
Deciding on new products using a computer-assisted real options approach

Alexandra Rese* and Daniel Baier

Institute of Business Administration and Economics,
Brandenburg University of Technology Cottbus,
Konrad-Wachsmann-Allee 1,
D-03046 Cottbus, Germany

E-mail: rese@tu-cottbus.de

E-mail: daniel.baier@tu-cottbus.de

*Corresponding author

Abstract: Technical and market uncertainties are significant challenges for R&D management. Especially, in the case of New Product Development (NPD), investment decisions have to be made under uncertainty due to unknown costs and returns which arise from project complexity and duration. The framework of real options has been proposed for a better understanding of R&D project's uncertainty, for modelling management's flexibility during the project and for selecting the best project alternative. This paper describes the application of a real options approach to the management of NPD projects using standard computer-assisted add-ons to spread sheet technology.

Keywords: New Product Development; NPD; real options; uncertainty; computer-assisted decision support; resources for risk analysis.

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Biographical notes: Alexandra Rese is a Research Assistant at the Chair of Marketing and Innovation Management at the Brandenburg University of Technology Cottbus. She obtained her PhD at the University of Karlsruhe while working at Fraunhofer Institute for Systems and Innovation Research in Karlsruhe. Her work focuses on conflicts and information need in new product development and entrepreneurship.

Daniel Baier is a Professor of Marketing and Innovation Management at the Brandenburg University of Technology Cottbus. His research interests concentrate in market-oriented development of innovative products and services, innovation management in enterprise networks as well as data analysis, statistics, and operations research.

1 Introduction

Most NPD projects are characterised by high levels of uncertainty; for example, with respect to future performance of the product, development costs, or market size (Ford and Sobek, 2003, p.1). In particular, their expected return on investment is difficult

to assess because technological success and quality, as well as market response, cost estimates and other economic developments are significantly uncertain or unknown. On the other hand, during the NPD project, R&D management has the possibility to gather information about uncertain technical and market characteristics and consequently to reduce uncertainty and to change the course of action and the initial project plan according to the new information (Huchzermeier and Loch, 2001).

While in common practice conventional projects or ventures are evaluated by the Discounted-Cash-Flow (DCF) method, it is not possible to apply this method in the absence of cash flow forecasts and in view of the high uncertainty about the successful completion for the valuation of high-risk technological R&D projects (Messica, 2006). Here, financial tools that can model uncertain events and developments, as well as possible managerial reactions in response to these threats and opportunities, provide R&D managers with the necessary flexibility in project evaluation.

One of these approaches, the so-called real options approach can help to better understand how specific managerial actions as reactions to uncertain events and developments influence the value of an R&D project (e.g., Dixit and Pindyck, 1994; Trigeorgis, 1996; Amram and Kulatilaka, 1999). There are several types of possible managerial actions that can be modelled in the real options approach: delays, improvements, expansions, innovations, contracts, shutdowns and restarts, switches e.g., of outputs or inputs as well as abandonment. These different options for the management often occur in a single project as not only isolated, but multiple and interacting (Pape and Schmidt-Tank, 2004; Barnett, 2005, p.63f).

This paper describes the application of the so-called real options approach to the management of NPD projects using standard decision support software. We will start in Section 2 with a short review of the real options approach and discuss their connection to other additionally or alternatively usable methods for R&D project evaluation: decision trees, sensitivity analysis based on Monte-Carlo simulations and scenario analysis. Then, in Section 3, computer-assisted add-ons to spread sheet technology (here: Microsoft Excel) are discussed for modelling real options, developing decision trees, and performing Monte Carlo simulations. Finally, in Section 4, as an application example, we outline the European and, especially, the German motorcycle market and present, in Section 5, within an R&D project, a quantitative evaluation of the options to continue, improve, and to abandon a motorcycle series at a German motorcycle company. Three different decision points at the time of the development of the series are evaluated from a retrospective viewpoint. For obvious reasons, we use modified facts and figures for the analysis.

