either to see any postponement as a loss of money valuated at CHF -0.4 Mio or to look at the low option price - less than 1.5 % of the NPV - as an incentive not to invest directly in the migration as the loss is acceptable.

Running Monte Carlo simulation on the real options model allows taking into consideration the volatility of the different model's variables. Instead of assuming steady numbers for the different cash flows, we could admit a probabilistic distribution for these variables. The simulation provides us with means for the net present value and the option value, and standard deviations. The cumulative distribution function yields an helping tool in finance by allowing to determine confidence intervals for the results. With the Monte Carlo approach, we find an NPV of CHF 26.8 Mio with 80 % confidence interval of CHF 24.8 Mio to CHF 28.7 Mio, and an option value to delay the last stage of the migration implementation of CHF -370'000 with an 80 % confidence interval of CHF -391'000 to -CHF 346'000. Thus, deferring the full scale launch of the project is not profitable under these conditions as time value money has a high impact on discounted benefits.

The sensitivity analysis performed on some of the variables of the model confirms the importance of objective probabilities. Varying the probability of full scale launch, we find a significant decrease of the net present value when P(Suc) is set to 75% in place of the 95 % admitted by the management. The option value is also behaving accordingly, but its absolute value being small compared to the NPV, the relative change in its value is minor. An increase in the benefits volatility only creates wider 80 % confidence intervals for NPV and option value without changing the size of these values. The scenario through which growth is expected when the full scale launch is delayed by one year changes both the net present value and the option value. We find in the case of the 20 % growth expectation an increase of the net present value, compared to the base case, of CHF 6 Mio to CHF 27.4 Mio, and the option value increases of about CHF 600'000, going from CHF -370'000 to CHF 218'000. For the first time in this analysis, we find a positive option value.

In this case, Table 7 shows that option value is increasing with the growth percentage and the option value becomes positive for an expected growth of the benefits between 12 % and 14 %. We see here the importance of the discount rate which is approximately the tilting point into positive value for the option. It is legitimate to understand that the value to delay the last phase of the migration project becomes positive only if the growth in the expected benefits perceived from the project surpasses the rate of money depreciation translated by the discount rate. In this case, where the discount rate is fixed at 13 %, we find that an expected growth of 14 % on the benefits yields a option value of CHF 42'000.

NPV							
Benefits growth	0%	10%	12%	14%	16%	18%	20%
Trials number	50000	50000	50000	50000	50000	50000	50000
Mean	CHF 26,777,282	CHF 27,076,916	CHF 27,128,376	CHF 27,190,594	CHF 27,254,089	CHF 27,291,150	CHF 27,357,008
1st percentile	CHF 24,840,556	CHF 25,135,690	CHF 25,191,938	CHF 25,235,190	CHF 25,304,583	CHF 25,329,290	CHF 25,398,448
9th percentile	CHF 28,754,025	CHF 29,043,514	CHF 29,122,104	CHF 29,183,747	CHF 29,256,653	CHF 29,283,844	CHF 29,353,114
Standard deviation	CHF 1,525,522	CHF 1,528,634	CHF 1,537,292	CHF 1,539,832	CHF 1,542,376	CHF 1,544,676	CHF 1,544,269
Kurtosis	3.03	3.05	3.07	3.00	3.04	3.05	3.03
Skewness	0.13	0.13	0.14	0.12	0.14	0.14	0.14
Volatility	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Option Value							
Benefits growth	0%	10%	12%	14%	16%	18%	20%
Trials number	50000	50000	50000	50000	50000	50000	50000
Mean	-CHF 369,084	-CHF 75,695	-CHF 16,995	CHF 41,677	CHF 100,379	CHF 158,962	CHF 217,664
1st percentile	-CHF 391,604	-CHF 81,007	-CHF 19,142	CHF 39,563	CHF 95,135	CHF 150,439	CHF 205,782
9th percentile	-CHF 347,025	-CHF 70,492	-CHF 14,870	CHF 43,854	CHF 105,741	CHF 167,681	CHF 229,792
Standard deviation	CHF 17,404	CHF 4,112	CHF 1,671	CHF 1,678	CHF 4,130	CHF 6,747	CHF 9,383
Kurtosis	3.04	3.04	3.04	3.02	3.04	3.06	3.02
Skewness	-0.14	-0.12	-0.03	0.14	0.14	0.15	0.15
Volatility	0.05	0.05	0.10	0.04	0.04	0.04	0.04

Tab. 7: NPV and option value behaviour for the growth scenario. Discrete steps of 2 % between 10 and 20% are considered.

Although the migration projects yields a positive net present value that leads management to start with the project, the scenario analysis gives the possibility to explore more in details the influence of some of the parameters and reveals the necessary condition to obtain a positive option value.

