Uncertainty as a key value driver of real options

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Abstract

Real option valuation can be difficult and time consuming. Therefore, we propose a framework which is aimed at facilitating the process of real option valuation and to make it more time efficient. The framework covers not only the valuation of real options but also the organizational- , strategic-, and controlling aspects necessary to apply real option valuation accurately. In particular this paper focuses on uncertainties underlying any real option. Uncertainties will be used not only to identify options but also to link the interaction of uncertainties with the interaction of options. Finally, we will demonstrate the applicability of the framework with a real life e-commerce case.

Introduction

Uncovering real options can be tough [Amram & Kulatilaka, 1999a]. Whereas some real options are likely to be inherent in the strategy or project description, others will remain unknown. Since those hidden options are hard to recognize, other means of identification are necessary. Thus the prerequisites of real options will be examined to reveal an alternative identifier for the presence of real options, which may be used for an option identification model.

The usage of the real options technique is deemed appropriate only if there is [Dixit & Pindyck, 1994]:

- uncertainty regarding the outcome which can be limited by
- the managerial flexibility to take action during that
- totally or partially irreversible investment involving
- asymmetric payoffs.

While it seems nearly or entirely impossible to identify options within a given strategy or a project based on irreversible investments or asymmetric payoffs (since this is true for almost any investment), uncertainty and flexibility to act may signal the presence of options in a better way. Moreover, those factors may even reveal the importance or added value of the option, since their magnitude directly influences the option value and is quantifiable. Both factors are interdependent. Since flexibility constitutes the option to react to a state of resolved uncertainty, the later seems key to the presence of options. Hence, flexibility is the necessary condition to validate the use of options to mitigate an uncertainty. Thus the identification of real options inherent in a strategy could be driven by the identification of those uncertainties towards which a reaction is possible [Benaroch, 2001]. Actually, the only exiting systematic framework used for the identification of options, PricewaterhouseCoopers' OpenFraming™ relies on assessing uncertainties as well. In that framework, options are identified using SWOT analysis, which is essentially identifying up- and downside potentials [Claeys & Walkup, 1999].

In this paper, we propose a framework for the valuation of real options that can be processed sequentially. The framework is visualized in Figure 1. While real option valuation has been recognized by the scientific community, the approach yet lacks a broad-scale practical breakthrough [Lander & Pinches, 1998]. Among other factors, the fact that the complete valuation process using real options is very long, complicated and time-consuming has often been cited as major disadvantage by practitioners. The framework presented in this paper aims at facilitating parts of the real options approach.

The framework is organized across organizational- strategic- valuation- and controlling aspects of real options.

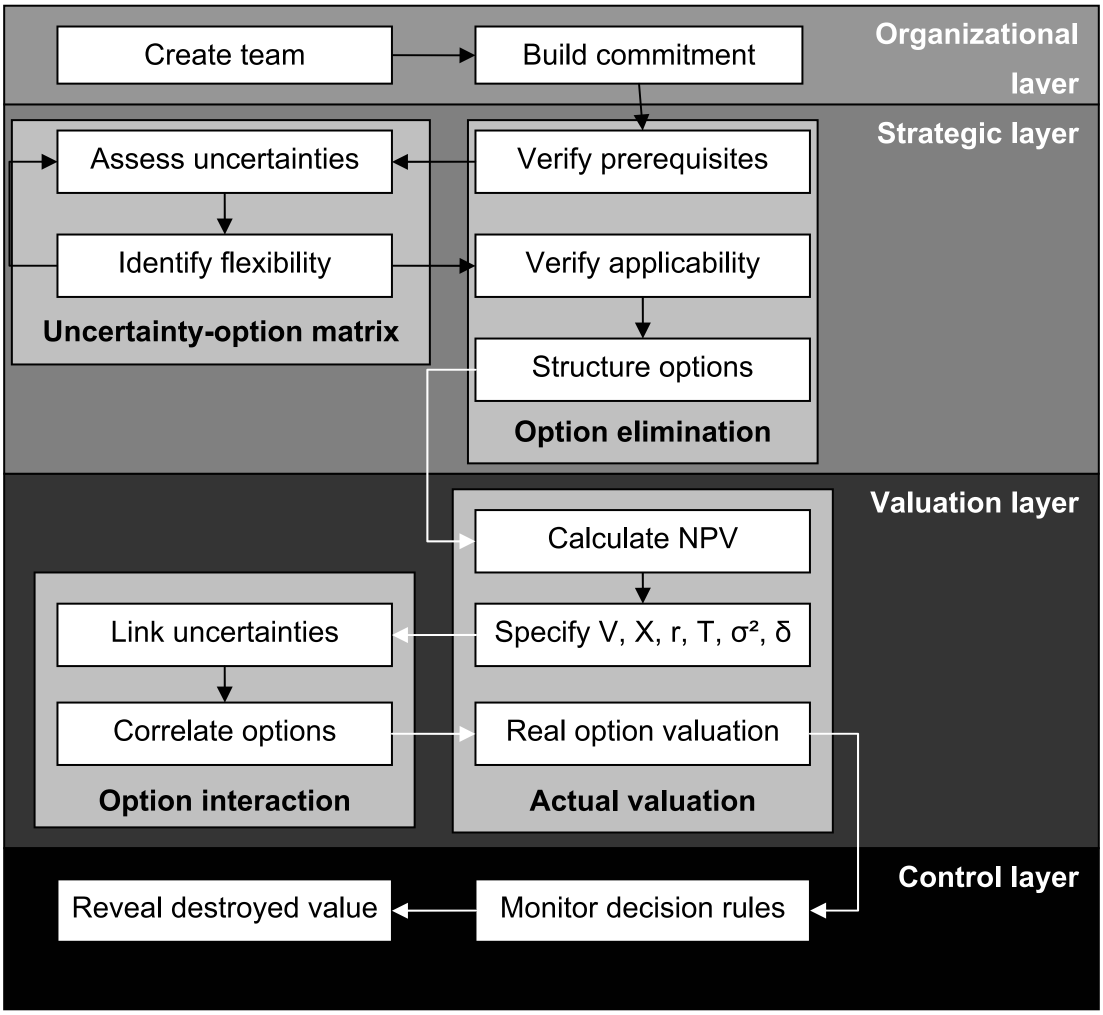
The **first layer** of the presented framework focuses on **organizational aspects** of real option valuation. Only if the input parameters are appropriate a real option valuation leads to reliable results. Since real option valuation is subject to the input of humans, organizational aspects of real option valuation have to be considered first in order to derive a proper and meaningful valuation result [Claeys & Walkup, 1999].