2 Real options in R&D

Option pricing methods were first developed to analyse financial investments (Black and Scholes, 1973). The main topic in this discussion was the 'price' for the right – but not the obligation – to buy (or sell) pre-specified traded assets at a pre-specified date for a pre-specified price, the so-called call (or put) option. Here, the call (or put) option reduces the risk of losing money if the asset value in the financial markets goes beyond (or below) the pre-specified price.

While the term 'option' refers to the way one deals with uncertainty to minimise risk (by limiting losses), the framework of options thinking recognises that uncertainty

(or volatility in financial terminology) adds value to options: If the development of the prices for the traded assets were highly uncertain, the options fulfil their purpose, if not, they are of limited use or even worthless. This perspective is proactive concerning risks, and views uncertainty as a driver of value and, therefore, as a positive element (Neufville, 2003, p.24). Myers (1977), a Professor at the Massachusetts Institute of Technology, transferred option pricing theory from financial options to real action alternatives to evaluate investment decisions.

The intuition from option pricing theory is that with starting an R&D project R&D managers get the possibility, e.g., to change the design or the product mix or to develop additional product line extensions, but are not obliged to exercise these options. If volatility increases the option holder can achieve a higher payoff when the value of the underlying asset increases, e.g., access to a profitable market, and he exercises the option, but he does not suffer a high loss when the underlying asset is losing value (Santiago and Vakili, 2005, p.1207). Therefore, in the face of uncertainty and substantial costs changing the strategy, overall project value can be increased by modelling management's flexibility to react to changes or to delay decisions (Ford and Sobek, 2005, p.175).

Typically, through ongoing processes of information gathering, uncertainty about the R&D investment's rewards is gradually resolved. In response to the new information R&D managers can react to environment and organisational changes by altering the initial operating strategy. The active role of management, therefore, creates real options and adds value to uncertain R&D projects which is referred to as 'real option value' (Huchzermeier and Loch, 2001, p.87). Because many R&D projects are lengthy, spanning years, they should be valued by a series of evaluations over the course of their lives (Barnett, 2005, p.62).

There are several types of real options which can be classified according to Hommel and Pritsch (1999) into three main categories: learning options, growth options, and insurance options. These different option types, referring to different types of uncertainty, can be associated with different phases in the innovation diffusion process (Katz, 2003, p.5). Learning options are related to a point in time before the actual investment takes place. The option value created by a learning option represents the flexibility to wait for new information and only investing if the environmental conditions are favourable. While a *defer option* allows management to postpone the actual investment decision, a *time to-build option* exists when investments are staged, i.e., R&D investments. The R&D project is financed by a sequence of smaller amounts which can be stopped before making all the investments.

Insurance options are related to an existing project when managers need to react to negative changes in the market environment with a reduction or modification of economic activity. Depending on the extent of reduction, *options to contract*, *options to shut down and restart* and *options to abandon* are distinguished. The *switching option* allows changes of the input factors depending on factor prices (process flexibility) or enables management to produce alternative products depending on changing customer tastes (product flexibility). Huchzermeier and Loch (2001, p.86) call the availability of product flexibility to improve the product performance or to correct its targeting to market needs in midcourse actions during projects an *option to improve*. Additionally, if the market conditions turn out favourable, expansion options allow an increase of investment in the current project, i.e., to expand production or distribution (Trigeorgis, 1993, p.204).

Growth options also refer to an existing project, but serve as platforms for potential future investments. As prerequisite or link in a chain of interrelated projects, a current R&D investment opens up future growth opportunities, e.g., access to new markets or the development of new product generations. The *option to expand* reacts to positive project or market developments with additional investments in *new* projects. The *option to innovate* provides the acquisition of new knowledge or skills through investment projects generating opportunities for follow-up projects based on these skills. In real-life projects, options often present themselves not as isolated, but as so-called *multiple interacting options* (Barnett, 2005, p.63f; Dimpfel and Algesheimer, 2002, p.4f; Pape and Schmidt-Tank, 2004; Trigeorgis, 1993, p.204).

Although the intuition from options pricing theory is that higher uncertainty increases the real option value of managerial decision flexibility, the relationship between different types of uncertainty and the value of managerial flexibility is still not clear. In addition to financial payoffs (e.g., price and sales forecast) Huchzermeier and Loch (2001) identified four so-called operational R&D uncertainties i.e., with respect to product performance (development uncertainty), market requirements, schedule adherence (time-to-market uncertainty), and budgets.

