VALUING MANAGERIAL FLEXIBILITY

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Valuing Managerial Flexibility

Challenges and Opportunities of the Real Option Approach in Practice

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In memoria di mia madre

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e

dedicata a mio padre

***Salvatore Scialdone**,*

per il loro continuo sostegno e il loro amore incondizionato.

Preface and acknowledgments

The topic for the present dissertation originated from my exchange term in 2003 at the Indiana University (USA). After a plant visit of the Anheuser-Bush brewery in St. Louis (MO) I read a working paper about the valuation of Anheuser-Bush's expansion plans in South America seen as a chain of different real options. This started my interest in real option's theory. When I returned to Zurich I visited the course on real options of Prof. Dr. Rajna Gibson. The conclusive message of the course was that real option's theory could in many different cases improve project valuation, but that it was confined to some specific sectors due to its difficult applicability and, mainly, to its high complexity. In this way my curiosity for the application possibilities of the Real Options Analysis (ROA) in real life projects and for the complexity of the real option's theory was raised, which, in turn, finally ended my struggle to find a topic for my research. The general insight I earned for life through my research efforts in real option's theory was a maxim already stated by Seneca, an ancient Roman philosopher. Seneca stated that: „Non quia difficilia sunt non audemus, sed quia non audemus difficilia sunt.", which means as much as "It is not because things are difficult that we do not dare, it is because we do not dare, that things are difficult." This mental attitude always accompanied me during my research and motivated me in trying to bridge the gap between complex theoretical constructs (what the ROA mostly is perceived for in business world) and user-friendly everyday project valuation models (what hopefully the ROA will get one day).

At this point I would like to thank the people who have led, joined and helped me over the time while this thesis progressed. Special thanks go to Prof. Dr. Rudolf Volkart, my supervisor, who always had an open ear for my problems, motivated and supported me in my research, and gave me the opportunity to work at the Swiss Banking Institute (SBI) of the University of Zurich, an environment of a number of exceptional people.

I am also grateful to my co-supervisor Prof. Dr. Hans Geiger for our discussions about science, sports and everyday life and for his interesting and lively questions through the oral examination. I liked it very much.

I wish to express my sincere thanks also to Dr. Brigitte Maranghino-Singer, my friend and office-colleague who always motivated me and who was a direct and never-ending fount of knowledge and pieces of wisdom on how to write a doctoral thesis. Moreover she was one of the main proofreaders for the questionnaire, as well as for the first manuscript of the complete dissertation. For this and for all the interesting and deep discussions during the time at the SBI I would like to heartily thank her.

Additionally I would like to thank my friends Cornelia Frei-Handschin and André Frei. Two marvelous people who did an unbelievable job in proofreading my manuscript and adding considerable improvements to my English, as well as to some practical aspects of the dissertation.

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Writing a doctoral thesis is like digging into a long and narrow tunnel. The longer and deeper you dig in it, the lower is the probability that you will be understood by others. Therefore I would like to acknowledge a huge thank to my sister Maria-Luisa and my father Salvatore who always tried to understand me, always put up with my odd moods when I got stuck with work, and always shared the joy when I progressed. Without this “save heaven” this thesis would never have been possible. Thank you very much!

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List of Abbreviations

This list of abbreviations contains only technical terms and commonly used abbreviations. Specific mathematical variables will be defined subsequent to their introduction.

Aka	Also known as
Atm	At the money
CAPM	Capital Asset Pricing Model
CBOE	Chicago Board Options Exchange
CEO	Chief Executive Officer
CF	Cash flow
CFO	Chief Financial Officer
CHF	Swiss Franc
DCF	Discounted Cash Flow
DTA	Decision Tree Analysis

e.g.	exempli gratia
et al.	et alteri
etc.	et cetera
FCF	Free Cash Flow
ff.	forth following
FMA	First mover advantage
GBM	Geometric Brownian Motion
i.e.	id est
Ibid.	ibidem (in the same place)
IRR	Internal Rate of Return
Itm	In the money
MAD	Market Asset Disclaimer
n.b.	nota bene
NPV	Net Present Value
OPT	Option pricing theory
OTC	Over the counter
Otm	Out of the money
p.	Page
p.a.	Per annum
PDE	Partial differential equation
PV(CF)	Present value of cash flow
R&D	Research and Development
r_f	risk-free rate of return
ROA	Real Option Analysis
ROV	Real option valuation
ROVG	Real Option Value Grid

SMA	Second mover advantage
SPI	Swiss Performance Index
SWX	Swiss Exchange

"It is not the strongest that survives, nor the most intelligent.

It is the one that is the most adaptable to change."

Charles Darwin

(English naturalist and author of the theory of evolution by natural selection. 1809-1882)

1 Introduction

1.1 Outline of the dissertation

Value creation is the company's main objective. Giving the right value to an investment can determine the success or failure of a firm. Viewed from this perspective, valuing "possibilities" in a management environment has become an important topic to master. Investment decisions are ubiquitous - the purchase of a new machine, the exploitation of an oil field, the acquisition of a firm - these are all investments. Today the central paradigm for valuing investments and making budgeting decisions is the net present value (NPV).[1] Unfortunately it is based on expected future cash flows, thereby failing to account for the value of managerial flexibility inherent in many investment projects. The value of operating and financing flexibilities, e.g., the options to expand the scale of a project, defer it, or abandon it; or the option to externally fund a project, can be extremely important. First, because without accounting for this potential additional values investment opportunities are being systematically undervalued and second,

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[1] See for example Graham and Harvey (2001), p. 9ff or Vollrath (2003), p. 354ff.

because taking into consideration the value of flexibility can show that a negative net present value project, which per definition would be rejected, can be worth undertaking because it may open up the way for profitable future investment opportunities, an exercise that is not possible under the traditional discounted cash flow methods.[2] Today's economy is marked by uncertainty, competition and rapid change. The question arises whether the fair value of a business can be determined without accounting for flexibility to act in this fast-moving environment. For these reasons, valuing managerial flexibility is important.

But how can flexibility be valued? In a seminal paper, Myers (1977) valued growth opportunities, i.e., the investment to gain the flexibility to growth, as a real call option, while considering the existence of growth opportunities as given.[3] This was the starting point for the theory of real options. As yet, only few corporations are beginning to employ the real options paradigm derived from the classic financial option pricing paradigm of Black-Scholes and Merton.[4] This is surprising, especially when we take into consideration the high relevance of top managers for strategic capital budgeting decisions and the real options' broad appeal, not only to the financial economic community, but also to the strategic management field.[5] The skeptics are questioning above all the complexity of the real options method and the fact that not all assumptions hold in practice.[6] Furthermore, many of the required input parameters are not readily available.[7] Finally, the perception that the real options methodology has been misused to justify excessive valuation propositions of internet companies has contributed to the stagnation of interest about real options by market participants in practice.[8] Chapter 3.6 of this dissertation discusses these issues, examining further difficulties with the practical implementation of the real options method, and presents possible alternative ways out.

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[2] See Gibson (2004).

[3] See Myers (1977).

[4] As documented by several surveys on the topic, see chapter 4. For the Black-Scholes paradigm, see Black and Scholes (1973).

[5] As we will see in the following thesis, the real option theory is placed between financial theory and strategic management theory insofar as it is a method which is able to account for the value of strategic actions, i.e. managerial flexibility. Assigning a value to these strategic actions is of great interest in business life as also seen in the survey carried out in Swiss companies. See also the results of the survey in chapter 4.5.

[6] For an overview of the critics on the real option theory, see chapter 3.6.

[7] See Bowman and Moskowitz (2001), p. 775.

[8] See, for example, Rice and Tarhouni (2003), p. 15ff, who noted that after the years of the e-bubble (around 2000) many internet companies used the real option theory to justify high future revenues which, however, were not real, as many proposed future managerial actions on which these revenues were dependent, were simply not implementable in reality.

Since the idea of applyying option pricing theory to capital budgeting decisions was published, there have been a number of publications in which researchers and practitioners are trying to seize and measure the value of flexibility within a project using the Real Options Analysis (ROA), some solving methodological problems, others focusing on selected niche applications, but in general concentrating on the detailed execution of the real options approach.[9] However, neither the academic nor the more practical-oriented publications attach much value to the preliminary decision, whether or not the real options method is relevant for the valuation of a particular project. Mostly the efforts and difficulties in applying the Real Options Analysis are not trivial. Firms are only interested in undertaking these efforts if they can gain as much advantage as possible out of them. For this reason, an important first step before implementing the real options approach is to analyze whether or not a real options valuation is worthwhile for the given specific valuation problem. This thesis wants also to shed light on this problem.

1.2 Objectives of the dissertation

The overall aim of the thesis is to study the application of the real options theory to the valuation of investment project in practice. The five main objectives of the dissertation are:

- *to show why valuing flexibility is important for a manager's decision.* This includes disclosing the various business activities where valuable flexibility can be hidden and to demonstrating why, without accounting for flexibility, the value of many projects is being underestimated.
- *to demonstrate how flexibility can be valued.* Nowadays, in academic domains, "valuing flexibility" is used almost synonymously with the idea of real options valuation.[10] In that sense showing how to value flexibility and explaining how to apply the ROA to project valuation will lead to nearly the same result.
- *to establish a comprehensive overview of ROA application areas discussed in literature and point out the critiques of the application of the ROA in real-life projects.* Besides application problems which could arise in practice the

[9] An overview of the application of the ROA in different industries, specific project types and even macroeconomic questions is given in chapter 3.7.

[10] However we want to be precise that in practice this is far from being the same. In fact, in practice, the value of flexibility is assessed in other ways than with the Real Options Analysis, as we will show in chapter 2.

overview will also focus on the theoretical critiques of the ROA, as theoretical critiques and practical problems are in part associated. Additionally, the relevance of the different critiques is briefly discussed, and arguments or solutions that can mitigate theoretical and practical problems are proposed.

- *to analyze how Swiss firms treat the value of flexibility within their project evaluation process.* More precisely to find out if Swiss firms account for managerial flexibility, and if the real options method is being used for this purpose or whether alternative approaches are preferred.
- *to develop a method which systematically permits the decision of whether a Real Options Analysis application is relevant or not for the valuation of a given investment project.* Focusing on the three constitutive characteristics of a real option, namely irreversibility, flexibility, and uncertainty, a method will be presented to assess the relevance of the application of the ROA to a given investment project.

1.3 Structure of the dissertation

Reflecting the main objectives formulated above, this thesis is divided into six chapters.

Chapter 1 is represented by this introduction outlining the major objectives of this thesis and presenting its structure.

Chapter 2 explains what we mean by “flexibility in investment decision” and gives the definition of managerial flexibility which we will use through the dissertation. Moreover, several alternative methods to the ROA are presented, which are also used to assess the value of flexibility and its importance for a practical investment decision.

Chapter 3 outlines the fundamentals of the real options theory and emphasizes the basics needed for the further development of the thesis. Moreover, a comprehensive description of the theoretical and practical critiques of the real options approach is laid out, and the relevance of these critiques is discussed. Finally several application areas of the ROA are presented in order to give a comprehensive overview of the different industries or project types where implementation work has already been examined in the academic literature.

Chapter 4 provides a survey investigating how Swiss companies treat managerial flexibility in project valuation. The survey focuses on the importance that Swiss firms assign to the valuation of flexibility and whether or not the companies are applying the real options approach. Additionally, basing our findings on the data gathered on uncertainty, irreversibility, and potential of real managerial flexibility, we highlight the main application industries and present the most frequently occurring real option types for the specific industries. Finally, some broad guidelines are given for showing in which cases of our data sample might other applications of the ROA could be of major benefit.

Chapter 5 describes the relevant framework about the preliminary decision of the practical implementation of the real options approach. We show that without too much complexity and with already existing information about the specific project, which can normally be found within a standard investment proposal, a quick judgment about the relevance of the application of the ROA can be made. The decision will be based on a rough approximation of the level of the uncertainty, irreversibility, and flexibility inherent in the single project, without necessitating advanced mathematical skills and knowledge. A case study will be discussed in order to exemplify the application of the concept and clarify the definitions presented in the framework.

Chapter 6 concludes the thesis, summarizing all findings and reviewing the single research objectives one by one.

Figure 1.1: Overview of the structure of the dissertation.

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2 Valuing Flexibility

The main goal of this chapter is to outline the reasons why the value of flexibility is important for a firm and for the valuation of a project in particular. First of all, the term “flexibility” will be clarified, and several domains where flexibility can emerge will be shown. We will see that the concept of a flexible plan as having greater worth than one without flexibility is not new to the business world. Additionally, the different ways of accounting for the potential added value given by flexibility will also be presented in this part of the dissertation.

2.1 What does flexibility mean?

For flexibility to be of any use in project valuation, its practical and theoretical aspects must be understood. Only then will management find a support for identifying, creating, managing, and giving a value to flexibility. Different definitions and dimensions of flexibility within companies can be found in today’s literature. For this reason, it is also important to clarify what types of flexibility are discussed in this work and to define the term flexibility for the purpose of this thesis.

"In psychological terms, a flexible person is open-minded and adaptable, whereas an inflexible person is unable to deal with ambiguity and uncertainty."[11] This is also the starting point for defining flexibility in an economic or a business environment. As already mentioned, the term flexibility appears in many business areas with different meanings, focusing on different points of view. Therefore, various definitions as related to different business functions and business areas are briefly considered at this point before the definition of flexibility as used in this thesis is given.

Starting from the financing structure of an organization, Bernstein (1978) defines flexibility as the ability to raise funds in adverse capital markets.[12] Harrigan (1985) defined flexibility from a broader market perspective; for him, the term strategic flexibility refers to a firm's ability to reposition itself in markets, change its game plan, or dismantle its current strategies.[13] Carlsson (1989) concluded that flexibility gives a firm the ability to deal with all forms of turbulence or uncertainty in a business environment.[14] In the field of policy formation, Evans (1982) defined strategic flexibility as the capability that aids repositioning when conditions change.[15] Concerning labor markets, Atkinson (1985) distinguished three types of flexibility that are desirable by employers: functional flexibility, which refers to the deployment of employees between activities and tasks; numerical flexibility, which allows work hours to be quickly, cheaply, and easily varied in line with short-term changes in the demand for labor; and financial flexibility, which relates to the possibility of a firm to manipulate labor costs according to the state of supply and demand in the labor market.[16] However, the largest number of definitions of flexibility has come from the manufacturing sector. According to Hutchinson and Sinha (1989), flexibility describes the ability to rapidly introduce new parts and to change the production mix to respond to short-run fluctuations.[17] Verter and Dincer (1992) defined flexibility as the ability of a system to cope with changes effectively.[18] Gunasekaran *et al.* (1993) defined flexibility as the ability of a manufacturing system to cope with changing

[11] Ku (1995), p. 290.
[12] See Bernstein (1978), p. 510.
[13] See Harrigan (1985), p. 3.
[14] See Carlsson (1989), p. 201ff.
[15] See Evans (1982) in Ku (1995), p. 85.
[16] See Atkinson (1985), p. 11ff.
[17] See Hutchinson and Sinha (1989), p. 51ff.
[18] See Verter and Dincer (1992), p. 13.

environments.[19] A shortcoming of these functional approaches is that flexibility in particular functions may be emphasized, and the influence on flexibility in other areas in the organization is overlooked. Suppose a firm buys new machines to adapt quicker to a higher demand in the market. This gives the flexibility to the firm to expand its output according to market demand. On the other hand it will make the firm more inflexible from a financial point of view as the ability to raise more money will decrease with rising outlays. Because of such problems, and because the research on flexibility is fragmented across many disciplines, creating confusion and misunderstanding regarding the term's meaning, some authors tried to find a common way to unify the various interpretations of flexibility.

Volberda (1998) divided flexibility into two types, namely internal flexibility, which is viewed as the capacity of organizations to adapt to the demands of the environment, and external flexibility, which describes the capacity of organizations to influence their environment and thereby reduce their vulnerability.[20] Thus, this definition involves the strategy of adaptation to the environment as well as the one of influencing the environment itself. Ku (1995) stated that the meaning of flexibility is too multi-faceted to give a single formal definition of it. Thus, after reviewing the literature on the definition of flexibility she identifies five necessary elements to define flexibility, namely *change, range, time, uncertainty conditions, and favorability*.[21]

1. *"Flexibility conveys a **change**, usually in the future tense, i.e. a potential. This is implied by the transition between two states, choosing between alternatives, barriers to change, and switching cost.*

2. *Flexibility denotes more than one way of responding to change, hence the notion of **range**. Range includes the **size of choice** set, number of alternatives, the extent to which demand can be met, and the levels of change.*

3. *Flexibility is different from gradual change. The **time** element is very important here, as typically we speak of a "rapid" response. Time includes responsiveness, lead time, and time to change.*

4. *The fourth element relates to the [...] existence of **uncertainty** and **alternatives** or **strategies** for the consideration of flexibility.*

[19] See Gunasekaran *et al.* (1993), p. 2.
[20] See Volberda (1998), p. 93.
[21] Ku (1995), p. 325.

5. *Inherent in the concept of flexibility is the notion of* ***favorability*** *which differentiates between the choices available."* [22]

Koornhof (1998) also considered various definition of flexibility by different business functions and arrived at the conclusion that for the purpose of her work the definition of flexibility has to encompass strategic as well as operative, administrative and behavioral aspects. Consequently, for her, the appropriate definition of flexibility is as follows:

"Flexibility is the process of being aware, responsive, willing and able to take action to reposition the resources and functions of the organization in a manner consistent with the evolving vision, strategies and goals of management as they respond proactively or reactively to new information on foreseen and unforeseen change in the organization and its environment." [23]

However, she also stated according to Puxty (1993), that a definition should delineate the space within a more detailed analysis takes place and exclude other spaces without creating a completely unique space for itself.[24] For achieving this target, it is essential to find a definition of flexibility for a special purpose without violating the broader meaning of flexibility.

In line with this statement, in this thesis we use a definition that emphasizes the production function of the organization and their ability to modify itself at little cost in the face of uncertainty, without to infringing on the five elements described by Ku (1995). This leads us to the definition of Trigeorgis (1993b), which stated managerial flexibility refers to the ability of management to alter its operating strategy, or the course of a single project, by acting in response to the resolution of market uncertainty over time in order to capitalize on favorable future opportunities or to mitigate losses.[25] This definition, moreover, emphasizes on the option character of an investment, as flexibility in this context implies for the manager the right but not the obligation to change the project settings according to market conditions. Although we agree with this definition, we add two more aspects to it, which are the time and the cost elements. The adaptation to the new situation should be fulfilled as quickly as possible and as inexpensively as possible. Otherwise the value of flexibility lessened because the probability of a real change tends to diminish. The following example explains what we mean. Suppose a company would have to pay CHF 500'000 for implementing

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[22] Ku means with favorability that if there are several states we can move to, we will move to the one that gives the greatest benefit, i.e., is most favorable.

[23] Koornhof (1998), p. 138.

[24] See Koornhof (1998), p.130.

[25] See Trigeorgis (1993b), p.202.

flexibility in a ten years lasting project. This flexibility will improve the net present value of the project from CHF 200'000 to CHF 210'000, whereby the increase of CHF 10'000 will only be reflected in the in the last cash flow in year ten. Nobody knows exactly what will happen in e.g. three years, much less in ten years. Therefore, this change which is expected to take hold not before ten years, and will result in an NPV increase of only CHF 10'000 is obviously most likely to remain undone. Consequently, in this case, we cannot really talk of having a real flexibility. It would infringe on point four in Ku (1995).[26] Therefore, the definition of flexibility used in this thesis and which matches the managerial business perspective is as follows:

Figure 2.1: Definition of managerial flexibility used in this dissertation.

Managerial flexibility is the ability of management to alter its operating strategy or the course of a single project rapidly and with low cost by acting in response to the resolution of market uncertainty over time, in order to capitalize on favorable future opportunities or mitigate losses.

Source: Based on Trigeorgis (1993b), p. 202.

Consequently, a flexible project may allow for downside protection against adverse market conditions, e.g., by abandoning the project or shrinking its scale; but as well it endows the manager with the possibility of profiting from growth opportunities in case of favorable market conditions, in for example expanding the scale or scope of the project. Thus, managerial flexibility reduces a project's exposure to uncertainty on the one hand, but also provides management with the ability to respond to evolving positive market developments on the other. This results in a clear distinction from risk management, which mostly concentrates solely on the control of downside risk. Coming back to the literature about managerial flexibility and real option, it can be noted that many authors classify the different flexibility options to clarify and emphasize the aspects of the definition and to provide a guideline to management in understanding, identifying, and designing flexible plans.[27] We will base this work on the classification of Trigeorgis of common real options, which presents a propensity to be adaptable to

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[26] See above.

[27] See chapter 3.4 for an overview of the different real option classifications.

real-life investments because its intuitive and practice-oriented option categories. As the same classification will be discussed in more detail in subchapter 3.4; the different option categories will only be presented summarized at this point in order to complete the discussion about what we understand about flexibility in the proceedings of the thesis.[28] Trigeorgis categorization is comprised of six different types of basic options and an additional one which represents any possible combination of them. The categories are:

1. *Option to defer*: This option refers to the ability of management to postpone an investment opportunity. An investment does not have to be done immediately when the opportunity is recognized but rather a manager can choose when the right time to exercise this opportunity has come. Management can, for example, wait x years to start the construction of a plant and exercise this investment opportunity only if the output prices of the plant's output will justify it.
2. *Option to expand/contract*: If market conditions are more favorable management can expand the scale of production of the project. On the other hand, if conditions are less favorable, it can reduce the scale of operations. In extreme cases, this can even lead to a temporarily halt of a project and a re-start at a later point in time. Additionally, the option to expand/contract refers not only to expanding respectively contracting the scale of a project but also its scope, for instance, a company that sells books can expand its scope to selling CDs or DVDs.
3. *Time-to-build option (or option to stage investments)*: In this case management can divide the project into different phases and decide after every phase if the project should be kept alive or abandoned, based on new information.
4. *Option to abandon*: An abandonment option provides the management with the possibility of completely giving a project when market conditions decline severely in order to realize the resale value of capital equipment and other assets on secondhand markets.
5. *Option to switch (e.g. outputs or inputs)*: Management can change the output mix of the plant according to decreasing demand or prices of the original output. Alternatively it can produce the same output using a different input mix.

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[28] See Trigeorgis (1993b), p. 203.

6. *Growth option*: The management decides an investment that is a prerequisite for another investment at later time. In this sense, the first investment is an option that opens up growth opportunities in the future. The difference from the option to expand and the option to stage investments is that a growth option refers to a strategic growth and not only to an expansion or a further planned step of the same project.[29]

7. *Multiple interacting options*: In real-life, management has the possibility to combine several of the flexibility options described above. For instance, it can first defer an investment, then alter the operating scale or switch the output, and finally abandon the project depending on evolving market conditions. Their combined value may differ from the sum of the separate option values. This fact creates a big challenge for the application of the real options theory in practice. We will refer to this issue in more detail later in chapter 3.4.1.7.

Now that we have clarified the meaning and the various types of flexibility that will be discussed in this thesis, it is possible to explain why a company should be concerned about the value of flexibility. The next chapter is dedicated to this aim.

2.2 Why is it important to value flexibility in project evaluation?

Already Baldwin (1987) noticed that *"Given the increase in variability in both product and financial markets worldwide, companies that recognize option values and build a degree of flexibility into their investments are likely to be at a significant advantage in the future, relative to companies that fail to take account of options in the design and evaluation of capital projects"*.[30] Starting from this statement, the importance of accounting for flexibility quickly becomes clear. The existing business environment is characterized by an augmented volatility. This increased volatility demands companies to adapt rapidly and smoothly in order to remain successful. Flexibility thus becomes an essential competence for organizations in a rapidly changing and unpredictable world. The flexible firm facilitates creativity, innovation, and speed, while maintaining better co-ordination, focus, and control of the actual investment environment. A manager should not only be able to ride out sudden hard blows, but also avail itself of unexpected opportunities in turbulent times. In this sense, a business should be flexible

[29] The exact difference will be discussed later in chapter 3.4.1 when we treat every single type of managerial option according to Trigeorgis.

[30] See Baldwin (1987), p. 61.

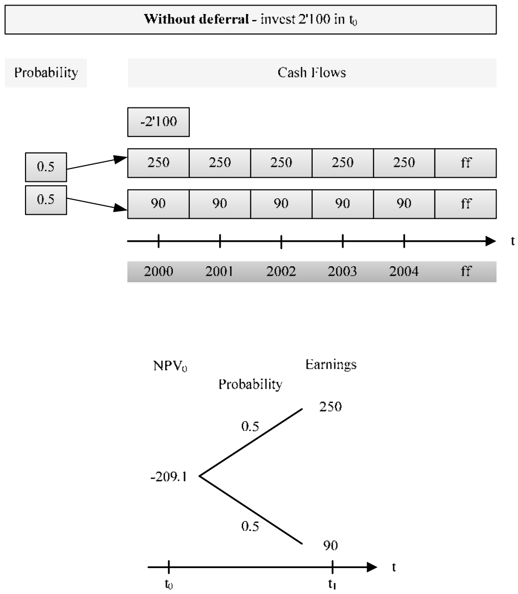
enough to handle both the unexpected threats and the opportunities posed by an uncertain future and unstable environment. Johnson (1992) argued that a failure to understand the costs of complexity and the benefits of flexibility caused American firms to lose market share and profitability to more focused and flexible competitors in the 1970s and 1980s.[31] Nowadays, managers of companies seem to be aware of the benefits of being flexible. For this reason, it is surprising that the methods they have adopted to value flexibility in their organizations are mostly ad hoc, rather than trying to use a comprehensive, systematic, and structured approach.[32] Failure to give the right value to a project could lead a firm to reject investment opportunities that would be worthwhile and thus easily to lose revenues.

The following example illustrates what could happen. Assume you can decide today to buy a machine which produces balls for CHF 2’100 to be paid at the end of the year. The price of balls becomes known at the end of the same year and will never change in the future, i.e. the revenues at the resulting price can be obtained forever. One ball is expected to be worth CHF 250 or CHF 90 with probability of 50%. The weighted average cost of capital for risks in the sports goods industry is estimated at 10% p.a. by a panel of experts. The situation is depicted in Figure 2.2.

[31] See Johnson (1992), p. 52.

[32] As it can be seen from the results of different surveys, the value of flexible actions is being considered frequently by companies all around the world when deciding about investments; however, this is mostly done with arbitrary adjustments of the project value. See 4.2 for the review of some empirical studies about the consideration of managerial flexibility in investment decision.

Figure 2.2: Example: ball machine without flexibility to wait.



Assuming that the decision to invest has to be made today or never, the question is whether this investment should be undertaken or not. Working through this example using net present value (NPV) criterion, we get following results (calculations in this example are always made in CHF):[33]

$$NPV_1 = -2100 + 0.5 * 250 + 0.5 * 90 + \sum_{t=1}^{\infty} \frac{0.5 * 250 + 0.5 * 90}{(1+0.1)^t} = -230$$

$$NPV_0 = \frac{-230}{1+0.1} = \underline{\underline{-209.1}}$$

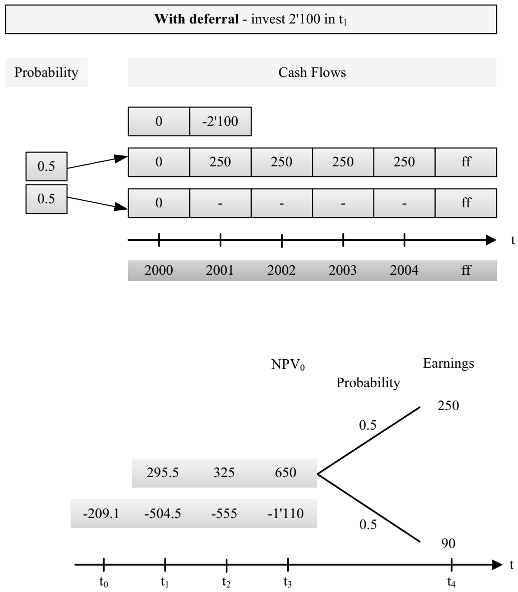
Clearly, according to the NPV criterion shareholders' wealth is being destroyed since the NPV is negative and, therefore this investment will be rejected. What if the decision

[33] At this point we use the NPV criterion as it is the most commonly used methodology to value investment projects in business practice, as we will see in the survey in chapter 4. We will give further explanation on the NPV itself in chapter 2.3.1. For the scope of this example, only the NPV's final results are of importance.

to undertake the investment could be deferred till the end of the first year, instead of pre-committing immediately?

Figure 2.3 illustrates the situation if the decision to buy the ball machine could be deferred to the end of the year.

Figure 2.3: Example: ball machine with flexibility to wait.



We continue to assume that the weighted average cost of capital is 10% p.a., and the price of the balls is either CHF 250 or CHF 90, with a probability of 50%. If we had the flexibility to wait to invest until the end of the first year, we would consequently know the price of the balls at the time when we had to decide about the investment. The results of the NPV calculation, and therefore the decision made will significantly change. If the price of the balls turns out to be CHF 90 (i.e. the lower price), we would get the following NPV values:[34]

[34] Note that the calculations are the same as for the NPV of a direct investment. The only step that changes is that we take the price as guaranteed as we wait for the end of the year and thus will decide to make the outlay of CHF 2100 at the beginning of 2001, and not in the year 2000 as before (note the difference between Figures 2.2 and 2.3).

$$NPV_{0,low} = \frac{\left(-2100 + 90 + \left[\sum_{t=1}^{\infty} \frac{90}{(1+0.1)^t}\right]\right) * 0.5}{1+0.1} = \underline{\underline{-504.5}}$$

Hence, we would obviously choose not to invest. On the other hand, if the price of the balls were CHF 250 (the higher price), we would get a positive NPV value:

$$NPV_{0,high} = \frac{\left(-2100 + 250 + \left[\sum_{t=1}^{\infty} \frac{250}{(1+0.1)^t}\right]\right) * 0.5}{1+0.1} = \underline{\underline{295.5}}$$

These numbers show that this investment contributes to shareholder value and, therefore, we would accept the project. To sum up, we will only invest if the price turns out to be CHF 250, but otherwise would choose not to invest if it is CHF 90. The flexibility to wait one year and decide to undertake the investment upon the ball's price development is clearly worth something; namely the difference between the investment given pre-commitment (CHF - 209.1) and the investment with the possibility to wait (CHF 295.5) which results in CHF 504.6.

If a manager would either not recognize this built-in value of flexibility or not take into account its right value, he would miss important investment opportunities and, consequently not only lose money, but also forgo the chance to provide new jobs or investment prospects. Thus, on a greater economic basis, and if we suppose that not just one but many decision makers could overlook the worth of flexibility inherent in some projects, there could be even some negative effects on the short-run dynamics of economic growth, only because the worth of flexibility is being neglected.[35] This makes it evident that valuing flexibility in a management environment has become an important topic to master, not only for the single firm, but also for the whole economy. Some concepts have been developed to take into consideration this value. These concepts will be introduced in the next chapter. The Real Options Analysis, which is also a concept aimed at valuing flexibility, will be presented more detailed in chapter 3 as it is the basic theme underlying this thesis.

[35] See Bloom (2000), p. 3.

2.3 Overview of techniques addressing flexibility valuation

Now that we have ascertained the important role that flexibility can play in everyday investment decisions, we need a measure for it and its economic value. This chapter reviews some methods currently used to measure the value of flexibility or at least to try to deal with the problem of the highly volatile business environment mentioned above, incorporating in a certain sense the importance of flexibility for project valuation. These methods are: rules of thumb, sensitivity and scenario testing, Monte Carlo simulation, and the Decision Tree Analysis (DTA). All this methods are alternatives to the Real Options Analysis, which among academics is the most promising theory to value flexibility.[36] We will look at what the ROA alternatives are intended to do and not do and emphasize the points where the ROA goes further. Reflecting the importance for this thesis the ROA itself will not appear in this short review, but rather be subject of an entire chapter for its own, namely chapter 3. As the aim of this thesis is to analyze the value of flexibility within an investment decision, we will first briefly turn our attention to traditional investment decision in general. Therefore, chapter 2.3.1 is dedicated to the net present value method, which is part and parcel of all ROA alternatives to value flexibility, and even of the ROA in some cases.[37]

2.3.1 Net Present Value

One of the most important findings in modern finance theory states that the value of an asset (or an entire company) equals the discounted present value of its expected future free cash flows.[38] This net present value is exactly the same as the increase in shareholders' wealth. Thus, given perfect capital markets,[39] companies contemplating investments in capital projects should always use the NPV rule to make funded decisions about their investment opportunities. That is, the company should take the project if the NPV is positive, but reject it if it is negative.[40] In its basic form (assuming

[36] As we will see in the survey presented in chapter 4 the utilization of the ROA in practice is by far not diffused in all companies, although the idea is more familiar to senior management as it was a couple of years ago. Consequently, in practice, the alternative methods presented in the following and the real option valuation (if applied) are used in combination in order to give a comprehensive view of the valuation problem to the decision maker.

[37] To calculate a flexibility value of a project we need to know its value without flexibility. For this purpose in ROA the NPV is often used as a base case of the project without flexibility.

[38] See for example Volkart (2006), p. 179.

[39] For perfect capital markets see Copeland *et al.* (2005), p. 353ff.

[40] See for example Volkart (2006), p. 281, or Brealey *et al.* (2006), p. 24.

no taxes), the NPV criterion expressed as a mathematical formula reads as follows: invest if

$$NPV = -I_0 + \sum_{t=0}^{\infty} \frac{FCF_t}{(1+WACC)^t} > 0 \qquad \textbf{(2.1)}$$

whereas I_0 = Investment cost at year 0, FCF = Free Cash Flow, t = life-time of the project, WACC = Weighted Average Cost of Capital.

The two central parameters within the NPV formula are, first the FCF and, second the WACC. The FCF used in the NPV criterion represents the cash that a company is able to generate after laying out the money required to maintain/expand the company's asset base. The appropriate definition of FCF for capital budgeting purposes is discussed in various places. As it is not the main topic of this dissertation we will refer to those authors for more detailed information.[41] The weighted average cost of capital, or WACC, represents the firm's cost of capital as a weighted average of the cost of equity and the cost of debt:

$$WACC = r_D * \frac{D}{V} + r_E * \frac{E}{V} \qquad \textbf{(2.2)}$$

whereas r_D = expected rate of return of debt, r_E = expected rate of return on equity, D = Debt capital, E = Equity capital, V = Total capital

Hereby the cost of equity of the firm (r_E) is represented by the risk-adjusted discount rate based on the expected return on marketable securities with similar risk to that of the underlying free cash flows of the asset being valued.[42] In practice, a suitable risk-adjusted discount rate would be set exogenously using CAPM or some other kind of model that enables the manager to price risky assets in equilibrium. Importantly, this discount rate should, according for modern portfolio theory, allow only for non-diversifiable market risk, and not for the technical or private risks associated with the asset or project.[43] The cost of debt (r_D) can be mostly directly observed and the debt and equity capital ratios (D/V and E/V) can be defined by a target ratio.[44] Having determined the FCFs and the WACC, a NPV calculation breaks down into a simple

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[41] See for example Volkart (2006), p. 53, Brealey *et al.* (2006), p. 113, or Copeland *et al.* (2005), p. 34.

[42] See Volkart (2006), p. 181, Brealey *et al.* (2006), p. 513ff, or Copeland *et al.* (2005), p. 29.

[43] See Volkart (2006), p. 224ff.

[44] The major problem in assessing the WACC lies in the circularity of the definition of the WACC and the debt- and equity ratios. In fact the WACC is depending on the debt- and equity ratios, whereby the equity ratio is in turn depending on the WACC (through the value of the total capital V). For companies which are not quoted in a stock exchange and whose equity ratio can thus not be observed directly on the market, there is nothing else for it but to define a target debt- and equity ratio to calculate the WACC. See Volkart (2006), p. 348.

division and an exponential calculation below the fraction brake as seen in formula 2.1. This exceptional clarity and simplicity of the NPV method besides its straightforward interpretation, led to its strong popularity for valuing investment projects in business practices. We will not go further into this method as there is a great deal of literature on the topic. Moreover, the net present value criterion is only important to this dissertation because first we will compare it in chapter 3.2.1 with the Real Options Analysis to see what it can do and what it omits, and second because the NPV will be, in most of the practical cases, the starting point for the ROA, as the present value of a project without flexibility is being needed as a base case to conduct a real options calculation. For these two purposes the NPV notions explained as yet are largely sufficient. The NPV approach, despite of all its advantages, carries a problem with it, which is sometimes overlooked and which will be the main thread of this dissertation. In its basic form, it does not account for the value of flexibility. Dixit and Pindyck (1994) gave an example of this flaw, reconfirming earlier research which has shown that:

"This rule is incorrect because it ignores the opportunity cost of making a commitment now, and thereby giving up the option of waiting for new information… That opportunity cost must be included as part of the total cost of investing." [45]

This is obviously not a fact that has stayed hidden in business practice. Therefore, it appears common for firms to use investment criteria which do not strictly implement the NPV criterion.[46] These criteria are reviewed in the following four subchapters.

2.3.2 Rules of thumb

The first criterion which consists of a more-or-less strong ad hoc nature and is sometimes hard to reconcile with what we teach in our business schools today, is referred as rules of thumb.