The **second layer** of this framework is build around the link **from real options to strategy** and vice versa. Since much of the value of the real-options approach comes from strategy, it is essential to properly frame the investment strategy [Copeland & Howe, 2002]. This paper is built on the notion that strategy is a chain of real options which interact with one another [Luehrman, 1998]. Science has confirmed the close ties between real options and strategic decision making [Kogut & Kulatilaka, 1993]. Both are instruments sharing the goal to maximize the return and hence the shareholder value [Amram & Kulatilaka, 1999b]. Interestingly enough, the nature of this relationship is bi-directional [Myers, 1984]: strategy influences real options, while the valuation process influences strategy [Remer & al., 2001]. Discovering the potential of a strategy is not the only benefit of the real option framework. The process of real option valuation also allows for optimizing the strategy with regard to strategy execution [Micalizzi & Trigeorgis, 1999]. Since strategy creates real options, the strategy description and the appertaining timeline are the first and most obvious source for identifying options inherent in a strategy. This layer of the framework is intended to structure, facilitate and enhance option identification beyond this process.

The **third layer** of the framework is focusing on the **valuation aspects** of real options. Obviously, valuation is an integral part of real option valuation. We suggest using the log-transformed binomial approach [Trigeorgis 1991] for this purpose, however the numerical aspect of it will not be discussed in this paper. Rather option interaction should receive a lot of attention [Trigeorgis, 1996]. We will focus on the topic of option- and uncertainty interaction. Examining both interactions is important, because several options may control the same uncertainty and are thus correlated.

The **fourth layer** of the framework is focusing on **controlling aspects** of real option valuation. The value of many decision rules lies more in the requirement for consistency than in optimality [Bowman, 1963] The same is true for real options. Agreeing on decision rules allows taking actions less emotionally and prompter in later stages [Copeland & Howe, 2002]. Given that options are only valuable if they are exercised accordingly, controlling is a very important aspect of real options. [Pritsch & Weber 2001]. Particularly monitoring the respective decision rules and properly executing options will enhance received project value.

Figure 1: Framework overview



Source: Own illustration

This paper will focus on the organizational- and the strategic layer of this framework. Within the strategic layer we will provide a structured approach to identify options within a project by focusing on the project's inherent uncertainties. Further, option interaction in the valuation layer will receive attention. The controlling layer is not discussed in this paper in further detail. Finally we will test the proposed framework with a real life case.

Layer 1: Organizational aspects of option valuation

Merely slight changes of input variables may significantly impact the value of real options. Hence, some measures should be taken to assure the reliability of the valuation. While some, such as a sensitivity-analysis or a Monte-Carlo Simulation, are of purely stochastic nature, organizational measures may be taken as well to improve the quality of the input parameters. This becomes evident considering that all forms of stochastic simulations are also based on input parameters. Since errors in simulation input parameters would result in false expected values, the error in project inputs may still exist. However, the joint use of simulation techniques and organizational measures should ensure an acceptable precision.

The further managers attempt to look into the future, the more their forecast errors grow. One possibility to deal with such errors is aggregating forecasts in two dimensions: across different managers and by breaking the forecasted value into its components. Essentially, the later is the accomplishment of the next section with respect to uncertainty prediction. The advantage of such aggregation is that error tends to be lower at aggregate level than at disaggregate level due to over and under-forecasts canceling each other out [Jain, 2002].

An important step to aggregate errors in the managerial dimension is the **creation of a valuation team**. Again, there is a trade-off between complexity and precision. While more team members would lead to more accurate parameters due to the aggregation, the team may be paralyzed by its sheer size. The emphasis should be put rather on bringing together the various functions involved in the project to include expertise across a number of fields, rather than just specifying a team size. While engineers are unlikely to consider all legal risks, a jurisprudent may not be able to correctly determine uncertainties concerning the performance of a new product. Thus a very diverse valuation team helps discover a huge range of real options and will be able to asses their value more precisely [Claeys & Walkup, 1999]. Generally a team including four to six members is likely to be sufficient, if competencies are well mixed.

Apart from the team size and composition, other organizational factors require attention as well. One such factor is to **build commitment of the team** to a common base. All members should share a common vision and have an equal understanding of success factors [Claeys & Walkup, 1999]. Such items may be set forward explicitly in a document and will ensure that no individual groups act in another way then specified, thus destroying project value. The real option approach is only valuable when options are exercised effectively [Remer & al., 2001; Coff & Laverty, 2001]. Attaining this goal requires reaching a consensus about which decisions need to be taken at which point.

Layer 2: Strategic aspects of option valuation

Limits and prerequisites of the option analogy

Uncertainty and ever-changing markets give the real options approach substantial advantage, as it is a very intuitive way to account for flexibility in valuation. However, a careful analysis as to the appropriateness of the use of real options valuation is required. Therefore, some limitations to the applicability of real options require attention, before developing an option identification framework. Primarily, the model's inherent prerequisites must be fulfilled. As is the case with other valuation models, these requirements theoretically limit the applicability to practical situations. However, such limitations are often ignored in practice and still lead to valuable results, despite the fact that they may not be exact.

A first condition for the applicability of the real options approach is the existence of **uncertainty** about the outcome of an investment. While almost any investment is subject to uncertainty, the **flexibility** to react to resolved uncertainty is not necessarily given. The lack of such flexibility would imply that no option existed at that point. As a third provision, the investment needs to be **at least partially irreversible**. Thus, if the investment fails to perform in the anticipated way, costs can not simply be recovered; otherwise the total transaction would be 100% risk-free. Finally, the valued project must feature an **asymmetric payoff function** [Hommel & Pritsch, 1999].

The above prerequisites apply to all options, financial and real ones alike. Real options are further limited when considering competition. While financial options are exclusive, real options may be shared. While competitive interactions may be modeled by combing real options and game theory, the approach is quite complicated for a practitioner [Dixit & Pindyck, 1994].

Apart from those general limitations of the real options approach, the log-transformed binomial model used to value the real options in this paper itself has several restrictions and assumptions as well, for example about the distribution of the underlying. The implicit assumptions and restrictions of the various models and their drawbacks may be found in [Lander & Pinches 1998].

Previous research concerning the classification of uncertainties

While the real options literature refers to the existence of uncertainty as a prerequisite of real options, little research has been conducted on the nature of uncertainty. Only two different categories of uncertainty have been identified by the standard options literature [Copeland & Antikarov, 2001; Dixit & Pindyck, 1994]: **endogenous or technical uncertainty** and **exogenous or market-related uncertainty**. Endogenous uncertainty refers to firm-specific uncertainty which is diversifiable by building portfolios, either on the company side (project and product diversification) or on the investor side (stock portfolios). Exogenous uncertainty applies to the entire market and thus is not diversifiable as all projects, products and companied will be affected [Boer, 2002]. Most uncertainties will neither be totally endogenous nor exogenous; rather they will tend towards one of the two. Therefore, the **uncertainties classification** presented in this paper will sort uncertainties **by their proximity to those two poles of uncertainty**.

At the end of this section the discussed uncertainties and their respective options will be visualized in a matrix, which may be used to identify the options inherent in a project. The proposed options may be considered rather as a likelihood indicator than a deterministic set of possible options. Usually, the applicable of options depend on the nature of the project and operational constraints of the company.