Santiago and Vakili (2005) found that increased variability of market payoffs generally increases the project value, contrasting the results of Huchzermeier and Loch (2001). Their results had indicated that this assumption only holds if uncertainty (regarding payoffs, budgets, market requirements, and product performance) is resolved and a decision can be made before major cost or revenues occur. Only in this case, Huchzermeier and Loch (2001) had found that it is worth maintaining flexibility and delaying commitments until additional information becomes available. Regardless of the structure of uncertainty resolution, schedule variability has a negative impact on flexibility, indicating that R&D management should not perform a trial-and-error-approach, but regular, formal reviews to obtain information on all sources of uncertainty for radically new projects. However, Santiago and Vakili (2005) could not make a definite statement about the impact of increased development uncertainty or market requirement uncertainty on the value of flexibility, except for some special projects. Only if the project meets the market requirements with a probability of more than 50% does an increase in variability increase the project Net Present Value (NPV); otherwise the project NPV is reduced.

Whereas the real options approach has its roots in the option pricing theory in assets or securities traded in financial markets, the direct application of option pricing models from assets or securities to R&D projects is somehow problematic. One limitation lies in the assumption of information about the values of assets and securities to arise continuously, but occurring in R&D at discrete points of time. Another important issue is the assumption of risky but continuous trading possibilities for assets or securities, which is not possible for major R&D research projects. Besides the already mentioned operational uncertainties with respect to product performance, market requirements, schedule adherence, and budgets, there are also technical risks such as the failure of an experiment or of a machine, or the inability to find the solution to a technical problem (Loch and Bode-Greuel, 2001, p.232). These project-specific risks are not correlated with any asset traded in the financial markets. An approximate solution, currently used, is to perform the valuation using a decision tree to represent managerial options during execution of the project. Another approach, which will not be explained any further, is to use system dynamics to model the product development process (Ford and

Sobek, 2005, p.180). The decision tree can also incorporate project-specific risks using subjective probabilities along with certainty equivalents for the payments and risk-free discounting (Loch and Bode-Greuel, 2001, p.231f; Santiago and Vakili, 2005, p.1206). In a practical example, Loch and Bode-Greuel (2001) evaluated growth options in pharmaceutical research projects using decision trees. Additionally, for modelling subjective uncertainties, i.e., operational and technical R&D uncertainties, sensitivity analysis and scenario analysis can be used to determine the main uncertainty factors. Monte-Carlo simulations can be performed to examine the effect of alternative plausible combinations of determinants on the project value to cope with complexity and to decide on optimal managerial reactions.

Despite the obvious advantages with respect to the evaluation of project uncertainty, managerial flexibility and value, real options have not found wide usage in R&D practice, because managers find them too technical and based on unrealistic assumptions (Huchzermeier and Loch, 2001, p.86; Loch and Bode-Greuel, 2001, p.230). Similarly, Lander and Pinches (1998, p.543) see the reasons for the little use in corporate decision-making in the required mathematical skills for understanding the modelling assumptions, in the frequent violation of the required modelling assumptions in practice, and in the limited applicability due to necessary additional assumptions required for mathematical tractability. In the following chapter, we present decision tools based on Microsoft Excel, supporting the application of real options to analyse any particular R&D project in a simple and visual way and facilitating the usage of real options.

3 Computer-assisted decision tools for modelling real options in R&D

Computer-assisted decision tools have proven to be useful for complex decisions in R&D management since they allow us to understand the problem structure and to have a deeper insight into the background of each decision. There are a number of tools available on the market, which can be used to perform decision analysis and decision tree analysis in particular (for an overview see, e.g., Kuhn, 2002). While most programs are standalone versions, we are concentrating in the following on the widely used software package Microsoft Excel and two add-ons working with familiar Excel-style menus and functions directly linked to Excel.