One of the most decisive parameter in this simple real option model is the discount rate. We can see it from the scenario analysis that varying the volatility of the benefits, or varying some of the objective probabilities, or even assuming a growth does not change the net present value significantly. The growth analysis reaffirms the critical influence of the discount rate by showing that as long as the growth rate stays below the discount rate, postponing the full scale launch of the project will result in a negative option price.

5.1 Restrictions and outlook

The framework for this real option valuation is particular in the sense that the tree diagram we developed for the case considers paths that DO NOT end in the same year. On the first path, we admitted that the project benefits - in form of license costs avoidance - will be perceived from year 2010 to year 2014. On the option path, the second path, the benefits of the migration project can be perceived from year 2011 to year 2015. And for the valuation of the real option, we did accept to value paths that do not end in the same year. In a conventional real options valuation, we should have had cash flows expectations for the year 2015 on the first path as well. Thus we could value the net present value and the option value over a steady timeline finishing up in 2015. This is the major restriction to our approach and lead to the second remark.

We have here looked at the real options embedded within the migration of an IT system, considering the migration project as a closed system, without looking at the downstream incidences on the firm productivity resulting from the migration. To really capture the whole value of real options valuation, one should look at the implication of new IT platforms on the business drivers. This means open up the framework of the migration we considered and take into account the benefits achieved by the business application running on the new platform. The diagram tree will comprise the migration project and the different applications contingent on the new IT platform and generating cash flows. We could then see the migration as inscribed inside a broader corporate process implemented to harmonised Swiss Re. Buy doing so, management would be able to have a much more realistic value of the IT migration and would be able to make the right decision about project implementation.

6 Conclusions

The case study proposed by Swiss Re allowed mostly fulfilling the goals set for this thesis. We could define a methodological and very detailed framework to tackle real options analysis with this case, as it should become common management practice at Swiss Re. However, each case has its specificity, and this case only suggests some paths to approach such a problem. The valuation of such case depends on the accuracy of the data, might it be data from business case or estimations made by managers. Investigating at the different levels of the management concerned with this project helped to better grasp the decisive issues. This case is in the end easily decomposable and embeds only one real option to value. But introducing real option appraisal methodology inside Swiss Re will widen up the view of the managers and will allow them to make project complexity explicit.

The four-step approach proposed by Copeland an Antikarov is very clear and simple to implement. Going through the steps allowed incorporating managerial flexibility in the NPV calculation. And applying Monte Carlo simulation to the decision tree with objective probability enabled to produce results with even more significance as we obtained distribution for the net present value and the option value. The different parametrisation of some of the variables showed the sensitivity of the model toward volatility.

Finally, we can conclude that real options approach is certainly superior to traditional discounted cash flow analysis as it deals with expected quantities or probabilities, and not with certainties.

A Appendix

A.1 Discounted cash flow analysis

Monaco Migration Case								
	2007	2008	2009	2010	2011	2012	2013	2014
Year	0	1	2	3	4	5	6	7
Total Effort (PDS)								
Costs	CHF -3,388,140.00	CHF -2,495,500.00	CHF -2,174,500.00	CHF -	CHF -	CHF -	CHF -	CHF -
IT	CHF -3,263,140.00	CHF -2,345,500.00	CHF -2,124,500.00					
Swiss Re staff	CHF -2,723,655.00	CHF -1,697,025.00	CHF -1,753,125.00					
Contractors	CHF -476,273.00	CHF -398,475.00	CHF -246,675.00					
IT infrastructure	CHF -63,212.00	CHF -250,000.00	CHF -124,700.00					
IT outsourcing								
IT otherExpenses								
Other	CHF -125,000.00	CHF -150,000.00	CHF -50,000.00					
Benefits	CHF -	CHF -	CHF -	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00
Costs savings				CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00
Revenue increase								
Profitability improvement								
Capital allocation optimised								
Free Cash Flows	CHF -3,388,140.00	CHF -2,495,500.00	CHF -2,174,500.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00	CHF 20,000,000.00
Coefficient	1.000	0.885	0.783	0.693	0.613	0.543	0.480	0.425
Discounted FCF	CHF -3,388,140.00	CHF -2,208,407.08	CHF -1,702,952.46	CHF 13,861,003.25	CHF 12,266,374.55	CHF 10,855,198.72	CHF 9,606,370.55	CHF 8,501,212.87
NPV	CHF 47,790,660.40							
Discount rate r	13.00%							

A.2 Scenario analysis: sensitivity of probability of success for full scale launch