Let us assume that we had to invest CHF 500 million in a facility which will result in an estimated present value of CHF 500.001 million. According to the NPV criterion, this investment should be undertaken as a positive NPV of CHF 1'000 will result. However, in reality few managers would find an investment of CHF 500 million in order to earn CHF 1'000 a worthwhile opportunity, though they are often unable to articulate a reason. Hence, it is not surprising that firms routinely make capital budgeting decisions that basic finance textbooks say they should not make, by putting forward as argument

[45] See Dixit and Pindyck (1994), p. 135.
[46] See Graham and Harvey (2001), p. 11.

the gut feeling of the manager.[47] As McDonald (1998) pointed out, however, the answers provided by some simple rules of thumb often resemble solutions produced by optimal decision rules that account for option-like features of many investments. This is observed particularly in the evaluation of highly uncertain investments.[48] Therefore, even if such rules of thumb are arbitrary and very imprecise, they can still provide first aid to the problem of valuing flexibility.

There are almost as many different rules of thumbs as there are managers. Busby and Pitts (1997) conducted a survey of how finance officers deal with flexibility in capital appraisal.[49] One of the questions they asked to respondents was to describe any rules of thumb they used to capture the value of flexibility.

One method cited was the use of periodic project reviews or project milestones.[50] If, for example, the target expenditure was exceeded by 10%, the investment proposal had to be re-submitted. This rule does not require any specification of what options there might be. It is only concerned with the flexibility to review the investment in case of cost overrun, although it does not assume anymore a fixed investment development like the standard NPV. A periodic review implies an adaptation to a changing business environment, which is obviously a notion of flexibility.

Another rule of thumb was to ask the project leader in what circumstances a project would have a zero or negative return.[51] This rule helps to mitigate the problem of a biased proposer's belief about a too positive return of a project's outcome. Although the rule encourages an examination of the uncertainty of the predictions of a proposal and may lead the proposer to change a decision on the way it has little to do with assessing flexibility in the project.

An additional rule of thumb was requiring projects with a long development period to have greater flexibility to react to the business environment. Projects with little flexibility on the other side were required to have greater return.[52] Projects with lower returns were required to be built in a way that the opportunity to withdraw if returns turned out to be lower would always have been open, whereas the higher the uncertainty of the project, the shorter the phases between its reviews.

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[47] See McDonald (1998), p. 1.
[48] See McDonald (1998), p. 24.
[49] See Busby and Pitts (1997), p. 180.
[50] See Busby and Pitts (1997), p. 180.
[51] See Busby and Pitts (1997), p. 180.
[52] See Busby and Pitts (1997), p. 180.

Additionally Busby and Pitts (1997) found out that another rule of thumb applied by managers was to privilege both, projects with clearly existing "exit strategies" to deploy in case the project fails, but also projects endowed with the opportunity to postpone their start without incurring in unacceptably high losses of operating revenue.[53]

McDonald (1998) also suggested that firms routinely use some other rules of thumb: Projects are taken if the Internal Rates of Return (IRR) exceeds arbitrarily high discount rates - so called hurdle rates - whereby these hurdle rates are higher for projects with greater specific risk.[54] Another rule of thumb observed by McDonald referred to the so called profitability index.[55] An investment is undertaken only if this index reaches sufficiently high values, whereby these values are also set arbitrarily.

Graham and Harvey (2001) defined the payback period (PBP)[56] and the IRR as well as rules of thumb and showed in their survey about capital budgeting and capital structure decisions that such rules of thumb are still widely used in practice, although their shortcomings from a theoretical point of view have been stressed in many financial textbooks.[57] Another aspect that emerged from their study was that these "non-NPV conforming" capital budgeting methods are mostly used in combination with the NPV to explore the multifaceted aspects of investment performance, as for instance, a highly volatile and unclear business environment which can require adaptation.[58] This shows as well that because the flexibility inherent or needed for investments is hard to quantify, additional helpers are demanded in business practice.

To sum up: although these rules of thumb are not formal or theoretically correct models for evaluating flexibility and the options associated with an investment project, they can be helpful inasmuch as the importance of the effects of these options can be grasped intuitively. It is obvious that the application of these rules of thumb depend strongly on the gut feeling and the experience of a manager but, as McDonald (1998) argued, in some cases these decisions can be even close to optimal.[59]

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[53] See Busby and Pitts (1997), p. 181.

[54] See McDonald (1998), p. 1. The IRR is defined by the value of the discount rate (WACC), which makes the NPV equal to zero. The resulting zero-NPV WACC is then compared to a discount rate (i.e., cost of capital) which is considered to be acceptable for the given project. If the IRR is lower the project will be accepted. If it is higher, it will not be accepted. This comparative discount rate is set arbitrarily and is called the hurdle rate. A higher hurdle rate than usually employed was seen as a rule of thumb for McDonald.

[55] The profitability index is computed as the NPV of a project divided by its investment costs.

[56] The payback period is defined as the length of time required to recover the cost of an investment and is calculated as (investment costs)/(annual cash inflows).

[57] See for example Copeland *et al.* (2005), p. 25ff.

[58] A fact that was also emphasized by Volkart, see Volkart (1998), p. 56.

[59] Mc Donald 1998, p. 24, pointed out that this is mainly the case when the timing option is more valuable, because then it is less sensitive to deviations from the optimal investment rule.

2.3.3 Sensitivity and scenario testing

In the same survey mentioned above, which was conducted in the United Kingdom in 1997 by Busby and Pitts (1997),[60] sensitivity analysis was found to be a common way of assessing options associated with projects by British firms. However, this is theoretically not 100% correct. A sensitivity analysis is a useful technique for testing the significance of various assumptions made and may support a firm to understand the drivers and impact of risk in meeting its objectives. Important and highly uncertain variables that strongly affect the outcome of a project can be identified and bound. In this way, areas in need of further attention and that require flexibility to adapt to unforeseen changes can be disclosed. Consequently by assessing whether an investment is likely to contain the scope to solve the possible problem induced by the change of a central variable, sensitivity analysis can help to assess the value of flexibility.[61] The concept, therefore, consists of two important steps: first the identification of potential real options which can mitigate the negative effects of averse business conditions on important key variables of the project (asking, e.g., what can we do if market demand decreases), and, second the valuation-based but still arbitrary managerial judgment about the value to assign to the identified real option (e.g., asking how much would we be willing to pay for having this flexibility to adapt to decreasing market demand). If the advantage of this method is that no complex valuation tools are being used, on the other hand, the decision rule it provides to the decision maker depends on the manager's experience and his ability to process all the available information and is, therefore, very subjective. However, the main drawback is that sensitivity analysis does not account for interdependencies of variables, and it rarely considers the statistical confidence level of the sensitivities. For instance, does it make sense to look at an effect of an increase in market demand without changing the prices? If the market demand turns out to be higher than expected, it is likely that prices will rise too. In order to fix these problems it may make sense to undertake a scenario analysis. Scenario analysis extends sensitivity analysis by considering complete future scenarios, with particular emphasis on the internal consistency of each set of parameters. It is also particularly helpful when there are many key parameters to apply sensitivity testing. In these cases, managers can look at different but consistent combinations of variables, changing them simulatneously to get a closer view of the most sensible project variables.[62]

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[60] See Busby and Pitts (1997), p. 178.
[61] See Sharp (1991), p. 70.
[62] See Brealey *et al.* (2006), p. 248.

Nonetheless, both sensitivity analysis and scenario testing leave the decision maker with a range of results but no decision rule for choosing among them. Calculating the consequences of a misestimation of certain variables helps the manager, in fact, to identify the key value drivers of a project for which additional information is required in order not to incur considerable failures; however, it cannot handle the optionality embedded within real options problems. Both methods are not valuation methods, but rather techniques that complement valuation methods, like for example the NPV, by enhancing their information content.

2.3.4 Monte Carlo simulation

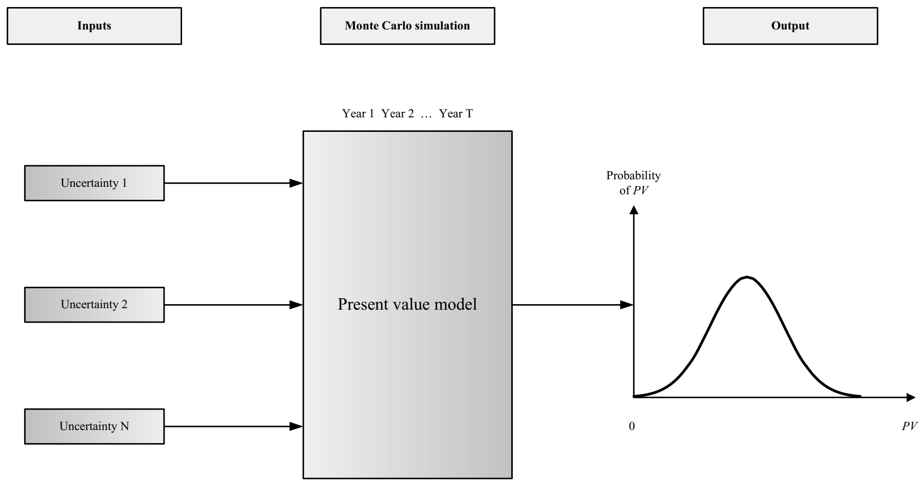
The Monte Carlo simulation extends sensitivity and scenario testing by replacing single parameters with probability distributions. Furthermore, it makes it possible to introduce more complex correlations between parameters than in a deterministic model. By considering all possible combinations of the different variables it enables the decision maker to inspect the entire distribution of project outcomes.[63]

Briefly Monte Carlo simulation works in three steps as illustrated in Figure 2.4.[64] First the valuation model must be specified and structured. Thus, the computer is being fed with all mathematical equations and identities for all important variables and interdependencies. In a second step, the simulation parameters must be specified by setting for each uncertain variable the probabilities for forecast errors. In a final step the computer fulfills iterative calculations of the distribution of the forecast errors and the resulting cash flow for each period. In this way, a distribution of outcomes is being produced, which can be used by a manager to detect the most likely value of the modeled project. Monte Carlo simulation allows one to see the probability rather than just the plausibility of various cash flows streams and the NPVs which result. Again, as with sensitivity and scenario simulations, if a certain outcome turns out to be completely different as predicted with a high likeliness, the manager should be prepared to take an action to overcome possible negative development or profit from new chances – i.e., the manager will be forced to put into light the valuable flexibilities the project set-up provides or elaborate some flexible action to deploy in case of unexpected developments.

[63] See Hertz (1968).

[64] See Copeland and Antikarov (2001), p. 245.

Figure 2.4: Three steps for Monte Carlo simulation.



Source: Based on Copeland and Antikarov (2001), p. 245.

Although this approach is viewed as providing a sound and adaptive framework to address decision flexibility, there are also drawbacks that cannot be overlooked.[65] In practice, it is difficult to derive actual probability distributions and correlations which are adequate for reality. Additionally the distribution of outcome can be difficult to interpret or give the illusion of an accurate project evaluation. Furthermore, Monte Carlo simulation is often used in a purely forward-looking manner and based on a specified operating strategy. This means that the flexible action is already predetermined and from this given point in time in the simulation, no longer flexible.[66]

2.3.5 Decision Tree Analysis

Decision Tree Analysis (DTA) is a visual analytical tool that accounts for the fact that decision makers operate in a dynamic world and therefore, need to capture the value of their flexibility to respond to events as they unfold. Since decision trees can be used to graphically structure many real options problems more emphasis is put on this approach than on the other three methods previously discussed. Decision trees can be applied in situations in which optimal decisions depend upon uncertain events as well as other

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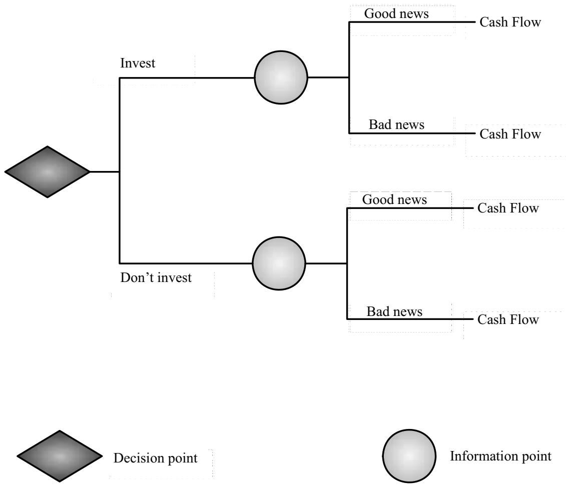
[65] See Rokke (2004), p. 92 and Robinson (2003), p .20.
[66] See Robinson (2003), p. 20.

decisions. Consequently, financial managers can use decision trees for analyzing projects involving sequential decisions and their interdependences.[67] Or, as stated by Brealey and Myers: *"If today's decision affects what you can do tomorrow, then tomorrow's decisions have to be analyzed before you can act rationally today."*[68] The DTA requires the decision maker to display his assumptions about future investment and operating strategies by laying out all available managerial actions or decisions that depend upon future uncertain events. The decision maker's goal is to choose the utility-maximizing set of actions among the different actions (i.e., its flexibility) available. The result of the DTA is the value of the investment based on the best possible combination of current as well as future choices and therefore enables the value of flexibility to be encapsulated into a single number, a result that is not possible with the aforementioned methods - rules of thumb, scenario and sensitivity analysis, and Monte Carlo simulation. Technically speaking the DTA is a combination of a forward induction (in which the decision problem is laid out) and a backward induction (where the optimal combination of decisions is determined). As shown in Figure 2.5 the decision tree is represented with two different types of nodes. On the one side, there are the nodes that represent the manager's decision points, i.e., decision nodes. On the other side are the nodes that represent the twist of fate, i.e., the outcome nodes. The outcome nodes symbolize points where uncertain events and unknown information is revealed to the manager and the decision nodes stand for points where the manager is asked to act according to new information.

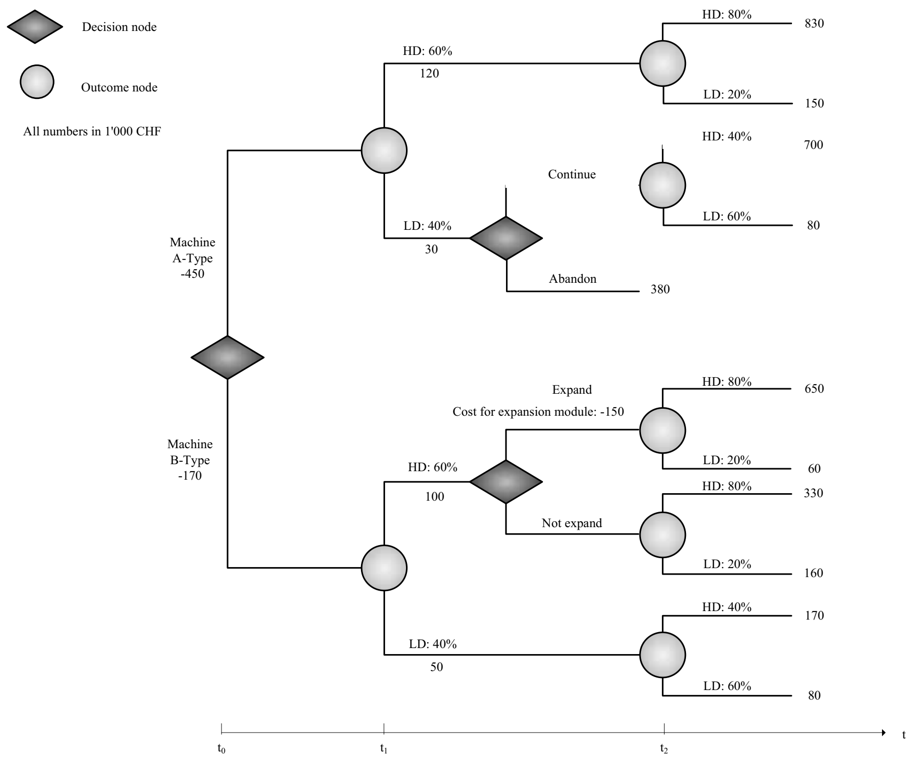
[67] See Magee (1964), p. 79ff.
[68] Brealey *et al.* (2006), p. 257.

Figure 2.5: Decision Tree Analysis with one decision.



The DTA is therefore a simple sound method to make the manager think about the important events and decisions to be taken during the life of a project, i.e., the flexibilities available. Moreover, in contrast to the other methods, it endows the decision-maker with the possibility to give a value to the ascertained flexible decisions. The following example in Figure 2.6 illustrates the DTA for an investment with three possible decisions to be made within two years.

Figure 2.6: Example: Decision Tree Analysis pasta project.



The manager of a pasta factory wants to launch a new sort of pasta. The new pasta should not only always be "al dente" regardless of the cooking time, but also tastier than the other sorts. For the production of this new pasta the manager can decide to buy either machine (A-type), at a cost of CHF 450'000, or another machine (B-type), with a cost of CHF 170'000, but which is based on older technology, which however does not affect the quality of the pasta. In the first year, the demand for the pasta can be either high, with a chance of 60% (which is denoted with HD in the figure), or low, with a chance of 40% (which is represented by LD). If the demand is high in the first year, there is a probability of 80% that it will stay high in the second year as well, since customers will get to know the pasta. If the demand is low in the first year, the manager estimates that there is a 60% chance that it will stay low. The two machines have two different purchase prices but, obviously, they also have two different revenue profiles. With the A-Type machine, in case of high demand in the first year the revenue will be

CHF 120’000. If the demand stays high in the second year as well, second’s year payoff will be CHF 830’000, otherwise CHF 150’000. On the other hand, if the demand is already low in year one, the payoff in year one will be CHF 30’000, and a subsequent low demand in year two will result in a payoff of CHF 80’000. If the demand should rise, nevertheless, the payoff will be CHF 700’000. Obviously the same probabilities for the demand apply to machine B-Type as well, but with payoffs of CHF 100’000, or CHF 50’000 in case of high respectively low demand in year one. Again, if demand is already high in year one, the probability is high that it will stay high in year two as well. This will generate a payoff of CHF 330’000 in the second year, or CHF 160’000 if demand declines in spite of a good first year. Finally, if the demand is already low in year one but recover in year two the payoff will be CHF 170’000 otherwise CHF 80’000.

Assuming a discount rate of 10% and if the manager holds the assets passively and watches the future unfold, the net present value of both opportunities (A-Type and B-Type) results as follows (calculations are made in CHF 1’000):

$$NPV_{A-Type} = -450 + \frac{0.6*120 + 0.4*30}{1+0.1} + \frac{0.6*(0.8*830 + 0.2*150) + 0.4*(0.4*700 + 0.6*80)}{(1+0.1)^2} = 79$$

$$NPV_{B-Type} = -170 + \frac{0.6*100 + 0.4*50}{1+0.1} + \frac{0.6*(0.8*330 + 0.2*160) + 0.4*(0.4*170 + 0.6*80)}{(1+0.1)^2} = 88$$

As the NPV of using machine B-Type is higher than the NPV of using machine A-Type, the NPV criterion clearly leads the manager to choose machine B-Type to produce the new pasta.

If business in the first year turns out to be poor, it may pay for the manager to sell the machine and abandon the project entirely. Therefore, the selling prices for both machines must be assessed. Let us assume that machine B-Type cannot be sold because, as stated before, it is based on old technology, unlike to machine A-Type, which will obtain a selling price of CHF 380’000 if it is sold at the end of the first year (the abandonment decision is represented in bold-style in the figure). In this case, the manager has a flexibility value with project A-Type that cannot be ignored. Redoing the NPV calculus with the possibility of selling the A-Type machine achieves the following results (calculations are made in CHF 1’000):

$$NPV_{A-Type_{Flex}} = -450 + \frac{0.6*120 + 0.4*30}{1+0.1} + \frac{0.6*(0.8*830 + 0.2*150) + 0.4*380}{(1+0.1)^2} = 96$$

In this case one would prefer to undertake the project with the A-Type machine, as the flexibility to sell the A-Type machine, in contrast to the B-Type machine which cannot be sold, will increase the NPV by CHF 17’000 to CHF 96’000. This is more than the NPV of the B-Type machine of CHF 88’000.

But what if sales in the first year are excellent? The A-Type machine will be able to satisfy the high demand, whereas the old technology B-Type machine will not. Also, in this case, the manager is comforted in the decision to go for the A-Type machine, keeping in mind the possibility of abandoning the whole project in case of low demand. After looking at the pasta machine market the manager learns that there is an additional module for the B-Type machine that can be bought for CHF 150’000 and through which the production capacity can be doubled (the expansion decision is represented in bold-style in the figure). In case of buying the expansion module and a resulting high demand in the second year, the payoff with the B-Type machine would now be CHF 650’000, whereas if it turns out that the second year’s demand is low a payoff of CHF 60’000 is expected. Obviously the chance of a high demand or a low demand is 80% to 20% also in this case. After the uncertainty about first year’s demand is resolved, the manager has to make the decision of whether to expand or not, paying CHF 150’000 for the additional module. So the expected payoff is: (Probability high demand * Payoff with high demand) + (Probability low demand * Payoff with low demand), which results in (calculations are made in CHF 1’000):

$$0.8 * 650 + 0.2 * 60 = 532$$

After having decided what to do if faced with the decision to expand, the manager can roll back the calculation to today’s decision. If the decision to buy the expansion module is taken this leads to a NPV of

$$NPV_{B-Type_{Flex}} = -170 + \left(0.4 * payoff_{lowD} + 0.6 * payoff_{highD}\right) * \frac{1}{1+0.1} = 123$$

Whereas $payoff_{lowD}$ and $payoff_{highD}$ are the payoff for the B-Type project in case of either low demand or high demand in year two and a subsequent expansion in case of high demand:

$$payoff_{lowD} = 50 + \left(0.4 * 170 + 0.6 * 80\right) * \frac{1}{1+0.1} = 155$$

$$payoff_{highD} = 100 - 150 + \left(0.8 * 650 + 0.2 * 60\right) * \frac{1}{1+0.1} = 434$$

If market demand is high, expansion obviously pays, compared with the B-Type situation without expansion (NPV of CHF 88’000). The flexibility to expand according the Decision Tree Analysis is worth CHF 123’000 - CHF 88’000 = CHF 35’000. Even compared to the decision to go for the A-Type machine (including the flexibility to sell the A-Type machine if the market turns out to have a low demand), the B-Type machine shows a better NPV and is therefore understandably the superior decision. An overview of the results is summed up in Table 2.1.

Table 2.1: Results overview of the DTA of the pasta project.

Decision taken	Resulting NPV
B-Type (with flexibility to expand)	CHF 123'000
A-Type (with flexibility to abandon)	CHF 96'000
B-Type (without flexibility to expand)	CHF 88'000
A-Type (without flexibility to abandon)	CHF 79'000

With this simple example, the strengths of the DTA have been laid open. With the initiation of a project, a decision maker gets valuable action flexibility, and this action flexibility must be priced and added to the project's value. This is exactly what a DTA accounts for. As a first step, the decision tree has been depicted and the action flexibility has been put into light. In a second step, with a simple NPV calculation, the value of this action flexibility has been calculated and expressed in one number - the value of flexibility. The advantage of the DTA is, therefore, that it can represent a lucid way to document and communicate the decision maker's thinking. Moreover, it may also be applied to help identify and structure real options as we will see later in chapter 3. Nevertheless, the DTA also suffers several disadvantages. From a theoretical point of view perhaps the biggest flaw as a project valuation tool is that, without specific adjustments, it does not apply the "law of one price". Choosing the action to expand the B-Type machine or to abandon the A-Type machine obviously changes the risk profile of the project. This means that different discount rates should be used to reflect these changes in risk, which would represent an almost intractable problem in theory and practice. Moreover, the DTA provides no guidance how to choose the discount rates.[69] Another weakness is the fact that decision trees get very complex very quickly. What if the manager in the example above faced a medium demand, instead of only a high or low demand? And what if the project goes on for four years instead of two, with perhaps a doubled or tripled possibility to sell either the B-Type machine or the A-Type machine? The decision tree grows very quickly to a "decision forest" and erases the advantages of the clear representation and communication of the manager's thinking.[70]

[69] See Brealey *et al.* (2006), p. 266.
[70] See Robinson (2003), p. 21.

Attempts are being made to overcome this problem. Lander and Shenoy (1999) suggested influence diagrams that can produce the same results as decision trees, but with the advantage of displaying them in a more descriptive, intuitive, and compact manner when there are multiple uncertainties and many time periods.[71]

[71] Lander and Shenoy (1999), p.12ff.

3 Fundamentals of the Real Option Theory

3.1 Introduction

In the previous chapter, we have explained why the value of flexibility is so important for a company's investment decisions. Of the different possible methods to value flexibility, the most appealing and promising one, at least from a theoretical point of view, is the Real Options Analysis. As a matter of fact, valuing flexibility and Real Option Analysis are almost treated as synonymous in current valuation literature. In this chapter we will present the evolution of the real option idea and develop their theoretical backgrounds. Furthermore we investigate the analogy between financial options and real option, which is helpful to understand how ROA can be implemented in real-life projects.

As a starting point it is important to clarify what is meant with a real option. Based on Copeland and Antikarov (2001) a definition of real option might be:[72]

Figure 3.1: Definition of a real option.

> **A real option is the right, but not the obligation, to take an action on an asset in place (e.g., deferring its purchase, expanding it, contracting it, or abandoning it) at a predetermined cost called the exercise price, for a predetermined period of time, that is, the life of the option.**

Source: Based on Copeland and Antikarov (2001), p. 5.

The link between managerial flexibility and the term real option can be seen in the derivation of the word itself: "Option" is derived from the Latin *optare*, meaning to choose, to wish, or to desire, whereas "real" is etymologized from the Latin *realis*, which stands for fixed, permanent, or immovable things, in opposition to illusory things. An option represents the flexibility to choose after the revelation of information and since real options depend on the value of real assets, exercising a real option is the act of choosing, or the freedom of alternatives on a set of actions to perform on a real asset. Using the graphical representation of the DTA in subchapter 2.3.5, the situation could be depicted as in Figure 3.2 according to Robinson (2003).[73] On the left side of the figure we see an investment without flexibility (which we call asset in place), i.e. as if it were an all-or-nothing irreversible decision. The decision whether to invest or not is made with the current available information and cannot be changed afterwards. By contrary on the right side, we have an investment whose decision can be delayed after the information about a specific outcome-influencing variable is disclosed. Clearly, this is the more realistic case in practice. With additional information, the uncertainty is being resolved or reduced, and a decision is being taken on a more reliable basis. Consequently, the possibility of deferring the investment is valuable and represents a real option.

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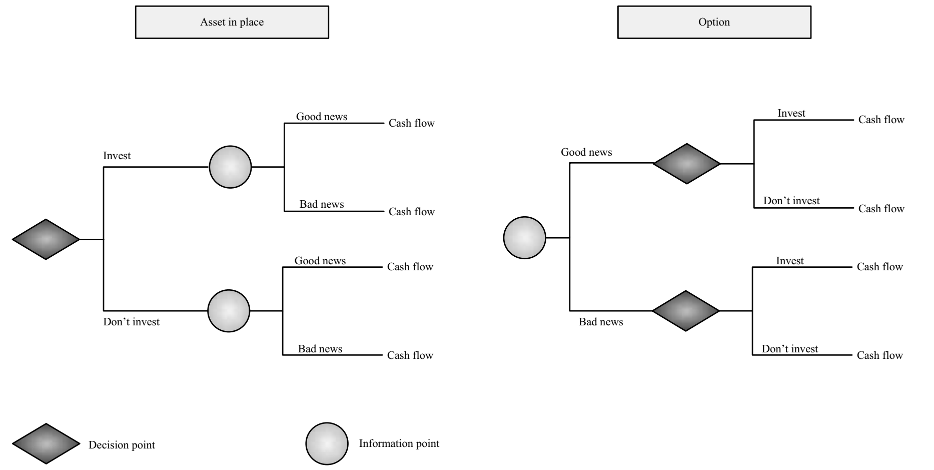
[72] See Copeland and Antikarov (2001), p. 5.

[73] See Robinson (2003), p. 4.

Figure 3.2: An asset in place compared to a real option.



Source: Based on Robinson (2003), p. 4.

The earliest records of transactions that had features of option contracts come from around 2000 B.C. in the Middle East.[74] Einzig (1970) reported about a document originating in Assyria in the first year of Hammurabi's reign (21st century B.C.) and preserved in the British Museum, authorizing the *"bearer to receive in 15 days in the City of Eshama on the Tigris 8½ minae of lead deposited with the Priestess of the Temple"*.[75] This type of business can be reasonably seen as the first evidence of an option trading. It was an option on an exchange rate used in commerce between Assyria and Babylonia, as lead was the currency of Assyria, whereas silver and barley were the standards of value and media of exchange of Babylonia.[76] The oldest recorded story of a real option, nevertheless, is probably the one of Thales of Miletus.[77] Amongst his works on any type of natural science and humanities Thales of Miletus also did research on meteorology. He associated weather with the movement of the stars and planets. Several anecdotes suggest that Thales was not solely a thinker; he was involved in business and politics, and so it came that one day he used his superior weather forecasting abilities to do some business on olive oil. After predicting the weather and a good harvest for a particular year, Thales bargained with the owners of the olive presses to grant him the right to rent all the presses in Miletus for the common rate (i.e., a small

[74] For an interesting historic review about real options and options generally see also Brach (2003), p. 1ff.

[75] Einzig (1970), p. 15.

[76] See Einzig (1970), p. 15.

[77] Sophist and philosopher who lived on the island of Miletus in the Mediterranean sea from 624 B.C. – 546 B.C.

amount of money) during the harvest season. As the harvest exceeded all expectations, the olive growers rushed to the presses. Thales paid the usual rent to the press owners – as stipulated in the contract – and charged the olive growers, who needed to use the press, with the a higher market price reflecting the extraordinary high demand. Thales made a fortune and demonstrated to his fellow Milesians that he could use his intelligence to enrich himself, although he principally was not interested in worldly wealth. Clearly, Thales assigned a specific value to the flexibility of having the exclusive right to rent the olive presses during harvest time. This value was represented by the price he paid in advance for renting them later. The underlying risky asset in this case was represented by the volatility of the price for the press rental and the time to maturity was the time until the olive harvest.

Coming back to modern times the theoretical literature on real options begins to appear in the late seventies. On April 26, 1973 the Chicago Board Options Exchange (CBOE) started its operations, coinciding with the publication of the Black and Scholes seminal paper on the pricing of call options on shares of stock; the birth of a greater extent of work upon derivatives began then.[78] In line with this new research area, academics started viewing corporate securities as an option on the assets of the firm.[79] Four years after Black and Scholes' work, Stewart Myers published a paper "*Determinants of Corporate Borrowing*" in which he explored the concept that financial investments generate real options and also coined the new term "*real options*".[80] He stated that the valuation of financial investments opportunities using the Discounted Cash Flow (DCF) approach, could lead the decision maker to ignore the value of flexibility arising when investing in risky investment projects. Tourinho (1979) was one of the first to conduct some practical applications of real options showing that natural resource reserves can be viewed as options to produce the resource.[81] Kester (1984) ensured broader dissemination of the real options approach when he published his work on growth options in the Harvard Business Review.[82] Brennan and Schwartz (1985) expanded Tourinho's work by publishing a paper on the natural resource valuation of a copper mine.[83] Amongst the most cited papers of the eighties, McDonald and Siegel (1986) on the option to delay takes an important place as it paved the way to the valuation of one

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[78] See Black and Scholes (1973)

[79] See for example Merton (1973).

[80] See Myers (1977).

[81] See Tourinho (1979).

[82] See Kester (1984).

[83] See Brennan and Schwartz (1985).

of the most frequently occurring options – the option to wait.[84] Myers (1987) elaborated on his first idea, adding to the valuation of corporate securities also the valuation of corporate budget and investment decision. He wrote: *"standard discounted cash flow techniques will tend to understate the option value attached to growing profitable lines of businesses."*[85] This study pointed out that some projects which would not be undertaken because of their negative NPV could nevertheless be valuable, if seen as a door opener to positive future cash flows. This research, which built the base for the application of option pricing analysis outside the world of finance, will be the main theme of the next subchapter 3.2. Kulatilaka and Marks (1988) were the first to explicitly take real option analysis into the strategic valuation of flexibility.[86] Pindyck (1988), in his publication on the irreversibility and capacity of choice, opened the discussion regarding another major weakness of the NPV approach.[87] The NPV rule fails to recognize irreversibility as a cost, i.e., the cost of giving up flexibility by committing resources irreversibly. Pyndick developed his work together with Dixit into a seminal book – *Investment under Uncertainty* – which was published in 1994 and focuses on a continuous-time framework, using the partial differential equation (PDE) to derive the valuation of real options.[88]

During the time between Pyndick's paper and Pyndick and Dixit's book, the real options research began also to move towards a new discipline in regard of real options theory, namely towards game theory. Among the more explicit game theoretic approaches Trigeorgis (1991a),[89] Smit and Ankum (1993),[90] and Grenadier (2000)[91] should be cited. These works take into account that an investment decision is influenced not only by managers inside the company, who can react as new information becomes available, but also by the actions of competitors or suppliers, and that their action can in turn be influenced by – as well as influence – the actions of the manager within the company. In 1996, Trigeorgis published his first book on real options, *Real Options – Managerial Flexibility and Strategy in Resource Allocation*.[92] This book is a financially oriented review of the real option literature and its applications and

[84] See McDonald and Siegel (1986). Also for the case of Switzerland we found in our survey that the option to wait occurs often in practice as shown in subchapter 4.5.4.3.

[85] See Myers (1987), p. 13.

[86] See Kulatilaka and Marks (1988).

[87] See Pindyck (1988).

[88] See Dixit and Pindyck (1994).

[89] See Trigeorgis (1991a).

[90] See Smit and Ankum (1993).

[91] See Grenadier (2000).

[92] See Trigeorgis (1996b).

concentrates on modeling as well in discrete as in continuous time and on the theory of real options in general.

It was from approximately the mid nineties that the first documented cases of the application of the ROA in real practical cases were published. Some important examples were the examination of the application of the ROA to Shell by Kemna (1993)[93], Nichols (1994)[94] on the Merck case, Faulkner (1996)[95] on R&D applications at Kodak and Stonier (1999)[96] on the Airbus case. In about the same time Luehrman published two articles in the Harvard Business Review that tried to make the ROA more accessible to practitioners getting away from the complicated mathematical approach and putting the whole conceptualization in a metaphorical framework – the Tomato Garden approach.[97] One year later a third book about real options came out: Amram and Kulatilaka (1999b) published a book aimed exactly at the management level that included many examples and applications of the ROA.[98] This was the time when the attempt to propagate the ROA in practice really began. Since then a great number of papers and books on this subject have appeared from the beginning of the twentieth century until now.[99] Some representative examples are Copeland and Antikarov (2001), who published the first book giving guiding advices how to use the ROA in everyday decision making including many case histories from their long lasting experience in this field,[100] Mun (2002), describing numerous case studies of various industries (pharmaceutical, oil, gas, manufacturing and technology) and focusing on the qualitative as well as the quantitative aspects of ROA,[101] Copeland and Tufano (2004), who published an article in the *Harvard Business Review* treating "*A Real-World Way to Manage Real Options*", [102] and finally Smit and Trigeorgis (2004) which came back to real options and game theory with their work "*Strategic Investment: Real Options and Game*" representing a major step beyond standard real options or strategy analysis and rounding up one of the two main directions in ROA literature of this new century.[103] Besides some niche application, indeed, the main themes for the present and

[93] See Kemna (1993).
[94] See Nichols (1994).
[95] See Faulkner (1996).
[96] See Stonier (1999).
[97] See Luehrman (1998a, 1998b).
[98] See Amram and Kulatilaka (1999b).
[99] See also the extended review on ROA application areas in chapter 3.7.
[100] See Copeland and Antikarov (2001).
[101] See Mun (2002).
[102] See Copeland and Tufano (2004).
[103] See Smit and Trigeorgis (2004).

the near future will still remain the combination of ROA and *Game Theory* and the simplification and standardization (as much as it is possible) of the framework for making ROA "palatable" to the practitioners' taste and, therefore, to guarantee a wide utilization of it as well as further developments.[104] Additional recent books on that topic are, for example, "*Real Options in Practice*" by Brach (2003) which is founded on the corporate application of the Real Options Analysis and gives many interesting examples of real options implementations for several areas,[105] or Hommel (2003), who in his book "*Reale Optionen Konzepte, Praxis und Perspektiven strategischer Unternehmensfinanzierung*" pools several interesting articles on practical and theoretical applications and challenges of the Real Options Analysis.[106]

As it can be seen after this comprehensive journey through the development of the Real Options Analysis, only in the last years are efforts being intensified to bring this new paradigm to work in a practical environment. This dissertation is intended to be a further piece of work in this area, trying to "translate" the theoretical language into daily business economic jargon and, in doing so, dismantle some of the hindrances for the real-life application of the ROA. The next chapter is aimed at explaining some basics needed for this purpose.