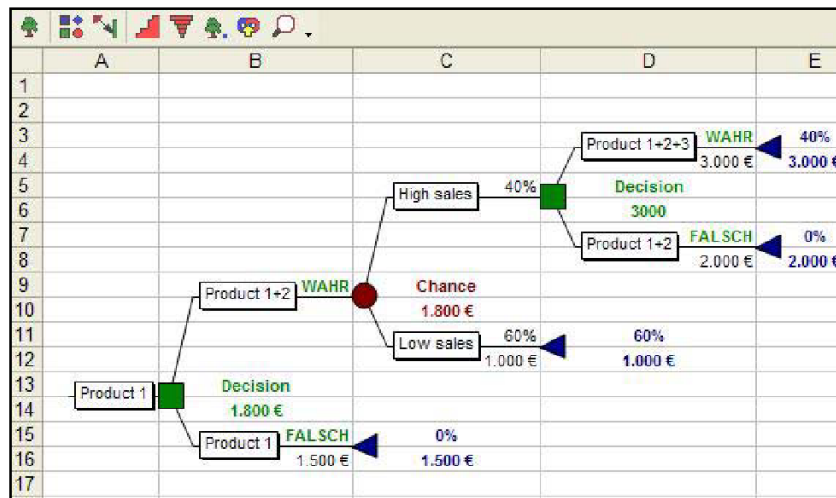
Excel is a very popular software package, which is used especially in economic and financial sectors as a decision tool. However, for complex decision problems Excel alone has its limitations. Although Excel has many advanced and excellent utilities, it is not sufficient for large and complicated decision support requiring a graphic representation of the model to organise efficiently all uncertainties and possible options, thereby identifying the best decision to make as well as the risks involved. To present the graphic construction of decision trees, to visualise sensitivity results and to analyse business and technical risks two Excel add-ons can be used. In general, add-ons (also e.g., plugins, extensions) are optional macro packages that expand the original software or hardware unit they are adding on to.

The first spreadsheet add-on software, 'Precision Tree 1.0' from 'Palisade in Ithaca, NY', provides the necessary tools for setting up and analysing decision trees working with Excel-style menus and toolbars. Decision trees are easily drawn directly into the spreadsheet of Excel by selecting cells in the spreadsheet, inserting different node types (chance, reference, logic, decision, or end nodes) and entering probabilities and payoffs

directly in cells in the tree (Winston, 2001, 2003; Palisade, 2005). At each decision node the best decision to make is determined and the branch is marked with a TRUE label. A decision analysis in PrecisionTree generates a Profile comparing the payoffs and risks of different decision options and displaying them with the help of various risk profile graphs. PrecisionTree's sensitivity analysis options allow one- or two-way sensitivity analyses, changing one variable or two variables at a time. Such decision tools can be easily used to model simple real options.

Figure 1 gives an example of such a simple decision tree built by PrecisionTree within Excel. R&D management has to decide about a line extension (product 2) for the already introduced product (product 1). Depending on the market acceptance of the line extension (high or low sales) a further line extension (product 3) could be introduced or not: a real option, an *option to expand*. Given assumed returns (assumed at the first decision node) for all end nodes of the decision tree and assumed probabilities for the branches at the chance node (high sales or low sales after introduction of product 2), the real option provides an additional value for the management: If expected returns are analysed without the possibility to introduce product 3 later, product 2 would not be introduced. However, if the possible later introduction of product 3 is additionally taken into consideration in calculating expected returns, product 2 would be introduced. The decision tree indicates these (calculated) decisions by marking decision branches with 'WAHR' (true) or 'FALSCH' (false).