Endogenous uncertainty

The uncertainty category which is closest to being just endogenous is **project uncertainty**. This category includes two sub-categories, uncertainty concerning **time** and uncertainty concerning **complexity**. Time impacts the project schedule as a whole as well as the individual milestones. It is almost certain that the actual duration is uncertain; less than 20% of all software projects are completed on time [Erdogmus, 2002]. Complexity increases as projects grow larger and unfamiliar [Dey, 2002]; it involves issues such as coordination and control [Datta & Murkherjee, 2001]. A recent survey deemed this uncertainty most threatening in the context of information technology investments [Jiang & Klein, 2001]. Staging can help to mitigate downside potential, by creating options to abandon or alter the project scale (contract and expand). The option to defer and staging may partially resolve uncertainty, especially if similar projects exist [Benaroch, 2002]. Such kinds of projects are typical of a large variety of initiatives in the e-business market. The wide-spread deployment of appropriate real options measures could directly benefit project managers by reducing uncertainty and thus limiting the adverse possibility of the currently growing claim management.

Especially in the context of high technology, **uncertainty about intangibles** has received increased attention. Generally, those uncertainties related to intangibles are mainly endogenous [Miller, 1992]. This category includes human capital aspects such as workforce productivity and workforce fluctuation, as well as soft factors such as knowledge and brand [Winston, 1999]. Workforce productivity may be influenced by the workforce's abilities as well as strikes or unwillingness [Miller, 1992]. Workforce fluctuation becomes important in the context of specialized and rare labor and may even result in total failure of the project. Knowledge may have an impact on a project in terms of a lack of ex-ante knowledge requirements for the project. While workforce productivity may be handled by switching the workforce or even the country in the long-term, the other aspects may only be handled by staging and thus creating options to abandon or alter scale or deferring the project as a whole [Benaroch, 2002].

Financial uncertainty is a very important uncertainty factor since it may actually affect all options inherent within a project. This is true in the case of cost uncertainty since project cost is essentially the strike price of the compound option as a whole. As for liquidity, managers tend to forget that liquidity divided by burn rate may set the effective expiration date of all real options within a company [Boer, 2002]. While liquidity uncertainty may only be resolved by an option to abandon or defer, cost uncertainty may also be resolved by outsourcing the project, which is a switching option [Benaroch, 2002].

Product uncertainty may be divided into uncertainty about quality [Pawlina & Kort, 2002], performance, intellectual property rights [Turvey, 2001] and standards [Lint & Pennings, 2002]. While quality refers to the quality of the material, e.g. the number of bugs in a program or the mere existence of a sellable product, performance refers to quality of the functionality, e.g. the speed with which the program may perform a certain task. Uncertainty about intellectual property rights includes ambiguity about the patentability or other forms of property rights protection as well as the feasibility to protect those rights from competitors. The music industry has been a good example showing that intellectual property rights may lose their value due to difficulties in enforceability. Closely related to intellectual property rights is the notion of standards. Standardization is an important issue, especially in the high tech sector. On the one hand this concerns uncertainty what the standard to use (for example DVD-Players), on the other hand companies face uncertainty whether they will be able to implement their specification as a standard, which could result in a tremendous gain from patents (for example Qualcomm Inc.). While quality and performance potentials may be controlled by staging the project and thus gaining options to abandon, intellectual property rights and standards may only be explored by waiting or an option to switch, e.g. by insuring using intellectual property coverage [Greenwald, 2001].

However, a company could bring a product to market estimating it will not be able to protect it against imitation or not knowing about the standard and plan to expand in the case of successful protection or standardization. Especially when expanding vertically, for example in opening joint ventures with competitors, this can be a very valuable strategy for companies having significant market power or operating in a market niche.

Exogenous uncertainty

Market uncertainty is essentially exogenous. But since the company itself is part of the market and thus one of the sources influencing the market, market uncertainty may be partially endogenous. In the extreme form of a sell-side monopoly, the company controls at least half of the market, the remainder being controlled by the demand-side. Uncertainty may exist concerning existing and potential competition, quantity and price on both, supply [Graham-Tomasi & Myers, 1990] and product markets [Miller, 1992; Turvey, 2001]. Concerning the supply-side, competition creates the option to switch to mitigate quantity and price uncertainty. In a lack of competition, mitigation can only be achieved through internalization [Williamson, 1975], which is an option to expand horizontally. On the sell-side, all market uncertainties may be controlled by altering the scale of the project, including shutting it down. The behavior of competition and customers may also be revealed by waiting. By technological investments (for example dual-fuel industrial steam boiler [Kulatilaka, 1993]) important switching options may be created, that enhance the value of the project significantly [Chang, 1998].

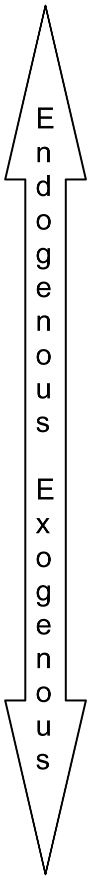
A very large category of uncertainty is the **region-specific uncertainty**. Applying to all industries in that region, it is entirely exogenous. Even huge companies will have little or no influence on those uncertainties. It covers political risks such as the potential of an armed conflict (war, riots), regulatory [Teisberg, 1993], taxation [Hassett & Metcalf, 1999] and legal issues, as well as natural phenomena (climate and natural hazards), infrastructure uncertainty [Datta & Murkherjee, 2001] and social risks (for example tradition, values and religion) [Miller, 1992]. Social uncertainty is often ignored, but impact may be significant, as was the case for Shell and Brent Spar. The impact of the other factors considered depends strongly on the country and industry. Note that legal issues concern not only the development status of the law and the respective band of applications it covers, but also its enforceability. The most important option in the context of political uncertainty is the option to switch, since it has an added value in representing a threat to the government and the local population in the form of a withdrawal of capital and work places, transferring it to another country [Kogut & Kulatilaka, 1993]. Assuming that all other input parameters stay the same (especially demand), the production capacity is needed to satisfy demand. Hence, the option to contract and the option to abandon usually do not exist, rather abandonment will not be an option but an obligation imposed by the government or other exogenous facts (for instance the circumstance that the factory bombed out). If the assumption is removed, which may be the case e.g. in regulatory issues, staging, and thus options to alter scale, have a serious impact [Teisberg, 1993]. Waiting may be valuable if risk and not uncertainty in the broad sense is concerned. For example investments in Iraq should be delayed facing a known possibility of war. Options applicable facing social risks, natural phenomena and infrastructure uncertainty were considered to firm-specific for general guidelines to be given.

A final class of uncertainties needs to be considered as well. **Unknown uncertainties** may be present in almost any investment. In fact, they are one of the primary causes of project failure [Royer, 2000]. With respect to applicable options, little may be said. Staging may partially control such an uncertainty by offering options to alter the scale. However, a valuation of such options seems quite impossible due to the problem of specifying appropriate input parameters. Only in very extremely uncertain and money-consuming situations does it seem useful to account for such options.