3.2 Fundamentals of the Real Option Analysis idea

As already noted in the previous chapters, the idea to apply option thinking to investment decisions stems from the fact that the NPV has been recognized to have some flaws if used for projects with dynamic choice opportunities during their lives, such as most projects in the real world.[107] The next subchapter will therefore be dedicated to compare the real option valuation with the net present value approach, to detect the NPV's flaws and to show when a combination of the two approaches can lead to a better decision. Moreover, some important project characteristics are discussed which have to be met for ROA to be of any use. As there are cases where these characteristics are more pronounced than others, it is natural to ask the question after the intensity of these characteristics, in order to detect the most beneficial application areas for a ROA. These basic characteristics are presented in subchapter 3.2.2 and are

[104] This can be also seen from the subjects treated at the international real options conference which is the largest and most important yearly conference on the topic of real options theory and practice. See www.realoptions.org.

[105] See Brach (2003).

[106] See Hommel (2003).

[107] See Myers (1987), p. 13.

important for the further purpose of this thesis. In chapter 5 the model for deciding if a ROA application is or is not useful for a specified investment project is constructed on these fundamentals.

3.2.1 Comparison of the Real Option Analysis and the Net Present Value

As already pointed out in chapter 2.3.1, the net present value methodology looks at projects in determining their future cash flows and discounting those to today's value at a project-specific risk-adjusted discount rate that reflects the perceived risk of these cash flows. Risk is measured indirectly in that sense that the risk-adjusted rate of return stands for the opportunity cost of capital, which is the rate of return an investor expects from traded securities with the same risk as the project being valued.[108] This is not the case with the ROA, where risk is measured in a direct way by assigning the appropriate probabilities to the expected future payoff of the investment as if it were risk-free. This expected future payoff, the so-called risk-neutral payoff, reflects all potential risks of the project, i.e., shows all possible ways the project can develop, making it possible to discount the payoff at the risk-free rate and to get today's value of the investment option. The exact way to assign risk-free probabilities to future expected payoff will be explained in more detail in chapter 3.3.2 by means of an example.[109]

Moreover, the NPV implicitly assumes that no decision or actions will be taken in the future once the project starts to take place, that is, it assumes that all expected cash flows are precommitted. The ROA, in contrast models optimal future actions in response to the resolution of uncertainty and, by adopting the concept of replicating portfolios, it meets the no-arbitrage condition and guarantees that the resulting present values conform to the law of one price.[110]

Assuming a rigid and inflexible path forward like in the NPV approach brings up also other differences. For instance, NPV mostly ignores that risk patterns of the project can change over time and therefore require also changing discount rates. ROA takes account of managerial actions, which can be undertaken during the life of a project to react to future uncertainties and, in this way, mitigates risk and preserves or even increases value. This fact will be reflected also in the risk-return profile. Behind a FCF forecast for a NPV valuation there is always a probability distribution.[111] Usually, for

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[108] See Myers (1998), p. 119.

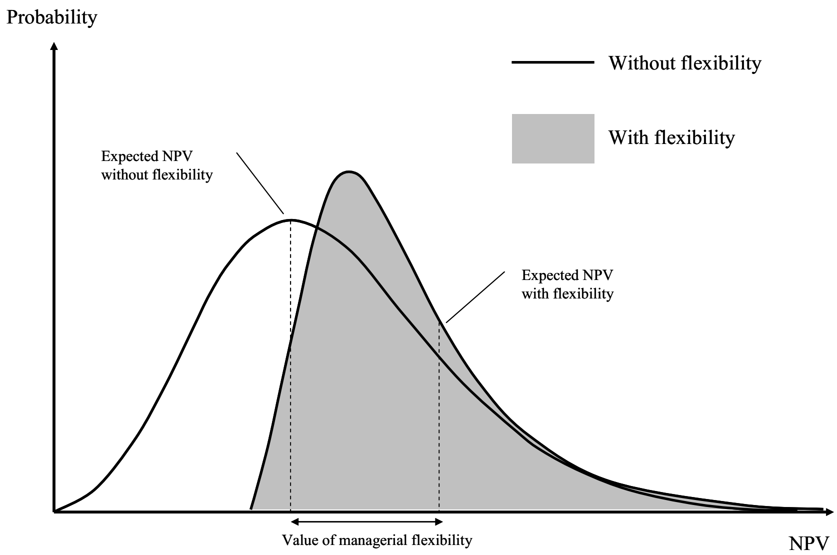
[109] See Brach (2003), p. 5.

[110] See Copeland *et al.* (2005), p. 310 and chapter 3.3.2 for the no-arbitrage condition.

[111] See Volkart (1999), p. 49.

matter of convenience, this is a Gaussian normal distribution, which implies symmetry in the possible outcomes of the cash flows.[112] In the real option framework, on the contrary, the management can take actions during the project's life, for example, expanding production to take full advantage of the upside potential or, if the market develops negatively, shrinking production to mitigate loss. This particular changes the distribution of the expected cash flow and consequently also of the according NPV as depicted in Figure 3.3 making it unsymmetrical, since it limits negative outcomes and enforces the positive ones.[113]

Figure 3.3: Distribution of cash flow seen through NPV and ROA lens.



Source: Based on Trigeorgis (1996c), p. 123.

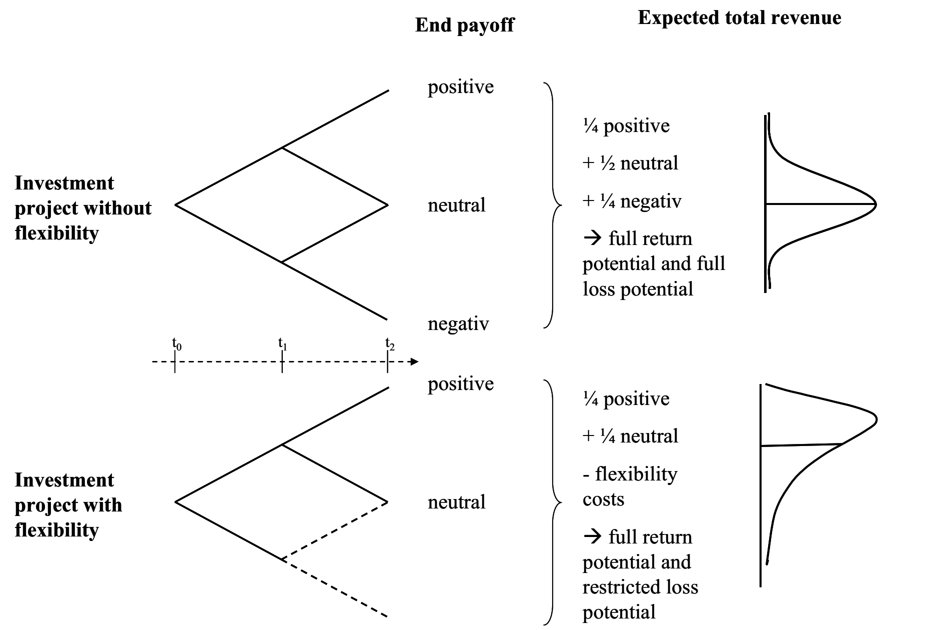
This fact can also been demonstrated in the valuation of an investment project in a two-period case, as illustrated in Figure 3.4. The upper binomial tree in the figure represents a project without flexibility. The project's outcome can go either up or down in both time periods. Accordingly, the outcome at the end of period two can be either positive (i.e. two times up), neutral (one time up and one time down) or negative (two times down). The middle outcome is twice as likely as the other two outcomes because it can

[112] See Bohley (2000), p. 395ff.

[113] See Hommel (1999), p. 11.

be reached in two different ways (either up and down, or down and up). This will result in a normal distribution. The lower investment, by contrast, incorporates flexibility considering the possibility to skip the negative outcomes (depicted in dotted lines). This results in a asymmetrical payoff, whereby the cost for allowing flexibility causes the distribution to attain negative outcomes as well; however, not that high as if the whole negative potential had to be incurred. Therefore, Fischer (2002a) concluded that the NPV on its own is unsuitable for valuing projects under high uncertainty and in the presence of managerial flexibility, as the NPV values the investment of a symmetric project, although most real-life projects are asymmetric.[114]

Figure 3.4: Value of an investment project with and without flexibility.



Source: Based on Fischer (2002b), p. 52.

A further important difference between NPV and ROA refers to the treatment of mutually exclusive projects. If we take the option to defer a project as an example, we can see that the NPV technique leads the decision maker to calculate different NPVs for each deferring possibility, e.g., for one year, for two year's, and so on. Among the

[114] See Fischer (2002a), p. 89.

"different projects" the manager will have to choose the one with the highest NPV as he can defer for one year, or for two years, but not for both.[115] This fact underlines the mutual exclusiveness of the different alternatives. By contrast the ROA calculates one single value for the right to defer and, by adopting state-contingent calculation it further gives a rule to set down the optimal time to defer. Thus, there are no false mutually exclusive alternatives which the decision maker must conceive and select among other future alternatives and to whom he must precommit in the present.[116] Table 3.1 summarizes the differences between the NPV approach and the ROA concerning their risk approach, their handling of flexibility, their assumed cash flow distribution, and their treatment of mutual exclusiveness.

Table 3.1: Differences between the NPV approach and the ROA.

	NPV	ROA
Risk approach	Risk is measured indirectly through the risk-adjusted rate of return.	Risk is measured directly in assigning probabilities to the expected future payoffs.
Handling of flexibility	All expected cash flows are precommited. No actions take place once the project has been started.	Optimal future actions can be modeled in response to the resolution of uncertainty.
Cash flow distribution	Usually a normal distribution of the cash flows is assumed.	Through managerial actions during the life of the project negative outcomes can be skipped and thus an unsymmetrical distribution results.
Mutually exclusiveness of the different starting time alternatives	One starting time must be chosen amongst different discrete alternatives.	One single optimal starting value is calculated. No false mutually exclusive alternatives are being laid out.

In order to use a more formal way to capture the difference between the two approaches we can say that in the NPV formula uncertainty is not explicitly modeled.[117] Instead of accounting for the many different paths of possible FCFs that could turn out between the start and the end of the project, the NPV rule models risk discounting the expected FCFs using only information that is available at the time of discounting. Mathematically this can be expressed as follows:[118]

[115] The different projects refer in this case obviously always to the same project but initiated in different years.

[116] See Copeland *et al.* (2005), p.310.

[117] Obviously the risk-adjusted discount rate in the NPV formula accounts for the business-specific risk the project will incur. However, this reflects only the statistical expectation of these risks. The real outcome could then be effectively higher or lower.

[118] See Copeland and Antikarov (2001), p. 73.

$$NPV_{rule} : MAX_{t=0}\left[0, E_0\left(V_T\right) - I_0\right] \quad \textbf{(3.1)}$$

whereas E_0 stands for the expectation at time t = 0, I_0 is the cost incurred in taking up the project and V_T is the value of the project at the time T

This rule is equivalent to determine the maximum NPV of a set of possible mutually exclusive alternatives. That is, to find out a maximum of expectations. In contrast, the ROA is defined by an expectation of maximums, as shown in the formula below.

$$ROA_{rule} : E_0\left(MAX_{t=T}\left[0, V_T - I_0\right]\right) \quad \textbf{(3.2)}$$

Applying the ROA rule a project is undertaken at a future time t = T (nota bene: when information is available at the future time, T), if and only if $V_T > I_0$, as opposed to the NPV rule which will lead to accept the project in t = 0 if and only if the expectation of the value of the project at time zero is higher than the cost incurring in starting the project, i.e. $E_0(V_T) > I_0$. Both rules will lead to the same result in the absence of uncertainty, as then the value of the project at time T will equal the current expectation of the future value, i.e. $V_T = E_0(V_T)$.

Finally, in referring to notion of standard financial option theory, Chesney (2004) argues that using the NPV approach is equivalent to exercising an American option as soon as it is in the money, and that this would be obviously suboptimal.[119]

All those weaknesses about the NPV rule mentioned above could lead the reader to the conclusion that one should completely replace the NPV criterion with the ROA and, if at all, use the NPV approach only in cases where uncertainty is fairly predictable and no managerial flexibility exists to adapt to it. This, however, would be a big fallacy. As already mentioned in chapter 2.3.1, the ROA builds on the NPV approach and its underlying concept in using the NPV as a base case scenario with no flexibility, including it in a new valuation perspective and taking it to the next level of financial and strategic analysis. A distinct example of what we mean is the Marketed Asset Disclaimer (MAD) presented by Copeland and Antikarov (2001). We will refer to the MAD later in this chapter in more detail when the various approaches for valuing real options are described.[120] Here it should be only briefly mentioned that trying to value an option with the replicating portfolio approach a marketed twin-security is needed in

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[119] The reason that it is never worth to exercise an American call option with no dividends before expiration can be mathematically proven. The time value of possessing the option will result higher than or equal to the intrinsic value at every point in time until expiration. More intuitively, it can be said that holding a stock option is equivalent to holding an insurance against falling stock prices. Exercising the option before expiration would be equal to giving up the insurance which would be always have a positive value or at least zero. See Chesney (2004).

[120] See also chapter 3.5.3.

order to build a so-called risk-free portfolio. Obviously, in the majority of cases, there is hardly another marketed project with exactly the same attributes as the one to be valued. Instead of searching in financial markets for this highly correlated twin-security, Copeland and Antikarov suggest the following solution:

"What is better correlated with the project than the project itself? We are willing to make the assumption that the present value of the cash flows of the project without flexibility (i.e., the traditional NPV) is the best unbiased estimate of the market value of the project were it a traded asset. We call this assumption the Marketed Asset Disclaimer MAD." [121]

Thus, the final conclusion to this question if one should replace the NPV criterion with the ROA is obvious: The NPV approach and the ROA should be regarded as highly complementary techniques and therefore should be used together to ensure a solid decision by the manager who must decide about a project. By no means should the two approaches be seen as mutually exclusive, as the NPV represents an important input for the ROA.[122]

3.2.2 Constitutive characteristics of real option value

Most investment decisions share three important main characteristics: uncertainty, irreversibility and the potential for inherent flexible actions. The degree of the influence of the single characteristics on the value of the project varies from case to case. These three characteristics are constitutive characteristics of a real option as well and, thus, for any investment decision to have option value, these three fundamental characteristics have to be met. For example, even if some opportunities for flexible actions should be given, the additional effort of a ROA may not be justifiable in the absence of irreversibility or uncertainty about the project outcome. If an investment is fully reversible, there is no point in considering uncertainty, no matter how high the uncertainty is, because all the costs of a decision which ex post turns out to be wrong can be reversed.[123] Thus, every single one of these characteristics is of great importance for understanding the value of a real option and will be the principle topic of subchapter 3.2.2. We will explain what they mean exactly and give some examples. These characteristics will build the base for the model in which we propose a way to

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[121] See Copeland and Antikarov (2001) p. 94.

[122] See Van Putten and MacMillan (2004), p. 134 and Trigeorgis (2000a), p. 124.

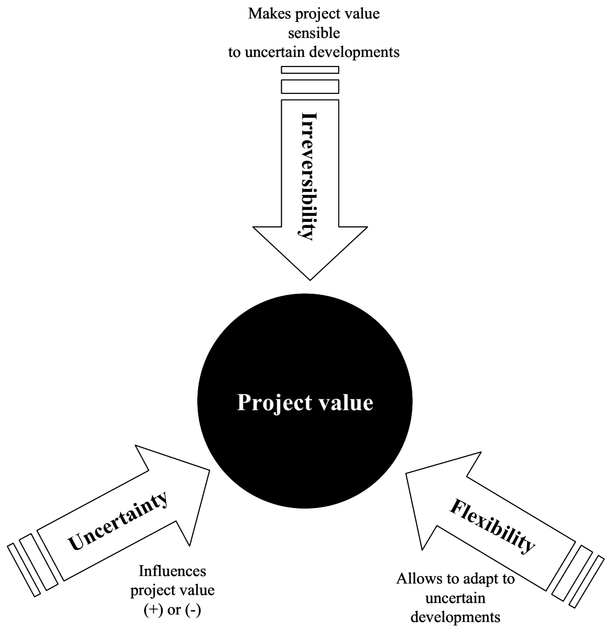
[123] Obviously a fully reversible investment is a theoretical construct and almost impossible in practice. However, the degree of irreversibility of an investment can change in real-life as well, making it reversible to an almost fully extent or only partly.

determine the relevance of a ROA application. Therefore, we will refer again to them later in chapter 5 when we discuss the model to assess the importance of a Real Options Analysis for an investment project. It should be mentioned at this point that besides these three main constitutive characteristics, there are obviously many other factors which can have influence on the value of a real option as well. Nevertheless, most of them can be related to one of these main characteristics. Furthermore, the importance of uncertainty, irreversibility and flexibility is of a greater extent, as every single one of them represents a condition sine qua non. To say it briefly with an example: There is no sense to meditate about the influence of different uncertainty sources[124] on the value of an option to wait, if we have the restriction that the available budget must be spent today or will completely be withheld by the budget plan makers. Figure 3.5 sums up visually the three fundamental factors which influence every investment project to some extent and, in doing so, give value to the possible inherent real options of the project. The individual factors, which we call "*constitutive characteristics of a real option*", according to Hommel and Pritsch (1999), will be explained in the following parts of this chapter.[125]

[124] E.g., technical uncertainty, uncertainty over interest rate movements, or uncertainty over demand.

[125] See Hommel and Pritsch (1999), p. 123.

Figure 3.5: Linkage between uncertainty, flexibility and irreversibility of an investment.



Source: Based on Trigeorgis (1999b), p. 7.

3.2.2.1 Uncertainty

The real options literature refers to the existence of uncertainty as a prerequisite of real option value.[126] To determine how uncertainty affects the real option's value, we must examine the nature of uncertainty and classify the many different types of it that can arise during the lifetime of an investment project.

To understand the nature of uncertainty, we have to look at it in combination with two other words which are always associated with it, namely risk and ignorance. A decision is called *risky* if both the probabilities and the different states of the outcome that will occur in the future are precisely known, e.g., in throwing the dice one knows that each number will come out with a probability of 16.7%. In contrary, an *uncertain* decision is one where the states of the outcome are known, but the probabilities are not precisely defined. Examples are the outcomes of soccer games, elections or, as in the case of this

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[126] See for example Trigeorgis (1999b), p. 7.

present study, most investment projects. Thus, risk and uncertainty can be distinguished only by the degree with which probabilities can be defined. In case of uncertainty, probabilities are not precisely known but people can form more or less vague beliefs about probabilities. If people are neither able to form any beliefs about probabilities nor about their outcomes, we speak of *complete ignorance*.[127]

The many different types of uncertainty can usually be attributed to the factors over which the decision maker lacks of information and/or control. As there is a wide range of these factors in general, the issue is simplified in grouping the uncertainties by their source, either endogenous or exogenous.[128] Endogenous uncertainty refers to firm-specific uncertainty and is, therefore, influenceable by managers to some extent.[129] Exogenous uncertainty applies to the entire market and is thus not influenceable by the decision makers as all projects, products, and companies are affected by it.[130] Not every uncertainty can be attributed exactly to one specific source, i.e., exogenous or endogenous. Instead, they tend to be either more exogenous or more endogenous. For explaining the influence that uncertainty can have on the option value of a project and to show how managerial flexibility can help to adapt to uncertain developments we propose the uncertainty-mapping in Figure 3.6 based on Micalizzi and Trigeorgis (1999).[131] We will slightly modify it in adding another risk factor and sorting the distinct risk factors by their proximity to either endogenous or exogenous uncertainty. As explained above, the terms risk and uncertainty differ only by the degree with which probabilities of outcomes can be defined. Thus, it is not surprising that they are mostly used interchangeably in the literature and in practice.[132] Micalizzi and Trigeorgis use the term "map of risk" for their overview of uncertainties that influence real option values. It should be therefore explicitly mentioned that we will use the term risk interchangeably with uncertainty as well through the study, in order to adapt with Micalizzi and Trigeorgis, as we base our explanations on their work.

Micalizzi and Trigeorgis show how different real options can be related to a specific uncertainty for capturing the inherent value of active management of a specific risk factor. Obviously not every single risk category is tied in a clear manner to a single specific managerial flexibility or vice versa. Nevertheless, following the explanations of the authors will give some examples which show in which way the possible types of

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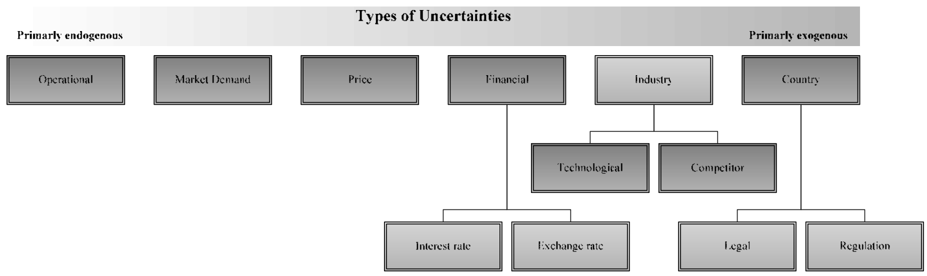
[127] See Aggarwal (1993), p. 16ff.
[128] See Hirshleifer and Riley (1979), p. 1376.
[129] See Hodder and Riggs (1985), p.134.
[130] See Bräutigam *et al.* (2003), p. 4.
[131] See Micalizzi and Trigeorgis (1999), p. 2ff.
[132] See Hertz and Thomas (1983), p. 4.

managerial flexibility can be related to the risk categories discussed. Also Ku (1995) emphasized on purposefulness of flexibility. If there is no purpose to play out the flexibility, there is no reason for having or creating it and, thus, flexibility will be of no value.[133] The different uncertainty categories will represent a purpose which renders a specific managerial flexibility valuable. Mapping flexibilities to risks will be one of the core concepts for deciding whether or not a ROA is relevant for a specific investment. This concept will turn back again in chapter 5 where we will explain in a less abstract and more intuitive way how we would assess the relevance of the application of the ROA for a given investment project, basing the discussion on the relevant flexibilities to play out in case of changes of the relevant risk factors.[134]

Figure 3.6: Uncertainties influencing the real option value.



Source: Based on Trigeorgis (1999b), p. 2ff.

A first risk category, which is to a greater extent endogenous, is the one Trigeorgis and Micalizzi call *operational risk*. Hereby operational risk refers to the variability of business results deriving from the nature of a firm's business activities and is, therefore, of great importance for understanding the role of managerial flexibility within an investment project. A business structure with high operational risks is characterized by a high level of fix costs, which makes it rigid and difficult to modify.[135] In this case, adapting the operations to changing market conditions once the project has been started can therefore be extremely difficult. This gives value to the *flexibility of delaying* a project's implementation and waiting for more information on the evolution of the state, as an immediate investment could bring forth high "reconversion costs". Looking at operational risk in this manner it is intuitive that, for example, the flexibility of *stage*

[133] See Ku (1995), p. 330.
[134] How we want to determine relevant risk factors and relevant flexibilities will be explained at that point in the thesis.
[135] See Damodaran (2001), p. 75.

investments or the *option to grow*, where an investment becomes the basis for an option to acquire the next investment, can also become of great importance as a full-scale outlay does not have to be done in advance. By contrast the types of managerial flexibility relating to operations, such as the option to switch input or output, the option to abandon, and the option to scale the project's size will be practically nonexistent with high operational risk, as these types of options imply a change of the parameter of the ongoing project, which is, by definition, extremely difficult in cases with high operational risk.

A second important risk category for real options application is *market demand risk*, which can derive from either exogenous (consumer preferences) as well as endogenous sources (price and quality). For instance, the degree of uncertainty of the firm is, therefore, also due to uncertainties regarding the variability of consumer preferences and needs which, in turn, determine the volatility of the consumer's demand for the company's product. Thus, companies focusing on the customers' intertemporal variability preferences and needs have the possibility of reducing this risk to some extent once production has started. In this context flexibility to first test the consumer preferences on a small scale and then expand the production, i.e. the *option to expand*, could be extremely worthy. Similarly, a flexibility to change the output product, an *option to switch*, could also help the firm to adapt to varying consumer preferences or product quality changes. Designing the project with the possibility of adapting to changing market demand can therefore be of great importance. Along the same line also the option to abandon (as an extreme case of the option to shrink) can protect from undesirable surprises in market demand decreases. The other three standard managerial flexibilities discussed in this thesis are also important in connection to market demand risk, but are less clearly related to the changes of market demand. The option to wait allows the decision maker to wait and see if market demand is enough high to start a project, while the option to stage permits to test the product with, e.g., only some main features incurring costs for the development of some expensive additional features only when market demand is clearer. Finally the option to grow would help in assessing or at least learning about the market demand in some completely new markets.

A further risk category, which can be driven to some extent by both, endogenous factors as well as exogenous factors, is the *uncertainty about prices*. Depending on how strong the forces of supply and demand influence prices and, consequently, on how strong the market power of the distinct firm is, price uncertainty can be controlled to some extent either by the firm itself or is exogenously given. Analyzing managerial flexibilities associated with the price risk of the underlying good finds traditionally place in real options theory. For instance, this is the case for prices of raw materials like crude oil or iron.[136] Investments in raw materials are usually highly irreversible, and the prices of the raw materials can be very volatile.[137] This circumstance gives a high importance to the *option to expand or shrink* production according to the prices of the produced good. The *option to abandon*, again, as an extreme case of the option to shrink, can therefore also be of value in the case of a product with high price fluctuations. Furthermore, having the ability to wait and see how prices develop on the market, i.e., the option to wait, can be of particular importance, at least at the beginning of an investment in goods with volatile prices in order not to get under water at the start of the project.[138] Other options, such as the option to grow, the option to stage, or the option to switch investments can also add value to project with high price uncertainty but are less directly tied to this specific risk category.[139]

Further, mostly exogenous uncertainties can be broken down into financial risk, industry risk, and country risk. Financial risk and industry risk are primarily exogenous. They are not completely exogenous in that sense that managers have the possibility to move entire markets and thereby change the risk structure of whole industries as the company is a part of the market by itself and, therefore, a source of market uncertainty.[140] *Financial risk* itself has two components, namely interest rate risk and exchange rate risk. Interest rate risk comes from a change in market interest rates and affects a project's value in the way that it can create unforeseen opportunity costs and variations of the prices of financial activities. Similarly, a change in exchange rates can generate extra costs for a firm which is exporting output- or importing input goods. As the two types of risk may be interrelated, a clear understanding of financial risk gives to the manager the possibility of identifying further strategic options in order to enhance the total investment value. Such an option could, for instance, be the *option to switch*, which here is seen as the possibility to shift production between two countries whose exchange rates fluctuate, in order to minimize production costs. In this case, this managerial flexibility can create additional value to an investment project.[141] However,

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[136] See Roemer (2004), p. 8.

[137] In this case price uncertainty is mainly exogenous.

[138] Especially in mining, the last two mentioned options (option to abandon and option to restart) are often described in combination as an option to shut down operations and restart. When market prices of the raw material, e.g. iron, is low, the mines are closed (option to abandon), and operations are only restarted (option to wait) when iron prices rise to levels which make it profitable again to re-open the mine. This combination of options is also referred as option to shut down and restart in real option's literature. See for example Brennan and Schwartz (1985).

[139] This comes from the circumstance that some risk-drivers may, of course, be interrelated, as in the case of the price of the good sold and its market demand.

[140] See Courtney *et al.* (1997), p. 74ff.

[141] See Trigeorgis (2000a), p. 3.

at this point it should also be mentioned that from the perspective of financial markets many risks, among them the exchange rate risk and the interest rate risk discussed in this paragraph, are largely diversifiable from an investor's point of view.[142] That is why for these uncertainties the other types of managerial flexibility seem, at least theoretically, of minor importance for an investment project. This is not the case for the managers of a specific project,[143] which may focus on total risk (including both unsystematic and systematic components).[144] This, again, gives importance to some types of managerial flexibility (above all, the aforementioned option to switch) and allows a reconsideration of the total investment value under flexibility also in the case of financial risks to some extent. Obviously, the managerial flexibility to, for example, switch the production between the two countries is only valuable if it is cost-effective and already planned in advanced; that is, the firm is not forced to shift production on an ad hoc basis at the moment when new information about the exchange rate or interest rate will endanger the project's outcome. This fact must be assessed for every specific investment project and every type of managerial flexibility by its own, which makes a general discussion impossible.

Another mostly exogenous uncertainty category described by Trigeorgis is the so-called industry risk. Industry risk is determined by two additional types of risk: competitor risk and technological risk.[145] *Competitor risk* comes out of the fact that market movements originated by competitors will have consequences on the industry structure and the cost-earnings of every firm in the same industry.[146] Competitor risk can have a negative influence on the value of the option to wait, in contrast to the general perception of risk influence. Management may need to be ready to exercise early when another competitor enters the market. This diminishes the value of the option to wait and may require management to undertake additional strategies and create new flexibilities to act quickly as markets evolve.[147] This circumstance of interactive competition makes other types of managerial flexibility highly valuable in an investment's context. Managers who are ready to react to a competitor's action will have an advantage which must be considered in valuing a project. Such valuable managerial flexibilities can be integrated into the project, e.g., in the form of an *option to grow* (for example, when a manager might wants to test the competitor's reaction when entering a new market), an *option to stage*,

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[142] See Hodder and Riggs (1985), p. 134.

[143] Or other groups which have interests which are not easily diversifiable in a CAPM's sense like creditors and suppliers.

[144] See Hodder and Riggs (1985), p. 134.

[145] Also called competition risk.

[146] For example, the market entry of a competitor can bring down prices.

[147] E.g., investment in people, trainings, systems, or new distribution channels.

an *option to scale*, an *option to switch*, or an *option to abandon* the project. Depending on the competitor's action, one can choose, for instance, to switch the product and re-position it, expand the scale of the project or shrink it, even to complete abandonment. Like already mentioned in the case of financial risk these different types of options are only of value if they are planned actively at the beginning of the project and not if they are simple reactions because one is forced to do so by competitors.

Technological risk is in some degree similar in its effects on project revenues like competitor's risk. It can be deemed as a combination of the factors that can cause a firm's loss of competitiveness, e.g., a malfunctioning product, a missing technology which could reduce production costs, or a faster means of transportation which is not yet available to the firm. This type of risk, which belongs primarily to the sectors characterized by continuous technological innovation, is an immense source of applications for a ROA insofar as the process of innovation is, by definition, uncertain, and the question about the timing for a new investment is crucial, not only at the beginning of an innovation project, but also considering an investment into a next development step. Examples for such investments might be R&D projects or the development of a new medicine in the pharmaceutical industry. From this perspective ROA offers important advantages over traditional valuation methods in considering different types of managerial flexibility. Considering the *option to wait* can help define the most advantageous time to invest or to take the next step of an investment if the total investment is divided in different investment tranches, i.e., *option to stage*. In this sense, too the *option to expand/shrink* or the *option to abandon* is of great importance. If a newly developed product, whether it is a specific software or a medicine etc., will, e.g., become obsolete very quickly, a manager might wants to shrink the scale or abandon the investment project. This situation can arise in branches with a high level of technological risk. For the *option to switch*, we see also a certain importance insofar that technological risk can, e.g., make a specific input factor production method very expensive, so the manager may wants to change the input factor or the production method with a more cost-effective one. As it was the case for many of the other types of risks also, the *option to grow* can help test and learn about technological risks in other branches or countries that could be the target of a firm that wants to expand its business activities. This could be the case, e.g., for an oil company that wants to examine a new region for exploiting new oilfields and is unsure about the quantity of oil in this new region.

The last category of exogenous uncertainty is *country risk*. Country risk is a very large risk category and covers, in addition to political risks such as potential wars or riots, also regulatory, taxation, and legal issues, as well as natural phenomena (climate and natural hazards), infrastructure uncertainty, and social risks.[148] Valuable real options in this case may be the possibility to *scale* or *stage production* or *abandon* the project, in the case of regulatory issues. Along the same line, if a regulatory or political question which could affect the project's revenues is not yet fully discussed, the *option to wait* with the start of the investment could also be of value. Furthermore, the *option to switch* to another country in case of political troubles could also prevent the company from major losses.[149] There is to say that a country switch is obviously only of value if it is already implemented in the design of the project and not merely forced by the foreign government. Finally, the *option to grow* is an important application of managerial flexibility to respond to country risk, because an investment seen as a growth opportunity in an other country could help gather a lot of valuable information about the new business environment and, in doing so, provide the firm with more certainty in case of a wider scale expansion to the other country.

We elucidated the categorization of uncertainties by Micalizzi and Trigeorgis to show in which cases the utilization of a specific real option could be of great importance in assessing the value of an investment project. There is to say that there are many other categorizations that could be used and many other types of managerial flexibility that could be modeled in a ROA. In that we try to conduct the discussion in a more general way, we considered only broad risk categories that are less firm-specific and could arise in varied extents in many different industries. The described risks and the association to specific types of managerial flexibility are therefore first of all examples which could be carried forward to many other investment situations. The main point of this chapter was to show how the different sources of endogenous and exogenous uncertainties could be related to valuable flexible managerial actions. An overview of the uncertainties discussed in this dissertation, their possible associated real options and their importance for a specific uncertainty category are presented in Table 3.2. Black circles represent an important link between the given uncertainty and the related flexibility, white circles a "softer" importance, and the empty cells of the table stand for rather unimportant flexibilities in regard to the given uncertainty. In chapter 5 we will show in a more concrete way how we would differentiate between relevant and irrelevant uncertainties and flexibilities for our purpose of assessing the relevance of the application of the ROA.

[148] See Bräutigam *et al.* (2003), p. 6.

[149] See Kogut and Kulatilaka (1993), p. 6.

Table 3.2: The influence of uncertainty on the relevance of a specific real option.

important ● rather important ○ rather unimportant […]

		Option to..					
		..wait	..stage	..expand/shrink	..grow	..switch	..abandon
Uncertainties	Operational risk	●	●		●		
	Market demand risk	○	○	●	○	●	●
	Price risk	○	○	●	○	○	●
	Financial risk					○	
	Competitor risk		●	●	●	●	●
	Technology risk	●	●	●	●	○	●
	Country risk	○	○	○	●	●	○

3.2.2.2 Irreversibility

The concept of irreversibility was originally developed from the economics of environmental preservation literature. So Arrow and Fisher (1974) defined irreversibility as the impossibility to reverse or correct a decision with no cost.[150] In case of investments, a decision to undertake a project carries along expenditures which cannot be reversed anymore, i.e. sunk costs. Even if returning to the initial state is possible, in most cases it is costly and not completely obtainable. Most investments are thus, at least partly, irreversible.[151]

If all costs of an investment could be fully reversed, there would be no point in caring about uncertainty, as the complete outlay of money could be regained in case of a negative development of the project. Irreversibility makes thus investment sensitive to uncertainty.[152] Irreversible investments that can be deferred are affected by uncertainty inasfar as uncertainty creates additional opportunity cost in investing now, rather than waiting for future information before committing to resources.[153] Empirical evidence

[150] See Arrow and Fisher (1974), p. 314ff.
[151] See Dixit and Pindyck (1994), p. 8.
[152] See Pindyck (1991), p. 1110.
[153] See Pindyck (1993), p. 273.

shows that the influence of uncertainty on the option to wait depends positively on the degree of decision irreversibility. This means that, for a fixed level of uncertainty, the more irreversible a project is, the more valuable an option to wait will be and, thus, the longer a manager will wait to commit.[154] The ROA considers these dependencies in accounting for the value of the option to wait.[155] Thus, since the degree of irreversibility can have great effect on the decision to invest in altering the value of the investment as well its timing, we should investigate the reasons that cause investments to be irreversible.

A first cause can be found in the cost structure of a company. A firm structure with a high degree of fixed costs compared to their variable costs tends to be rigid and difficult to modify. This means that the "reconversion cost" will be high if the firm has to sell its investment to adapt to changing market conditions.[156] Damodaran (2001) defined the *operating leverage* as the ratio between fixed and variable costs.[157] Consequently, investments with a high operating leverage, i.e. those that show a high percentage of fixed costs compared to variable costs, are likely to be irreversible to a greater extent.

A second reason for irreversibility is the *inefficiency of the second-hand market* and could be explained by means of the "lemon" effect studied by Akerlof (1970).[158] Akerlof argued that, in a second-hand market, given the existence of quality differences which cannot be identified by the buyer, the quality decreases, the market gets more illiquid and as a last consequence of this phenomenon it can even collapse. Akerlof explaind this effect using as an example the market for second-hand cars and building on a classical effect described in principal-agent-theory, namely the adverse selection problem. As the buyers of used cars cannot asses the quality of the cars, that is they cannot distinguish between bad quality cars (lemons) and good quality cars, they will only pay an average price for every second-hand car on this market. The sellers with good quality cars will be reluctant to sell good cars for an average price. So only the average and low quality cars will stay in the market, which, in turn, will lower the average price offered to the buyers. This process can go on as until the market collapses. In a market with such a "lemon problem", even second-hand goods with above-average quality or non-specific goods, like office-equipment, cars, or computers, are hard to resell at their original price. This property of the second-hand markets thus, makes an undertaken investment at least partly irreversible.

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[154] See Folta *et al.* (2001), p. 23.

[155] See Hayes and Garvin (1982), p. 78.

[156] See Micalizzi and Trigeorgis (1999), p. 2.

[157] See Damodaran (2001), p. 75.

[158] See Akerlof (1970).

An important cause of irreversibility is the *degree of the specificity* of the investment goods, whereby it can be distinguished between firm-specificity and industry-specificity.[159] Marketing and advertisement expenses, e.g., as well as costs to train employees, are of specific use for the company itself; these costs are sunk costs and cannot be reversed anymore once paid. A similar situation can apply for industry-specific investments. For instance, an industrial coffee roasting machine can only be used to roast coffee and can, thus, only be sold to other coffee roasters. If the investment is seen badly by one firm in the industry, it is likely that other firms will view it as a bad investment too, given a more or less competitive market. This makes the investment in equipment hard to resell at its original price and, thus, partly irreversible.