Figure 1 A simple line extension decision tree built by PrecisionTree

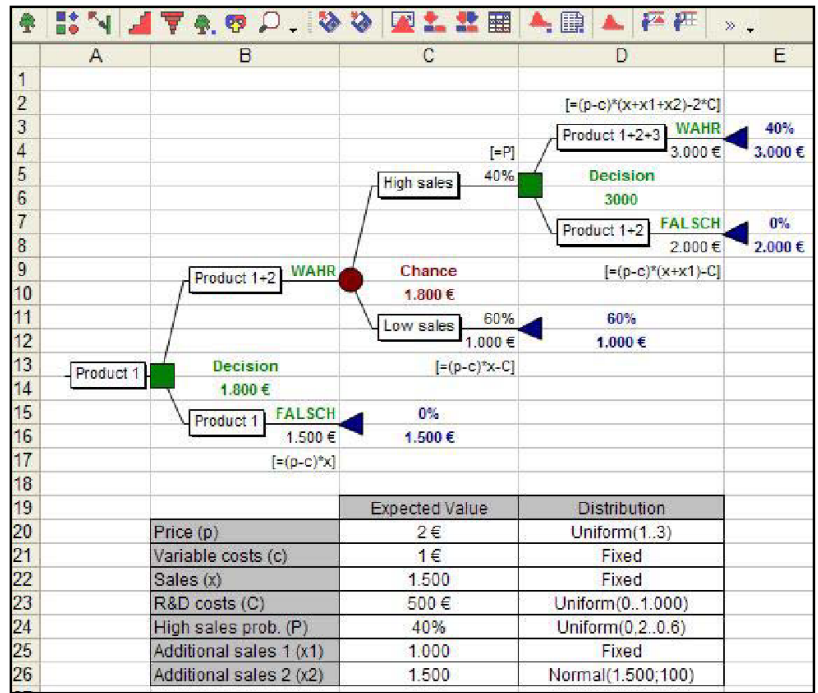


Additionally, a dynamic sensitivity analysis is offered by the second Excel add-on '@Risk 4.5', from 'Palisade in Ithaca, NY', providing risk analysis and simulation (Winston, 2001, 2003; Palisade, 2004). Using @Risk uncertain events in any decision trees and supporting spreadsheet can be defined as continuous probability distribution functions.

Figure 2 shows, how the above decision tree can be extended. The calculation of the returns at the end nodes of the tree is specified. The return depends on the product prices p and variable costs c (identical prices and costs are assumed for all three products), on the sales of products 1, 2 and 3 (modelled as 'low sales' x for product 1 and possible

additional sales x_1 and x_2 for the two line extensions if introduced), on the R&D costs to develop a line extension C and on the probability P that the additional sales for the line extensions can be realised after introduction ('high sales probability'). The calculation of the returns for each end node is given in brackets in Figure 2.

Figure 2 Integrating uncertainty and risks into the line extension model



Some of the above assumptions are uncertain at the moment when the decision with respect to the introduction of product 2 has to be made, but estimates can be given: So, e.g., the high sales probability P is assumed to be uniformly distributed between 20% and 40%. And the additional sales 2, x_2 , (the on-top sales from product 3) are assumed to be normally distributed with a mean of 1.500 and a standard deviation of 100.

With this information, @Risk performs a Monte Carlo simulation of the decision tree, analysing every possible outcome, showing the range of possible results with some measure of likelihood of occurrence and graphically illustrating the risks that decision-makers face.

Figure 3 shows the result of such a Monte Carlo simulation for the return, if product 2 is introduced. After each draw of the uncertain parameters from their distributions (simulating the uncertain future) the decision tool reflects the possibility, or otherwise, of introducing product 3 and whether the new products raise the sales or not.

Moreover, with sensitivity and scenario analyses @Risk provides two additional advanced analyses to determine the critical factors in spreadsheet models. Sensitivity analysis can be used to rank the uncertain input factors in the model according to their impact on the simulation outcomes. Scenario analysis identifies which scenarios or combinations of inputs lead to particular output target values helping e.g. to find out which situations to strive for or avoid (see, e.g., Albright et al., 2006 for more details).

So, in our example, Figure 4 provides a sensitivity analysis in form of a tornado chart: The effect of the different varying critical factors (p , C , P and x_2) on the return is analysed via regression analysis. The standardised b coefficients indicate that the variation of the price has the strongest impact on the returns, followed by the R&D costs for introducing products 2 and 3.