Discovering options

Findings from the previous section may be summarized in form of a matrix as follows (highlighted fields are the most probable options for each uncertainty):

Figure 2: Option-uncertainty matrix



		Defer	Abandon	Expand	Contract	Switch
Project	Time					
	Complexity					
Intangibles	Workforce productivity					
	Workforce fluctuation					
	Knowledge					
	Brand					
Financial	Cost					
	Liquidity					
Product	Quality					
	Performance					
	Property rights					
	Standards					
Market	Quantity					
	Price					
	Competition					
Regional	Armed conflicts					
	Regulatory					
	Taxation					
	Legal					
	Natural Phenomena					
	Infrastructure					
	Social					
Unknown uncertainties						

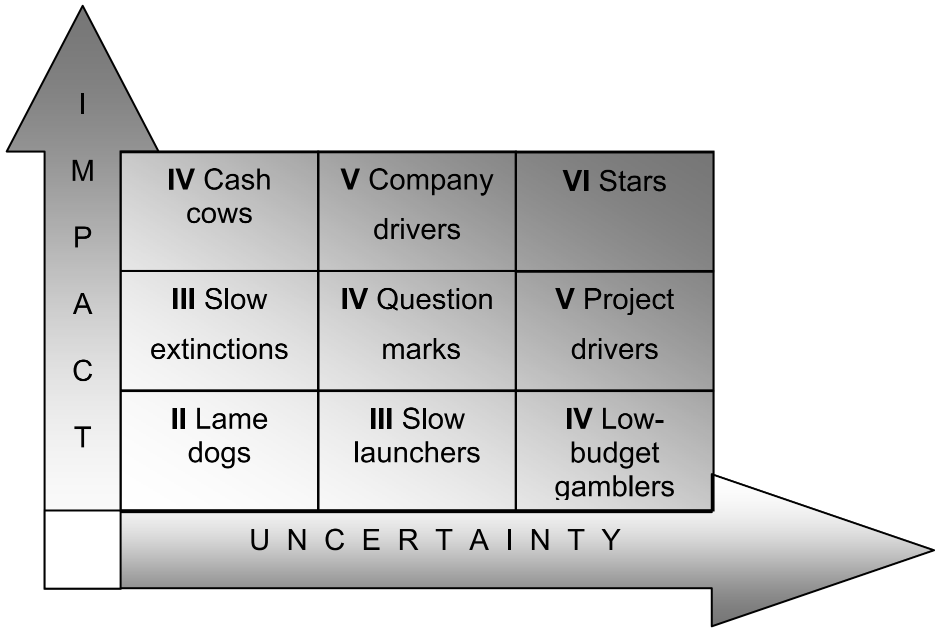
Source: Own illustration *Similar: Benaroch 2002*

The uncertainty-option matrix visualizes which options may potentially be able to control a specific uncertainty. Uncertainty is the key value driver of a real option and therefore the scope of uncertainty will increase option value in most cases [Dixit & Pindyck, 1994].

A **first step** is to **decide on the uncertainties which are applicable** in the current situation. For example the risk of armed conflicts is quite negligible in Germany and hence could be ignored. For the sake of simplicity uncertainties not providing a significant added value will be ignored. This encompasses those uncertainties with a relatively low importance with respect to the success of the project. Based on the notion that identification of some key options will reveal a good enough approximation of the project value [Trigeorgis, 1996], options will have to be weighted concerning their value impact. Considering all uncertainties and thus all options would result in a very complex binomial tree requiring quite complicated mathematics. Consequently, a simplified approach should be used. A formal justification of it will be delivered in the next section.

To assess the added value of an uncertainty, the uncertainty rating below may be used:

Figure 3: Impact-uncertainty matrix



Source: Own illustration Similar: [Dey, 2002]

On the **horizontal axis uncertainty is quantified** in terms of low, middle or high uncertainty. The **vertical axis** divides the **importance of that particular uncertainty** to the company in the same three categories. Uncertainties with high impact and high level of uncertainty will evidently be the value drivers of the project, since high uncertainty increases the value of the real option and a high impact implies that the uncertainty is a value driver of the project. Instead of using a visual matrix, the rating may be implemented attributing points to impact and magnitude of every uncertainty, which are subsequently added up (low=1, high=3). Those uncertainties scoring the maximum of six points will essentially be the value drivers for a given project.

A **second step** in identifying options inherent in a certain project, given the applicable uncertainties, is to **evaluate the possibilities to respond to a resolved uncertainty**. More precisely, from those options identified by the matrix as candidates to control a specific uncertainty, the ones being executable in the given case have to be chosen. For example, for a city power company, switching distribution countries is not an option in response to regulatory issues. To adjust the matrix for firm- or project-specific issues, some options not indicated may require reflection as well. If multiple options may control an uncertainty, some of them will not affect the project value significantly. This is especially true if options are of the same type, have the same maturity and the same point in time of execution. In those cases, only the more valuable options, the one which may better control the specific uncertainty, need to be considered. Take the example of a European option to contract with same maturity and strike price as a European option to abandon. The first will be worthless as the second option may control the same uncertainty to a better degree in the same respect. Generally, additional options will increase project value only marginally [Trigeorgis, 1993]. A more detailed explanation of the factors influencing non-additivity of options is provided in the following when option interaction is described when considering option interaction. As options controlling different uncertainties should be additive, whereas options based on the same uncertainty are likely to be non-additive, the estimation that multiple options derived from one source of vagueness will add little more value than one should hold.

It may be necessary to repeat this two step process since the execution of options may raise new uncertainties [Benaroch, 2002]. For instance, mitigating unfavorable regulatory and taxation issues in developed nations by switching production to a developing country usually implies social risks and may even trigger the risk of armed conflicts. Up to this point, a broad range of options inherent to the project should have been discovered. To reduce the complexity of valuation, only a limited number of options should be accounted for. While a first step in this respect has been done by ignoring uncertainties with a low degree of impact or magnitude, further eliminations may be needed. Those fall into two classes: Eliminations in consequence of the order of options and disqualifications attributable to non-implementability of the described option.

Verification of applicability and structuring of options

As Benaroch states not every revealed real option is necessarily viable. In fact certain conditions have to be met to make a specific type of option executable. For instance an option to defer does not exist wherever an investment is a now or never decision. [Benaroch, 2002]

Furthermore, the combination of option executions for each scenario has to be discovered maximizing the total project value. The decision tree approach is best suited to such uncertainties, since they model the hierarchical and sequential nature of management decisions [D'Souza, 2002, Lander & Pinches, 1998]. Using the decision tree, the operating strategy and the ex-ante decision path are revealed. Decision trees allow reorganizing project for value maximization and thus discovering the optimal decision-taking process [D'Souza, 2002]. Since only one path is optimal, with implies that the decisions on this path would be implemented by every rational agent given a certain environment situation; all options not on this path are completely worthless. Consequently, some options identified using the uncertainty-option matrix may become obsolete. This makes the process of strategy planning and decision-making far more transparent and therefore objectively assessable. To prevent the tree from growing burdensome, a special form, the binomial tree [Lander & Shenoy, 1999], should be employed. Some researchers refer to this as “event tree” [Copeland & al., 2000]. As decision trees or binomial trees force decisions to occur in a certain order as well as at a certain point in time, the approach requires taking the interactions between the decisions into account [Trigeorgis, 1996]. This raises a new issue in option valuation: the nature of the correlation of the options.