Furthermore, irreversibility may arise because of *transaction costs*. As a matter of fact, a sale of an investment good causes several costs, such as search costs and the costs for the realization of the sale negotiation, the form of contract, the contract conclusion and the sale execution.[160] These costs cannot be regained if a manger wants to reverse an investment, which thus makes the investment partly irreversible.

Finally, irreversibility can also be originated by *government regulations* or *institutional arrangements*. Dixit and Pindyck (1994) noticed that, e.g., capital controls can prohibit the selling of foreign direct investments and the high costs associated with hiring, training and firing employees can make human capital irreversible, too, in this case. Hence in many cases irreversibility affects international investments as well.[161]

We presented some reasons that can cause the irreversibility of an investment. Although these are important reasons and encompass many other situations which can lead an investment to be irreversible, there should be mentioned that the list is not-closing and that there might be further grounds to be considered when assessing the total degree of irreversibility of an investment. In the present study, we will use some of the above mentioned reasons for constructing the model for the relevance of the application of the ROA in chapter 5. In every specific case, though, it is advisable to to think about further reasons in order to assess the full irreversibility degree of a single investment. Thus, the higher the irreversibility turns out to be, the more necessary a differentiated examination of the inherent option value of investment should be taken into consideration. Finally, it should be also mentioned that irreversibility is not only a concept of business life. In fact it is, for example, also applicable to marriage or

[159] See Dixit and Pindyck (1994), p. 3.
[160] See Damisch (2002), p. 72.
[161] See Dixit and Pindyck (1994), p. 8.

affiance in this sense that sometimes it can be very costly to reverse those decisions, and future happiness is mostly uncertain.[162]

3.2.2.3 Potential of flexible actions

Real Options Analysis can only be of relevance if management succeeds in two functions. First, it must be capable identifying and setting up potential flexibilities to respond to evolving events as uncertainty is resolved. Second and utterly important, it must be able to fulfill these actions. Every project comprises a specific potential for these realistic flexible actions. Not all of these possible actions are immediately apparent. Thus, they must be unveiled, structured, and designed into the project's set up. We are of the opinion that it is this initial step, and not the mathematical inexperience, that often creates the hardest stumbling block standing in the way of the application of a Real Options Analysis in practice. We, therefore, propose a framework to identify and structure the flexibility potential of the projects in chapter 5. The theoretical basis is laid following this section where we explain to which indicators we will have to pay attention to determine whether a flexible action is really inherent in a project or not. We base our discussion about potential flexible actions on Ku (1995) who presented indicators of flexibility originated by its definitional elements.[163] The following indicators are individually not sufficient, but together they meet the criteria to capture the potential of flexibility inherent in a project. The seven indicators to be explained in the following are the capability to change, the purposefulness of the change, the size of choice set, the disablers, the enablers, the motivators, and the likelihood of the change.

A central indicator of flexibility is the *capability to change*, which reflects the potential for change available in the future. Flexibility is the property to move from a first period stage to a second period stage, where the first stage is the initial position providing the flexibility which can be realized in the second stage.[164] Flexibility is related to the initial state but measured by the number of states it can move to, that is, the number of choices available in the second stage. An initial position of a project has flexibility if there is at least one other state it can move to, for example, the state "change" and the state "do not change", which is an always to use default option. The level of flexibility is then dependant on the choice made in the first-stage decision, as every subsequent state has its distinct, consequent options.

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[162] See Dixit and Pindyck (1994), p. 24.

[163] See Ku (1995), p. 330 and chapter 2.1 for the definitional elements.

[164] See Hobbs *et al.* (1994), p. 167ff.

The addressed change or transition must be a *purposeful* one. As flexibility is costly, it should be deployed only in response to a stimuli and not accidentally. For our purpose, it should be applied in response to an uncertainty; namely for avoiding negative outcomes in case an uncertainty has bad effects on the outcomes and to profit from a positive outcomes in case the uncertainty has a better influence than expected. In this sense, every uncertainty has a flexibility to respond to, which leads us to an uncertainty-flexibility mapping.[165] Hereby the relevant uncertainties causing the change are called "trigger events". A trigger event has two or more possible states and determines the type of flexibility required. The change is thus a response to the trigger event and is called "decision". In this manner, trigger events affect flexibility decisions. A state that matches a subsequent decision choice is called "trigger state". Just as different trigger events correspond to different types of decisions, different trigger states correspond to different choices. The following example should clarify and recapitulate the main ideas of this concept. Let us assume that the trigger event is the demand uncertainty. In this case, a flexibility to respond to this trigger event could be "purchasing or selling extra production capacity", which represents the decision type. Furthermore, high demand is associated with purchasing extra capacity, and low demand with selling extra capacity. High and low demand, in this case, are trigger states for the decision choice of either purchasing or selling extra capacity, respectively.

Another aspect of flexibility is the *size of the choice set*. Mandelbaum and Buzacott (1990) defined flexibility as the number of options open at the second period.[166] It is important to note that not every choice which is feasible is also likely to be chosen. Therefore, among the feasible choices the size of the choice set, which is of use for our scope to assess the relevance of a ROA application, must be abridged by the unlikely, trivial choices. The criteria for eliminating choices are desirability, quality, and diversity among the choices.[167] In fact, not every available choice is desirable in all cases, e.g., firing 80% of the employees; neither will every choice be of good quality, i.e., will bring an advantage to the decision maker; nor will every choice be that different from another to justify the design of another action flexibility into the project, e.g., the flexibility to expand the capacity by 5% compared to the flexibility to expand the capacity by 6%. In order to operationalize the selection of the decision choice to include in the set of the relevant choices, a range of decision types is needed.

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[165] See Ku (1995), p. 331.

[166] See Mandelbaum and Buzacott (1990) in Ku (1995) p. 332.

[167] This is what we mean when we speak of trivial versus non-trivial types of managerial flexibility actions.

Upton (1984) defined flexibility as *"the ability to change or adapt with little penalty in time, cost, and effort of performance."*[168] The barriers mentioned by Upton (time, cost, effort) make change unlikely to happen as they represent additional costs. Removing these frictional elements, i.e., reducing lead time or response time and reducing the switching costs, will make a change more probable and thus a real option more valuable. Ku (1995) calls these costs, which are only incurred if change takes place, *disablers*.[169]

The above-mentioned costs are not the only costs a decision maker incurs when he is willing to "exercise" flexibility actions. On the one side, there are the disablers, i.e. the cost of fulfilling the change itself. On the other side, there are the *enablers*, i.e., the cost of providing the flexibility.[170] To clarify the concept, we can draw an analogy to fixed and variable costs. While the enabler is a premium cost associated with the first decision, which guarantees the flexibility later on and is, therefore, comparable to a fixed cost, the disabler is more like a variable cost, which may or may not occur, depending on the decision maker's choice. Speaking in option language, we would say that the enablers are the option's price, and the disablers represent the exercise price, which NB in many cases in real investments is rather stochastic than fixed.[171]

Further indicators to assess the potential of a flexible action are the benefits or payoffs associated with available choices. The favorability of flexible choice must be reflected into positive values which are desirable. Ku calls these indicators *motivators*.[172]

To complete the picture of Ku's indicators, the *likelihood* of a change must be appraised. Likelihood is considered as the probability of the occurrence of the trigger state, indicating the probability of the subsequent choice being selected. In Ku's framework, the likelihood is dependent on two factors: first, the disablers (the more difficult and costly the change, the less likely), and, second, the motivators (the better the outcome, the more likely the change).[173]

According to the seven indicators stated above flexibility represents the *potential* or capability to *change* from an *initial position*, but measured by the *number of favorable choices* available in the second position and, further on, whereby positive returns or benefits called *motivators* stand for the favorability. The cost to guarantee future

[168] Upton (1984), p. 77.
[169] See Ku (1995), p.333.
[170] See Ku (1995), p.333.
[171] For readers which are not familiar to the notions of financial option theory the terms "option price" and "exercise price" are explained in chapter 3.3.
[172] See Ku (1995), p. 333.
[173] See Ku (1995), p. 334.

flexibility is captured by *enablers*. The availability of the different decision choices is higher the lower the switching costs and other frictional elements, called *disablers*, will be and vice versa. The type of flexibility is chosen in order to response on a *specified type of uncertainty that triggers th*e subsequent choice. The *likelihood* of the change depends on the probability of the trigger state (the higher the probability of the state the more likely the change), as well as on the disablers (the lower the frictional costs the more likely the change), and on the motivators of the choices (the higher the profits and benefits the more likely the change). Flexibility must be seen in relation to other choices in the first stage. Thus, flexibility increases with the number of choices in the second stage, the likelihood of favorable choices, and the ease of change.[174] If those indicators are met, then it is most likely that a potential flexible action has been identified, and that this flexibility will represent some material value relevant in assessing the value of an investment project.

3.3 Option pricing theory as a starting point for the ROA

As the real option theory is based on the fundamentals of the option pricing theory itself, it is essential to understand how a financial option works to realize the benefits derived from an application of the option pricing theory to real investment problems. Even though we do not want to spend too much time on the technicalities of option pricing, it is important to explain some terminology and some special issues that come up when discussing real options. Furthermore, the comparison between financial and real options will be discussed and the limitations and pitfalls of the presented analogies will be analyzed.

A financial option is a contract that provides the holder with the right to buy or sell a specified quantity of an *underlying* asset at a fixed price (the strike price or *exercise price*) at or before a specified date (the *expiration date*).[175] This fixed length of time is also referred to as *maturity of the option*. The option gives the holder the right to execute the action (buy or sell the underlying asset) or leave it and allow the option to expire. Thus, the option is a right and not an obligation. For acquiring this right, the option holder has to pay an *option price*.[176] There are two basic types of financial

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[174] See Ku (1995), p. 334.

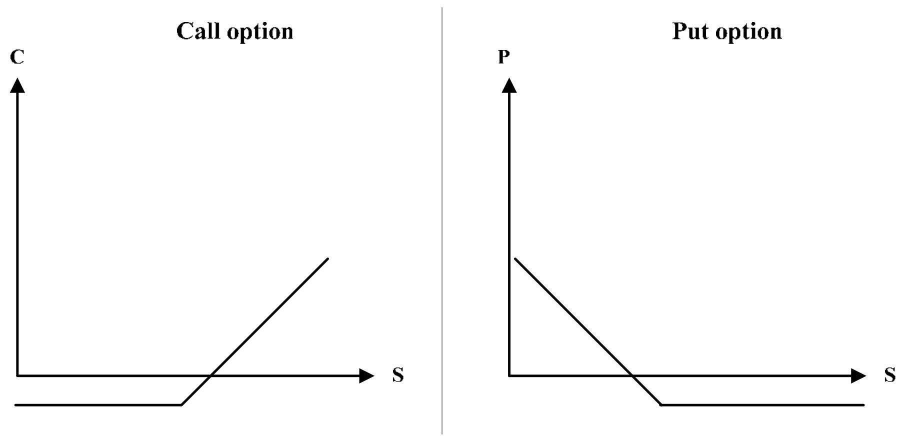
[175] For the following basic explanations on option theory we will refer to Hull (2006), p. 181ff.

[176] Strictly speaking, there are also options which are “free”. For instance, “employee stock options”, which must not be paid in cash because they are integral part of the salary of some employee, or “rights issue”, which are cost free in case of the dilution of equity in a company’s capital increase.

options, *call options* and *put options*, which are referred as an option class. A *call option* represents the right to buy the underlying asset, whereas the *put option* stands for the right to sell it.

With respect to the call option, if at the expiration date the value of the underlying asset is less than the strike price, the option is not exercised and expires as worthless. If, by contrast, the value of the underlying asset is higher than the strike price, the option holder exercises the option, buys the underlying for the specified exercise price, and takes in the difference between the current price of the underlying and the exercise price specified in the option contract. Thus, the net profit on the investment will be the difference between the current price of the underlying and the exercise price, diminished by the price paid for the call option. Figure 3.7 illustrates the net profit situation at maturity for a call option and for a put option.

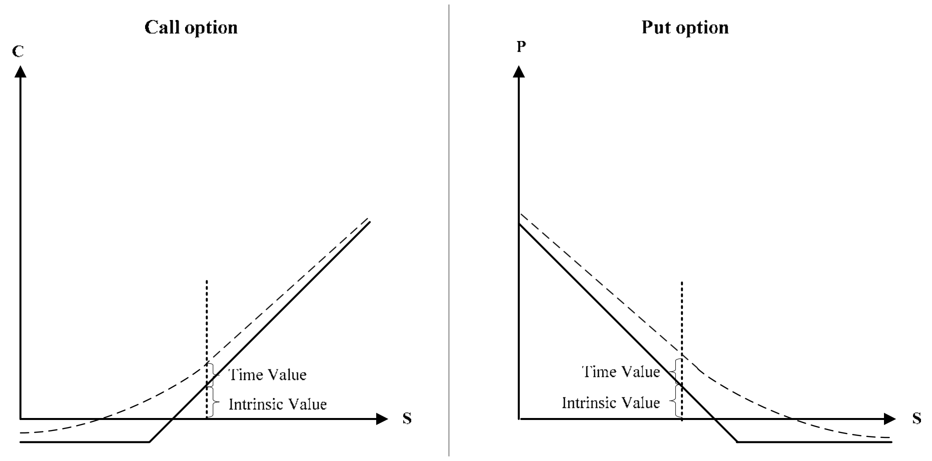
Figure 3.7: Net profit for buying a call option or a put option at maturity.



Source: Based on Hull (2006), p. 182-183.

If S is the price of the underlying asset and X is the exercised price, a call option is referred to as *in the money* (itm) when S > X, as *at the money* (atm) when S = X and as *out of the money* (otm) when S < X. The opposite holds for put options, where the put is itm when S < X, atm when S = X and otm when S > X. The *intrinsic value* of an option is defined as the maximum between zero and the value if the option were exercised immediately. This means max [S-X, 0] in the case of a call option and max [X-S, 0] in the case of a put option. These statements are valid at maturity. Before maturity the option is said to have *time value*. This means that, as there is still time for the underlying to move, at this point the option must have a higher value than its actual intrinsic value.[177] This probabilistic value is called *time value* and depends on the time to expiration as well as on the *volatility* of the underlying's price. The intrinsic value and the time value together build the value of the option. As time moves towards maturity, the time value tends to decrease, ceteris paribus, because the chance of an additional upward movement decreases as well. At maturity, the time value will be zero and the option value will equal its intrinsic value, or zero if the option is at or out of the money. Figure 3.8 exhibits the price of a call and of a put option as a function of the underlying price. The intrinsic value and the time value of the option can be recognized as the vertical distance from the x-axis to the straight line (intrinsic value) and vertical distance from the straight line to the dashed line (time value), whereby the straight line represents the value of the option at maturity and the dashed line its actual value.

Figure 3.8: Intrinsic value and time value of call and a put option.



Source: Based on Cox and Rubinstein (1985), p. 155.

European options are options which can be only exercised at maturity, whereas *American options* can be exercised at any time until their expiration date. This circumstance makes American options more valuable compared to European options.

[177] As an option is a right but not an obligation, the downward movements do not concern the option holder, whereas he can fully profit from every upward movement.

Most of the options that are traded on exchanges are American options.[178] Nevertheless European options are of great importance as their analysis is much easier than the analysis for American options and many properties of an American option can be derived from its European counterpart.[179]

Besides the simple options discussed above, there are also more complicated options that often arise especially in Real Options Analysis. A *compound option*, for instance, is an option on an option.[180] This means that the underlying of a compound option is another option, e.g., a call on a call, or a put on call, etc. This is often the case when describing real options as in the case when an option to expand the product capacity of a project can depend on a foregoing expansion of the same project.[181] Another complex option is the so called *rainbow option*. A simple option is only linked to one underlying, whereas a rainbow option is an option with more than one underlying asset.

3.3.1 Factors affecting the value of an option

The value of an option is determined by six factors related either to the underlying asset or to the financial markets. These factors are:[182]

1. the price of the underlying asset (S)
2. the exercise price or strike price (X)
3. the time to expiration (t)
4. the volatility of the price of the underlying asset (σ)
5. the risk-free rate (r_f)
6. the dividends expected during the life of the option (D)

It is important to have a closer look at those factors since they increase or decrease the value of a financial option, as well as the value of a real option. These factors are also of relevance in deciding whether or not a detailed ROA should be performed for a given project. This is obviously because it would make more sense to devote limited

[178] See Hull (2006), p. 181. The same applies for the great part of the real options as well. Normally investment projects can be initiated (i.e., the option can be exercised) at any time until the expiration of the investment opportunity and, therefore, a real option is mostly an American option.
[179] See Hull (2006), p. 181.
[180] See Hull (2006), p. 531.
[181] See Perlitz and Peske (1999), p. 264.
[182] See Hull (2006), p. 205.

resources (time, efforts, and attention for performing a complex ROA) to a real option that shows higher potential value than to an option which shows lower potential value.[183]

As a financial option is written on an underlying asset, the value of the option is dependent by definition on the *current price of the underlying asset*. In the case of a call (put) option, the option value increases (decreases) with a higher price of the underlying and decreases (increases) with a lower price of the underlying.

The *exercise price* or *strike price* represents the cost an option holder has to incur in order to exercise the option. In the case of a call option, where the holder has the right to buy the underlying asset, the option value declines with an increasing exercise price and vice versa. In case of the put, where the holder has acquired the right to sell the asset, the value of the option will increase as the strike price increases, whereby the put value will never exceed the value of the exercise price itself.

The longer time to maturity, the more valuable are both American call and put options. This stems from the fact, that with an option with a longer *time to maturity*, the option holder has more time to wait and see if profit can be realized from an upward movement of the underlying's price. This relation between time and value, however, is not correct for European options. As they can be exercised only at maturity, it can be the case that, for a European call, an option with a shorter time to maturity is more valuable than one with a longer time to maturity when a large decline of the underlying price is expected between the two expiration dates.[184]

The *variance in value of the underlying asset* is a measure of how uncertain the future movements of the underlying's price are, and is therefore used to quantify the risk. The higher the variance the more valuable both call and put options. At first glance, it may seem illogical that an increase of risk should increase value. Options are different from other securities in that the option holder can on the one side never lose more than the price of the option, and on the other side fully benefit from every upward movement of the underlying's price.

The effect of the *risk-free rate* on the value of a call or put option is more ambiguous than the effect of the other factors discussed until now. With increasing interest rates in the economy, the expected growth rate of assets tends to increase, while the present value of all future cash flows received by the holder of the option decreases. Thus, as the risk-free rate increases, the value of a put option decreases, other than with a call

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[183] We will explain what we mean in more detail in chapter 5.3.

[184] See Hull (2006), p. 206.

option, where the first effect tends to increase the value and the second effect tends to decrease it. Since the first effect is always larger than the second, the call value always increases with a higher risk-free rate. Note that those considerations are made ceteris paribus. If the interest rate in the economy rises, asset prices in the market tend to fall, and the net effect on options may differ from the one explained above.[185]

As the payment of a *dividend* decreases the price of an underlying asset and an option holder cannot capture the foregone dividend's value, the value of a call is a decreasing function of the size of the expected dividend payments, while the value of a put is an increasing function of the expected dividend payments.[186]

Table 3.3 represents a summary of all discussed factors and their effect on the value of either a call or a put option.

[185] See Hull (2006), p. 208.
[186] See Hull (2006), p. 208.

Table 3.3: Variables affecting the value of a call or put option.

Variable		European call	European put	American call	American put
Current price of the underlying asset	(S)	+	-	+	-
Exercise price	(X)	-	+	-	+
Time to expiration	(t)	?	?	+	+
Volatility	(σ)	+	+	+	+
Risk-free rate	(r_f)	+	-	+	-
Expected dividends	(D)	-	+	-	+

\+ indicates an increasing option price with increasing variable
\- indicates a decreasing option price with increasing variable
? indicates an uncertain relationship

Source: Based on Hull (2006), p. 206.

3.3.2 Valuation of call and put options

There are mainly two principle approaches which are followed to price an option on any underlying asset. The earlier is the *Black-Scholes model* which was derived by Fisher Black and Myron Scholes in 1973 for pricing a European option on a non-dividend-paying stock.[187] The later is the *binomial option pricing model* presented by Cox, Ross, and Rubinstein in 1979 and is a somewhat more intuitive than the Black-Scholes approach because it does not require much mathematical background to be understood.[188] We therefore start by discussing the binomial option pricing model.

3.3.2.1 The binomial option pricing model

The *binomial option pricing model* is based on the following crucial assumptions: the capital markets are frictionless, competitive, and no riskless opportunity can exist. Moreover, the asset price process follows a multiplicative binomial generating process like the one depicted in Figure 3.9A in which the asset, in any time period (from t_0 till

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[187] See Black and Scholes (1973).
[188] See Cox *et al.* (1979), p. 6.

t_6), can move to one of two possible prices.[189] To simplify matters, we use as an example the pricing of a simple European call option on a stock that pays no dividend.[190] Therefore, S in Figure 3.9B stands for the current stock price, which moves up to S_u with the probability q and down to S_d with the probability (1-q). Respectively, the price of the call option with the strike price X is denoted with C. At expiration (in t_1, when the time is over), the call option will denote the maximum between S_u-X or zero in case of a upward movement of the stock price, and maximum between S_d-X or zero in case of a downward movement of the stock price.[191] Thus, as depicted in Figure 3.9B we have two periods of time in which the stock price as well as the price of the call option can have two states, either high or low. We, therefore, can construct a portfolio which will have in both states the same payoff. This portfolio will consist of a specified amount of stocks, plus a single call option. In this way, there is no uncertainty about the value of the portfolio at the end of the second period, and as we assumed that there are no arbitrage opportunities the portfolio must earn the risk-free rate of return. This insight allows us to calculate the cost of setting up the portfolio and, therefore, also the option's price.

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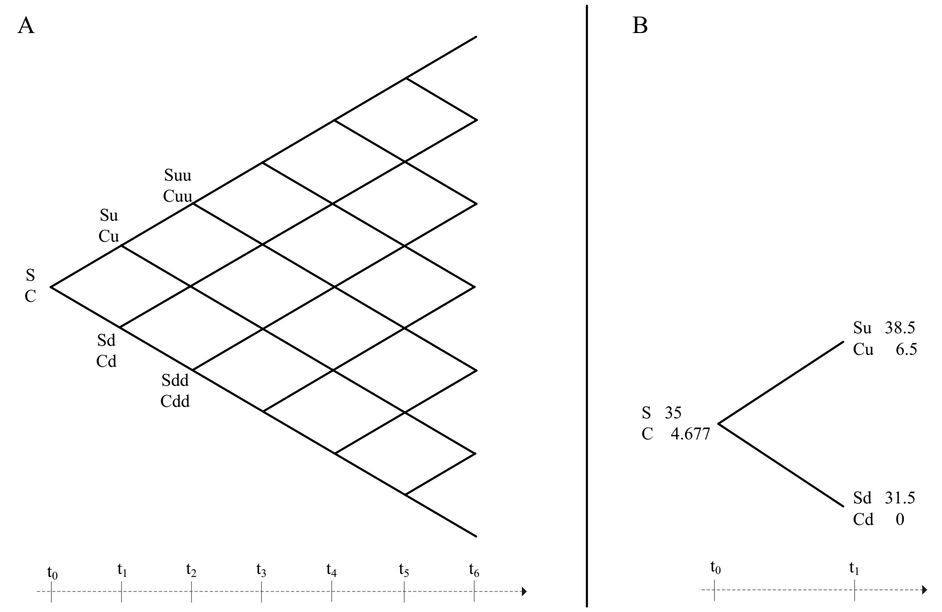
[189] The following explanations are made according to the original paper of Cox, Ross, and Rubinstein, see Cox *et al.* (1979), where not otherwise explicitly mentioned.

[190] Obviously the pricing of an option on a bond, an index or real estate, etc. will function in a similar way with some specific adjustments. This will not be emphasized in this work as it not needed for the purpose of the dissertation.

[191] Note that if S-X is smaller than zero the option is out of the money, and the option holder will not have to pay the negative difference, but rather the option will be allowed to expire worthlessly. Thus the option value will equal zero.

Figure 3.9: Binomial price path.



In order to set up a risk-free portfolio using the numbers in Figure 3.9B we proceed as follows: the portfolio must be composed of a long position of a specified share of stocks, which we denote with Δ*S, and a short position of one call option on this stock, C, whereby Δ stands for the specified amount of stock. A risk-free portfolio would result in the same payoff at expiration, either after an upward movement of the stock or after a downward movement. Therefore at maturity

$\Delta * S_u - C_u = \Delta * S_d - C_d$ must hold.

Solving for Δ we get

$\Delta = \dfrac{C_u - C_d}{S_u - S_d}$, which using the numbers in the example gives us 0.929.

Thus, a riskless portfolio is composed of 0.929 shares of a stock and one call option, and the portfolio is worth CHF 29.25 in either case, be it after an upward movement of the stock price, or after a downward movement. This portfolio must thus earn the risk-free rate of return, and to get its current value, we must discount the maturity value with the risk-free rate r_f, which we assume to be 10% p.a. in our example. We obtain CHF 27.832 for the current value of the portfolio and, detracting from the Δ*S (which represents the stock quantity currently hold in the portfolio), we get a call option price of CHF 4.677. Generalizing the argument with Δ as stated above, the present value of the portfolio using continuous compounding results in

$$\left(\Delta * S_u - C_u\right) * e^{-r_f T}$$

and, equating it to the cost of setting up the portfolio, this leads to

$$\Delta * S - C = \left(\Delta * S_u - C_u\right) * e^{-r_f T}$$

Solving for the current price of the call option, C and rearranging the equation with $p = \frac{e^{rT} - d}{u - d}$ (which is called the risk-free probability), we finally obtain the formula for pricing a call option in a one-step binomial model

$$C = e^{-r_f T}\left[p * C_u + (1-p) * C_d\right] \quad \textbf{(3.3)}$$

This result provides important insights into the determinants of option value in general. The value of the option is not determined by the probabilities of the stock's price moving up or down (which we called q and (1-q) at the beginning of this chapter)[192], i.e., it is not determined by the expected price of the asset. The reason is that the option is valued in terms of the current price of the underlying stock and not in absolute terms, and this current price, in turn, already reflects all future expectations. Thus, the probability of up and down movements is already accounted for into the current stock price itself, and we would just double count it if we took them into account again when valuing the option in terms of the current stock price.[193] Moreover, as the valuation is made setting up a riskless portfolio using the risk-free probability p, we obtain that the stock price grows on average at the risk-free rate. This result leads us to a crucial principle of option pricing, which we will encounter in any other option pricing formula, and that is known as *risk-neutral valuation*. This principle permits to value options assuming that the world is risk neutral, i.e., investors do not care about risk and, more importantly, it implies that the option price calculated in this way will be correct in any other world as well, i.e., also in a risk-lover's or risk-averse world.[194]

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[192] Note that these are not the risk-free probabilities p and (1-p).
[193] See Hull (2006), p. 244ff.
[194] See Hull (2006), p. 244ff.

3.3.2.2 The Black-Scholes option pricing model

The second basic model for pricing options is the *Black-Scholes option pricing model.* It is said to be less intuitive in its derivation than the binomial option pricing model, but builds on the same fundamentals, namely the risk-neutral valuation and the no-arbitrage condition. The difference between the two models is that the former requires a large number of inputs in terms of expected future prices at each node,[195] whereas the Black-Scholes model needs only five variables to price a European call or put option on a non-dividend-paying stock, as Black-Scholes showed in their seminal paper in 1973.[196] The Black-Scholes model results in a closed-form solution which in practice is obviously very convenient in the case of pricing financial options. Unfortunately, as we will see in chapter 3.6.1, in many circumstances it is not easily adaptable for real option valuation because several assumptions made for deriving it do not hold for the real option valuation of an investment project. The Black-Scholes model is an extreme case of the binomial option pricing model inasfar as the time intervals between each price movement (each node in the binomial model) converge to zero in the case of the Black-Scholes model. This leads to the assumption that the limiting distribution for the continuous stock price process is the normal given small price changes and infinitely small time intervals.[197] The assumptions Black and Scholes used to derive their option pricing formula are thus as follows:[198]

a) *"The short-term interest rate r_f is known and is constant through time.*

b) *The stock price follows a random walk in continuous time with a variance rate proportional to the square of the stock price. Thus the distribution of possible stock prices at the end of any finite interval is lognormal. The variance rate of the return on the stock is constant.* $dS = \mu \cdot Sdt + \sigma \cdot Sdz$ *, where dt is an infinitesimal time interval, dz a movement of a variable following a Wiener process, μ is the expected rate of return of the stock and σ is referred as the stock price volatility.*

c) *The stock pays no dividends or other distributions.*

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[195] The more the nodes and the shorter the time periods, the more inputs are needed.

[196] See Black and Scholes (1973).

[197] In case of large price changes, the limiting distribution is the Poisson distribution, which allows price jumps, see for example Merton (1976).

[198] Black and Scholes (1973), p. 640.

d) The option is "European", that is, it can only be exercised at maturity.

e) There are no transaction costs in buying or selling the stock or the option.

f) It is possible to borrow any fraction of the price of a security to buy it or to hold it, at the short-term interest rate.

g) There are no penalties to short selling. A seller who does not own a security will simply accept the price of the security from a buyer, and will agree to settle with the buyer on some future date by paying him an amount equal to the price of the security on that date."

Under these assumptions, the option price depends only on the stock price, the time, the constant volatility, and the constant risk-free interest rate. Thus, under the no-arbitrage condition, it is possible to set up a risk-less portfolio as in the case of the binomial option pricing model and solve for the current option price in this case as well. The difference between those approaches is that the binomial option pricing model is a discrete-time model, whereas the Black-Scholes model is a continuous-time model and requires some mathematical background to be solved. As it is not the scope of this dissertation to show the exact derivation of the Black-Scholes solution, the interested reader is referred to Black and Scholes' paper itself. Black and Scholes derive following differential equation:

$$\frac{\partial C}{\partial t} + r_f S \frac{\partial C}{\partial S} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 C}{\partial S^2} = r_f C \tag{3.4}$$

which, using the boundary condition at expiration of the option, that is $C = \max(S - X, 0)$ and $P = \max(X - S, 0)$ when t = T,[199] they solve for C and get the value of a European call option on a non-dividend paying stock

$$C = SN(d_1) - Xe^{-r_f(T-t)}N(d_2) \tag{3.5}$$

whereby

[199] In words: At expiration a call option will in maximum either be worth S-X or zero and a put option will in maximum either be worth X-S or zero.

$$d_1 = \frac{\ln(\frac{S}{X}) + (r_f + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}} \quad \textbf{(3.6)}$$

and

$$d_2 = \frac{\ln(\frac{S}{X}) + (r_f - \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}} = d_1 - \sigma\sqrt{T-t} \quad \textbf{(3.7)}$$

In this context C denotes the price of the European call option, S the stock price, r_f the risk-free rate, T the time at expiry and t the current time. Moreover, the expression N(x) stands for the cumulative probability function for a variable that is normally distributed with a mean of zero and a standard deviation of one. Using a well known relationship between a call option and a put option, called *put-call parity*, the price of a put option with the same exercise price and exercise date can be derived as well.[200] This gives

$$P = Xe^{-r_f(T-t)}N(-d_2) - SN(-d_1) \quad \textbf{(3.8)}$$

where P stands for the price of a European put option and all the other variables are the same as seen before.

3.3.3 Comparison between financial options and real options

In light of the theoretical aspects discussed up to now, it is evident that in term of the generic character of their respective payoff structure, financial options and real options are very similar and, therefore, it makes sense to apply financial options valuation techniques to value real options. Nevertheless, there are some significant differences that can lead the evaluator of a project to inadequate or even wrong results and interpretations. For that reason, these differences must be recognized and understood. The following chapter will be dedicated to this matter.

The fact that both financial options, as well as real options represent a right to do something but not an obligation, leads to the conclusion that investment valuation can be done with help of models developed for pricing financial options. For instance, if

[200] The put-call parity states that because the no-arbitrage condition holds, a portfolio composed of an European call option and an amount of money equivalent to the present value of the strike price, must equal another portfolio, which comprises a put option on the same stock and with the same exercise price and date as the call plus the stock itself, thus $C + Xe^{-r_f(T-t)} = P + S$. See Hull (2006), p. 212ff.

one buys a financial call option on a stock, he has the right to buy this specified stock at a predefined price and date. If the exercise of the option is not valuable at maturity, i.e., the stock price lies below the exercise price, the option holder will let expire the option without doing anything. The same applies to investment projects. If a manager has, for example, bought the right to exploit an oil field, he will only build the oil refinery if the price of oil will be enough high to justify the expenses. Otherwise, he will wait and see or even forgo the investment opportunity if the exploitation rights are bound to a given time window. The structure of the cash flows thus will be similar in both cases: First, pay an amount of money in advance to acquire the right; second, wait until new information unfolds, and pay the money of exercising the option only in case these costs will be lower than the price of the underlying asset; and, finally, cash in the difference. Even as intuitive and simple as this analogy might seem, so many differences exist.

Typically, independent financial institutions issue financial options and, after writing it, they have no influence on the actions of the management and no control on the stock price itself. The opposite is true for a real option. The underlying asset of a real option, i.e., the project, is obviously controlled by the management. By enhancing the value of the underlying a firm can consequently enhance the value of the real option as well.[201]

Another difference arises in respect to the complexity and the style of the options. Financial options are mixed American style and sometimes European style. Real options are always American style and can thus be exercised at any point until expiration.[202] Furthermore, a great part of financial options sold on markets consists of simple options with one source of uncertainty. Real options, in contrast, are almost always exotic options, options on other options (e.g., in the case of an expansion of an already existing project) and options with multiple sources of uncertainty.[203] This makes real options more complex to analyze compared to standard financial options.

Different real options within the same project refer mostly to the same underlying. Therefore, the exercise of one of those real options can have effects on the value of the underlying and, consequently, on the value of the other real option as well. Real option's values are for this reason non-additive. The degree of interactions and of non-additivity depends on the option type, on the autonomy of the different point in time of

[201] See Copeland and Antikarov (2001), p. 111.

[202] This correct at least theoretically. Practically a project's start can be bound to company-internal rules and regulations.

[203] See Robinson (2003), p. 36.

the exercise, on the probability of the exercise, and on the sequence of exercise.[204] This interaction effect is also known with financial options, however, it is much more remote than with real options.[205]

A further important difference is the property of the options right. Whereas financial options are proprietary, which means that once someone buys the option he has the exclusive right to exercise it, real options are in general shared. The possibility to start the development of a new medicament, e.g., is available to every pharmaceutical firm until the first one files a patent on it. This first-mover advantage will change the value of the underlying of the shared real option and, consequently, have a negative effect on its value for all other firms that want to produce the same medicament. The exercise by one of the competitors will thus generate a competitive loss for the other competitors.[206] It is true that once the patent is filed, the real option becomes proprietary as well. This, however, is not the case for the majority of the real-life projects and their respective real options.

The marketability of the underlying asset and of the option itself is a further difference between financial and real options, which can cause problems in valuing real investments with option pricing theory. Whereas financial options are in general traded on exchange markets and thus very liquid, apart from OTC options,[207] real options are little or not liquid at all and, thus, if we want to set up a risk-less portfolio as discussed in chapter 3.3.2.1, the no-arbitrage condition would not work.[208] In the case of financial options, the underlying itself is often a traded security with observable historical market prices, whereas the underlying risky asset of a real option is usually not traded.[209] This makes it more difficult for real options to estimate their parameters for the application of an option pricing model like, for example, the Black-Scholes model previously discussed. Also, when exercising a financial option, the transaction costs are simple and well structured, while, on the contrary, transaction costs for exercising a real option, that is, initiating a project, may take many different forms.[210]

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[204] In subchapter 3.4.1.7 we will discuss the case of compound real options in more detail, as interactions among real options can play an important role in real-life.

[205] See Trigeorgis (1996b), p. 232-240.

[206] See Trigeorgis (1996b), p. 128.

[207] An OTC (over the counter) option-contract is a bi-lateral contract in which two parties agree on how a particular trade or agreement is to be settled in the future. In contrary to classic options these contracts are not traded on exchange markets and are therefore less liquid.

[208] See Robinson (2003), p. 7.

[209] See Copeland and Antikarov (2001), p. 111.

[210] See Robinson (2003), p. 7.