Figure 3 Distribution of the returns for the line extension model

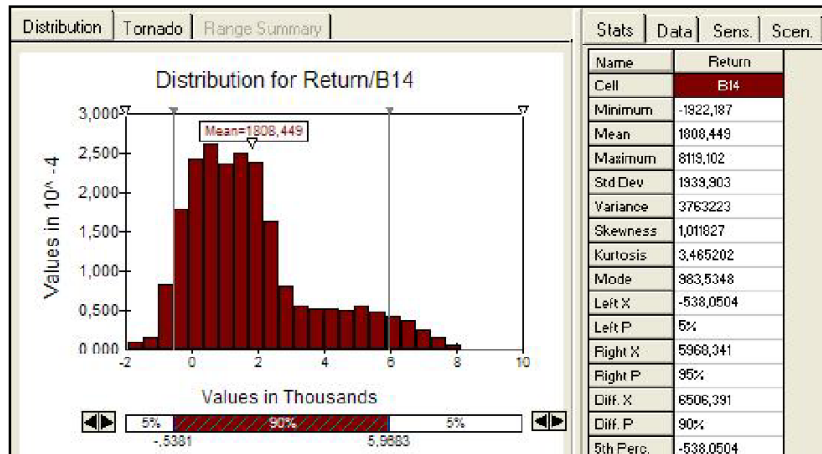
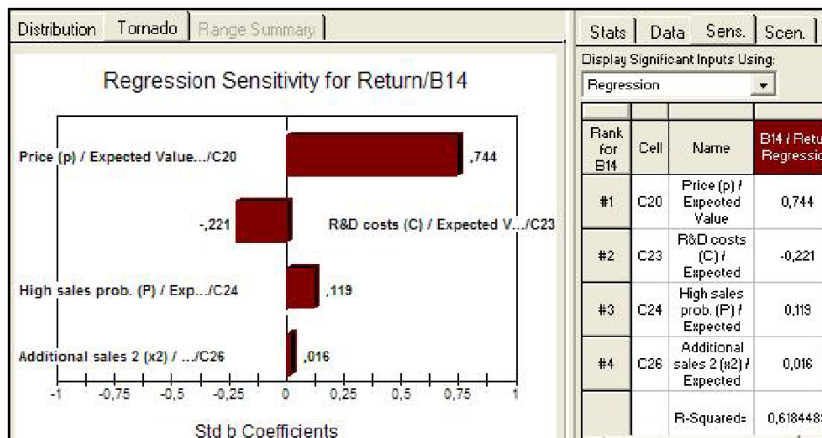


Figure 4 Sensitivity analysis for the line extension model



In the following, a larger scale application in the German motorcycle market is discussed. For obvious reasons, we use modified facts and figures for the analysis.

4 European and German motorcycle market

Ever since the invention of the motorcycle in the late 19th century Europe has been a leading production base for powered two wheelers with long-established famous marques such as Peugeot (France), Triumph (UK) or BMW (Germany) driving

technological development. In the meantime more European motorcycles marques were established, providing mass transport or filling specific niches, e.g., Aprilia (Italy), Derbi (Spain), Ducati (Italy), KTM (Austria), or Piaggio Vespa (Italy). Because Europe is also a key market for many Non-European brands, manufactures such as Honda, Suzuki and Yamaha (Japan) have established production facilities in the EU to be closer to consumers.

The market for powered two wheelers consists of two distinct vehicle types: motorcycles higher than 125cc and light scooters or mopeds up to 125cc. The latter market segment includes motor-assisted bicycles, small scooters, small motorcycles and mopeds up to 50cc, which do not have to be registered at local registration offices. The current market for motorcycles in Europe is around twice the size of the scooter or moped market and, by comparison, more stable. Since 2000, around 1.2 million motorcycles were newly registered per year, but new registration of scooters dropped from around 1 million to around 680.000.