Layer 3: Valuation of real options

The Valuation layer comprises the actual valuation of real options given in a certain project.

This paper will not discuss the calculation of the NPV, the specification of the input parameters and the real option valuation. However, for the purpose of this paper we assume the log-transformed binomial approach [Trigeorgis 1991] to be known to the reader and we will refer to it for option interaction.

Option interaction

Option interaction can take place in **two dimensions**: Either option may be **correlated within a compound option** or within a **portfolio of projects**. Such correlation may be either based on an alternation of the value of the underlying by an option or by the correlation of the underlying uncertainties that drive option value. First, option interaction will be examined in a qualitative manner to gain a better understanding of the importance of option interaction. The subsequent section will focus on techniques to account for the correlation of uncertainties. In the third section, the interaction of compound options will be solved numerically.

Qualitative interaction

Calculating the option value for every single real option in an isolated manner in a first step before adding up the respective resulting values in a second step can significantly overestimate the value of a project. The option to abandon for instance eliminates the value of the underlying asset and thus renders all other option obsolete and worthless and options to alter the scale of the project change the value of underlying asset and thus influence all options onwards [Trigeorgis, 1996]. Trigeorgis identified the option characteristics influencing the correlation with other options in a project. While for the first characteristic, the order of sequence becomes evident from the binomial tree, the other factors do not allow the exact determination of underlying correlations, but show a range or rather a tendency towards a certain correlation coefficient. They are displayed in Table 1, with their effect on correlation indicated.

Table 1: Determinants of the correlation of options

	Additive	Non-Additive
Type (Put/Call)	Opposite	Same
Separation of exercise times	Low	High
Strike prices	Out-of-the-money	In-the-money
Order of sequence	Evident from binomial tree	

Source: Own illustration

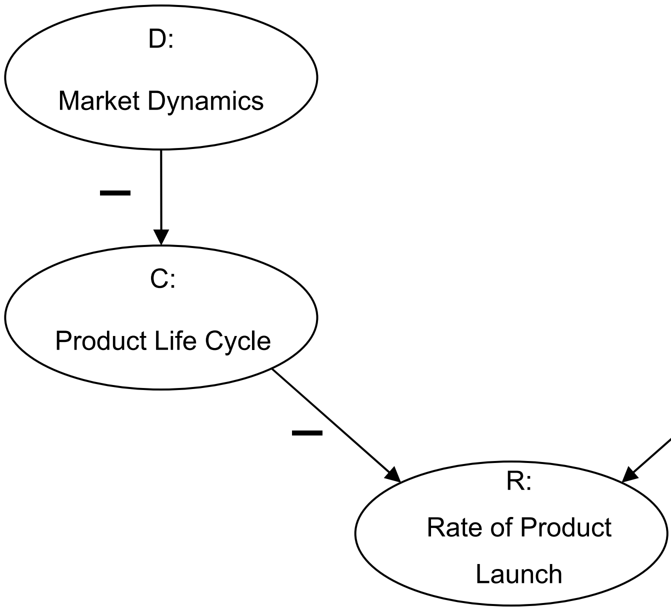
Moreover, the uncertainties from which real options arise may be correlated as well. This needs to be taken into consideration, too [Senbet & Triantis, 1997]. For instance, a political change in upcoming elections may have an impact on regulation as well as taxation and layoff laws. Since this qualitative model can only account for the correlation of two options, the correlation for every option with every other option has to be determined. This is why accounting solely for key options decreases the complexity of the valuation process significantly. Moreover in practice, negative interactions among options are more customary [Trigeorgis, 1996]. Thus, the marginal contribution of each additional option decreases [Benaroch, 2002]. To value compound options being composed of more than two options or to assess options more precisely, a more detailed analysis is needed. Separately, the correlation of uncertainties and the interaction of options will be derived in the next two sections to achieve a more consistent valuation.

Correlation of uncertainties

While the correlation of options has been acknowledged by many researchers, another fundamental problem has escaped their attention most of the times. The drivers of option values, the uncertainties may be correlated as well. Contrary to the interaction of options, correlation of uncertainties may generally not be determined in any mathematically precise way. Rather subjective correlations will have to be determined and visualized. It is important to draw those correlations out very carefully, since the terminal value of cash flow uncertainty in which all other uncertainties have to be embedded needs to be determined quite precisely to use the correct volatility for the option calculation.

Causal maps offer an easy, intuitive way to map out the relations between uncertain events. They may be very useful to determine the correlation of uncertainties and accumulate uncertainties to a final measure of project uncertainty. First all uncertainties and their respective drivers present in the context of the project need to be drawn. Uncertainty drivers may be discovered by enquiring the nature of a particular uncertainty. Drivers of uncertainty will quite often be other uncertainties. For instance, costs may be uncertain due to an uncertain legal situation such as litigation over licensing rights. Arcs are drawn from every driver to its respective uncertainty. An example is provided in the Figure below.

Figure 4: Causal map example



Source: Shenoy & Nadkarni, 2001

Finally, all uncertainties have to influence price, cost or quantity, which in turn determine cash flows. That final uncertainty will be the project uncertainty.

The diagram does now graphically represent the correlation of uncertainties. **Subsequently, values have to be attached as well.** Any uncertainty with only one driver will be assigned the value of one with respect to that driver. For instance, regulatory issues for a special industry may be dependent solely on a change of government. Thus regulatory uncertainty may be denoted as exclusively dependent (correlation of one) on a change of government. Uncertainties driven by various sources require estimations about the weighted impact of each source. For example, project uncertainty could be 20% reliant on cost uncertainty. Assuming that cost uncertainty is composed of 50% uncertainty about project schedule and 50% uncertainty about wages, project uncertainty may be described 10% project schedule vagueness, 10% wage risk and 80% other uncertainty. Climbing up the dependencies in such a way permits to denote any uncertainty as a composition of the uncorrelated uncertainty drivers. Hence, two uncertainties both determined partially by the same value driver are correlated. The correlation coefficient equals the product of the percentage of dependency on the same uncertainty driver.

Given the correlations, the option tree must be considered again. For instance, assuming that a government change implies lower taxation but also unfavorable regulation, the perspective of options inherent to an acquisition may change significantly. An option to expand was considered valuable in the case of lower taxation. Yet, an option to abandon was deemed important, if regulatory bodies tightened their control. Obviously, both options need to be reconsidered in this case.

Correlation of options

[Trigeorgis 1991] uses a backward iterative process to determine the expanded net present value of a project. Each time an option is encountered, the opportunity value R is revised by the rules in Table 2.