Most option pricing models use to some extent the six option valuation parameters suggested by Black and Scholes.[211] As real option valuation is amongst other things the art of transferring models developed for financial market to actual investment decisions the analogy between financial options and real options concerning the input parameters for the Black-Scholes model must be analyzed.[212] The six input parameters are discussed in the following:

The *price of the underlying* builds the main input for an option valuation. For a financial option, the price of the asset underlying the option can be observed in financial markets and is the same for every market participant. By contrast, the underlying of a real option can usually not be observed in financial markets. It is represented by the present value of the free cash flows of the investment project and in case of, for example, a R&D project, it can be unique to a firm, not well defined or not even exist yet.[213]

The second parameter is the *exercise price*. In case of a financial option, the exercise price is specified in the option contract and mostly fixed. In case of a real option, the exercise price is represented by the present value of the investment costs and must be determined first.[214] Once the exercise costs are identified, it is by no means certain that it will stay the same over time. The cost for setting up an investment can namely be stochastic as well, depending on the exercise time and on the situation of the competition on the investment goods market.[215]

The *volatility* of the asset price as a measure of uncertainty for the underlying is a further parameter which is needed for calculating the option value. For financial options, the volatility of the price of the underlying asset can be observed directly in the securities market. In case of real options where usually no market price exists yet for the project value, it is obvious that the volatility of the project's market price cannot be observed. Therefore, the volatility of the project value must be estimated or better simulated.[216] Moreover, the volatility for financial options is assumed to be constant over time and exogenous. This is a reasonable assumption since an individual option holder cannot control or influence the risk of the underlying on the market. The opposite holds for a real option, where the action of a company that owns it may affect

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[211] See chapter 3.3.2.2.

[212] See Perlitz and Peske (1999), p. 258ff.

[213] See Wang (2002), p. 36.

[214] See Ernst and Häcker (2002), p. 50.

[215] See Dixit and Pindyck (1994), p. 46, and Hommel and Pritsch (1999), p. 132.

[216] See Copeland and Antikarov (2001), p. 244ff.

the actions of competitors and, therefore, the uncertainty that the underlying is exposed to.

A fourth parameter that differs when comparing financial and real options is the *time to maturity*. In the case of financial options, the time to maturity is specified in the contract and fixed, usually no longer than one or two years, mostly it is even shorter. For a real option, the time to maturity is the time until the opportunity to invest disappears.[217] This time is unknown at the beginning of the opportunity's opening and is often difficult to determine even thereafter.[218] Moreover, the exercise time is dependent on the competitor's action. If a competitor, e.g., preempts the exercise, the underlying might disappear and the option will become worthless for all other competitors. The time to maturity of a real option also influences another fact. As this time can get very long, the model assumptions inherent in most standard option pricing models about, e.g., the constant volatility, the constant risk-free rate and the constant exercise price can become problematic as well in this long-run perspective, since with more time to go, it is more likely that this parameter will no longer be constant.[219]

The fifth parameter we will refer to is the *risk-free rate of return*, which is the same for both financial options and real options and can be determined by the term structure of interest rate.[220] At most, the problem that can arise for real option valuation concerning this parameter is the one mentioned in the paragraph above. Because of the possibility of a long-run maturity, in the case of a real option the assumptions about a constant risk-free rate can be violated in practice.

The last parameter to look at is the *dividend* paid during the option's maturity. Dividends in financial options are all payments made to the holder of the option's underlying asset. The holder of the financial option will miss this extra income if he does not exercise the option before the dividend is paid out. In the case of real options the dividends are represented by all lost payments through waiting to invest.[221] These lost payments could be represented by missed rents because of waiting to build a real estate, for instance. Every different real option case must, therefore, be analyzed separately concerning the possible arising dividends, i.e. lost payments due to the investments deferral. These dividends are often not exactly known by time, frequency, and amount, and are moreover quite difficult to determine.[222] Additionally, in the case

[217] See Wang (2002), p. 37.
[218] See Perlitz and Peske (1999), p. 262.
[219] See Amend (2000), p. 83.
[220] See Hommel and Pritsch (1999), p. 132.
[221] See Wang (2002), p. 37.
[222] See Perlitz and Peske (1999), p. 261.

of real options there are two types of dividends to be differentiated: on the one hand, the dividends payable to the holder of the underlying (e.g. the rents when the apartments in a real estate can be drawn by the building owner); on the other hand, the dividends payable to the holder of the option itself. For instance, if a piece of agricultural land can be converted into construction area, it generates profits for the holder of the land, that is, for the option holder which, NB, is not the holder of the underlying asset (i.e., the owner of the real estate). The second dividend payment type is not considered in financial option pricing and, therefore, makes the valuation of real option more complex.[223] As a preemption by a competitor can also cause “a lost payment through waiting to invest”; actions taken by competitors can be regarded as a “dividend” as well in real option valuation.[224]

As can be seen from the comparison of financial options and real options, the analogy does not always hold at 100%, and thus transferring option pricing models to real investment valuation must be done with extreme caution and the awareness that while the precision in valuating a financial option is very high, the same does not hold every time for a real option as well.[225] The real options values are in many cases based on rough approximation of the above-mentioned parameters and, thus, in those cases, they should more represent a price range than a single exact price.[226] Amram and Kulatilaka (1999a) call the difference of analogy between financial and real options parameters the *distance of the market* and agree that the closer the parallels between financial options and real options are, the more practicable a valuation of real investments with option pricing models will be.[227] We will join the mentioned theoretical problems with the practical problems of a real options application later in this work in chapter 3.6 and propose and list some possible solutions at that point. Table 3.4 summarizes the differences and analogies between financial options and real options presented in this chapter.

[223] See Perlitz and Peske (1999), p. 261.
[224] See Trigeorgis (1991a), p. 146ff.
[225] See Robinson (2003), p. 8.
[226] See Volkart (2003), p. 352.
[227] See Amram and Kulatilaka (1999a), p. 99.

Table 3.4: Comparison between financial options and real options.

	A **FINANCIAL OPTION** is a right but not an obligation	A **REAL OPTION** is a right but not an obligation
GENERAL		
Issuer	The issuer is usually not a company member and thus has no influence on the underlying.	The management controls and can influence the underlying asset on which the real option is "written".
Style	Mostly American, but also European	American
Complexity	Simple or exotic	Mostly very exotic
Exercise	No interactions between exercise of different options.	Interactions possible when exercising options on the same project because the exercise of a real option has effects on the cash flos of the underlying project.
Property	Proprietary (nobody disputes the exercise)	Mostly shared (risk of preemption)
Marketability of underlying	Written on marketed securities, thus the availability of valuation paramters on financial markets is given.	Underlying not traded on a market and therefore the valuation parameters are mostly not observable.
Trading	Liquid	Not traded
Transaction costs	Simple (according to derivative exchange)	Many different form
VARIABLES		
Underlying's price	Asset price	Present values of expected free cash flows
Type of underlying	Financial asset, clearly specified.	Real asset (may not exist yet, e.g. R&D), not well defined and unique to firm.
Influenceability of underlying	Can not be influenced by excercise of other option or by actions of competitors.	Can be influenced by excercise of other option or by actions of competitors.
Exercise price	Fixed price (at least for simple options, not exotics).	Present value of investment costs, to be ascertained and stochastic.
Uncertainty	Asset price volatility (constant, can be observed in markets).	Project value volatility (not constant over time, must be estimated respectively simulated).
Influenceability of uncercainty	The uncertainty of the underlying is assumed to be exogenous (in general the underlying is influenced by one single uncertainty factor).	The uncertainty of the underlying is assumed to be exogenous when in reality it is not because the company can affect risk in e.g. doing research or undertaking an action on the underlying (in general the underlying is affected by several risk factors, i.e. real options are rainbow options).
Time to maturity	Fixed date	Time till opportunity vanishs (is not fixed).
Terms	Mostly short term (month, year)	Differing (month till several years)
Interest rate	Risk-free rate	Risk-free rate
Dividends	Payments to shareholder (if stock)	Lost revenues (through waiting to invest)
VALUATION		
Precision of valuation	High precision through well defined closed-end option pricing models.	Valuation models must be mostly customized on the specific investment case. The real option values must be considered more in bandwith than in a single precise value.

3.4 Categorization of real options

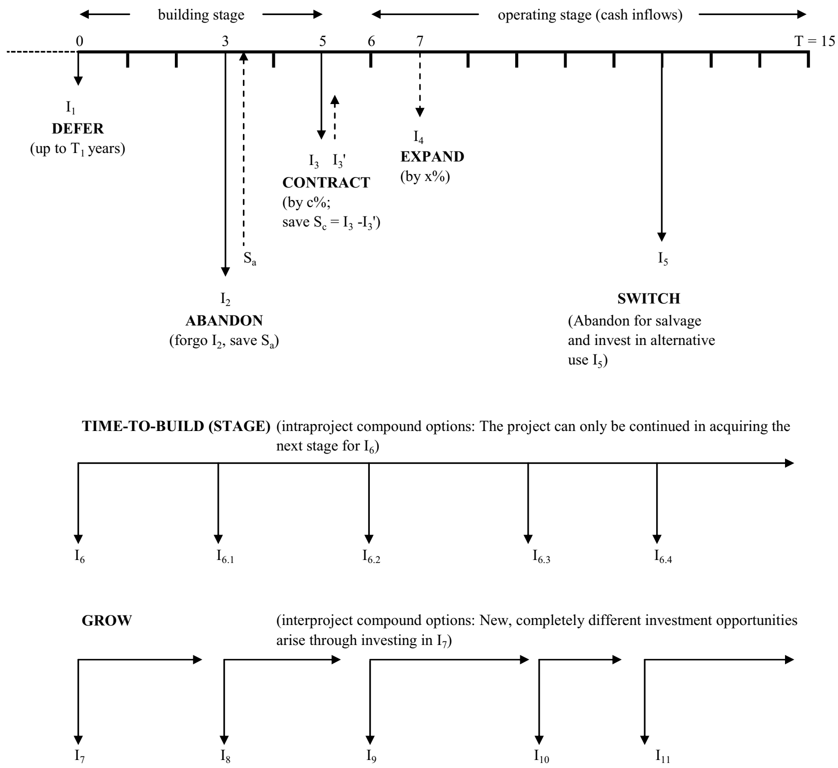
There is general agreement on the basic types of real options; however, each taxonomy varies slightly. Some researchers class options into growth and flexibility options; while others add contractual and insurance options as categories; still others sort them into growth, deferral/learning, and abandonment options, depending on the main focus of their research, whether it helps for their identification or to guide their subsequent valuation. We first present the types of real options used in this dissertation, where we adapt the categorization of the classic types of common real options by Trigeorgis (1993b).[228] The list of real option types presented therein is obviously not exhaustive as there are simply too many applications with myriad of options. However it gives a good description of the basic real options types arising in practical investment problems and from whose combination one can derive many other company-specific real options. It is widely recognized that these combinations of real options, also called multiple options, are the most frequently found in real-life problems.[229] Thus, the basic real options are sufficient to describe in real options terms many investment valuation problems found in the real world. After outlining the real options according to Trigeorgis, we will make a link to other categorizations. We will show how other authors classify different real options and what differences and commonalities can be found between them and Trigeorgis's taxonomy. This is important insofar as there is little consistency between the different types of classifications, although, to some extent, everyone is concerned with the same managerial flexibilities.

3.4.1 Classic types of common real options according to Trigeorgis

The aim of the classification by Trigeorgis is to provide the reader with a labeling system to help supporting the identification of real options and also to guide their subsequent valuation. For this purpose, he devised a list of basic managerial actions to describe both some actions that catch an upside-potential, such as deferring or expanding an investment and other actions which protect the manager from downside risk, such as abandoning or contracting an investment.[230] Following the time bar in Figure 3.10 we present an overview of the different types of managerial flexibility described by Trigeorgis (i.e., real options) that arise during a project's life. These are the option to defer (or option to wait), the option to alter the operating scale (i.e., to expand or contract), the time-to-build option (or option to stage), the option to abandon, the option to switch (outputs or inputs), and the growth option.

[228] See Trigeorgis (1993b), p. 204. We already touched the topic in chapter 2.1. At this point we want to deepen the different real option categories of Trigeorgis and to draw parallels to other categorizations.
[229] See Trigeorgis (1993b), p. 206.
[230] See Trigeorgis (1995), p. 2.

Figure 3.10: Managerial flexibilities during the lifetime of a project.



Source: Based on Trigeorgis (1996c), p. 9 and p. 133.

At the beginning of a project an initial investment I_1 has to be done. This investment, however, can be postponed (*option to wait*) until some uncertainty has been resolved. After the initial investment has been done, the project's size can be expanded in paying I_4 or contracted, getting S_c, depending on the market conditions (*option to alter operating scale*). If the market conditions are extremely bad, the project can be given up (*option to abandon*) for cashing in the salvage value S_a. Different from the option to wait, the last two options can come up at any time during the life of the investment. The same also holds for the possibility to change the input or output of the product (*option to switch*) for I_5. Additionally, the whole project can be organized in different stages, where the next stage can only be initiated if the antecedent stage has been successfully completed (*time-to-build option*). Furthermore, it may happen that the project is started only because it is a prerequisite or link in a chain of interrelated projects. It can open up future growth opportunities, help gather information about new investment areas, give access to new markets, and so on (*growth option*). Finally, in real-life, a combination of some of the aforementioned is obviously possible as well (*multiple interacting options*). In Figure 3.10 the difference between intraproject and interproject options is denoted as well. While intraproject options are options within a single project where the exercise of the preceding option is a prerequisite for continuing the project itself (I_6, $I_{6.1}$, $I_{6.2}$ etc.), interproject options generate completely new investment opportunities (I_7, I_8, I_9 etc.). The time-to-build option is consequently an intraproject option, whereas the growth option is a interproject one.

In the following subchapters, every single real option will be discussed and some possible real-life applications are specified. Unless otherwise noted, the statements made in this chapter are taken directly from Trigeorgis (1996b).[231]

3.4.1.1 Option to defer

The option to defer derives its value from the possibility of a manager's delaying the investment decision in order to wait for new information to resolve or reduce a part of the uncertainty. Net present values are exposed to uncertainty and can change over time. Consequently, an investment with a negative NPV today is not doomed forever and may have a positive NPV tomorrow. This change in the project's value gives an option character to the investment opportunity. As long as the decision maker does not have any positive information about the cash inflows, the initiation to invest may be deffered. At this point, it should also be mentioned that obviously the danger with this type of option is that the manager does not generally have an exclusive right to exercise the option. As soon as a competitor enters the market, it has to be considered that in waiting to invest, a part of the cash inflows (if not all) can be lost. To simplify matters, let us assume that the manager has exclusive rights to a project for the next n years. If we define the discounted cash flows as PV(CF), and the initial investment to be made for initiating the project as I_0, the manager's decision rule can be read as follows:

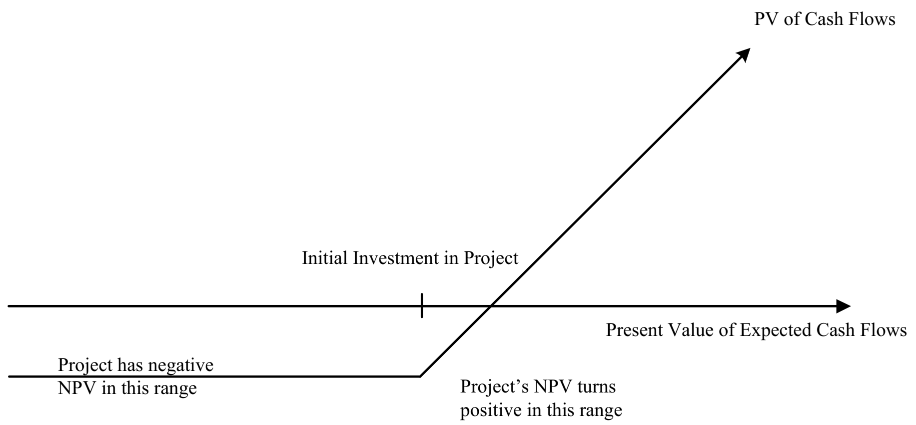
If PV(CF) > $I_{0,}$ take the project because of its positive NPV. If PV(CF) < $I_{0,}$ refuse the project because of its negative NPV.

Since both the cash flows and the discount rates can change over time, even if the current situation would be PV(CF) < I_0, nothing is lost. The manager has the opportunity to wait and invest at any time when PV(CF) is higher than I_0. This relationship is depicted in Figure 3.11 and is equal to the payoff diagram of a financial American call option. In fact, if we compare it to Figure 3.7, the option to defer an

[231] See Trigeorgis (1996c), p. 2ff.

investment represents an American call option with a maturity of n years (i.e., the time-frame as long as the exclusive right holds) on the discounted cash flows of some new assets received by paying the initial investment I_0.

Figure 3.11: Payoff diagram of the option to defer.



Source: Based on Damodaran (2001), p. 377.

Even though the discussion takes still place on a theoretical level, some implications for a company should be stated here. First, a project with a negative net present value is perhaps still a "valuable" project because of its option characteristics.[232] Thus, the managerial flexibility to defer the start of the project implies value to the firm. Second, similarly to financial options, giving up this flexibility by committing to an investment creates opportunity cost.[233] Consequently, it may be not optimal to accept a project just because it has a positive NPV. There could be still a gain from waiting and accepting the project at a future time, especially if the firm holds the exclusive rights for a long time and the variance of the cash inflows is high.[234] Accordingly, management should be willing to pay a premium for giving up the right to wait since early investment implies sacrificing the value of the option to wait, which can be seen as an additional opportunity cost.[235] Hence, the critical trigger to invest is represented by the net present value plus this premium for giving up flexibility.[236] Typical industries where this type

[232] See Damodaran (2001), p. 383.
[233] For early exercise of financial options, see Hull (2006), 215ff.
[234] See Damodaran (2001), p. 384.
[235] See Trigeorgis (1996c), p. 10.
[236] See Dixit and Pindyck (1994), p. 135 ff.

of option occurs often are, for example, resource extraction, farming, paper products, real estate development, and bio-technology or, in general projects where the uncertainty about the cash flows is high, the investment horizons are long, and the investment opportunity can be protected through a patent or any other type of exclusive rights, such as mining rights, franchise, or special federal authorizations.[237]

3.4.1.2 Option to alter operating scale (expand/contract)

The flexibility to alter the operating scale includes two types of options; namely, the option to expand if market conditions turn out to be good, and the option to contract if the demand is disappointing compared to the expectations.

The *option to expand* can evolve in two different ways. First there is the possibility to *scale up* an investment. This allows the firm, if market share grows and successful outcomes are achieved, to increase the capacity of the project and profit from the new chances by incurring a follow-on cost for buying the expanded capacity. This flexibility can be interpreted as an American call option on the cash flows generated by an additional part of the base-scale project, paying the exercise price for acquiring this additional capacity. If we define the value of the base-scale project as V_{base} and the follow-on investment for acquiring an additional capacity of x% as I_e the option to scale up the project can be viewed as $V_{base} + \max(x\% * V_{base} - I_e, 0)$, i.e. the base-scale project plus an American call option on the cash flows of future investments. Secondly there is the possibility to *scope up* the project. This allows the firm to extend its core competencies into new products, services, or distribution channels and, in doing so, to capitalize on future growth opportunities. Also in this case, the firm owns an American call option on supplemental cash flows generated by some new demand in others but similar market segments. By undertaking an additional investment (i.e., pay the exercise price of the option), the firm can profit from these new opportunities. The difference between scale up and a scope up expansion options is consequently only given by the underlying. Whereas the scale up expansion capitalizes on the larger market share of the same product, a scope up expansion derives its value from the exploitation of new market opportunities. A good example for the option to scope up is Amazon.com, which started its business activity with books and subsequently extended the scope into CDs, videos, and other lines. Similar to the option to grow as explained later in 3.4.1.6, this option can also make an apparently unprofitable base-case investment (on the basis

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[237] See Trigeorgis (1996b), p.10. In line with Trigeorgis statements we found also in our survey that the option to defer is often used in chemicals and materials, see 4.5.4.3.

of a "static" NPV) worth undertaking because it considers the chance that consumer demand for a specific new product will pick up in future.

The option to contract (also referred to as option to shrink) works similarly to the above mentioned option to expand. The difference between them is that the flexibility to contract allows the firm to respond to unfavorable market conditions and downsize its capacity (scale back) or even narrow its focus (scope down) instead of scaling or scoping it up as in the case of the option to expand. Therefore, this type of flexibility is an American put option on a part of c% of the base-scale project V_{base}, renouncing to the cash flows of the capacity of c% and thereby mitigating loss by saving part of the planned total investment outlays I_c (representing the exercise price of the option). This results in a value of the option of max (I_c – c* V_{base}, 0). The option to contract provides a sort of "sheet anchor" to the manager when there is no further potential in a business opportunity.

The main practical implication of the option to expand as well as the option to contract is the fact that these options can help the manager think about project design and may consider and argue for a more expensive initial technology with a built-in flexibility to alter the scale of the project during ongoing operations. This can be valuable in industries with highly variable market demand or in the case of introductions of a new product in uncertain markets. Typical industry where options to alter the operating scale can be found are, for example, natural-resource industries (such as mine operations), facilities planning, and constructions in cyclical industries, fashion apparel, consumer goods, and commercial real estate.

3.4.1.3 Option to stage (time-to-build option)

Most large real-life projects often unfold in a series of subsequent stages. In these cases the required investment is not due all in once at the beginning of the project but sequentially, as a series of several outlays over time.[238] Dividing the investment into different portions may reduce upside potential, but it also protects the firm against downside risk. In fact, it endows the manager with the flexibility to evaluate the project at each stage and decide thereafter whether to continue or "default" the whole project. This flexibility is equivalent to a series of sequential American call options, where each stage can be interpreted as an option on the cash flows of subsequent stages by incurring an investment cost I_0, which is a part of the whole investment I_{Tot}.

[238] See Trigeorgis (1996b), p. 10.

Consequently, it can be valued similar to a series of options on options, also referred to as *compound options*.[239]

Similar to the option to defer, the option to stage investment exposes the success of the project to some risks deriving from competition. Competitors who decide to enter the business on a full scale can capture the market leaving the "stage investor" with only a fraction of the gains could have been made by investing all at once. Moreover, the staging of investments may also lead to higher total costs, since the firm is not taking full advantage of the economies of scale.[240] Nevertheless, this type of option has also several positive implications for a firm's investment decision. First, it allows the firm to protect itself from two main sources of risk: specifically, the technical risk or private that relates to the ability of the firm to handle the project's challenges step by step, and the market or non-private risk that refers to the future demand uncertainty.[241] The key managerial flexibilities in this case include both the choice of timing (about when a specific part of the total investment must be done) and the choice of abandoning the project after each milestone, depending on the information about resolution of the uncertainty. Second, it can reveal that some projects that look poor on a full investment basis may be value creating if the firm can invest in stages. Third, it can advise the manager about when the gains from staging investments are the largest. This is particularly valuable for a) industries where there are significant barriers to entry for new competitors, and taking advantage of delay in full-scale production; b) projects where there is a significant uncertainty about the size of the market and the success of the product; thus investing in phases helps the firm to reduce its losses if the product does not sell as well as predicted; and finally c) for projects with large investments in infrastructure (large fixed costs) and consequently a high operating leverage. This is based on a simple argument that states that the larger and more inflexible the investments are, the more likely and larger the savings from investing in stages tend to be.[242] Consequently, this type of flexibility is valuable in all R&D-intensive industries like pharmaceuticals and bio-technology, in highly uncertain, long-term development, capital-intensive industries such as energy-generating plants, and in venture capital-financing.[243]

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[239] See also chapter 3.4.1.7.

[240] See Damodaran (1999), p. 49.

[241] See Brach (2003), p. 97.

[242] See Damodaran (1999), p. 49.

[243] In comparison with the theoretical predictions we found in our survey on the Swiss market, together with the chemicals and materials, a large utilization of the option to stage also in the financials and the consumer goods, see 4.5.4.3.

3.4.1.4 Option to abandon

The *option to abandon* a project can be seen as an extreme case of the option to contract. When market conditions are poor and the cash flows of a project decline severely over time, there is no sense to continue incurring the fixed costs of the project. The firm instead can abandon the project forever, liquidate its capital equipment, and invest the salvage value in alternative, more valuable assets. To reason by analogy this flexibility to abandon the project is equivalent to an American put option on the cash flows of the project for n years. Exercising the option entails the holder to get the salvage value from abandonment, which represents the exercise price of this put option, and renounce the remaining cash flows of the project. In short, an option to abandon is an escape route in an economic downturn. If we assume that V_{rem} is the remaining value of a project if continued till the end, and L represents the liquidation value or best-alternative-use value for the same project, the payoff of such a put option as a function of the expected project's value can be depicted like in Figure 3.12. If the value from continuing V_{rem} is greater than the liquidation value L the project should be continued. On the other hand, if L is greater than V_{rem}, the management should consider exercising the option, abandon the project, and cash in L. This results in a value of the put option of max (V_{rem}, L).

Moreover, there is to say that the exercise of an abandonment option can be tied to some additional costs, e.g., severance payment to the workers, loss of valuable expertise, erosion of crucial organizational capabilities that might be applicable elsewhere in the business or that could generate new growth opportunities in other areas etc. In addition, the salvage value or best-alternative-use value, which represents the exercise price, is not always fixed, and these fluctuations can dramatically change the value of the option to abandon.[244] Because of both the uncertainty over the salvage value and some possible further abandonment costs, the valuation of an option to abandon must be taken with extreme caution in order not to incur into the mistake of valuing a managerial flexibility bound to high additional costs, which makes it de facto not realizable or at least much less valuable than expected.

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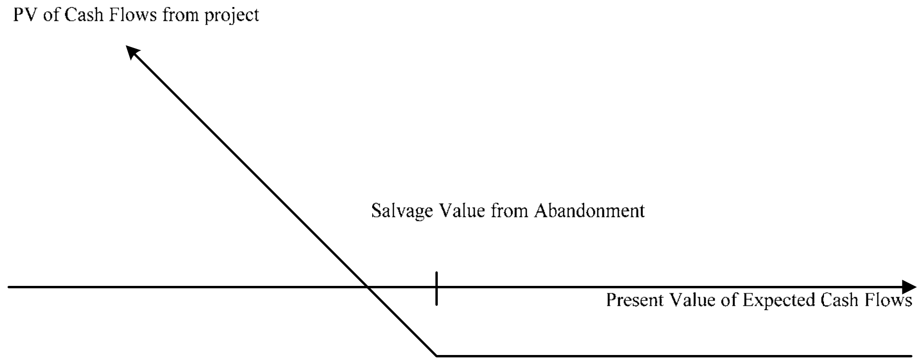
[244] In practice it is very hard to identify a fixed salvage value. In fact the salvage value of e.g. machinery tends to get smaller and smaller as the degree of wear increases in time. A fixed salvage value may only be guaranteed in the case when some exit clauses are defined in advance in a contract.

Figure 3.12: Payoff diagram of the option to abandon.



Source: Based on Damodaran (1999), p. 54.

The fact that the option to abandon has a value can provide a firm with several operating flexibilities that should be built into the project.[245] For example, the contracts with suppliers can be written on an annual basis instead of a long-term basis, or employees may be hired with temporary contracts rather than permanently. Large and expensive capital investments, such as plants, planes, and storehouses, can be leased on a short-term basis instead of purchasing them. Obviously there is a cost in building in this flexibility that must be compared to the expected benefits received when market expectations remain unfulfilled. However, in capital-intensive and highly volatile industries, these gains can be very high. According to Trigeorgis, valuable abandonment options can, therefore, be found in the airlines and railroads industries, in financial services, and in new-product introductions in uncertain markets.[246]

3.4.1.5 Option to switch

The *option to switch* describes the flexibility to alter the modus operandi of any given business. This includes the change of input or output products and, on a broader range, also the change of processes, global locations, relationships with different suppliers, and so on. Also, an option to start up, shut down and re-start a facility can, for instance, be an option to switch (between to operating modes). This is also the reason why this

[245] See Damodaran (1999), p. 56.

[246] In our survey in Swiss practice, we found that, in general the option to abandon does not occur very often. However, amongst the branches which seem to use it more frequently, we found the financials beside the chemicals and industrials and the technology and telecommunications, which indeed (especially the last two mentioned) often launch new products; see 4.5.4.3.

type of option is also called "flexibility option" in some categorizations.[247] Consequently, it can be found almost in every business and project. The necessary condition to be met is the one that the firm must be able to respond to changes in, e.g., prices or demand, paying a fix cost for switching from a more expensive mode of operating to one that is more cost effective, or to alter the product mix in order to profit from additional cash flows. A firm that develops extra uses for its assets (whether on the process or the products side) may has a significant advantage over its competitors. This advantage provided by this built-in flexibility must obviously be paid with a premium representing the price of the option. In this context, the cost of switching from one mode to the other is equivalent to the exercise price.

To illustrate the many ways for what the term option to switch stands for, some short examples should be given. In real estate development, it is useful to design the building so that it serves as an apartment house as well as office or retail space in accordance to the market demand and prices in both utilization modes.[248] A plant can be designed in a flexible way insofar as it can be operated with alternative forms of energy, e.g. either gas or electricity.[249] Further, a multinational oil company may locate production facilities in different countries in order to shift production to the lowest-cost producing facilities, depending on relative costs, local market conditions, and exchange rates. A car-manufacturing firm can maintain contracts with various aluminium-part suppliers switching among them as the suppliers' prices change. As can be seen, there are myriad applications of the option to switch. However, all of them have one aspect in common: pay for the flexibility to leave one mode of operations and start another one to respond to future uncertainties, working on cost-driving operational parameters, or possible additional cash flows. Consequently, the option to switch represents a combination of both at the same time, an American put and a call option on the assets-in-place. According to Trigeorgis, these options are valuable mostly in feedstock-dependent industries, such as oil, electric power, chemicals, and agricultural crops, relating to a switch of the process, and in automobiles, consumer electronics, toys and pharmaceuticals, with regard to the flexibility to change the product, where product differentiation is important and demand is very volatile.[250]

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[247] See 3.4.2 where we treat other possible categorization of real option.

[248] See Brach (2003), p. 88.

[249] See Kulatilaka (1993).

[250] In respect to this we found evidence in our survey for the chemicals and materials and the technology and telecommunications, see 4.5.4.3.

3.4.1.6 Option to grow

Growth options are early investments that open up the possibility for future growth opportunities, i.e. for subsequent valuable projects. This type of flexibility is similar to the option to stage as described in chapter 3.4.1.3 or the option to expand in chapter 3.4.1.2. The main difference stems from their position within a firm's overall strategy. Growth options are *interproject* flexibilities whereas the option to stage and the option to expand are *intraproject* options. Intraproject options embody the concept of flexibility within one single project, e.g., the different stages that must be undertaken to develop one single medicament or to sell more of a particular product. Interproject options describe the interdependencies that arise between two distinct subsequent projects. For example, a pharmaceutical firm starts developing a drug against hypertension and while this project turns out to be a complete failure, the knowledge accumulated during the research gives the opportunity to the firm to develop a medicine against alopecia and, therefore, creates the opportunity to start a valuable new project.[251]

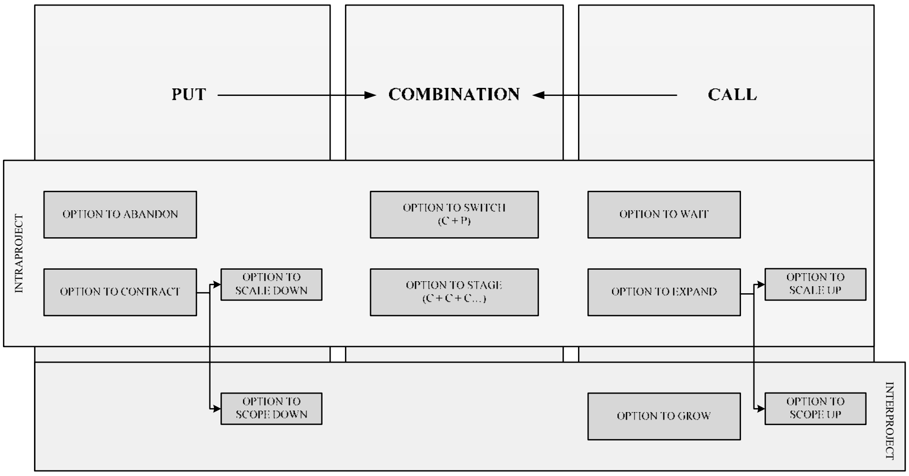
Typically, investments with this type of flexibility are investments with poor or negative NPV. In fact, the precondition to undertake such a project does not come from the directly generated cash flows, but more from the new opportunities it creates. Not investing in the early project could preclude many other profitable investments for the firm. Drawing again a comparison to financial options, the option to grow is an American call option on new assets. Assuming that the early project is a prerequisite for the subsequent one the exercise price of the call option is equivalent to the investments that have to be made for taking the new project. The value of the first project (if negative) will represent the price of the option. As yet we spoke only of two subsequent projects but obviously, in reality, there may be a series of succeeding projects once a ground-breaking project has been completed. Consequently, the option to grow can be seen as a portfolio of sequential compound call options that link different growth and expansion steps, leaving the manager with the flexibility to stop the chain at the next expansion step, depending on the actual market conditions. Moreover, the experience gained by undertaking these steps, if proprietary, can create a competitive advantage, which may become even stronger if the firm can profit from learn-cost-curve effects. Some proximate examples for growth options might be a R&D or pilot project without which a firm would not have enough knowledge to start a greater scale. The lease of undeveloped land with potential oil reserves is another possible growth opportunity. The strategic acquisition of a competitor in a new market may be a further possibility.

[251] See Trigeorgis (1996b), p. 132.

There are innumerable growth options in every industry but, in general, they are more valuable in infrastructure-based, volatile businesses with higher returns on projects, such as R&D, industries with multiple product generations (e.g., semiconductors, computers, and pharmaceuticals), multinational operations, and strategic acquisitions.[252]

The above-mentioned option types are summarized briefly in Figure 3.13. In order to give a quick overview of their analogy to financial option as well as their position within a firm's strategy, they are divided into call and put options and intra- and interproject options.

Figure 3.13: Types of real options.



3.4.1.7 Multiple interacting options

The option to grow, the option to expand/shrink, the option to switch, and the time-to-build option already signalize that within a single project there may be more than just one type of managerial flexibility to take advantage of. These options are referred to as *options on options*. This means that as soon as an option is exercised, another one is created. These real options are consequently portfolios of multiple interacting options, where the type of interactions is called compoundness and can be divided into

[252] Trigeorgis (1996b), p. 14. For the Swiss case we found evidence that the option to grow is one of the most widely occurring options in every industry and company size. Respondents in the chemicals and materials, the technology and telecommunications, and the financials mention it more often than respondents in other industries.

intraproject and interproject compoundness.[253] By contrast, the option to wait and the option to abandon have been treated as if they were single and standing-alone managerial flexibilities within a project. In real-life, however, a manager has many different options to choose from and will usually take a combination of several to have better control over a project. Within such a portfolio of real options, their single values may interact with, what in turn can cause their non-additivity.[254] The interactions stem from the fact that real options are “written” on the same underlying project and their exercise can, therefore, directly change the value of this underlying and consequently of all other real options “written” on it.[255] As multiple real options are the most common category of managerial flexibility in real-life, understanding them should allow a smoother transition from a theoretical stage to an application phase of the real options theory.[256] We will not emphasize on their exact mathematical valuation because it would depart from the scope of this thesis; however, some types of interactions will be introduced to demonstrate that they might not be so trivial as one could think at a first glance, but neither are they so influential that they could highly complicate the real options analysis and thus endanger its application in praxis.

Trigeorgis (1993a) was the first to point out that a single project often contains several different real options whose value may interact.[257] He stated further that the degree of interaction of two options depends on the dimension of the overlap of their exercise regions. The bigger the overlap of the exercise regions, the higher is the probability of a common exercise and, consequently, the stronger the interaction. These interactions lead to the non-additivity of their values. In fact, the higher the probability of a common exercise, the less additive are the values of the options. The size of the overlap of the exercise regions, in turn, depends on four factors:[258]

1. the *type of the option* (either put or call),
2. the *separation* of the option (how far in time are their exercise points away from each other),
3. the option’s *degree of being in/out of the money* and
4. from the *sequential order* of the options involved.

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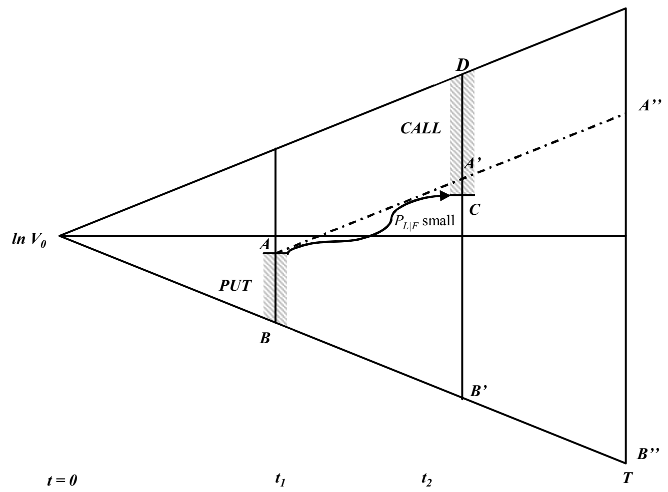
[253] See Trigeorgis (1996b), p. 132 ff.
[254] See Trigeorgis (1996b), p. 227.
[255] See Trigeorgis (1996b), p. 232.
[256] See Copeland *et al.* (2005), p. 325 and Trigeorgis (1996b), p. 19.
[257] See Trigeorgis (1993a).
[258] See Trigeorgis (1996b), p. 227.

Figure 3.14 shows the situation for the case of a combination of a put and a call option (e.g., an option to contract and an option to expand) where the put matures earlier and both options are out of the money.

Figure 3.14: Exercise regions for the combination of a put option and a call option.



Source: Trigeorgis (1996c), p. 231.