NPV				
P(Succ)	base case: 95%	75%		uniformly distributed around 95%
Trials number	50000	50000		50000
Mean	CHF 26,777,282	CHF 20,590,004		CHF 26,775,998
1st percentile	CHF 24,840,556	CHF 19,023,216		CHF 24,541,409
9th percentile	CHF 28,754,025	CHF 22,197,688		CHF 29,079,235
Standard deviation	CHF 1,525,522	CHF 1,242,933		CHF 1,762,644
Kurtosis	3.028	3.035		2.948
Skewness	0.129	0.131		0.147
Volatility	0.06	0.06		0.07
Option Value				
P(Succ)	base case: 95%	75%		uniformly distributed around 95%
Trials number	50000	50000		50000
Mean	-CHF 369,084	-CHF 297,056		-CHF 369,036
1st percentile	-CHF 391,604	-CHF 315,213		-CHF 395,350
9th percentile	-CHF 347,025	-CHF 279,255		-CHF 343,442
Standard deviation	CHF 17,404	CHF 14,056		CHF 20,207
Kurtosis	3.044	3.039		2.947
Skewness	-0.144	-0.136		-0.156
Volatility	0.05	0.05		0.05

A.3 Scenario analysis: increasing benefits volatility

NPV						
Benefits growth	10%	12%	14%	16%	18%	20%
Trials number	50000	50000	50000	50000	50000	50000
Mean	CHF 26,777,282	CHF 26,773,741	CHF 26,769,164	CHF 26,750,941	CHF 26,759,764	CHF 26,794,319
1st percentile	CHF 24,840,556	CHF 24,489,625	CHF 24,124,028	CHF 23,746,735	CHF 23,414,554	CHF 23,063,070
9th percentile	CHF 28,754,025	CHF 29,102,847	CHF 29,498,931	CHF 29,869,874	CHF 30,258,543	CHF 30,709,048
Standard deviation	CHF 1,525,522	CHF 1,811,003	CHF 2,094,830	CHF 2,400,239	CHF 2,689,257	CHF 2,981,554
Kurtosis	3.028	3.083	3.016	3.066	3.119	3.082
Skewness	0.129	0.164	0.182	0.212	0.251	0.271
Volatility	0.06	0.07	0.08	0.09	0.10	0.11
Option Value						
Benefits growth	10%	12%	14%	16%	18%	20%
Trials number	50000	50000	50000	50000	50000	50000
Mean	-CHF 369,084	-CHF 368,984	-CHF 368,958	-CHF 368,746	-CHF 368,861	-CHF 369,240
1st percentile	-CHF 391,604	-CHF 395,698	-CHF 400,470	-CHF 404,840	-CHF 409,321	-CHF 414,493
9th percentile	-CHF 347,025	-CHF 342,827	-CHF 338,643	-CHF 334,117	-CHF 330,003	-CHF 326,149
Standard deviation	CHF 17,404	CHF 20,795	CHF 24,141	CHF 27,753	CHF 31,117	CHF 34,533
Kurtosis	3.044	3.085	3.021	3.079	3.121	3.080
Skewness	-0.144	-0.165	-0.191	-0.219	-0.251	-0.273
Volatility	0.05	0.06	0.07	0.08	0.08	0.09

A.4 Scenario analysis: benefits growth

NPV							
Benefits growth	0%	10%	12%	14%	16%	18%	20%
Trials number	50000	50000	50000	50000	50000	50000	50000
Mean	CHF 26,777,282	CHF 27,076,916	CHF 27,128,376	CHF 27,190,594	CHF 27,254,089	CHF 27,291,150	CHF 27,357,008
1st percentile	CHF 24,840,556	CHF 25,135,690	CHF 25,191,938	CHF 25,235,190	CHF 25,304,583	CHF 25,329,290	CHF 25,398,448
9th percentile	CHF 28,754,025	CHF 29,043,514	CHF 29,122,104	CHF 29,183,747	CHF 29,256,653	CHF 29,283,844	CHF 29,353,114
Standard deviation	CHF 1,525,522	CHF 1,528,634	CHF 1,537,292	CHF 1,539,832	CHF 1,542,376	CHF 1,544,676	CHF 1,544,269
Kurtosis	3.03	3.05	3.07	3.00	3.04	3.05	3.03
Skewness	0.13	0.13	0.14	0.12	0.14	0.14	0.14
Volatility	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Option Value							
Benefits growth	0%	10%	12%	14%	16%	18%	20%
Trials number	50000	50000	50000	50000	50000	50000	50000
Mean	-CHF 369,084	-CHF 75,695	-CHF 16,995	CHF 41,677	CHF 100,379	CHF 158,962	CHF 217,664
1st percentile	-CHF 391,604	-CHF 81,007	-CHF 19,142	CHF 39,563	CHF 95,135	CHF 150,439	CHF 205,782
9th percentile	-CHF 347,025	-CHF 70,492	-CHF 14,870	CHF 43,854	CHF 105,741	CHF 167,681	CHF 229,792
Standard deviation	CHF 17,404	CHF 4,112	CHF 1,671	CHF 1,678	CHF 4,130	CHF 6,747	CHF 9,383
Kurtosis	3.04	3.04	3.04	3.02	3.04	3.06	3.02
Skewness	-0.14	-0.12	-0.03	0.14	0.14	0.15	0.15
Volatility	0.05	0.05	0.10	0.04	0.04	0.04	0.04

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