Table 2: Option execution

Switch use (or abandon for salvage S)	R' = max(R,S)
Expand by e	R' = R + max(eV-X,0)
Contract by c	R' = R + max(X-cV,0)
Abandon	R' = max(R,0)
Defer	R' = max(R_j,exp(-r*T/N) * E(R_{j+1}))

Source: Own illustration

To account for the interaction of real options, the same simple rules may be applied. Since all opportunity values are calculated taking the higher assessment of value with option execution and value without option execution, the presence of a second option would imply that the higher value of the two opportunity values would be exclusively considered at that node. A precise measure for interaction may be obtained by valuing each option separately and comparing the result to valuing all options simultaneously. The difference is the sum of all interactions.

Basically this approach may be transferred to any backward iterative process, since the assumption that only options enhancing opportunity value will be executed holds true for any rational agent. However, this clearly shows that options must be executed effectively to really capture their full value. While this process appears quite simple, other more complex solutions to value compound options exist as well [Geske, 1979; Kulatilaka, 1995].

The subsequent **controlling layer** will not be subject to this paper. However, modeling implicit options with the real options approach makes the valuation transparent, understandable and controllable to other managers. In contrast to other methods, the real options approach allows the definition of decisions rules depending on the environment situation at the point of decision-making, allowing for truly optimal decisions. Thus, real options are a suitable tool for controlling. Further real options are only valuable if they are exercised properly. Hence, monitoring and controlling projects incorporating real options and executing options accordingly is necessary to maximize value. For an overview of this topic please refer to [Pritsch & Weber 2001].

Application of the framework to Lastminute.com

Hypotheses

The project to be valued in this case has not been chosen for its suitability to the real options approach but rather on a basis of being a common business decision to Lastminute.com. Hence the project was neither been checked a priori to have a negative net present value and a positive expanded net present value, nor was the amount and the types of options inherent to the project investigated beforehand.

This case shall serve mainly as an illustration of the methodology and the findings of the previous sections. It may not be regarded as a proof of the developed theory, but rather as verification in the sense that the theory may not be deemed disproved unless evidence suggests so. The hypotheses presented next are in line with the key findings of this paper.

Hypothesis 1: The presented option framework helps to identify options not discoverable from the project description.

Hypothesis 2: This does not only raise the value of the project but also reveals ways to enhance the strategy of the project.

Hypothesis 3: Option interaction is part of real-world projects and leads to significantly different results than the valuation of each individual option.

Hypothesis 4: The valuation takes no longer than two man-days.

To gain an understanding of the case, a detailed project description will be provided next. It will also serve to assess which options were visible before applying the framework. Such findings are needed to prove or disprove hypothesis one.

Case description

The case took place in the beginning of January 2003. The project to be valued is a cooperation between **MultiTVConsult** and **Lastminute.com**. MultiTVConsult markets the **weekly world of wonders show**, which includes the right to acquire partners for co-branded products. Lastminute.com is Europe's leading online travel and leisure site, selling its products via its website, the Lufthansa City Center travel agencies, numerous partner sites and its call center in Munich. Lastminute.com and MultiTVConsult plan to enter a **cooperation** set forth with the purpose to **weekly sponsor a journey travel lottery** in the world of wonders show and to sell that same journey on a special website under the brand of world of wonders. The lottery will be the culminating point of a six minute travel reportage about a special destination.

The negotiation between the partners are in a final stage, a preliminary letter of intent has been set forward, but not signed yet. The letter of intent is the only written project description and should therefore included various options already. The charges to both parties involved in the project may be described as follows:

Lastminute.com will

- provide a holiday to the featured destination for two persons
- sell that same journey and handle the fulfillment
- produce a special world of wonders travel shop
- market and update the site frequently
- inform about the next show on the site
- have the right to use the world of wonders brand to market those holidays

MultiTVConsult will

- integrate the holiday editorially and give away one journey through a lottery
- mention that the same journey may be acquired through lastminute.com
- respect lastminute.com for the duration of the contract as an exclusive partner
- market the holidays on the world of wonders site and link to the special shop

Moreover, the contract states important details concerning the distribution of gains as well as the duration of the cooperation. Gains from selling the holidays, which is essentially the commission, are equally split among the parties after subtracting the cost of sales. The accounts are settled by the end of each month. The contract is **valid for a period of 12 month** with an **option to extend by an additional 24 month**. After an **initial period of two month**, however, the contract may be cancelled with **30 day's notice**.

World of wonders is the most popular science broadcast in German television. Every week, world of wonders has 2.5 million viewers and is especially popular among people of ages from 14 to 29 years. World of wonders is broadcasted by Pro7 a major German channel. The affinity of viewers towards the internet is 86% higher than the average of the German population; the affinity towards credit cards however is only just above average. This is important in the context of credit cards as the only payment form in the context of this project. The online reach Monitor 2002 II states that 4.8% of the users on www.pro7.de have bought at least one holiday (excluding lastminute holidays) online in the last twelve month, which is 182% higher than the average of the paneled population.[1] Given that the world of wonders website has about 100,000 unique users a year, this would amount to a **theoretical maximum of 4800 customers buying a holiday** on the site.

[1] Data retrieved from Spiegel's mediaservice at media.spiegel.de

Methodology

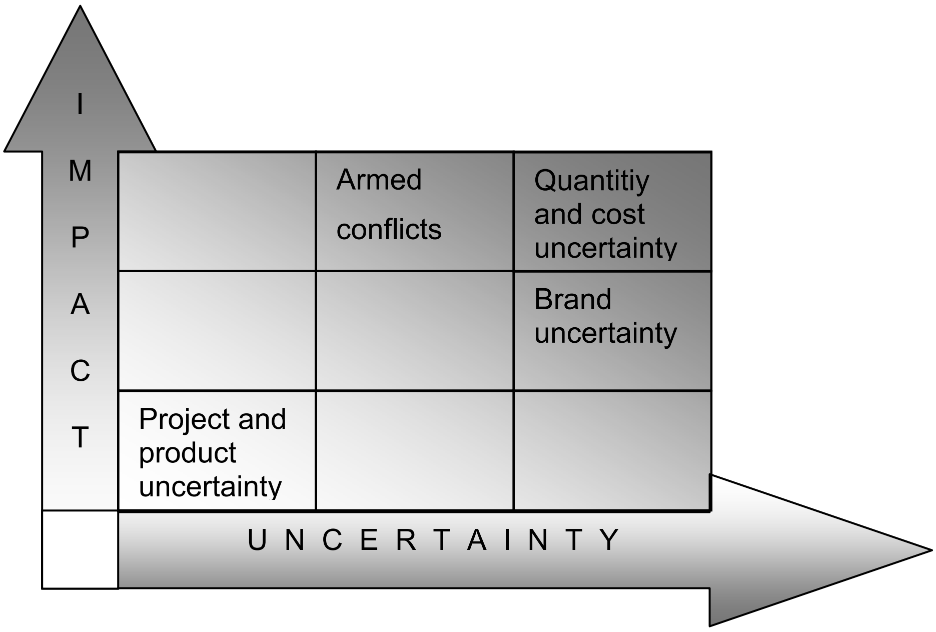
Lastminute.com has no previous experience with the usage of real options. The **team was composed** of the managing director, the head of information technology, the finance director, the two project managers who will execute the project later on and the CEO of MultiTVConsult, who possessed valuable expertise in marketing. The team has been composed as presented in the beginning of this paper with respect to size and composition; however the team did not assess the project collectively. Instead single runs of the procedure were conducted by each individual member of the team and the results aggregated. Aggregation took account of the hierarchal power of the individual team members. More precisely, the estimations of the managing director and the finance director were granted more weight, since they had more experience and a prominent position as the key decision makers. Moreover, the verification of the option analogy and the valuation of the discovered options including correlations have been conducted by the authors.