In Trigeorgis's model, the logarithm of the gross project value, ln V, follows an arithmetic Brownian motion in discrete time. For successively smaller intervals this can be approximated by an equivalent binomial Markov random walk[259] developing in a triangular lattice as shown in Figure 3.14.[260] The exercise region for the put option corresponds to AB, whereas the one for the call is represented by CD. If the underlying in t_1 reaches a value within the exercise region of the put option lnV will move only within the trapezoidal area ABB'A' for t_2 respectively ABB"A" for T. This area overlaps the exercise region of the call option only by a small part, i.e. A'C. This means simply that once the put option (option to contract) has been exercised the probability that the value of the underlying asset will reach the exercise region of the call option (option to expand) is very small. Consequently, the probability of an exercise of the call

[259] For Brownian motion and Markov process see for example Hull (2006), p. 263.

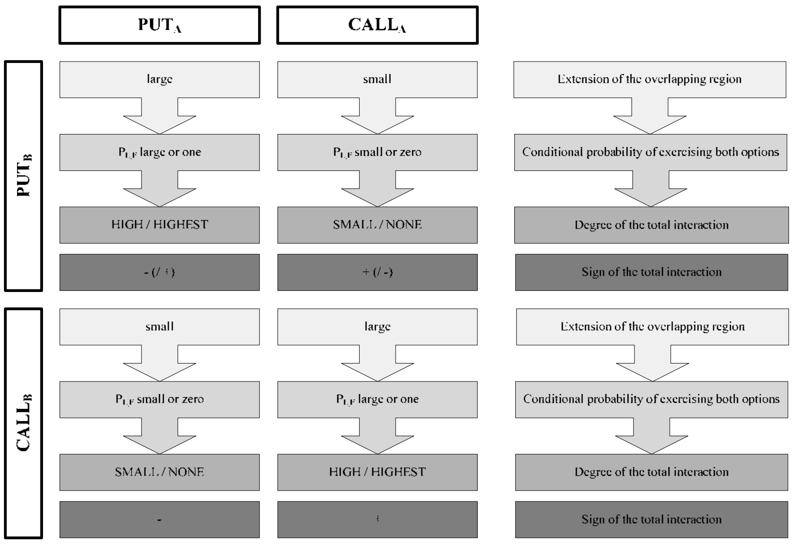
[260] See also Trigeorgis (1996b), p. 230.

option will be small as well; the interaction between the two options is very small and, hence, their values are almost completely additive. In general, the smaller the overlapping area of the two exercise regions of two options, the lower the probability of a common exercise. This results also in a lower interaction of their values and, thus, lower valuation errors if the two option values are simply added together.

In the above mentioned example, we presented the case where a put option is followed by a call option. Obviously, it is also possible to encounter the situation with a put option followed by a put, or a call option followed by either a call or a put. The interactions will be different in each case. Generally, the nature of interaction, and consequently the degree to which the values of two interacting options can be added, can be summarized, as shown in Figure 3.15. If the conditional probability of exercising both options before maturity is zero or small, there is no or small interaction and, consequently, the separate option values will be additive or at least approximately additive.[261] The other way round, if it is certain or most probable that both options will be exercised, that is the conditional probability of a joint exercise is 1 or high, the interactions between to the options is highest or at least high, which can lead to large valuation errors if adding together the separate option values. The interaction will typically have a positive sign if the prior option is a call, and a negative sign if it is a put. In the case of a prior put (as when the separation between two similar-type options is negligible), the combined option value is represented by the higher of the separate individual values (or only somewhat higher). In this case, the additional value of the lesser option may be negligible, or at least very small.

[261] Conditional in this case means: exercising the later option if the first has already been exercised in advance, in mathematical notation: P(later option | first option).

Figure 3.15: Interactions of two real options.



As mentioned above, two options that interact strongly are less additive than two options that do not interact. Consequently the total value of a portfolio of several options will always be less than the value of each single option added together.[262] It is not trivial to describe the nature of interactions and assess the fraction of value that is overlapping and is consequently non-additive. Trigeorgis tried to solve this problem with a log-transformed variation of the binomial model for financial options. This model can be used to value financial options, as well as multiple real options within a project.[263] As this is beyond the scope of this dissertation, we will not go any further into the explanation of the mathematics of this model.

Up to now we have discussed only the case with two options. If a project includes more than two real options, the interactions obviously become more complex, although the factors on which the interactions depend stay the same as in the two-options case.[264] Trigeorgis (1993a) showed in a numerical example that, depending on the type of real options embedded in the project, the marginal option value effect will diminish, the

[262] With exception of the quite unrealistic situation where none of the options interact with each other.

[263] See Trigeorgis (1991b), p.320.

[264] See Trigeorgis (1996b), p. 236.

larger the number of real options within the project.[265] Consequently, for a practitioner who wants to value a project as a portfolio of real options, a limitation to the three most important real options of the project is an assumption that will mostly not lead to large valuation errors.

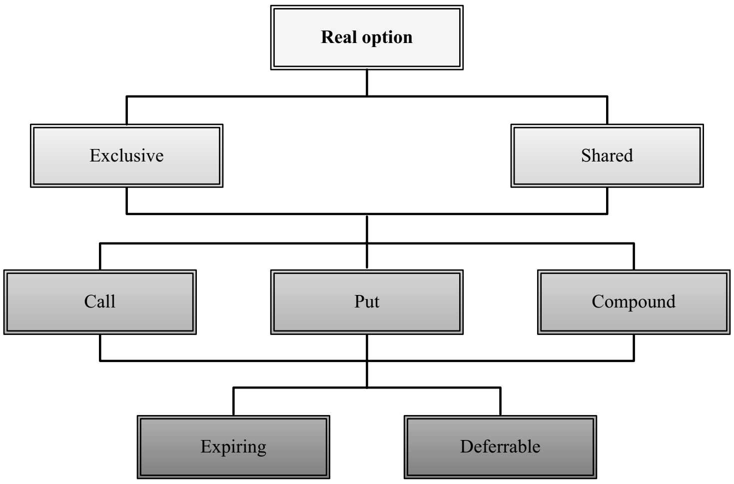
3.4.2 A review of different real option categorizations

In the previous chapter we presented the categorization of real options by Trigeorgis. However, in real options literature, writers try to categorize the different flexibilities using many different labels. Mainly the aim of these different categorizations is to support their identification, to guide their subsequent valuation or to describe portfolios of strategic projects. To achieve this aim, the authors focus on different specific strategic questions about the underlying decisions. Thus, unfortunately, there is little consistency between the different categorizations, which can create confusion to the beginner in studying real options literature. This subchapter should shed some light on this point and draw some parallels between similar real option features which appearing in different categorizations under different names.

A first strategic question refers to the exclusivity of a real option. If a firm has some exclusive rights (e.g., secured through a patent, a lease, or a license), the option is said to be a *proprietary* real option. If, on the other hand, the investment opportunity and its strategic flexibilities are open to other firms as well, the firm is in possession of a *shared* real option.[266] Another distinction between types of real option can be made in looking at their expiration. An *expiring* real option has a confined time window in which it can be exercised, whereas a *deferrable* real option is characterized by the possibility of postponing the decision to exercise to an indefinite point in the future.[267] A third simplistic type of differentiation among real options goes back to the financial options classes referred to in chapter 3.3. Accordingly real options can be categorized in call-like real options, put-like real options and compound real options, which represent any possible combination of the first two mentioned option classes.[268] The three presented differentiation criteria are a first simple approach to categorize real options. They are summarized in Figure 3.16.

[265] See Trigeorgis (1993a), p. 17.
[266] See Kester (1984), p. 157ff.
[267] See Trigeorgis (1999a), p. 14.
[268] See Neufville de (2004), p. 17.

Figure 3.16: Classification of real options based on propriety, expiration and options class.



However, the distinction between the real option's propriety and their expiration is not always that clear cut in reality.[269] Moreover, in real-life a lot of investment opportunities or strategic actions have features which span a number of the above-mentioned categories. Consequently, some types of managerial flexibility cannot be assigned to one distinct category, which makes another type of categorization indispensable. Therefore, Trigeorgis as well as other authors base their categorization on the type of flexibility available to the manager. However, even in-between this type of categorization there are some differences that must be understood to avoid confusion in trying to systematize a real option application within a firm. Therefore, we will present shortly some of the most frequently encountered flexibility-based real option categorizations and compare every single one of them with the categorization according to Trigeorgis, explained in chapter 3.4.1, to highlight the analogies and the differences of the distinct option types explained by the different authors. Table 3.16 summarizes our journey through the different selected real options categorizations. To avoid confusion in reading the table, it should be explicitly stated that during the explanation of the different categorizations we will apply the same order of explanation used by the

[269] If a firm has a patent on the product it wants to market, the option is clearly proprietary. But what if there is no patent on it? The propriety will depend on the competitive power of the firm. The stronger the competitive position the more proprietary the investment opportunity.

various authors. However, to compare the different categorizations and represent them in Table 3.5 the order had to be switched for convenience.

Amram and Kulatilaka (1999a) defined five categories of real options, namely the "*Waiting to Invest Option*", the "*Growth Option*", the "*Exit Option*", the "*Flexibility Option*" and the "*Learning Option*".[270] The "waiting to invest option" and the "exit option" are equal to the categories explained in Trigeorgis's framework, whereas Amram and Kulatilaka used other names. As reported in Table 3.5 Trigeorgis' "option to defer" corresponds to Amram and Kulatilaka's "waiting to invest option" and the "option to abandon" corresponds to Amram and Kulatilaka's "exit option". Also the "option to grow" in Trigeorgis and the "growth option" of Amram and Kulatilaka are almost the same, with the difference that the option to grow encompasses also a part of the "learning option" of Amram and Kulatilaka. In fact, the "learning option" in Amram and Kulatilaka is not that clear cut and, therefore, a very broad category which, to some extent, can be associated not only to Trigeorgis "option to grow", but also to the "time-to-build option", the "option to alter operating scale" and even to a "multiple interacting option". At this point, there is to say that, in general, every option in every categorization embodies a learning element. In fact, with every type of real option a manager can wait and learn from the evolving events before committing to an investment. This is also the main reason why the "learning options" cannot be clearly associated to one of Trigeorgis's categories. The "flexibility option" according to Amram and Kulatilaka refers to the possibility of building more than one production facility and switch between the use of both of them depending on the production costs. This, again, is a concept explained in Trigeorgis "option to switch", whereas Trigeorgis allows also for the possibility to switch the production output, which is not described in Amram and Kulatilaka's "flexibility option".

Brealey and Myers (2003) defined a further categorization approach.[271] The authors divide the real option universe into four different categories, whereas they do not give any exact definition of the categories but explain them by means of some examples. This makes it difficult to draw the analogies to Trigeorgis's categorization. The option categories adopted by Brealey and Myers are the "*Timing Option" (*also called *"Option to wait", "Option to Learn*"), the "*Abandonment Option*", the "*Option to Vary the Mix of Output or Production Method*" and the "*Option to Expand*". Although the way some of the real options categories are named can lead to the conclusion that there are many analogies between the two categorizations, this is not always the case. The "timing option" of Brealey and Myers is the only one which can be clearly associated with the

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[270] See Amram and Kulatilaka (1999a), p. 10ff.

[271] See Brealey and Myers (2003), p. 268-276 and p. 617-634.

"option to defer" of Trigeorgis, whereas Brealey and Myers also used other synonyms for it in the same work like "option to wait" or "option to learn".[272] The "abandonment option" according to Brealey and Myers, is similar to the "option to abandon" of Trigeorgis. Both are put option on an asset in place. The main difference stems from the categorization of a partial abandonment. Whereas for Trigeorgis a partial abandonment is a sub-type of the "option to alter operating scale", a so called "option to contract", for Brealey and Myers a partial abandonment is a sup-type of the "abandonment option" itself. A similar difference applies for the "option to expand", which for Brealey and Myers is a category on its own and comprises also the "time-to-build option", "option to grow" and a part of the "option to alter operating scale" by Trigeorgis. For Trigeorgis, namely, the "option to expand" is just a sub-type of the last mentioned option category, i.e., the "option to alter operating scale". Finally, the "option to vary the mix of output or production method" can be related to the "option to switch" of Trigeorgis, whereas Brealey and Myers underlined in their description the fact that a manager cannot only vary an input factor if necessary, but also a complete production process. A possibility which is not excluded by Trigeorgis, but neither is it especially emphasized in his framework. Finally, Brealey and Myers treated only simple options in their framework and therefore none of their option types can be directly related to Trigeorgis's "multiple interacting options".[273]

De Neufville put emphasis on the valuation aspect dividing the option categories into "*Call-like Options*", "*Put-like Options*" and "*Compound Options*".[274] In these three broad categories, De Neufville differentiated between eight subcategories. First, the call-like options which include the "*Waiting to Invest*", the "*Expand*" and the "*Restart Temporarily Closed Operations*" options; second, the put-like options comprising the "*Abandon*", the "*Contract*" and the "*Temporarily Shut Down Operations*" options; and last, the compound options that De Neufville divided into "*Switching Between Modes of Operation*" and the "*Combinations of Options*" which summarizes any other portfolio of multiple interacting options. Drawing a comparison to Trigeorgis the "option to defer" can be equated to the "Waiting to Invest" option of De Neufville. The "option to abandon" was described in both categorizations in the same way. For the "switching between modes of operation" option of De Neufville, by contrast, it can be only found a partial correspondence with the "option to switch" of Trigeorgis, who more broadly

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[272] As already explained within Amram and Kulatilaka's categorization every option category embodies a learning element, and it is consequently not surprising that also Brealey and Myers use this terminology also as a synonym for the timing option.

[273] Although in some way the „option to expand" could be viewed as an option on another option and consequently as a „multiple interacting option".

[274] See Neufville de (2004), p. 17.

defined it as also allowing a switch of outputs or inputs. The "Expand", the "Contract", the "Shut Down" and "Restart" options of De Neufville can be all associated to the "option to alter operating scale" of Trigeorgis which encompass as well expanding, contracting, and restarting flexibilities. Finally the "combination of options" of De Neufville comprehends the "time-to-build option", the "option to grow" and any other "multiple interacting option" of Trigeorgis.

Table 3.5: Different categorizations of real options.

Trigeorgis	Option to defer	Time-to-build	Option to alter operating scale (Expand/Contract)	Option to abandon
Amram/Kulatilaka	Waiting to Invest	Learning Option	Learning Option	Exit Option
Brealey/Myers	Timing Option (Option to Wait, Option to Learn)	Option to Expand	1) Abondnment Option 2) Option to Expand	Abandonment Option
De Neufville	Waiting to Invest	Combinations of Options	1) Expand 2) Restart Temporarily Closed Operations 3) Contract 4) Temporarily Shut Down Operations	Abandon
Copeland/Weston/ Shastri	Deferral Options	Compound Options	1) Expansion Options 2) Contraction Options	Abandonment Options
Hommel	Lernoption	Lernoption	Versicherungsoption	1) Versicherungsoption 2) Lernoption

Trigeorgis	Option to switch	Option to grow	Multiple interacting options	Not existing in Trigeorgis
Amram/Kulatilaka	Flexibility Option	1) Growth Option, 2) Learning Option	Learning Option	-
Brealey/Myers	Option to Vary the Mix of Output or Production Method	Option to Expand	-	-
De Neufville	Switching Between Modes of Operation	Combinations of Options	Combinations of Options	-
Copeland/Weston/ Shastri	-	Expansion Options	Rainbow Options	Extension Options
Hommel	Versicherungsoption	Wachstumsoption	-	-

Copeland *et al.* (2005) defined six different types of real options, that is the "*Expansion options*", the "*Contraction options*", the "*Abandonment options*", the "*Extension options*", the "*Deferral options*" and the "*Compound options*".[275] As already found in comparing Trigeorgis's categorization to the others, the "option to defer" and the "option to abandon" are between the most clear cut categories in general. Also in Copeland et al., there can be found two categories, the "deferral options" and the

[275] See Copeland *et al.* (2005), p. 321.

"abandonment options" which directly compare to Trigeorgis's categories. The "expansion options" and the "contraction options" moreover, can be compared to Trigeorgis's "option to alter operating scale", in either case, for an expansion or a contraction. Copeland et al. use the term "expansion options" synonymous with "growth options". This is not correct in the notion of Trigeorgis, as the "option to growth" refers to interproject flexibilities, whereas the "option to expand" refers to intraproject flexibilities, where the distinct expansion stages stay within the same project and do not open up chances for completely new projects. Furthermore, "compound options" for Copeland et al. correspond to the "time-to-build" option of Trigeorgis. In both cases, they describe a row of investments with the possibility for the manager to defer or abandon at the end of each phase. The "rainbow options" in Copeland et al. is the last category which can be associated with a category of Trigeorgis. According to Trigeorgis, rainbow options are a sub-type of "multiple interacting options" that depend on multiple sources of uncertainty. A completely new category coined by Copeland et al. is the so-called "extension options" category. This type of options cannot be found in any of the flexibility-based categorizations explained above and refers to the ability to extend the life of a project. Consequently, it is a European call-option, whereby the cost of the extension represents the exercise price. Copeland et al. note that an example of such an extension option could be the renewed lease of office space.

To conclude the discussion of different categorizations of real options we present the one of Hommel and Pritsch, who are the most prolific authors of real options writings in German-speaking literature. Hommel and Pritsch (1999) based their categorization of real options on the needs of the firm.[276] For Hommel and Pritsch, the firm has three different broad strategic needs, which can be met with a correspondent managerial flexibility: namely to assure itself against negative outcomes, to learn about future developments, and to grow. Therefore, they determined three types of real options, the "*Versicherungsoption*" (assurance option), the "*Wachstumsoption*" (growth option), and the "*Lernoption*" (option to learn).[277] The only category which can directly be associated to Trigeorgis is the "Wachstumsoption", which corresponds to Trigeorgis's "option to grow". The other two categories of Hommel/Pritsch are so broad that they can be associated with almost any of Trigeorgis's categories. The main difference between the "Versicherungsoption" and the "Lernoption" is that the first is a put-like option, and the second is, in most cases, a call-like option and rarely a put-like option.

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[276] See Hommel and Pritsch (1999).

[277] As the description of the German categorizations is intended above all for the German-speaking readers we will keep primarily the German names and give a translation only the first time they are mentioned.

Thus, the “Versicherungsoption” embraces any put-like real option by Trigeorgis, i.e., the “option to switch” (as well the inputs, the outputs or the production process),[278] the “option to alter operating scale” (limited to the contraction part), and even the “option to abandon” if the business results turn out to be extremely bad. The “Lernoption”, on the other hand, subsumes every possibility to wait and see before taking the decision to invest or disinvest. In Trigeorgis’s categorization this corresponds to the “option to defer”, the “time-to-build” option and the “option to abandon”. Each of this options, the call-like as well as the put-like options, endows the manager with the possibility to wait and learn how the state of affairs evolves. Finally, the “multiple interacting options” of Trigeorgis are not explicitly mentioned in Hommel and Pritsch; however, it is neither excluded that some of the mentioned option types can occur in combination.

3.5 Real option valuation approaches and their practical implications

The author of this thesis is of the opinion that also in valuing real options the division of labor as described by Adam Smith applies without restriction. The specialization and concentration of workers in their special single subtasks will lead to better skill and therefore to greater productivity as a whole. A project leader in the chemical industry, for example, will know his business inside out. He is informed about the uncertainties that might be encountered during the project’s lifetime, the irreversibility of some investments and the possible strategic flexibilities, i.e. real options, he will be able to play out. At the same time a mathematician will know how to model the value of the real option once he gets the specifications from the project leader. Consequently, we want to separate the two aspects of recognizing the real options and technically valuing them. The focus in this dissertation will be put on the former aspect, as we are of the opinion that in real options literature, not much attention has been dedicated to the preliminary decision of properly determining the potential real option inherent in a project, but rather they are always given as existent, and then the mathematical work is being explained and applied to them. Despite this clear-cut separation, we want to provide the ROA user[279] with an overview of the possible option-based approaches to

[278] Whereby in this case only one part of the option to switch is a „put-like option“, namely the part concerning the abandonment of the old modus operandi. Obviously, the other part of acquiring the new operating mode is a call-like option.

[279] Hereby we assume that in most cases the ROA end-user is not a mathematician and therefore is extremely challenged by the application of the mathematics of the real options approach. This assumption is quite reasonable as, like we observed in the survey in subchapter 4.5.3, for managers of Swiss firms the lack of mathematical knowledge

value flexibility for two reasons: first, for supporting the ROA user in the communicating with the mathematician or real option specialist, who has to technically solve the problem; second, to provide the ROA user with some guidelines to show him what is possible and what is not with the different valuation approaches. For this purpose, we firstly explain for which situations in general an option-based valuation method is of greatest advantage for the valuation of an investment project. Then we will turn our attention to the different valuation approaches and discuss their strengths and weaknesses in regard to their application for real-life projects.

From a theoretical point of view, option-based techniques would solve all the problems arising with the scenario-based techniques discussed in chapter 2.3. Specifying the correct valuation parameters would account for not only uncertainty but also for all possible subsequent managerial flexibilities. Moreover, an option-based method would not require a risk-adjusted discount rate, but only the risk-free rate, which in turn would lead to theoretically valid market values.[280] Regardless of their theoretical supremacy, the option-based techniques suffer from their applicability. First, they obviously require a specific understanding of options theory and, second, the valuation parameters are very difficult to determine. Therefore, Hommel proposed to apply an option-based technique only for specific valuation cases. Only in cases with high uncertainty and high flexibility are the efforts of taking the difficult way adequately rewarded. In cases with low uncertainty and low flexibility, the results and decision rules coming from an option-based valuation technique are the same as the one of a common NPV application. In cases with high uncertainty but low flexibility, in turn, Hommel recommends a sensitivity analysis or a Monte Carlo simulation as a more accurate treatment of uncertainty may is relevant, however no or little flexibility to adapt to unforeseen changes is available. Lastly, a decision tree analysis (DTA) is proposed for projects with low uncertainty and a high degree of flexibility because the DTA can deal fairly easily with flexible managerial action, but is more challenging in cases with ever-changing risk.[281] Hommel's statements are outlined below in Figure 3.17.

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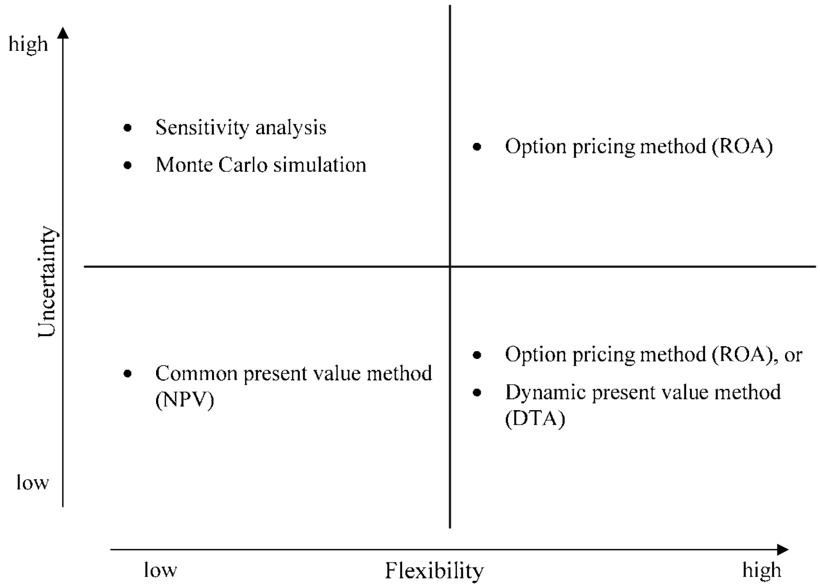
is one of the major hindrances for applying the ROA in practice. Analogous observations were made as well in many other international surveys on the application of the ROA. See chapter 4.2 for an overview of the surveys.

[280] This holds due to the risk-neutral valuation explained in chapter 3.3.2.1. To be more precise: In the case where the underlying is represented by the NPV of the project without flexibility this is not completely correct, as a risk-adjusted discount rate is needed to discount the free cash flows for getting the NPV.

[281] This would require an ever-changing discount rate, which in practice is hardly applicable in a DTA.

Figure 3.17: Systematic choice of the capital budgeting technique.



Source: Based on Hommel and Pritsch (1999), p. 129.

For implementing a real option valuation, there are several different approaches that can be pursued. Thus, after that the choice is made for an option-based valuation technique, there must be still decided on which approach exactly one should rely on. In fact, despite of their theoretical supremacy in practice, the assumptions made within the different valuation approaches can have important consequences for the usefulness of the results. Moreover, the availability of the input parameters is not always given and sometimes requires bold estimations. Also this fact should be taken into consideration when interpreting a result of a ROA in order to avoid not only a lack of academic correctness, but also wrong investment decisions, lost value, and a loss of confidence in the new technique.

The next sub-chapters will be aimed to shed some light on the practicability of the most frequently mentioned option-based approaches in real option literature, and describe what their results stand for and what type of estimation or assumptions are needed to derive them. An interesting discussion about these questions was done by Borison (2005), who divided the different valuation approaches into five broad categories:[282]

[282] See Borison (2005).

1. The classic approach
2. The subjective approach
3. The MAD approach
4. The revised classic approach
5. The integrated approach.

Borison discussed the five approaches in focusing his attention systematically on three issues that are fundamental for a ROA application in practice: first, on the validity of the assumptions made; second, on the difficulty associated to its mechanics; and, third, on the meaning of the resulting value in adopting a specific approach and on its appropriateness for a given investment case. We will discuss each approach, basing our statements on his work, unless otherwise noted.[283]

3.5.1 The classic approach

The *classic (no-arbitrage, market data) approach* starts from the assumptions that the capital markets are complete.[284] Many authors, among them Amram and Kulatilaka (1999a), Copeland *et al.* (2000)[285] and even Trigeorgis and Mason (1987)[286] adopted this view above all for the sake of its simplicity. In fact, it allows a full application of an analytical closed-end solution like the Black-Scholes option pricing model described in chapter 3.3.2.2. The classic approach makes the same assumptions as the Black-Scholes model and emphasizes the point that to value the real option, a portfolio of traded investments must be constructed to replicate the returns of the option. In doing so, it implicitly assumes that the option is valued by means of the standard no-arbitrage, replicating-portfolio arguments of financial option theory. Moreover, the asset price movements should be described by a geometric Brownian motion (GBM) – another assumption from classical financial option valuation. Additionally, in adopting the classic approach, no subjective estimations are needed as all information about the

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[283] See Borison (2003) and Borison (2005).

[284] To the matter of completeness of the markets in regard of the utilization of option pricing for investment valuation, Dixit and Pindyck (1994) explicitly state that, *"The use of contingent claims analysis*[which is a more general term for option pricing] *requires one important assumption: stochastic changes in V* [the value of the project in question] *must be spanned by existing assets in the economy. Specifically, capital markets must be sufficiently "complete" so that, at least in principle, one could find an asset or construct a dynamic portfolio of assets… the price of which is perfectly correlated with V. This is equivalent to saying that markets are sufficiently complete that the firm's decisions do not affect the opportunity set available to investors".* See Dixit and Pindyck (1994), p. 147.

[285] See Copeland *et al.* (2000).

[286] See Trigeorgis and Mason (1987).

replicating portfolio can be observed in the market. For this reason, Borison denotes the classic approach as well as the no-arbitrage, market data approach. Also from the mechanics of applications, it is very powerful and extremely straightforward:

1. identify and specify the replicating portfolio
2. size the investment relative to the portfolio
3. use the standard option pricing models with the collected input parameters.

Value calculated in this way represents additional shareholder value created by the investment, or better, what the investment would trade for in the capital market. Although from a didactic point of view this method is very useful in that sense that nonessential complexness is avoided to focus on the main ideas of flexibility valuation, there is to say that the classic approach is inadequate from a real-world point of view. In fact, there is no empirical evidence or argument supporting the thesis that a replicating portfolio exists for an exact specified investment. Moreover, many assets are not freely traded, which makes the no-arbitrage argument of financial option pricing invalid.[287] The results stemming from a direct application of financial option pricing to investment valuation (i.e., applying the classic approach) should, therefore, be treated with extreme caution. Real-life investments are typically affected by both private and public risk. Applying no-arbitrage and portfolio-replicating arguments on public risk may make sense. Doing it on private risk certainly does not, as a private risk is, by definition, unique and not replicable. Even authors who adapt the classic approach, e.g., the above-mentioned Amram and Kulatilaka, admit that using financial option pricing on real investments could led to “tracking errors”. However, details on how to treat these errors are not explained in their work.[288]

3.5.2 The subjective approach

The second approach, the *subjective (no-arbitrage, subjective data) approach*, is similar to the classical approach in that it is based on no-arbitrage arguments as well; however it renounces the identification of a replicating-portfolio. Thus all input parameters for applying standard financial option pricing methods stem from subjective estimations of the valuator. Some authors adopting this approach are, for example, Howell (2001)[289]

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[287] See Borison (2005), p. 19.
[288] See Amram and Kulatilaka (1999a), p. 54.
[289] See Howell (2001).

and Luehrman (1998a).[290] Except for the subjective estimation of the input parameters the same assumptions made before for the classical approach hold in this case as well.[291] The mechanics of the subjective approach however are somewhat different:

1. estimate subjectively the price and volatility of the underlying asset
2. apply financial option pricing models (like e.g., the Black-Scholes model).

This second step represents a major advantage of this approach considering the clear and simple handling of most closed-end financial option pricing models. However, the reliance on the replicating portfolio on the one side and the simultaneous use of subjective input parameter on the other is hard to accept. If there are no traded assets to develop inputs for valuation (i.e., to build a replicating portfolio), how is it possible to value an option by means of no-arbitrage arguments using this “nonexistent” portfolio? The results seem to be at least questionable. Therefore, the main disadvantage of the classical approach, i.e. to identify a replicating portfolio, is simply eliminated by introducing the subjective estimates which, however, are neither easily developed nor simply to justify.

3.5.3 The MAD approach

The *MAD (equilibrium-based, subjective data) approach* is a terminus coined by Copeland and Antikarov (2001).[292] These authors are also the first to provide a comprehensive description of this approach. The MAD Approach departs from the other two approaches in that it does not rely on the existence of a traded replicating portfolio. Consequently, there is neither the need to find a replicating portfolio (as in the classical approach), nor to make any subjective estimations about it (as in the subjective approach). However, in applying the MAD approach, a manager has to make some subjective estimations as well. In fact, the underlying’s parameters, such as price and volatility, must be determined with the NPV criterion. Calculating the NPV value of the investment project for the case without flexibility will give the best proxy of the market value of the project as if it were traded.[293] This NPV calculation, in turn, needs obviously the same subjective estimations as for a classical NPV calculation. The complete renunciation of finding market data for the twin-security also gives the name to this approach – Marketed Asset Disclaimer. Copeland and Antikarov (2001) justified

[290] See Luehrman (1998a).
[291] No-arbitrage condition, replicating portfolio, geometric Brownian motion.
[292] See Copeland and Antikarov (2001).
[293] See Copeland and Antikarov (2001) p. 94.

their assumption by comparing it to the assumption made for applying the NPV criterion. Also the NPV assumes traded assets of comparable risk (comparable betas) to value an investment. Consequently, the MAD approach does not make any stronger assumptions than the original NPV calculation.[294] Trigeorgis (1996b) followed the same line of argumentation, arguing although that the correct use of the NPV criterion is bound on the assumption of market completeness.[295] According to these arguments, the NPV of the inflexible investment project represents an estimation of the project's value if it was traded. Therefore, the real option value of the flexible investment will represent the estimation of the value of the project's flexibility if the project were traded on the capital markets. Moreover, adherents of the MAD approach also make the assumption that the asset prices follow a geometric Brownian motion (GBM), as assumed for the classic approach and the subjective approach. Without this random walk hypothesis, it would not be possible to apply binomial lattice models for valuing the real option value.[296] Thus, we first have the statement that the inflexible NPV will be an estimate of the value of the project's underlying if it was traded, and second, the other assumption that the GBM will be an estimate of the future behavior that the project's value would have, if it was traded. This leads to the final conclusion that the real option value is an estimation of the value of the option if the underlying assets were traded on capital markets and behaved the way supposed by the GBM. An advantage of this approach is certainly that in not adopting this view, most real option applications were limited to situations where the prices of the underlying could directly be observed in capital markets, such as oil, gold, etc. By applying MAD and GBM, by contrast, a manager can also value flexibility for a much wider set of problem where market prices are not observable, as it is the case for most investment projects.[297] Another advantage is that the steps for a MAD application are also not too demanding from a technical point of view and develop as follows:[298]

1. build a spreadsheet cash-flow model for the underlying asset (based on subjective assumptions) and calculate the project's NPV
2. estimate the uncertainty related to the inputs of the model and apply a Monte Carlo simulation on it
3. use the resulting distribution to build a risk-neutral binomial lattice for estimating the value of the option.

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[294] See Copeland and Antikarov (2001), p. 67.
[295] See Trigeorgis (1996b), p. 127.
[296] See Copeland and Antikarov (2001), p. 219.
[297] See Copeland and Antikarov (2001), p. 415.
[298] See Copeland and Antikarov (2001), p. 248.

These calculations are internally consistent, and the value of the option is thus a forecast of what will be achieved in equilibrium over time. However, no effort is made to bind the estimation to market values. This disconnection from capital markets is the major reason to question the MAD approach. We know that the underlying asset and the option are priced consistently, but we do not know if both may are priced wrongly relative to the market. Moreover, another difficulty arising with this approach is the development of the many subjective inputs needed to value the real option.

3.5.4 The revised classic approach

Until now the discussion has been based on the limitation of the different approaches and the questionableness of the no-arbitrage and the replicating portfolio assumptions. The followers of the above-mentioned approaches, however, do not discuss what to do if the assumptions do not apply, or even state explicitly that the assumptions are not restrictive, as in the case of the MAD approach. The *revised classic approach* recognizes the difficulty with the restrictions of some assumptions. Consequently, it suggests using the classic finance-based real option approach in cases where the assumptions apply. In cases where it does not, the user is referred to management science-based approaches like dynamic programming or Decision Tree Analysis to solve its flexibility valuation problem.[299] Authors who adopt this view are, for example, Dixit and Pindyck (1994), who proposed the use of contingent claim analysis (i.e., a more general term for option-based valuation techniques) where the requirements for the stochastic component of the asset to be valued can be exactly replicated by the stochastic component of the return on some traded assets. In the other cases, one should move to dynamic programming since it does not make any assumptions about the market replication of the returns.[300] Amram and Kulatikala (2000) who earlier supported the classic approach, changed their opinion in later works. This change of opinion is why Borison called this approach the *revised* classic approach. Amram and Kulatilaka stated that in the cases where the investment project can be reasonably tracked by traded assets, i.e., the investment is dominated by market-priced or public risk, option-based valuation techniques (like in the classic approach) can be fully applied. By contrast, for investments dominated by corporate-specific or private risk, other frameworks, such as the scenario-based decision analysis, should be employed.[301]

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[299] See chapter 2.3.5 for the Decision Tree Analysis and ff for dynamic programming for example Dixit and Pindyck (1994), p. 93.

[300] See Dixit and Pindyck (1994), p. 120-121.

[301] See Amram and Kulatikala (2000), p. 16.

In an earlier work the same authors tried to give a schematic view of their arguments. Figure 3.18 illustrates their statements. One axis is labeled with "the distance from the financial markets", whereas the "complexity of the investment decision" is assigned to the other axis. The more complex the investment decision and the farther the real option from the financial markets, the less reliable are the classic financial option pricing models and the more necessary are some customized valuation models for getting more accurate results in flexibility valuation. The departure from the market assumption can be that strong, and the complexity of the decision that high, that the investment decision will achieve what the authors call the "*Real Options Frontier*". This frontier represents the point where any flexibility valuation attempt becomes impracticable, whether with option-based techniques or with scenario-based techniques. The authors argued however that this frontier is in continuing expansion as new markets emerge.[302] This is a phenomenon that is already known from financial option valuation.[303] In addition, the valuation models become more sophisticated and the computational power in IT higher. We believe that these circumstances, in turn, will further broaden the real options frontier.

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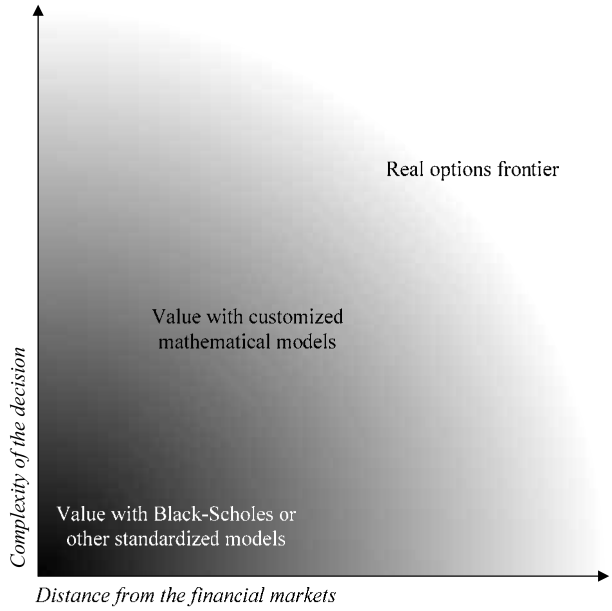
[302] See Amram and Kulatilaka (1999a), p. 99.