While some key markets such as Germany, France and the UK are declining, the motorcycle market is growing in other countries, e.g., Spain, Italy, Czech Republic, Denmark, Finland and Sweden. The overall production of powered two wheelers has fallen by more than one-third over the period 1998–2005 to about 600.000–7000.000 units per year. The reasons for this shifting demand for new mopeds and motorcycles are the decline of new young riders accessing powered two wheelers due to expensive regulation testing and licensing, and high-priced vehicles. Nevertheless, 5.7 million registered motorised two-wheelers, or 1.47 powered two-wheelers per 1.000 inhabitants in Germany, clearly points to the significance of the motorcycle and scooter business in Germany. The focus lies on larger capacity, higher value and enthusiast machines which are manufactured and sold, but of late the sales figures of scooters have been increasing. Regarding market share among new motorcycles in Germany the dominant manufactures are BMW (18.5%), having displaced Honda in 2006 from the pole position to rank 2 (18.2%), followed by the three other Japanese manufacturers, Suzuki being second in 2005 (17.4%), Yamaha (14%), and Kawasaki (10.4%), and the US-American manufacturer Harley-Davidson (5.3%). In 2005 and 2006, the travel enduro R 1200 GS of the manufacturer BMW was the top seller and market leader in Germany.

Concerning the motorcycle market different market segments can be distinguished with classic bikes, enduros and travel enduros, touring and luxury bikes, choppers, sportive and super sport bikes. Since 2000 there has been an obvious preference for sportive motorcycles in Germany, as can be seen from the growth of this market segment, from 18.6% to 31.2%, in 2006. The segment of enduros and travel enduros also moderately increased, from 17.1% to 19.5%. Therefore, continuous observation of market trends and the permanent development of new motorcycles is of enormous importance for the manufacturers. Motorcycle trends and new models are introduced on trade shows as the INTERMOT in Cologne or the EICMA in Milan. For example, in 2006, BMW, Ducati and Kawasaki presented five new models, Suzuki, Yamaha and Aprilia, three new models, and Honda-even six new models (For a more detailed overview see ACEM, 2006; IVM, 2005, 2006).

5 Modelling real options for one producer in the German motorcycle market

Some years ago, at one producer's unit in the German motorcycle market, there was a heavy discussion on whether to invest in a new motorcycle series or not. It was clear that the introduction of the first model of the new series would be followed by improved models and variants for different market segments to deal with sales problems and with market and technological opportunities. So, a financial evaluation using the real options approach should be helpful to support the decision whether the new series should be developed and introduced or not. In a small project at the University of Cottbus the decision for the new series and the follow-up decisions three and six years later for improved models and variants were modelled using a computer-assisted real options approach. The project should clarify, whether the real options approach could have supported the top management decisions or not.

In a first step, the available information at the three decision points (1: first model of the new series, 2: improved model or not, first variants, 3: improved models or not, further variants) was collected: expected developments of costs, prices, and sales for each candidate/model according to a rough model-roadmap at each decision point (4–6 candidates/models within the series at each decision point) for a time span of ten years.

Then, in a second step, the uncertainty with respect to these values at the three decision points was modelled using distributional functions and the above decision tools. Of course, the uncertainty with respect to the different values reduced over time, but also the expected values changed (due to, unexpected dramatic shrinking of the total motorcycle market in the time span between the three decision points).

Finally, in a third step, for all three decision points, financial models were derived where the rough model-roadmaps were used as bases to model mainly options to expand, options to defer and time to-build options, as well as options to abandon.

The developed financial models were analysed to decide about their usefulness. In total, the following observations could be made with respect to the real options modelling approach: First, the modelling of the model-roadmap with all possible model relaunches and variants proved the most difficult problem in the real options approach. Only a restriction to four to six candidates/models at each decision point with only one or two possible dates for market-entry constrained the complexity of (certain and uncertain) information to an applicable amount. Second, a comparison between the three decision points proved to be difficult, since the market situations changed dramatically. So, a 'prove' whether the real options based decision at a former decision point was right or wrong seemed to be difficult. Third, nevertheless, the real options modelling provided an interesting new viewpoint to the decision process at the motorcycle producer: The effects of uncertain information on the decisions proved to be a promising tool for further analyses.

6 Conclusions

The paper has shown that nowadays the real options framework can be comfortably applied using standard decision tools. The modelling of technical and market uncertainties during the NPD process as well as the modelling of the active role

of the management in this process is possible using decision trees and risk analysis. However, as already the small example and the larger practical example have shown, the complexity of the underlying assumptions and their interconnections, as well as consequences for derived decisions, require further analyses and sample applications.

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