Valuation process

Identification of uncertainties

All team members were presented the sheet in Figure 2. In a first step, participants identified uncertainties applicable to the project, whereas in a second step, the impact and degree of uncertainty was attributed using points.

Figure 5 : Impact-uncertainty Matrix applied



Source: Own illustration Similar: [Dey, 2002]

A strong consensus was obtained as to which uncertainties were predominant. Neither project nor product uncertainty were deemed to have a serious impact on the project. **Regional uncertainties**, more precisely the risk of armed conflicts were attributed five points, especially since the threat of **Al Qaida terror attacks and a potential Iraq war** were estimated to potentially involve huge amount of cancellations. **Brand uncertainty** was one of the central concerns of Lastminute.com. While the impact on project value was average, the impact on the level of the company was recognized to be very high. Since Lastminute.com lacked experience in the field of television marketing, the magnitude of uncertainty was deemed very high. **Cost uncertainty** was considered yet more important. Especially with respect to ongoing operating cost of special co-branded sites, Lastminute.com simply lacked familiarity with the required workload and associated expenditures. Finally, **uncertainty towards quantity on both, supply and demand side**, was voted to be the primary concern. On the demand side, no such activity has been carried out by either party and thus no track record exists. Yet quantity is a key driver of project value. As for the supply side, worries about limited capacities of the tour operators offering the holidays were expressed. Given a demand above such uncertainties, this could lead to loosing money by being sold out.

Price uncertainty, which commonly is a major concern in forecasting, does not exist in this situation. Since prices towards a certain destination are well known in advance as well as commissions, the profit for any holiday sold is fixed. **Uncertainty about liquidity**, a common issue for information technology start-ups, could be disregarded as well, since the total cost of the project could not damage the cash reserves significantly.

As to the **correlation of uncertainties**, the team members expressed the relationships verbally. This modification of the procedure relying on graphical representation as stated above could be chosen since only few uncertainties were relevant in this context and correlations were quite obvious. Regional uncertainties were estimated to have a direct impact on quantity. On the demand side, correlations were negative, that is, in the case of war, quantity in demand would shrink by 10-20%. As for the supply side, correlations were positive since armed conflicts would increase available capacities. For the duration of the project, brand was deemed to have little or no influence on quantity, since brand has more a long-term value. Cost uncertainty only impacted on profit margins, which in turn determined the total uncertainty about free cash flows together with quantity uncertainty.

Revealed options

Having assessed uncertainties, the participants attempted to determine which actions may be able to control uncertainties. At this point, a first reference to the project description was made. The option to extend the project by another 24 month was reformulated as a **European option to abandon** the project after 12 month by not renewing the contract. Another **option to abandon, an American one**, was correctly recognized in the right to cancel the project after 30 day's notice. Following the identification of such options recognizable from the contract, focus shifted back to the uncertainty-option matrix. For all of the uncertainties, deferral was not considered an option, since Lastminute.com would not be able to learn from its usual business how such marketing cooperation may affect returns. Also, no competitor has or had such an agreement which could be compared to the present one. Since the value of an option to defer is essentially to learn and have better estimates about future expected earnings, the **option to defer was worthless** in this case.

As an answer to brand uncertainty, three actions were deemed possible: If brand value is destroyed, then contracting or even abandoning seems attractive. In the opposite case Lastminute.com may wish to intensify the cooperation to increase brand awareness and brand recognition even more. Taking into account Lastminute.com's current brand name and the empirical effects of television marketing, all team members agreed that uncertainty existed concerning upwards potential whereas the possibility of damaging the brand was deemed impossible. Consequently, the option to expand is the only viable option. We will call this option the **strategic growth option** form hereon. At this point questions arose as to how such expansion could take place. It turned out, that during prior negotiations the possibility to form a joint venture to conduct the described activities could be founded, which may ultimately result in an own world of wonders travel show we will call this option the **expansion option** form hereon. Such a show of its own would have the potential to increase sales significantly as the group of potential viewers would be very travel affinitive.

For some uncertainties, no options may exist. Such is true for the uncertainty about armed conflicts. The business of Lastminute.com is essentially travel. A war in Iraq or acts of terror would affect the industry as a whole. The travel destinations subject to the contract where not in Muslim countries and thus the risk could not be minimized any further.

While uncertainty about quantity on the demand side was quite straight forward, the same is not true for the supply side. The only option deemed feasible here was the **option to switch**. When a holiday is sold out, an alternative, similar holiday may be proposed. Previous experiences by Lastminute.com indicate that customers are generally willing to accept such proposals.

The final issue was **uncertainty about cost**. While participants indicated that outsourcing the creation of a world of wonders travel site would decrease the uncertainty significantly, Lastminute.com and MultiTVConsult expressed a strong wish to clarify the issue of costs in the contract. Thus at the time of concluding the contract, cost uncertainty would not be relevant anymore. Table 3 gives an overview of the revealed options.

Table 3: Option Input Parameters

Revealed Option			Description
Options apparent from the contract	Option A	Option to abandon	End contract after 12 month
	Option B	Option to abandon	End contract anytime with 30 days notice
New options	Option C	Option to switch	Sell alternative holidays
	Option D	Option to expand	Produce own travel show after 36 month
	Option E	Strategic growth option	Call on brand value during 36 month

Source: Own illustration

Specification of input parameters

The input parameters were specified as summarized in Table 4.

Team members were required to estimate a minimum and maximum sales potential for each month. Using this data the value of the underlying was determined jointly with the variance by applying Monte-Carlo analysis. Other determinants of the expected present value of the project were accounted for as well. Operating cost was estimated to be dependent on the demand and thus was modeled as a fraction of cash flows, 13%. The commission was estimated to be 12%, however, only 50% of it was attributable to Lastminute.com as gains were distributed evenly.

Table 4: Option Input Parameters

Input parameters	Value
V – obtained by Monte-Carlo analysis	40,463.98
σ^2 - obtained by Monte-Carlo analysis	43.9%
R – German federal bonds maturity 2006	2,87%
T – contract duration	3 years
Ex – price per holiday of lottery	€ 1,500

Source: Own illustration

The only option requiring individual input parameters was the option to expand (Option D). Here the factor by which project value could be expanded and the associated cost had to be determined. Those estimations were pure guesses by the participants. Required investment outlays for production were estimated to be 5,000,000 €, sales were anticipated to rise by factor six. Realistically, such a show would be produced only after the 36 month period. Therefore, the option was included in the last period.