[303] See thereto Cox and Rubinstein (1985), p. 428ff. The authors state that a securities market has to perform three basic economic functions, namely first, the individual wealth allocation; second, the firm resource allocation; and, third, the source of information. In general, the greater the variety of securities provided by the market, the better the three functions are fulfilled. A financial market which provides all of these functions at its best is called "complete". The higher the "degree of completeness", the better the theoretical financial valuation models (as, e.g. the Black-Scholes model for pricing options) will hold. Consequently, the authors concluded that the wider the financial markets get the better the standard option pricing models will hold in practice.

Figure 3.18: The real options frontier.



Source: Amram and Kulatilaka (1999a), p. 99.

One of the main problems of the revised classic approach is that its application mechanics suffer from an increase in complexity compared to the other above-mentioned approaches. The mechanics for the revised classic approach develop as follows:

1. determine if the investment is dominated primarily by market risk or by private risk
2. if the former applies proceed as in the classic approach
3. if the latter is true apply a Decision Tree Analysis.

Especially the first step concerning the segmentation of public and private risk is by far not trivial.[304] Once this step has been taken the difficulties are the same as in the classic approach if public risk is dominant. In the other case, where private risk is dominant

[304] The authors do not give any guidance on how to assign investments either to the market risk dominated category or the private risk dominated one.

and Decision Tree Analysis must be used, the challenge is to find the appropriate subjective inputs for building the decision tree.

3.5.5 The integrated approach

The *integrated approach* is based on the same notion that investment projects are subject to two types of risk: on the one side, the market or public risk; on the other side the corporate or private risk. In the case of the classic and the subjective approach, private risk is a source of error which reduces the explanatory power of the calculated real option value. According to the revised classic approach, investment projects should be segmented into the public risk dominated investments and private risk dominated investments, and valued with the appropriate techniques depending on their risk affiliation. The integrated approach goes a step further and argues that there are many investments in the "grey-zone", which cannot be forced into one category or the other, but, rather, are influenced by both risk categories. Consequently, the integrated approach provides a solution to value flexibility by accounting for both types of risk at the same time. Smith and Nau (1995) were the first to describe the integrated approach although they did not use the term real option per se but, starting from management science, refer to this approach as the integration of decision analysis and option pricing. The authors argued that, assuming complete markets, an investment decision can be based on market information which is the same for all shareholders and for the management. Therefore, all of them will agree on the same decision, which will result in the maximization of the wealth of the shareholders and managers.[305] By contrast, if markets are incomplete, individual risk preferences and unshared probability assessment about the beliefs on the outcome of the project may play an important role. In such a situation, the integrated approach assumes that the shareholders completely agree with the probability assessments of private risks made by the managers, a view which is adopted as well by all other approaches described before. In short: the management's goal is to maximize the wealth of firms' shareholders and where subjective assessment is needed management supplies it in accordance with the shareholder's belief. If this holds, any corporate investment project can be valued with the integrated approach, even though markets are assumed to be only "partially complete". The implementation of the integrated approach requires: identifying public and private risks, mark-to-market the part of value of the asset driven by public risk, and do some estimations for the part of value of the asset affected by private risk. From this perspective Smith and Nau developed what they a call a "risk-adjusted decision

[305] See Smith and Nau (1995), p. 812.

tree", removing any arbitrage opportunity and accordingly incorporating the possibility for hedging private risk.[306] The mechanics of applying the integrated approach result as follows:

1. identify the investment risks as either public or private
2. for the former proceed as in the classic approach
3. for the latter apply a Decision Tree Analysis
4. integrate the result from the classic approach into the result of the DTA.

Consequently the integrated approach is the only one that incorporates both, the application of the traditional DTA for one extreme (private risks) and the utilization of option pricing for the other extreme (public risks). However, the mechanics of the integrated approach are not trivial, what probably, besides its ambiguous position between management science and finance theory, makes it hard to track for academics and practitioners.

Summarizing all findings in the different approaches described above Borison concluded that in real options analysis a state of confusion prevails because of the different approaches and different results (coming from the different approaches) for the same valuation problem. Consequently, he argued that it is not surprising that potential practitioners are hard to convince about the usefulness of such an analysis. However, he stated that the crucial task to master is to critically evaluate the overall quality of each valuation approach and apply the appropriate approach to the specific investment project to be valued.[307] Figure 3.19 summarizes the statements made according to Borison.

[306] See Smith and Nau (1995), p. 796 ff.
[307] See Borison (2005), p. 30.

Figure 3.19: Valuation approaches for real options.

Augmenting quality of results for real-life investments (↓)

Name	Nature of capital markets	Data source	Main assumptions
Classic approach	Complete for all corporate investments	Capital market	no arbitrage, existing replicating portfolio, GBM
Subjective approach	Complete for all corporate investments	Subjective judgment	no arbitrage, estimated replicating portfolio, GBM
MAD approach	Absent for all corporate investments	Subjective judgment	equilibrium-based, subjective data for price movements GBM, NPV equals inflexible investment project value
Revised classic approach	- Complete for all market-oriented corporate investments - Absent for all private-oriented corporate investments	- capital market for market-oriented corporate investments - subjective judgment for private-oriented corporate investments	complete markets and replicating portfolio (for market-oriented investments)
Integrated approach	- Complete to market risks of corporate investments - Absent to private risks of corporate investments	- capital market for market risks - subjective judgment for private risks	partially complete markets (only complete with respekt to public risks), limiting assumption about relationship of public and private risks

Augmenting ease of use in practice (↑)

Source: Based on Borison (2003), p. 26-27.

3.6 Cutups of the real options approach

Even though it looks like that the Real Options Analysis is the most promising technique to value managerial flexibility within investment projects, there are several critiques it must undergo. An awareness of these critiques is a further important aspect to analyze, when deciding about a ROA application or interpreting the results deriving from a real option's calculation. We divide the different critiques into three main categories – first, the *theoretical critiques*; second, the *implementation problems*; and, third, the *reputational problems*. Some problems have already been considered in other parts of the dissertation. In order to generate a comprehensive overview of the cutups of the real option's theory, they will be briefly mentioned in this chapter again. Moreover, it should be noted that we will only list some potential solutions for every distinct problem but not go deeply into the description of every single solution as this is beyond the scope of the present study.

3.6.1 Theoretical critiques

Most of the theoretical cutups regarding the real options methodology stem out from the limitations of the option analogy discussed in chapter 3.3.3. Clearly, it is obvious to ask how a manager could apply a technique which has being developed for pricing financial options to investment projects, if the investment projects are limited in their analogy to financial options. On the other hand, there are many different investment decisions and investment opportunities that are indeed similar to financial options. Therefore, turning down the real option method rapidly, only due to these analogy limitations, would be too superficial and wrong. We are of the opinion that every project manager knows his business at best and, therefore, he should be provided with the information about some "stumbling blocks" that should be checked when trying to implement the ROA to a specific projects. Certainly, not everyone is aware of every cutup and/or what can be done to overcome a specific problem. Therefore, most managers tend to set aside real options valuation and stay within their standard approaches, which they obviously know well.[308] Thus, discussing different theoretical limitations and proposing some directions that can help will hopefully mitigate some reservations concerning the Real Options Analysis. We divide the theoretical problems into five different categories - the problems deriving from the *market incompleteness*, the *complexity* problems, the "*endogeneity*" problems, the *implicit distribution function*, and the *counterparty risk*.

3.6.1.1 Problems deriving from market incompleteness

The first category of theoretical critiques subsumes all the problems related to the assumptions about market completeness made for the derivation of the pricing models for standard financial option pricing.

A first problem is the *non-tradability* (in financial markets) of most of the *underlying assets* (i.e. investment projects in the case of real options). In fact, option-pricing theory assumes that the underlying asset (e.g., a stock for financial options) can be freely traded in financial markets without transaction costs. As explained in chapter 3.3, the logic of option pricing is based on arbitrage: if it is possible to form a replicating portfolio in order to avoid arbitrage, an option will always have the same value as the replicating portfolio. If we cannot construct the risk-free portfolio the risk-neutral valuation[309] would no longer apply and the option's value will in this case depend on

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[308] As we found in our survey of Swiss companies, where the majority of the respondents stated to use the NPV and only few were willing up to now to undertake the efforts to acquire knowledge about the real option theory. See chapter 4.5.1 and 4.5.3.

[309] See also chapter 3.3.2.1 for an explanation of risk-neutral valuation.

the expectations about future price developments of the underlying asset.[310] Finding a market priced underlying for investment projects, however, is seldom possible, which therefore makes the simple applicability of financial option pricing models for real-life project difficult to accept.[311] In most future-oriented R&D projects the *underlying asset does not even exist* and, if it does, then it is mostly *not liquid* enough to form the replicating portfolios required by the standard option pricing models. Therefore, estimates are needed for the value of the underlying asset (without flexibility) and its volatility. Due to the questionable reliability of these estimates Hommel and Pritsch (1999) suggested working with "band width" to assure conservative values.[312] Trigeorgis (1996b), on the other hand, suggested another solution. He stated that every contingent claim on an asset, independently of the fact whether it is traded or not, can be priced in a world with systematic risk by diminishing its actual growth rate by a risk premium that would be appropriate in market equilibrium. This method, thus, which he calls "rate of return shortfall", uses a certainty-equivalent rate and proposes to price the option as if the world were risk neutral.[313] However, it requires an estimate as well, namely the one about the risk. Another remedy to the non-tradability of the underlying asset is the one to assume the existence of a suitable market-priced security sufficiently correlated to the riskiness of the underlying asset being valued, a so-called twin-security.[314] This twin-security would allow the valuator to calculate the underlying asset's fair value and its volatility that would be valid in capital markets if it were traded, assuming market completeness in order that every payoff structure for the replicating portfolio can be constructed.

The introduction of a twin-security, however, immediately brings up another problem. The question arises in practice about where to find this twin-security for constructing the replicating arbitrage-free portfolio, i.e., whether the underlying asset in question is *replicable or not*. A first approach will be to take a suitable market-priced security, such as gold for pricing a goldmine which is not traded on markets. Nevertheless, this rarely works in practice because the sources of uncertainty for e.g. the aforementioned goldmine are many, and not only those of the gold commodity price.[315] Another possibility is to identify publicly traded firms with projects similar to the one to be valued, although the company's risk is mostly not the same as the project's risk and it is

[310] And not only on the underlying's price itself as assumed in standard financial option pricing.
[311] See Borison (2005), p. 19.
[312] See Hommel and Pritsch (1999), p. 45.
[313] See Trigeorgis (1996b), p. 101ff.
[314] Various authors adopted this view, see for example Mason and Merton (1985) or Majd and Pindyck (1987).
[315] See Robinson (2003), p. 22.

difficult to isolate the project's risk from the stock volatility.[316] The most common alternative to identify the twin-security, however, is the MAD approach (mentioned in chapter 3.2.1 and 3.5.3), which states that the net present value of the project itself, but without flexibility, is the best estimation for the value of the project if it was traded on markets. This links the real option valuation method tightly to the NPV criterion. If the cash flows are estimated wrongly, not only the real option's value will be incorrect, but also the traditional "static" net present value.[317] In the author's view, this seems the most practicable way to derive a twin-security when using classical financial option pricing theories for deriving the value of a project. A last method to account for the problem of the nonexistence of twin-security is the so-called "Hotelling Valuation" proposed by Sick (1989).[318] Sick suggested to estimate the market potential from the product which underlies the project and then to use it as the underlying for the ROA. Although this method provides a reasonable estimate for practical applications, it is theoretically not correct as the aggregate project risks are different from the risk of the product on its own.

Another difficulty regarding the theoretical fundaments of option pricing is the assumption that the underlying asset follows a *geometric Brownian motion (GBM)*. This assumption guarantees that prices fluctuate randomly and allows its variance to increase over time.[319] Dixit and Pindyck (1994) gave as a contrasting example the case of oil prices, where in the short run a price movement as described before could effectively happen, but in the long run would tend to draw back to a certain level. In those cases, it is may more appropriate to use a different stochastic process describing the underlying's price movement. Dixit and Pyndick suggested for their example regarding the movement of oil prices the mean-reverting process[320] and stated that the choice of the stochastic process in real option valuation is a crucial matter to be considered.[321]

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[316] See Wang (2002), p. 38.

[317] The NPV approach is often referred to in valuation literature as a "dynamic approach", and not a static approach. Dynamic hereby refers to the ability of the NPV to differentiate between cash flows in different years in discounting them with an appropriate rate of return and accounting for the distance of years between the time of investment and the point when the specified cash flow accrues. This is not possible with e.g. the cost comparative method, which does not discount values from different years with different factors, which are therefore denominated as "static approaches". In our study we nevertheless use the term "static" for the NPV as well, referring to the fact that the NPV does not allow for managerial actions during the project's life time. A NPV value implicitly assumes a fixed strategy once the project has been set up and the calculations are being executed. In this regard, it is "static" in our definition.

[318] See Sick (1989), p. 10-12.

[319] See for the assumptions of the Black-Scholes model in chapter 3.3.2.2.

[320] The mean-reverting process or, also known as the Ornstein-Uhlenbeck process, models the prices so that they always tend to come back to a specified equilibrium price: the farther away the prices from the equilibrium level, the higher the tendency to revert to the mean. For modeling values of many real-life projects this process shows more economic logic than the geometric Brownian motion.

[321] See Dixit and Pindyck (1994), p. 74-79.

Looking back at all the mentioned theoretical critiques on the real option valuation method as yet should lead the reader, irrespective from the proposed solutions methodologies, to be very careful in applying any chosen option valuation method to real-life investment problem and discussing the obtained results. Nonetheless, Arnold and Shockley (2002) argued that applying the NPV to real-life investment decisions is often very problematic as well, depending on the same critiques on the complete markets made for the real option analysis. However, nobody puts much weight on these problems as the net present value criterion is widely accepted in praxis, whereas option pricing is not, among other reasons, mainly because of its complexity.[322]

3.6.1.2 Complexity problems

The second category of theoretical problems is the one we call the complexity problems, according to Hommel (1999).[323] These problems derive from the fact that real options are often not as trivial as a standard financial option. For example, with undertaking a project there might be interactions with other projects or influences on competition or from competition respectively. All these complexity problems can have a great influence on the value of a real option, i.e., of the investment project and, therefore, an awareness relating to them must be built up.

In chapter 3.4.1.7, when discussing multiple interacting real options, we have seen that often in real-life real options do not occur alone but in a bundle. In this case, we must account for their *interactions*, which will have influence on the value of every single option of the firm and, therefore, have an important strategic impact on the firm's overall value. An example might be the compound options where the exercise of an antecedent option provides a new option. These kinds of options occur in particular when the investment is split in discrete partial stages and management gets progressively new information for a successive new investment stage. The valuation of these multiple interacting options becomes a mathematical sequence problem.[324] Thus, the variance parameters of these compound options are interdependent as well. Because of this fact the valuation cannot be realized with a closed-end formula like the Black-Scholes formula for the reason of its constant volatility assumption.[325] We previously presented Trigeorgis's solution to the problem of multiple interacting options in this work and will not go deeper into the matter. The interested reader is referred to

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[322] See Arnold and Shockley (2002), p. 2ff.

[323] See Hommel (1999), p. 62. Even though we use the same label for this type of problems, we go further compared to Hommel inasfar as we add other issues to this category.

[324] See Copeland and Antikarov (2001), p. 13.

[325] See Wilmott *et al.* (1995), p. 48.

Trigeorgis (1993a) who proposed a log-transformed variation of the binomial model for financial options and stated that the incremental value of every further interacting real option is strongly diminishing after the third option.[326] Another possible solution was shown in Gamba (2003), who proposed to decompose a complex capital budgeting problem with multiple options into a set of simple options that he called “building blocks”. These building blocks subsequently help the valuator identify the interactions and assess their influence correctly in the valuation of the investment project.[327]

Financial options on shares are exclusive properties of the holder that does not have to worry about competition for investing in the underlying asset. Financial options pricing models are therefore build on this assumption. But in the case of real options the optimal exercise also depends on the reactions of competitors. Kester (1984) speaks of *exclusive options* and *shared options*.[328] The former are more valuable in giving their holder the exclusive right to exercise them. For instance, these real options can derive from patents, unique knowledge, exclusive rights from the government, or technology that the competitors cannot imitate. Shared options, by contrast, are less valuable because they represent “collective” opportunities held by the entire industry. For example, the introduction of a new product on the market is typically a shared option, because obviously the new product can also be launched by a competitor. As soon as the competitor launches the product the option’s underlying will decrease in value for all other market participants and so will the value of the investment project itself.[329] In many real options valuation models however the assumption is made that the exercise of a real option will have no influence on the real options in possession of other market participants, which may not coincide with reality.[330] It can go that far, that in perfect competition the option to defer an investment will become completely valueless, because competitors will preempt the investment and, thus, there is no time left for waiting. Thus, in such circumstances, the classic net present value approach will hold because there is no flexibility left. Perfect competition changes the investment decision to a simple “now or never” decision.[331] Consequently, in the cases with the apparent influence of competition, it is necessary to put a game theoretic idea into the real option valuation models. This was done to great extent by Smit and Trigeorgis (2004) in their seminal book about the game theoretical approach to real option valuation.[332]

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[326] See chapter 3.4.1.7.
[327] See Gamba (2003).
[328] See Kester (1984), p. 153ff.
[329] See Laux (1993), p. 955.
[330] See Grenadier (2000), p. 99.
[331] See Brennan and Trigeorgis (2000), p. 8.
[332] See Smit and Trigeorgis (2004).

3.6.1.3 Endogeneity problem

Another theoretical problem is the one Hommel (1999) called the endogeneity problem.[333] In real option valuation there are some valuation parameters (e.g. volatility, price of the underlying) that can be influenced by competitors or by the real option holder itself. By contrast, in a financial options pricing formula, these parameters are given exogenously and are not influenceable by market participants. Thus, Hommel introduces the term "endogeneity problems" for this type of criticism. Such problems partly derive from the competitive situation described above, insofar that the underlying's value can be influenced by competition. However, through their active project management, not only competitors can influence the value of the underlying, but also the firm in possession of the real option itself. As described in chapter 3.3, one of the fundamental assumptions for pricing financial options is that the underlying asset follows a stochastic process (or random walk). If management can influence the underlying asset's value, then we cannot claim anymore that it follows a random walk, and this crucial assumption is therefore violated. Howell (2001) suggested that in the cases where the underlying can be influenced by market participants, the game theoretic approaches are maybe more adequate than the standard real options theory.[334] Smit and Ankum (1993) addressed this problem in the same manner in applying game theoretic approaches to the ROA and using both of them in combination.[335] Obviously, not only the value of the underlying can be influenced through project management but also the investment's uncertainties, for example, by doing more pre-clinical testing for a medicament or gaining additional expertise on potential oil reserves. Standard financial options theory, by contrast, treats market uncertainty as an exogenous factor as well. The solution to this type of problem is proposed by Kulatilaka and Wang (1996) by separating the different sources of uncertainty (i.e. in endogenous and exogenous uncertainties).[336]

3.6.1.4 Implicit distribution

A further problem is the one concerning the simplifying assumptions for the *probability distribution of the underlying's return* made for financial option pricing. For pricing financial options, Black, Scholes, and Merton assume that stock prices follow a log-

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[333] See Hommel (1999), p. 18.
[334] See Howell (2001), p. 194.
[335] See Smit and Ankum (1993).
[336] See Kulatilaka and Wang (1996).

normal distribution,[337] whereas Cox, Ross, and Rubinstein make the assumption of a binomial distribution for the movement of the stock prices.[338] A stock price cannot go negative. Thus, for standard option pricing formulas for pricing stock options, the assumption of a log-normal distribution or a binomial distribution seems reasonable. In the case of real options, the value of the underlying project can go negative. Hence, it is better to describe the value of the underlying with an arithmetic or additive process.[339] The critical task to master in such cases is the choice of the right probability distribution subject to the characteristics of the specific investment project.

3.6.1.5 Counterparty risk

The *counterparty risk*, which is the risk that the counter party is unable to deliver the underlying asset, is minimal for financial options. The options' clearing corporation guarantees that the option writer fulfills his obligations under the terms of the option's contract.[340] However, in the case of a real option in general, there is no counterparty to guarantee the delivery of the underlying asset, which additionally is often not even traded on markets.[341] Even though the default risk for financial options is very small, various solutions for this problem are being studied in options literature. Among them Jarrow and Turnbull (1995) should be cited.[342] An application on real option analysis, however, has not been done as yet.

3.6.2 Implementation problems

After examining the theoretical critiques towards the Real Option Analysis, we focus on the second main category of critiques deriving from the practical implementation and the subsequent organizational questions arising when applying this new valuation paradigm in practice. In fact also these hurdles must be surmounted in order to propagate the real options theory in real-life investment project valuation. While there has been much work done to overcome many of the theoretical problems described above, this is not the case concerning the critiques coming from practical implementation issues. We divide the implemental critiques into five different sub-

[337] See chapter 3.3.2.2 regarding the Black-Scholes option pricing model.

[338] See 3.3.2.1 regarding the binomial option pricing model.

[339] See Copeland and Antikarov (2001), p. 123.

[340] See Hull (2006), p. 195.

[341] See Rams (1998), p. 680.

[342] See Jarrow and Turnbull (1995).

categories: the problems deriving from the *perception of the necessity of a ROA* and the availability of the *mental models* in practice; the problems coming from the *lack of methodology knowledge and modeling ability*; the difficulty of getting the *appropriate input parameters* and the probability of miscalculations; the challenge of *managing the real option portfolios*; and finally the problem of *communicating the value* to third parties.

3.6.2.1 Mental models

First of all the perception for the necessity of a ROA must be present in a project evaluator's mind. Consequently, the problems in this category, which we call mental models, arise in the very first steps of approaching the real option paradigm. In general there are some fixed institutionalized ways of seeing business and project valuation. These *mental models* can be changed only over a long period and with extensive learning processes. We can take as an example the net present value criterion, which was described for the first time in academic literature in 1958 by J. Hirshleifer in his seminal work *"On the theory of Optimal Investment Decision"*[343] and was widely accepted in business practice only roughly 30 years after its first appearance.[344] The same may happen to many innovations. In the case of real options, e.g., the chance to act during a project's lifetime not always is being regarded as valuable at first glance.

Moreover, and this is maybe the more important point, many people don't see the sense of introducing a new valuation technique if correct decisions can be made by intuition or with the well-known standard valuation techniques used for a lifetime. This "if it's not broken, don't fix it" mentality hides the fact that sometimes "it *is* broken". Many decisions that have been taken with the net present value criterion or just on the intuition of the project manager might have been different if the value of managerial flexibility had been properly quantified. An ex-post valuation of already completed projects or fully implemented ongoing projects, with a rationale for the deviation from the ex-ante targets using the real option valuation method, could show the strength and the benefit of the approach in many valuation cases in a more intuitive way. Unfortunately there is little project data available for performing such an exercise on a wide basis. Especially if it was a bad decision (a case which would be interesting for a re-evaluation with another technique NB), project data are obviously kept private in order not to endanger the manager's reputation.

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[343] See Hirshleifer (1958).

[344] See Pritsch and Weber (2003), p. 160.

Another problem arising from this mental model category is that uncertainty is frequently seen as a bad, i.e. something we do not want and we try to eliminate a priori. In adopting the real option mentality in contrary every uncertainty will have one or more responses, i.e. action flexibilities, if the uncertainty could cause to put the project to fail. By contrast, if the uncertainty produces a deviation from the expected results in a positive direction, a planned real option can be the means to profit from such unexpected beneficial developments. Speaking by analogy, a real option can be the surfboard to ride the waves of uncertainties - either way, whether the wave comes or not, or whether it is high or low, the manager will be prepared, and the reason why he goes out is still to catch the wave, and not for avoiding it.

However, the *identification of the various sources of uncertainty and their possible corresponding action flexibilities* is mostly not trivial but is obviously central for a real option valuation. Furthermore the *estimation of the amplitude of the uncertainties* is mostly arbitrary and will have a decisive effect on the value of the real option. This is another reason that can make a manager reluctant to change the valuation technique without being well-versed in estimating the volatility of the specific projects.

A further problem which deters managers from applying the real options approach is the fact that *real options are difficult to identify*. In this case there are basically two errors which can be made, respectively two problems which can be encountered: first, there is the difficulty of overlooking an action flexibility (i.e., a real option) which could be helpful against a specific uncertainty source. Second, the mistake could be made in valuing an action flexibility as a real option when it is not one. While we believe that the first problem can be solved easily by a systematic analysis of the potential action flexibilities and by the manager's experience, the second is not so trivial. As explained in chapter 3.2.2.1, the type of flexibility is chosen in order to respond on a specified type of uncertainty, which triggers the subsequent choice. If there is no definite uncertainty, a flexibility does not create any value to the firm, and it is therefore not sensible to apply a real option valuation.[345] An example could be taking a call option on a share whose exercise price will be 95% of the share's price at expiration. The value of this call today is obviously 5% of the share price today independently on the time to maturity and the volatility. Recent work on this subject was done by Adner and Levinthal (2004) who distinguished real options from more generic notions of path dependent investments and come to the conclusion that the less

[345] The option analogy described in chapter 3.3.3 is also helpful to avoid this problem because if the structures of the cash flows look similar to the ones of financial options then the probability that the investment valuation can be done with the option price model is higher.

systematic a flexibility decision is, the more difficult it is to distinguish this decision from a standard sequential stream of investments.[346]

3.6.2.2 Methodology and modeling

Once the importance of managerial flexibility has been recognized and its influence on the value of the project assessed, the next step is to find a model to evaluate its impact on the project's value. Only few managers are familiar with real option models[347] and, moreover, depending on the project, decisions have to be made very quickly without loosing too much time with complex models.[348] Getting the appropriate model is, therefore, not always easy but obviously extremely important.[349] An outsourcing of the modeling problem to a specialized team within the company or to a consultant specializing in flexibility valuation could ease this problem. Nevertheless, the project manager must know what *models are available* and what types of *problems deriving from the application of the wrong model* could endanger the value's reliability, in order to better communicate with the model specialist and to understand the right meaning of the calculated value. We therefore proposed an overview of different real option valuation approaches in chapter 3.5 and a listing of real option problems that can result from the wrong application of a specific model to a distinct project in chapter 3.6.1.

3.6.2.3 Input parameters

Having decided which model to apply to a specific valuation case immediately brings up the next challenge. In fact, the models must obviously be fed the right data. Mostly those data have to be estimated, and, what is similar to the above mentioned problem with the uncertainties, there are no or not enough heuristics yet which would allow a manager to form educated guesses about the involved parameters. If the inputs are inappropriate, it is clear that the model will fail.[350] Unavailable proxies, errors in estimation, and the coordination in getting inputs from the different functional areas of a company (e.g. marketing, controlling etc.) can have negative consequences on the accuracy of the real option's value and, therefore, create a loss in confidence in the whole approach. The selection of the right model and the correct estimation of the inputs are strongly interrelated. On the one hand, a model that depends on specific

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[346] See Adner and Levinthal (2004).

[347] In our survey on the Swiss market, we found only seven companies out of 83 respondents which acknowledged using the real options approach - a rate similar for other surveys in other countries and times. See chapter 4.

[348] Statement of an interview partner.

[349] See Howell (2001), p. 195.

[350] See Bowman and Moskowitz (2001), p.775.

inputs that are impossible to get is of no use. On the other hand, available input parameters that do not fit the specified model, will prevent the calculated value from being acceptable to any involved party.[351] The inputs for a real option calculation are the following: the price of the underlying, the strike price, the volatility of the underlying's price, the time to maturity, the risk-free rate, and the dividends (i.e., the opportunity costs of not investing). As they have already been presented in chapter 3.3.3 in discussing the differences between a real option and a financial option, we will not go repeat the challenges in estimating every single parameter. In general the volatility of the underlying's price and the price of the underlying are the two parameters that are most difficult to estimate but which have a great influence on the real option's value calculation. Analogous difficulties concerning the appropriate estimation hold also for the time to expiration and the exercise price of the real option. How does one know, for example, when the investment opportunity will disappear, or what the exact outlay will be at the moment the decision about starting the project has been taken?

An extensive work on the analysis of each parameter is done by Perlitz and Peske (1999), who proposed a structured way to analyze and determine every input parameter for a real option valuation. First of all, they presented the specific states in which the input parameters can be found in real-life: for instance, the volatility can be deterministic (known and constant) or stochastic (ever-changing). Then they analyzed three different classic financial option valuation models on their adaptability for each presented state of the input parameter.[352] The three models are the binomial method, the Black-Scholes model, and the Geske model.[353] Perlitz and Peske's work showed that choosing the right model to use depends on both the optimality of the model to the specific valuation problem and the state of the available input data. A valuator who wants to use option pricing models for valuing investments must, therefore, find a compromise between them, optimality regarding project characteristics and availability of the input data, and be aware of the difficulties and subsequent interpretations of the results in making the one choice or another about the valuation model.

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[351] E.g. we have an estimate for the volatility but we know that it is not constant. In this case it is not advisable to use the Black-Scholes model for the reason that it implies a constant volatility (see 3.3.2.2).

[352] See Perlitz and Peske (1999), p. 258ff.

[353] The compound option model of Geske (1979) shows how to price financial options on other financial options. This can turn out to be very expedient in some real option's valuation problems when the investment opportunity is represented by a series of staged capital outlays.

3.6.2.4 Managing the real options

After identifying the real options and calculating their value there is another critical task to perform. The real option portfolio must be managed in the right way over time. Describing and calculating the value of a possible action flexibility is of no use if this flexibility is not exercised once the time arrives for the action to occur. Take, for example, the exercise of an option to abandon. Calculating the value that an abandonment may could generate and effectively giving up a project are two completely separated acts; obviously the second one is associated with a certain reluctance by the project initiator since an abandonment would be seen as a negative sign by many of the involved parties if they do not understand correctly the real option's value.[354] Because of this, it is important to identify and to exercise the options in a disciplined way, and then to clearly communicate in advance the possible actions to be put in practice once uncertainty dissolves.

Another critique of the real option analysis is the one that a real option's calculation is strictly speaking only an isolated observation that holds only for the specific point in time when it is done. There is the implicit assumption that the decision maker does not know the new forthcoming additional action flexibilities at the time of valuation and, consequently, does not include them in the decision. This, however, is not realistic in daily business practice where new managerial flexibility can influence all the other real options as well as the value of the whole project. The only solution to this problem is given by a continuous examination of the state of the project, accounting for new, relevant upcoming action flexibilities and setting aside flexibilities with little or no remaining value. The examination of dynamic real option portfolios has been scarcely treated in literature. Probably because of its complexity laying not only in the mathematical handling, but also on the purely conceptual consideration of the problem. We are, nevertheless, of the opinion that this is an interesting area to explore for further research. Some pioneering work has been done by Luehrman *et al.* (2001) who used the metaphor of a tomato garden to explain how to distinguish the ripe tomatoes, i.e., the in-the-money real options, from the ones that may ripen or the ones that will never be of value in the future.[355] Their work, which focused on qualitative aspects, is one of the rare attempts to put a ROA into a dynamical framework allowing for a maximum of flexibility consideration.

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[354] As, e.g., the employees, the senior management, the stakeholder, and the shareholders.

[355] See Luehrman *et al.* (2001).

3.6.2.5 Communicating real options value

The last of the implementation problems involves the communication of the calculated values. In fact, because of its higher technical complexity and above all its scarce utilization in practice, it is hard to make the value of a real option comprehensible to every involved party – namely, on the one side, the company internal parties (e.g., senior management, associates, employees, co-workers) and, on the other side the company's external parties (e.g., shareholders, creditors, tax authorities, suppliers). Gibson (2004) stated that the remuneration policies for managers are generally not consistent with the decision to delay investments, and that analysts and the press measure a firm's performance over short-term horizons that ignore long-term investment's optimization.[356] Consequently, there is more to it than only adopting ROA within a company. Without being able to communicate the value in a comprehensible way internally and externally, it would make less sense to take up the efforts for calculating real option values which nobody seems to "esteem". We are of the opinion that this step also can decide whether the real options methodology will be applied or not in future in the long run and, above all, can speed up its utilization in the short run. While for the internal parties it could be more ore less simple to organize trainings and information events to explain to those involved where the real option value come from, this is obviously hardly possible for all involved external parties. A structured framework to value and communicate flexibility value in an easy and most intuitive manner as possible is therefore necessary to overcome this further real option application hurdle. In chapter 5.4 we present a possible solution to the communication problem by means of what we call a "flexibility appropriation request".

3.6.3 Reputational problems

The last problem area we want to discuss is what we call reputational problems. We are of the opinion that these are mainly short-run problems if the real options approach will be able to take off in future. Nevertheless for the sake of completeness we cover also briefly these issues. We divide the reputational problems in three categories, namely *moral hazard problems*, the "*rocket scientist*" problem, and the "*e-bubble 2000*" problem.

The main challenge of the capital budgeting process is to base the evaluation on relevant information and to ensure that the project leader has no incentives to put the

[356] See Gibson (2004).

investment into a better state than it really is. This is a classical *moral hazard problem.*[357] The person responsible for the project, as an agent, tries to convince management, as a principal, about the advantages of the project using arguments to augment the economic value of the project. From a real option view, the agent may can argue that, e.g., the real options are deep in-the-money, or their time values heads towards zero, i.e., that their immediate exercise seems to be indispensable. Moreover, economically doubtful projects can be kept alive by compensating a non existent inner value and a negative (static) project value with a high-set time value of the project's inherent real options. Fernández (2002) described this as the "play with volatility" and stated that as the estimation of the volatility is a difficult task to cope with, a valuator who wants to make the project appear in a good light will as a matter of fact push on the volatility in order to easily obtain a higher project value.[358] We agree with the statements made above, although we believe that a problem of dispute about some key parameters comes up in the discussion about other valuation paradigms as well.[359] Therefore, a sound analysis and understanding of each valuation parameter is necessary in applying every valuation method. In that sense, the ROA represents no exception. The only difference comes from the fact that disputing about the cost of capital or cash flow estimation for NPV calculations is a standard argument in daily business life of a "project valuator", whereas doing the same about volatility or time to expiration is not. As long as this conception will stay in the minds of most practitioners, the reputation of the real option approach as a doubtful technique to use will remain. That is also the reason why we place this problem in the "reputational" category and suggest the propagation of more information and training on this matter, in order to clarify the ROA and avoid this type of problem.

A second problem in this category is the so called *"rocket scientist"* problem. In today's real option literature, the main focus remains on increasingly complex models to catch specific investment situations. In the case, when practical considerations are made, the analyzed project valuation problems are that specific that they can hardly be applied or transformed for a different situation. This research behavior creates in the practitioner's conception a clear cut between theoretical innovations and adaptability in practice which, in our opinion, is the reason for many of the answers given when asking a practitioner why a real option approach is never been taken into consideration. They

[357] See Hommel (1999), p. 17.

[358] See Fernández (2002), p. 7.

[359] As, e.g., the NPV, where the discussion about the employed cost of capital or the estimated cash flows is by far not a precise science and is therefore also subject to some arbitrariness which will have great influence on the project's value.

simply dispatch it in saying: It's too complex.[360] Once this reputation is entrenched in the minds of the potential end-user, it is very easy to dismiss the technical innovation when the reason for doing is given mainly by the innovator itself, putting greater complexities on the table where perhaps a rational assumption would be absolutely sufficient. We are not of the opinion that that only "rocket scientists" can understand and use the real option approach. Even though we agree that modeling some investment problems can may require substantial mathematical assistance we think that the main problem is to understand the basic idea of the real option approach, i.e., the effect an action flexibility will have on the value of the project and its parallels to a standard financial option. As soon as this is worked up in mind, the modeling problem can be left to specialists who know exactly how to support a project manager with mathematical assistance for a specific situation. Obviously, these specialists have to be provided with confidence which in turn is difficult without seeing them at work. To make an analogy: everybody is confident in flying with a plane, although only few of us know how a jet engine works or how it is maintained. We want to move away from this "rocket scientist" reputation and this is the reason why we intentionally put this study into a more practical light, passing on complicated formulas and difficult modeling concerns and focusing on a more structured thinking about real options management.

A last issue in this category of reputational problems is what we call the "e-*bubble 2000*" problem. To explain the gigantic rise of the new economy during the late 90's and early in the year 2000 the traditional methods were insufficient.[361] Therefore, management of many internet companies decided to use the real option valuation. In applying the ROA, management could explain multi-billion dollar values even for many internet companies with a negative accounting income. The stock market participants trusted these valuations. Thereby the intuition was as follows: large losses were associated with high valuation, stating that the losses were followed by much larger profits somewhere down the road. In augmenting the volatility parameter of the real option valuation in an arbitrary way, these larger profits were easy to demonstrate to blindfolded investors, which were on the search for quick and large profits, as the variability in stock return was effectively very high in these times. This fact obviously, in turn, raised the real options' values and consequently the firms' value to exorbitant levels. Firms participating in the new economy boom therefore promptly adopted the real option theory, which was still a valid theory but was unfortunately simply

[360] The initial effort and for getting the ROA's know-how and the subsequent adaptation exertions are e.g. stated to be major problem by Swiss companies, see chapter 4.5.3.