Finally, the valuation of the strategic growth option was ambiguous. A direct impact on future cash flows could not be determined. In the case of complete markets, however, the media value, that is the cost of advertising in order to reach a specific number of persons, should provide a good estimate for the impact of brand on cash flows. If this relationship was not true, this would imply that all companies engaging in television commercials wasted money. The media value was determined by adjusting the cost of a 30 second spot (20,000 €) to 7 seconds divided by the number of viewers in the commercial brake (1.43 million) and multiplied with the number of users during the show (2.5 million). Weekly media worth was hence 8,158.51 €. Management indicated a strong preference to keep this measure separated from the project cash flows for two reasons. First, they argued that such media value would not be spent and thus second, media value could not be treated the same way as cash flows. To account for the cash preference, a brand utility index was introduced to manipulate the "cash-equivalent" value of the media value. That factor was set to 0.2, consequently one euro of media value was regarded as important as 20 cents in cash. The resulting cash flow of 1,631.70 € (8,158.51*0.2) was added weekly. In order to gain insight into the importance of the factor, a second Monte-Carlo analysis was conducted, assuming a normal distribution for this factor.

Option elimination and modeling

The way the project tree was set up required some attention. As for the time step, weeks not month were relevant, since investment cost outlays occurred monthly. The 156 iterations accounted for that.

Option to abandon

An obvious decision in the modeling of options was the elimination of one of the abandonment options. Since both abandonment options had the same strike price, but one was European and one American, the European option would never be exercised. The American abandonment option existed from the end of the third month onward (13th week), as the cancellation of the project could occur after two month followed by a 30 day's notice. The project may not be sold and thus the abandonment option would be executed whenever the expected present value would fall below zero. However, this would not forego the last investment outlay in the 13th week, since the holiday lottery in that week would still take place.

Option to switch

To avoid the pitfalls of estimating available quantities, which in fact would have to be modeled in another tree, the valuation team shared the opinion that the option to switch could be modeled implicitly. Instead of setting a salvage value S, the opportunity value was expected to grow as if no restrictions apply. This implies that if quantities on the supply side are sold out, another holiday will be offered and accepted by the customers. Records from previous marketing activities suggested that customers would be willing to accept such an alternative in almost all cases.

Valuation results

The net present value for the project would have set a clear signal to abandon the project immediately. With investment **outlays totaling at 224,174.40 €** facing only **40,463.98 € expected present value**, the total project value would **equal -183,710.42 €.** The project **including all real options** however amounts to **61,108.349 €.** In other words the project's value differs by more than 100% of the required investments or 244,818.77 €. As for the value of the each option individually, the option to abandon was worth 165,774.85 € whereas the option to expand only had a very limited value of 987.41 €. As intuition may suggest, the strategic growth option was most valuable, being worth alone 243,882.52 €.

With respect to the optimal path decision, the option to abandon was never executed in the base scenario, since the expected net present value at any moment was greater than zero. The option to expand needed only to be revised for the purpose of execution in the last period and was carried out whenever the terminal value exceeded 1,000,000 €. The strategic growth option was always executed.

When varying the brand utility index, the expected project value is increased to 75,828.64 €. Accounting for the linear influence of the brand utility index on the expanded net present value, any distribution with the mean of 0.2 should lead to a value of 61,108.349 €. Consequently, the option to abandon has increased project value as the growth option diminished.

Discussion of case results

During the valuation process, an **option to expand, an option to switch and a strategic growth option were identified by the framework**. Compared to the two options known previously from the project description, this is a major advance. However, one must admit that the strategic growth option could have been valued with the same result using net present value rules. The **first hypothesis** could thus **not be disproved.** As estimated, the presented option framework helped to identify options not discoverable from the project description for the case of this project.

As for the **second hypothesis**, the option to expand is a good example. Not considered previously, the option to expand not only increased project value, but also helped to discover a strategy element which could serve as a valuable option for both parties involved. As options are rights, not obligations, this is a true win-win situation. Thus the hypothesis could **not be disproved** either. Surprisingly, the approach did not only help to reshape strategy, but also to discover solutions to operative problems. This is the case for the option to switch, where an operational uncertainty could be eliminated very easily.

The **third hypothesis** was also confirmed as the combined option values amounted to 410,644.78 € whereas the total option value accounting for interactions was only 244,818.77 €. Especially, the American option to abandon and the strategic growth option were exclusive with respect to each other, that is only one of the two could be exercised at any given point in time. Moreover, one of the two abandonment options was worthless.

A major benefit of the case was the ability to test the framework under real-world condition and provide a measure of efficiency by assessing the amount of man-hours required. Contrary to other research objectives, this one could hence be quantified and thus allow for a precise comparison with other models. With an average of an hour per person, the total man-hours involved amounted to five. While this project was certainly not one of the outmost complex ones, it sure was exemplary for common investment problems. A reserve of a man-day and 3 man-hours to the self-set goal of an option framework executable in less than two man-days seems to provide quite a buffer for **confirming the fourth hypothesis**.

Critical discussion of the framework and real options

The presented framework offers a robust approach to discover real options. Being based scientifically on the relationship between uncertainties and real options, the model as displayed in this may be subject to critical discussion with respect to option types and uncertainty categories, but the basic idea still holds. Other option types and uncertainties could be easily integrated. As for practitioners, the model allows for an intuitive discovery process of options, which is close to managerial thinking. The framework allows identifying options easily, using a three step approach. First, uncertainties are identified, then some of the uncertainties and their respective options are eliminated and finally options are correlated to assure a proper valuation of the compound option as a whole.

Like any other valuation model, real options in general and the presented framework in particular are subject to inputs by humans [Buckley et al., 2002]. Such input will always be based on flawed assumptions and subjective beliefs of individuals. Therefore, they may not evaluate all available information correctly. In most cases, they are even unlikely to possess all information necessary to assess a specific project correctly. Moreover, executives have positive illusions and exaggerated confidence [Bazerman & Hoffman, 1999]. Such overconfidence has been the subject of numerous studies in the field ob behavioral finance and refers to the failure to know the limits of one's knowledge [Zacharakis & Sheperd, 2001]. Generally, overconfidence will lead to upwards biased numbers. Information may even further increase the magnitude or occurrence of overconfidence and illusions of control [Davis et al., 1994; Langer, 1983; Oskamp, 1965].

The framework presented and the methodology used afterwards in the case were designed to reduce the impact of human errors. Using a log-normal distribution for the possible values of the underlying for instance implies a lower mean than a normal distribution. Hence, overconfidence may be partially eliminated. The organizational aspects of this work enhanced forecasts of input parameters by aggregating them across different people and specializations.

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