[361] For instance Yahoo!'s market capitalization appreciated by 3800% over a three-year period ending in 1999, see Rice and Tarhouni (2003), p. 15.

abused.[362] Moreover, many values of internet firms arose from projects that had not yet been invented. Thus, buying a stock in these firms was like buying an option on the endless ways in which a firm could grow in the future, whereby the firms were seen as a portfolio of multiple real options.[363] The big problem in adopting a real option pricing for many of those internet companies was that it does not make an important distinction between what is possible and what is doable. Although a company may have some options, it must also have management skills and financial resources to exercise them, otherwise the options have no value. When the bubble achieved its peak, the use of the real option methodology was inappropriate. It was principally used for rationalizing prices rather than predicting them. The bursting of the new economy bubble in the year 2000 can therefore partially explain the sudden but temporary decline in interest in the ROA, which was abused to justify exorbitant valuation that could not be explained otherwise.[364] We do not see this "e-bubble 2000" problem as a serious obstacle to future real options application, but it does nevertheless show that on the way of taking confidence in the application of a new theory, a misuse of this innovation can throw it back by many years.

3.7 Overview on ROA application areas

The present chapter is aimed at building a link between the theoretical issues we discussed as yet and the practical consideration we will cover in the next sections of the thesis. We stated previously that a lot of work has been done in real options literature as of niche applications or mathematical modeling work. At this point, we want to give a brief overview of the literature for those cases where authors became more practical and exemplified their statements on specific real valuation cases for distinct business areas. As there are obviously a large number of conceivable applications for the real options approach, we cannot present an analysis of the different examples until the last parameter value. Our scope is to show in which application area most real option work has been done and give a short idea of the many potential ROA applications. Moreover, we will highlight cases where a ROA application to a specific project type or business can be found, in order to create a sort of bookmark catalogue for the reader interested in a specific area. Additional broad reviews have been done by Trigeorgis (1996b),[365]

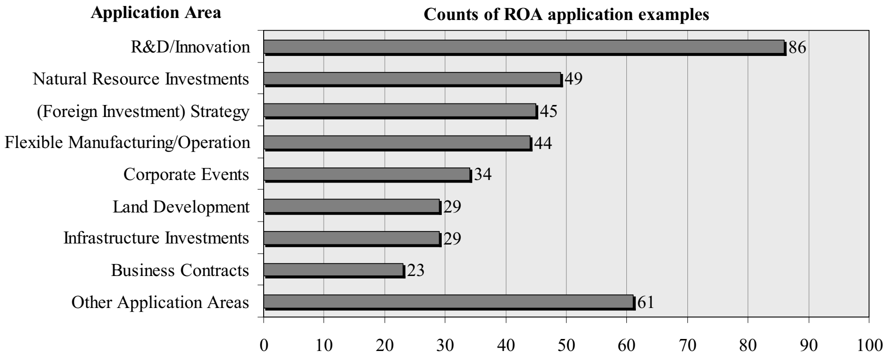
[362] See Rice and Tarhouni (2003), p.15ff.
[363] See McClure (2003), p. 1.
[364] See for example Milano *et al.* (2000).
[365] See Trigeorgis (1996b), p. 341ff.

Dixit and Pindyck (1994),[366] and Lander and Pinches (1998).[367] As we are not aware of more recent and extensive overviews on this matter and we think that in almost ten years of research a lot of further interesting ROA application examples have grown the field of practical implementation of the real options approach, we believe that it is interesting to expand the review, founding our work on the three mentioned authors. Even though our review includes a large number of papers and books, it is just indicative and is in no way meant to be exhaustive and capture all of the contributions. Nevertheless, we think that it gives a representative description of the work that has been done in trying to "make real options real".[368]

For our purpose we examined 400 real option application examples. By real options application examples we mean pieces of academic literature that treat the application of the real option theory in a specific business area, whether in form of a single paper, a case study, or a section within a book. In Figure 3.20 we report the counts of the various application examples described in the literature. While the initial area of application was on natural resources, over the years, many different applications have been modeled using real option frameworks.[369] In the following, we will briefly describe each application area with their respective rationale why ROA application could be of importance and their potential occurring real options types. At the end of this section, an up to date guide to the academic literature treating the specific application areas can be found in Table 3.6 for the main application areas and in Table 3.7 for the other application areas.

[366] See Dixit and Pindyck (1994), p. 394.
[367] See Lander and Pinches (1998).
[368] See Copeland and Keenan (1998).
[369] See Lander and Pinches (1998), p. 540.

Figure 3.20: Counts of ROA application examples.



Innovation and research and development (R&D) is characterized by its nature of uncertainty and strategic positioning.[370] High-technology companies invest heavily in technologies that may result in a wide range of possible outcomes and new potential markets, but with a high probability of technical, scientific, or market failure. Usually, development horizons are long and, consequently, the respective cash flows are remote and highly uncertain (a 40-60% standard deviation for biotechnology stocks is not uncommon) and, moreover, their associated costs are high and irreversible also because their high specificity.[371] In the pharmaceutical industry, for example, the development of an innovative new drug is associated with many uncertainties. It takes 10 to 15 years to bring a new drug to market; in addition, the costs for large pharmaceutical companies were estimated by Gilbert *et al.* (2003) to be US$900million, and including the costs for failed prospective drugs even to US$1.7billion, while the technical success probability for the new drug is only by 8%.[372] After market introduction, the potential drug candidates additionally face market risk that results from a unpredictable commercial performance.[373] Thus, their benefits are remote, highly uncertain and hard to quantify, even though the growth potential seems promising. To control risk and preserve its abandonment options, larger pharmaceutical companies often stage their investments with an early investment that allows for further subsequent investments.[374] Risky R&D

[370] See Wang (2002), p. 27.
[371] See Trigeorgis (1996b), p. 340ff.
[372] See Gilbert *et al.* (2003), p. 3ff.
[373] See Hartmann and Hassan (2006), p. 344.
[374] See Trigeorgis (1996b), p. 341ff.

investments are thus embedded with sequential investment options (time-to-build options) and may create long-term strategic options (growth options) for the firm.[375]

Another application area well described in real option literature is the *natural resource investment* area. As natural resource or commodity prices are available on financial markets (e.g., oil, gold, copper, etc.), but also due to high volatility and long duration of their extraction projects, it is not astonishing that the first real options application examples are found in this area.[376] It is not uncommon that prices of natural resources can fluctuate by 25-40%, and this high degree of uncertainty attached to output prices is obviously of immense importance when evaluating projects in natural resource industries.[377] Natural resource investment projects incorporate strategic potential (option to grow), the flexibility to stage investments (time-to-build option), and other elements of operating flexibility. These are options to expand production (option to expand), abandon for salvage value (option to abandon), or the delay of the project's start (option to defer).[378]

Another great deal of work can be found in *strategy investments* (particularly in strategic investments in foreign countries). Business strategy is much more like a series of options than a series of static cash flows.[379] Strategic sources of value can arise from synergies among parallel projects undertaken simultaneously or interdependencies among projects over time.[380] For instance, a foreign investment project may has a negative NPV, but also it can be the initial step in a foreign investment strategy and create valuable future growth opportunities. Thus, the initial investment can be seen as a growth option.[381] Real options typically arising in strategy decisions and foreign investments are consequently the option to grow or the option to stage an investment.

Other examples of real option application are found in the area of *flexible manufacturing*. Flexible manufacturing systems and operational flexibility allow executives to respond to changes in demand, costs, input/output prices, and other variables. Especially in industries where those variables are highly volatile, operational options such as the option to switch inputs/outputs or to expand or shrink capacity are of great importance when making irreversible investment decisions.[382]

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[375] See Wang (2002), p. 28.
[376] See Trigeorgis (1996c), p. 363.
[377] See Trigeorgis (1996c), p. 356ff.
[378] See Trigeorgis (1996c), p. 363.
[379] See Luehrman (1998b), p.90.
[380] See Trigeorgis (1996c), p. 257.
[381] See Kester (1984), p.153ff.
[382] See Aguerrevere (2003), p. 1239ff.

Real options can also be applied to value managerial flexibility embedded in *corporate events* like such as mergers and acquisitions (M&A), joint ventures, divestitures, new ventures, or initial public offerings (IPO). Acquisitions or joint ventures may create valuable growth options, incorporate the option to divest (for instance the option to abandon the acquired target or a part of it) or include contracts with option-like features, such as earn-out models.[383]

Land development is an important source of ROA application as can also be observed from the results of the survey we conducted with Swiss firms.[384] The presence of vacant land real estate markets is considered as anomaly in a world with an efficient and thriving real estate market. However, this is not the case when the land is viewed as an option under uncertainty.[385] Various sources of uncertainty such as fluctuations of real-estate prices or construction costs have important effects on irreversible property investment decisions.[386] Wang (2002) even postulated that real estate markets rank among the most volatile industries in the United States, due to the persistence of excess vacancy and the volatile patterns of housing starts.[387] Valuing land with the ROA allows one to account for the inherent option to defer the development of the property. In this sense, a landowner holds an American call option to develop the land at an optimally chosen time in future.[388]

Large-scale irreversible *infrastructure investments* in an uncertain or cyclical environment are full of embedded options. In the first place, there are many operational options embedded in these projects like the option to alter scale or the option to abandon. Moreover, they also incorporated strategic options like the option to grow.[389] According to Smit and Trigeorgis (2004), infrastructure provides a platform and creates the strategic context for a firm's additional growth opportunities. It is namely their defining characteristics to generate follow-on investment opportunities.[390]

Business contracts (e.g., leasing contracts, annuity contracts, or delivery and supplier contracts) may incorporate various option-like features, or even the flexibility to adjust the terms of the contract during its life.[391] An example would be a leasing contract with

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[383] See Ernst and Häcker (2002), pp. 61ff.

[384] See chapter 4.5.3.

[385] See Quigg (1995), p. 266ff.

[386] See Sing and Patel (2001), p. 313ff.

[387] See Wang (2002), p. 31.

[388] See Quigg (1995), p. 266.

[389] See Rose (1998), p. 711ff. and Kulatilaka and Venkatraman (2001), p. 3ff.

[390] See Smit and Trigeorgis (2004), p. 366ff.

[391] See Trigeorgis (1996b), p. 349ff.

interacting operating options to cancel the lease before expiration of the contract, extend its life, or purchase the leased asset. A further possibility in this application area is the one of managing and switching the supplier according to the input prices and the possibilities offered in the supplier's contract.[392]

Table 3.6 summarizes the review for the major application areas before going on to further application areas less frequently discussed in the academic literature.

Table 3.6: Main application areas and sample references.

Application Area	Sample Reference
R&D and innovation	Copeland and Weiner (1990), Hamilton and Mitchell (1990), Faulkner (1996), Ott and Thompson (1996), Pennings and Lint (1997), Grenadier and Weiss (1997), Lint and Pennings (1998), Perlitz and Peske (1999), McGrath and Nerkar (2004), Villiger and Bogdan (2005), Amram (2005; Eapen (2005), Hartmann and Hassan (2006), Amram *et al.* (2006)
Natural resource investment	Brennan and Schwartz (1985), Paddock *et al.* (1988), Trigeorgis (1996c), Davis (1998), Tufano (1998), Smith and McCardle (1999), Slade (2001), Lazo *et al.* (2003), Tsekrekos *et al.* (2003), Weir (2004), Dias (2004), Sick and Li (2004), Armstrong *et al.* (2005), Trigeorgis (2005), Chorn and Shokhor (2006)
Strategy/foreign investment	Roberts and Weitzmann (1981), Buckley and Casson (1981), Baldwin (1982), Kester (1984), Bowman and Hurry (1993), Luehrman (1998a), Luehrman (1998b), Kulatilaka and Perotti (1998), Arnold and Schockley (2001), Bernardo and Chowdrhy (2002), Brach (2003), Adner and Levinthal (2004), Smit and Trigeorgis (2004), Copeland and Tufano (2004), Barnett (2005), Smit and Trigeorgis (2006)
Flexible manufacturing and operation	Kulatilaka (1988), Triantis and Hodder (1990), Kogut and Kulatilaka (1993), Kamrad and Ernst (1995), Aguerrevere (2003), Kallapur and Eldenburg (2005), Abadie *et al.* (2005)
Corporate events	Sahlman (1988), Willner (1995), Smith and Triantis (1995), Smit (2001), Herath and Jahera (2002), Ernst and Häcker (2002), Lambrecht (2004), Morellec and Zhdanov (2005), Franke and Hopp (2005), Dunis and Klein (2005), Turowski (2005)
Land development	Titman (1985), Quigg (1993), Capozza and Li (1994), Grenadier (1996), Sing and Patel (2001), Capozza and Li (2001), Paxson (2005), Wang and Zhou (2006), Cunningham (2006)
Infrastructure investments	Rose (1998), Panayi and Trigeorgis (1998), Benaroch (2000), Kulatilaka and Venkatraman (2001), Kim and Sanders (2002), Smit (2003), Lin *et al.* (2005), Abadie *et al.* (2005), Rothwell (2006)
Business contracts	Grenadier (1995), Bjerksund and Ekern (1995), Grenadier (1995), Trigeorgis (1996a), Triantis and Triantis (1998), Brach (2003), Swinand *et al.* (2005), Ulm (2006), Riddiough and Williams (2006)

The last category in our review, named *other application areas*, includes all application areas that we found of interest but which have not been treated in great number in ROA literature. All reviewed application areas share three important characteristics at a high level: namely, they face a high degree of uncertainty, include irreversible decisions and

[392] See Brach (2003), p. 263.

investments, and leave room for managerial flexibility.[393] These "other application areas" are not explained in detail but simply listed in Table 3.7 with some sample references for the interested reader who wants to get additional information regarding a specific issue.

Table 3.7: Other application areas and sample references.

Application Area	Sample Reference
Labor force	Pindyck (1991), Dixit and Pindyck (1994), Bloom (2000), Foote and Folta (2002), Belke and Göcke (2005)
International management	Kogut and Kulatilaka (1993), Capel (1997)
Firm regulation	Teisberg (1994), Panteghini and Scarpa (2003)
Environmental compliance and conservation and policy making	Pindyck (1991), Dixit and Pindyck (1994), Edleson and Reinhardt (1995), Saphores and Carr (2000), Pindyck (2002), Heal and Kriström (2002), Gollier and Treich (2003), Baranzini *et al.* (2003), Lin *et al.* (2007)
Firm valuation	Kester (1984), Pindyck (1988), Berger *et al.* (1996), Schwartz and Moon (2000), Schwartz and Moon (2001), Oriani and Sobrero (2002), Amram (2003), Martin and Fernandez (2006), Andres-Alonso *et al.* (2006)
Outsourcing	Nembhard *et al.* (2003), Alvarez and Stenbacka (2003)
Corporate structure and taxes	Pennings (2000), Sureth and Neimann (2002), Sureth (2002), Leon *et al.* (2003)
Performance evaluation and compensation	Bjerksund and Stensland (2000), Mauer and Ott (2000), Grenadier and Wang (2005), Childs *et al.* (2005), Siller-Pagaza *et al.* (2006), Wonder (2006)
Risk management	Vila and Schary (1995), Charitou and Trigeorgis (2000), Miller and Waller (2003), Alesii (2003), Carter *et al.* (2003), Hillegeist *et al.* (2004), Mason (2005)
Supply chain management	Huchzermeier (2003)
Customer valuation	Kronimus *et al.* (2003)

We made the general observation in our discussions with practitioners, as well as with academics, that when it comes to speak about Real Option Analysis, most people see it quite tightly connected with R&D and natural resources valuation. This stems also from the fact that the greatest amount of work has been produced in these two application areas as we have seen from this review. However, there are many additional application areas where ROA could be useful. Unfortunately, many of these application areas are only familiar to the real options researchers and thus hardly disclosed to the wide audience. For making the ROA appealing in practical spheres, more work has to be done also on areas where the ROA application is not so evidently like in the case of R&D or natural resources, but can be, nevertheless, as much rewarding. We put together a list of application areas that have been treated in literature and hope that by

[393] Three characteristics which we described in chapter 3.2.2 as "constitutive characteristics of a real option" and which are often also encountered when undertaking real investments. As we will see in the result of our survey in subchapter 4.5.4 they also arise within the industries with a main real option's approach application potential.

means of finding itself with the same valuation problems, some readers may find additional help in some of the works cited in the tables above. Moreover, in the next two chapters, we will see in what real-life application areas the ROA might is useful. First, in chapter 4, by means of a survey we conducted with Swiss companies, and second, with our framework to determine the relevance of ROA application explained in chapter 5.

4 Valuing Flexibility in Practice: The Swiss Case – An Exploratory Survey

4.1 Introduction

Until this point of the dissertation, we have focused on the theoretical basis of the Real Options Analysis, the drawbacks of current tools, and the occasions where the ROA could – at least theoretically - be of help for practical applications. Despite the great quantity of work in academic journals, international surveys report a scarce utilization of the ROA by practitioners.[394] This could be due perhaps to the problems described in chapter 3.6, or simply to the fact that innovations always need a certain time to reach a critical utilization level to become adopted by a majority of the firms.[395] In the last years, the surveys about the utilization of ROA got scarce and scarcer. This may be due in part to the low expected return rate when asking questions about Real Options Analysis to managers in senior positions,[396] and, as another reason, to the even lower rate of respondents who are informed about the new method and can give substantial answers to the questions posed. Consequently, only few surveys have been conducted on the matter.[397] Most surveys reporting real option's utilization rates are focusing on general capital budgeting topics and only marginally touch the real option's approach. Especially in the case of Switzerland, where the market is not very large, we are not aware of any substantial surveys about the application of the real option's approach. The fact that the latest surveys on real option's are dated 2001 and that there were no surveys available for the Swiss Market, made the question natural to assess the real option application in Swiss firms. Nevertheless, because of the aforementioned problems we chose an indirect approach to ask questions about the ROA. As we believe that the worth of managerial flexibility is not a new question senior management has to deal with and is therefore very well known, we tried to avoid the "real options" label as much as possible, using instead the term *"flexibility"*. Therefore, this central chapter of the dissertation presents an exploratory survey done in Switzerland to investigate how well Swiss managers perceive and assess managerial flexibility within investment projects, and if and to what extent they are aware of ongoing research about the Real Options Analysis. Moreover, we examined the presence of the three constitutive characteristics of an investment project, which give importance to a real options valuation (as explained in chapter 3.2.2). It should be mentioned here that as an exploratory survey, the main topic of the research is to give a picture of the assessment of managerial flexibility in capital budgeting decisions in Switzerland rather than to test firm hypothesis on the subject.[398]

This part of dissertation will be organized as follows. The next chapter presents a review of existing studies. As we are not aware of studies carried out in Switzerland, we

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[394] See for example Busby and Pitts (1997), Collan and Langström (2002), or Vollrath (2003).

[395] "*Inertia is not only a law of physics. It applies to organizational change too.*" See Copeland and Antikarov (2001), p. 28.

[396] There is a sort of "unproved" agreement between academics that the new paradigm has not yet arrived in the high levels of the firm management. Additionally there is to say that placing questions about the valuation of strategies (as may be the case with ROA) only makes sense at the highest level of management. As explained later in chapter 4.4, we chose to send the questionnaire to the CFOs of Swiss firms.

[397] We will discuss the most relevant of them in chapter 4.2.

[398] Although we tested some correlations and comparisons of median's equality where we had appropriate data.

chose comparable studies in Finland, Germany, the USA, and the UK. Chapter 4.3 specifies the scope of the survey and emphasizes on the four main research questions. Chapter 4.4 explains the methodology used in the survey. Finally the results and the conclusions are reported in chapter 4.5 and chapter 4.6.

4.2 Review of existing studies

Before explaining the methodology used in the actual survey, we want to present briefly some other international surveys that treat the problem of managerial flexibility within investment projects. Among the very few survey about real options, we chose following four works: Busby and Pitts (1997), who analyzed the UK market on the question of managerial flexibility,[399] Borison and Triantis (2001), which interviewed senior management of US firms on the topic of real options,[400] Collan and Langström (2002), who conducted a survey in Finland about the application of the Real Options Approach, and Vollrath (2003), who carried out an empirical study on how German firms deal with managerial flexibility within investment projects.[401] For the aforementioned studies the date of publications of the surveys is not equal to the sending date of the questionnaire itself. Thus the newest published survey on the general application of Real Options Analysis we are aware of is the one of Borison and Triantis (2001), who conducted the interviews in the same year of their publication. Apart from these four surveys, all other surveys mentioned in this section are mainly concerned with general questions about the capital budgeting process and only touch the real options topic marginally.[402] Nevertheless, they are of a certain importance at least because they show the rate of firms using the ROA for years when no specific survey has been conducted. For instance, one extensive survey on capital budgeting, which also reported interesting insights about the application of the ROA, is the study of Graham and Harvey (2001), who surveyed 392 CFOs of companies in the US market.[403]

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[399] See Busby and Pitts (1997).

[400] See Borison and Triantis (2001).

[401] See Vollrath (2003).

[402] For the sake of completeness, there is a newer study about a survey on the application of the Real Options Analysis (conducted in the end of 2004 and published recently) focusing although only on the pharmaceutical sector. We will not emphasize on this study because of its specificity on a distinct branch on the one side and its generality concerning the geographical target of the participants (Europe, USA and Japan) on the other. However, the general finding about a low rate of application of the ROA was confirmed also in this study, even for the pharmaceutical branch where might a high rate of application would be expected. See Hartmann and Hassan (2006).

[403] See Graham and Harvey (2001).

Busby and Pitts (1997) pursued the objective of finding out to what extent decision makers perceive the existence of real option and in what way they value managerial flexibilities associated to investment projects. For this purpose, they sent a questionnaire in written form to all former finance directors of the FTSE 100.[404] The respondents had senior or very senior position within their firms; and the "real option" label was avoided as much as possible in order to first, not induce the participants to trash the questionnaire only because of a semantic problem and, second, not to let them confound real options with financial options.[405] Forty-four responses were received, which showed for the first time interesting results concerning the valuation of managerial flexibility in practice. Busby and Pitts found that real options occur in UK firms, and that they are important in deciding whether to undertake an investment. In fact, in about the half of the cases, decision makers stated that "flexibility" was in average at least moderately important (if not higher) when deciding about the realization of an investment project. Not every managerial flexibility occurred with the same frequency. The "growth option" and the "option to defer" an investment were the two most frequent flexibilities. Furthermore, when it came to the question about the valuation of these options, most respondents stated that there were no standardized procedures to asses the value of managerial flexibilities. For example, in the case of the postponement options, only 20% of the respondents stated to have procedures to value it, although the postponement option was one of the most frequently occurring flexibilities. The few firms who valued the flexibilities answered that the sensitivity analysis was the most often applied method for this purpose. Surprisingly none of the respondents used the Decision Tree Analysis for evaluating flexibilities. A fact that shows, that at that time, the difference between risk management and valuation of active managerial flexibilities was not that clear cut in decision makers' minds. Finally, participants were asked whether they knew the term "real option". Very few respondents knew the term (roughly 14%), and almost all of them did not interpret it in the sense as it is used in literature. This shows that hardly anyone was informed about the new developments concerning the valuation of flexibility made in academic research. However, it is remarkable that despite their lack of knowledge, decision makers generally agreed with the theoretical predictions of option pricing theory. For instance, when asking the question about the influence of uncertainty on the value of managerial flexibility, more of the half of the respondents agreed with the statement that higher uncertainty makes managerial flexibility more valuable - which is perfectly in line with standard option pricing theory. Respondents also agreed on theoretical

[404] The survey was conducted in 1995 and published only two years later in 1997.

[405] As we will see later in chapter 4.4.1, regarding this issue, we chose to utilize the same practice like Busby and Pitts.

predictions about the effect on the value of flexibility generated by the exercise costs, the time over which flexibility is available and the interest rate. To sum up, Busby and Pitts found that real options were occurring frequently (although not named as "real option") in the investment decisions of British firms and were also often significant in deciding whether to start a new investment. Nevertheless, only few firms (even among the largest U.K. firms) had standard procedures to identify or valuate real options. In spite of the fact that most decision makers agreed with the predictions made by option pricing theory, very few were aware of ongoing academic research about real option's theory.

The second survey in time was the one of *Collan and Langström (2002)*. The authors conducted a survey among leading Finnish companies in the year 2000. Their scope was, similar to the scope of Busby and Pitts, to explore the use of ROA and the methods that Finnish firms apply to consider the worth of flexibility when planning and valuing investments. For this purpose, the researchers sent a written questionnaire in April 2000 to 86 Finnish companies listed in the Helsinki Exchange's (HEX) main list. Once again also in this case the term "real option" was avoided, and the respondents where checked for seniority within the firms. Collan and Langström got back 32 useful questionnaires from participants in senior or very senior positions. For almost all types of managerial flexibilities inquired (that is the option to wait, the option to scale, the option to abandon, the option to grow and the option of technical changes), on average, they found that the occurrence of flexibility was inherent in 41% to 60% of all investments. In the case of the option to abandon the percentage was lower (21% to 40%). Similarly to the survey of Busby and Pitts, the option to wait and the option to grow were the two options with the highest possibility of occurrence whereas the option to abandon was the least frequent one. Collan and Langström agreed that the reason may be found in the perception of abandonment which in practice is always attached to failure. Moreover communicating that a project will possibly be abandoned can also weaken the organizational commitment to the project, which is obviously not viewed as an achievable objective. Furthermore, executives were asked about the importance they attach to the different types of managerial flexibilities and, again, the results were similar to Busby and Pitts's. All options but the abandonment options were regarded as desirable and at least moderately important in an investment project.[406] The most desired of the different types of managerial flexibility was the "option to technical change a project", which according to the authors reflects the shortness of production cycles and of competition based on development and innovation. This last option was

[406] The median was in the category "moderately important" for the option to postpone, the option to grow, and the option to scale. For the "option to technical change", the median was found to be even in the category "important".

not included in the survey by Busby and Pitts. In asking the firm about the methods used for valuing flexibility, the majority gave sensitivity analysis as the most important add-on method for this purpose. About one fifth of them stated that they used simulation techniques, about 40% rules of thumb, and roughly 15% stated that they did not apply any method to value managerial flexibility.[407] As with Busby and Pitts, Collan and Langström also asked the firms about the effect of time, uncertainty and interest rate on the value of managerial flexibilities. Other than in the British survey, the perception of Finnish managers about the effect of those variables on flexibilities value was not in line with option theory. This stands out especially for the case of uncertainty where 68% of the respondents were of the opinion that an increased uncertainty would diminish the value of managerial flexibility. When more explicitly asking the firms about the knowledge and the usage of real options, most of the surveyed firms answered that the term was not known, and none of the respondents had ever used the methodology. Also in the case of Finnish firms, it can be observed that the real options thinking is neither known as a concept nor as a way of thinking. The perception of the importance of managerial flexibility is given, although it is based on ad-hoc methods rather than on a systematic way of conduct. Surprisingly, general uncertainty was seen to have a negative effect on managerial flexibility which additionally showed that managerial flexibility was not seen as an active planned opportunity to gain extra return, but more as a way to mitigate bad outcomes. Finally, the authors found neither for larger companies nor for firms with higher expenses in R&D the application of the real options method or more sophisticated tools for valuing flexibility.

A further interesting survey was carried out by *Vollrath (2003)* among German firms with the goal of determining the diffusion rate of the Real Options Analysis within German companies. In mid 2000 Vollrath sent a written survey to the 200 largest German companies plus 100 random companies from branches where an increased occurrence of managerial flexibility was supposed.[408] Of the 300 companies, Vollrath got back 51 useful responses.[409] Also in the case of Germany, the results about the dissemination of the ROA and the importance of managerial flexibility were in line with the other two surveys. More than the half of the respondents agreed that managerial

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[407] Neither the simulation techniques nor the rules of thumb were specified more explicitly.

[408] The size of the company was defined by the market value of the equity plus the book value of the liabilities as of August 1999.

[409] Vollrath sent two questionnaires to every firm, one to the senior management and one to the operative level of the company, to check for differences between them. Where not otherwise mentioned we will report Vollrath's results concerning senior management in order to guarantee a certain comparison possibility to our study. We decided not to send two questionnaires to every firm, first, because we wanted to increase the return rate and, second, because the insights from the two-level survey of Vollrath show that the differences between the two levels are very small presumably because of the leading companywide-directives of senior management.

flexibility was important when deciding about investments; 20% of the investments would not have been done by the median of the respondents if they had not at least one option associated with it, and 91% of the decision makers agreed that investments with inherent options were preferable to those without any options. Among the different managerial flexibilities, those that mostly influenced the investment decision are the option to wait, the option to abandon and that option to grow. On the other hand, for more than two-thirds of the respondents "Real Options Approach" was an unknown term, and none of the respondents who stated to know the term had ever used the method to value an investment.[410] The companies stated further that the methods to assess the importance of managerial flexibility within an investment project were merely qualitative, i.e., by intuition or by experience gained through former projects. The few firms whose officers stated to apply quantitative methods used merely rules of thumb, such as a raise of the discount rate, or a reduction/extension of the payback period and only five respondents reported using Decision Tree Analysis for valuing managerial flexibility. The authors noticed that assessing the value of flexibility by qualitative intuition does not mean that the decision makers would always come to an inferior investment decision. Depending on whether their intuition is in line with the predictions of the option pricing theory in regard to the influences that, e.g., the uncertainty or the duration of the project have on the value of the flexibility the decision could also be a good one. Similar to Collan and Langström (2002) Vollrath found that the intuition of the majority of the decision makers did not match option pricing theory. For example, only 29% agreed that a longer duration of the project would augment the value of managerial flexibility, and only 40% concurred that an increased uncertainty would lead to a higher value of managerial flexibility. To sum up, we can say that the survey showed that to be in possession of managerial flexibility is regarded as highly important within an investment decision for German companies. Assessing the value of this flexibility, however, was not found to be a structured exercise. Most companies did it by intuition, and mostly they stuck to qualitative complements to the value's calculation. Significantly, ROA as a term was known by only 30% of the firms, but it had never been applied in project valuation. Vollrath feared that the intuitive decisions were probably of minor quality, given that most respondents did not argue in line with the general predictions of the real option's theory.

The last survey we want to review was conducted by *Borison and Triantis (2001)*. This is the most recent work on assessing explicitly the state of the practice of ROA application. Borison and Triantis' survey differed from the others insofar that they did not use a written questionnaire to collect information. Rather, they selected individuals

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[410] On the operative level, a single respondent reported to have used the real options approach at least once.

who were familiar with the real option's theory within 34 US firms in seven different industries and interviewed them personally. In this survey, the main focus was not to assess the application rate of ROA. The authors tried to understand the reasons why practitioners decided to adopt ROA. Moreover, they asked participants how and where the ROA was being applied, and what were the success factors for its application. The majority of respondents stated that the ROA was not a revolutionary solution to new business conditions, but rather an evolutionary process to improve the valuation of investments and the allocation of capital. And, in this sense, they decided to adopt the new framework to keep up with the evolution of valuation methodology so that it could pass into a long-term competitive advantage through better decision-making. This statement that "the consideration of managerial flexibility was nothing new to business life" is in line with the other surveys, as participants to the British, Finnish and German surveys declared that the value of managerial flexibility was important to them and that they tried to incorporate this added value into the investment decision with qualitative methods or by intuition. Another interesting insight came from the question about how and where the real option approach is being used. Managers mentioned mainly three different forms of the approach, namely "real options as a way of thinking", "real options as an analytical tool" and "real options as an organizational process". The answers were distributed fairly evenly. "Real options as a way of thinking" was interpreted as a language that frames and communicates decision problems, whereas "real options as an analytical tool" was understood as an approach to value investments. Finally "real options as an organizational process" was meant to be a part of a greater process as a comprehensive management tool to identify and exploit strategic options. This insight was of great importance for our Swiss survey in the sense that it led us to specify exactly what we meant in the questionnaire when asking about a "real option application", as it could be the case in Switzerland like in the US that managers understood different things by the same term. Finally, Borison and Triantis asked the firms for the success factors in the application of the real option approach. All of them agreed that the adoption of a new valuation paradigm was a staged process similar to the introduction of a new product, where every stage must be passed successfully to sustain momentum in the implementation of the "novelty". As this question is of less importance for the comparison to our survey, we refer the interested reader to the mentioned paper for further details.

Many intersectoral surveys about general capital budgeting topics also report the utilization rate of the ROA. Graham and Harvey (2001), for example, surveyed in 1999, 4'440 CFOs of selected firms throughout U.S. and Canada and got 392 useful answers.[411] Among other questions they asked also the question if the CFOs *"incorporate the real options when evaluating project"*, 26% stated they did so "always" or "often". Although the question posed is very general if we recall the findings of Borison and Triantis (2001) reporting the different forms of how a "ROA-Application" was intended by the interview partners, it can be said that compared to the surveys carried out in Europe, managers of Northern American companies seemed to be more aware of the real option approach in project evaluation. In the year 2000 (only one year later), Black *et al.* (2002) asked the same question about the ROA to the CFO's of all 136 listed companies on the New Zealand Stock Exchange (NZSE) as of July 2000. In this case, 25% of respondents stated that they incorporated real options "always" or "often" when evaluating projects. However, only 26 firms responded to the questionnaire, which limits the possibility of drawing conclusions for a wider population. Ryan and Ryan (2002) surveyed a sample of 205 Fortune 1000 firms in 2001 and found that 35% of the firms used ROA at least "rarely" as an auxiliary method, 11.4% used ROA at least "sometimes", and only 1.6% used it "often" or "always". The utilization rate seems to be in line with Graham and Harvey (2001), who surveyed a similar population two years before. Nevertheless, it is interesting to note that Ryan and Ryan defined the "utilization of ROA" as "utilization as an analytical capital budgeting tool" and the statements "rarely" with "utilization in more than 25% of the cases", "sometimes" with "more than in 50% of the cases", and "often" with "more than in 75%". This clarifies that roughly 35% of the participants were applying the ROA as an analytical tool in at least every fourth project. Finally Truong *et al.* (2005) surveyed 356 Australian companies quoted in the All Ordinaries Index as of August 2004. From the 87 answers, they found that 32% used real option techniques; however, none of the respondents ranked the use of real options as very important, and only 9% stated that it was at least of moderate or higher importance. The authors concluded that the ROA had established a toehold in Australian capital budgeting practice, although it had not achieved yet the status of a mainstream technique. As the authors explained, Australia has a large natural resource sector which is a classic sector for ROA applications. Thus, this was stated to be a potential reason for the quite high utilization rate of the real option approach.

Based on the information in the surveys, we can generally say that the "real options revolution" anticipated by Coy (1999) has not taken place yet.[412] In fact, a very heterogeneous but generally low utilization rate of the ROA for the different surveyed

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[411] The 4'440 managers taking part in this survey where chosen from the members of the Financial Executive Institute which embodies 14'000 policy-making individuals in 8'000 firms in the U.S. and Canada. Moreover, all CFOs of the Fortune 500 list as of 1998 were contacted as well.

[412] See Coy (1999), p. 123.

markets was observed over countries and time. Even if applied, the respondents often assign a minor importance to the real option approach. However, it is to say that there seems to be a positive tendency over time in the knowledge and in the application of the method at least as an auxiliary tool in the valuation set applied by the companies. This is might also due to the fact that nowadays nearly all MBA courses and standard textbooks on corporate finance cover the topic to some extent.

4.3 Scope of our survey

In line with the above-mentioned surveys, we wanted to check similar questions also on the Swiss market and expand on some other points mentioned as follows in brief. As already stated the greatest part of this survey is dedicated to describing the way that Swiss companies treat managerial flexibility within the investment project valuation process. We wanted first to explore what instruments are used in general in project valuation and what types of adjustments are made for accounting for managerial flexibility. Further, we asked directly for the utilization of the Real Options Analysis. Finally we were interested in checking every single constitutive characteristic which is necessary for a managerial flexibility to be of value.[413] Consequently, the three main research targets of the survey split up as follows:

- To explore the actual methods used by Swiss firms to value investment projects and to identify adjustments or specific methods Swiss firms use to account for the value of managerial flexibility.
- To find out whether senior management of Swiss firms know the term ROA and whether it is actually applied. Moreover, to determine the reasons why it is not being used if it was known and to ascertain what were the biggest problems in applying it in the cases where ROA has been used.
- To analyze the degree of the three constitutive characteristics of investment projects, that make a real option valuable and give validity to a ROA, that is:
    - To investigate what types of uncertainties mostly affect the specific firms and to what degree.

[413] As explained in chapter 3.2.2 these characteristics are uncertainty, irreversibility, and the potential for flexible actions.

- To investigate whether there is generally a high level of irreversibility in capital investments, or if it is the case only for some specific sectors or firms.
- To investigate if during the life of a project the types of managerial flexibility by Trigeorgis occur often in Swiss practice or if they are mostly impossible to implement in reality.

In particular we focused on the third research target, as we were not aware of surveys that asked about these very central characteristics to determine the existence of real option value. In fact, most authors in theoretical papers take it for granted that uncertainty, irreversibility and flexibility is inherent in every investment project. Even if we agree that this is true for every company to a some extent, we wanted to explore in which industries these characteristics play a more important role and in which there is perhaps less possibility for, e.g., the realization of different types of managerial flexibility and, consequently, no (or less) need for a real option valuation.

4.4 Methodology

The methodology and conception of this study will be explained in the following subchapter. We believe that the most important part of survey research is designing an instrument which asks clear and relevant questions and to delivering it to the appropriate respondents. To make each stage of our process as clear as possible, we divided the chapter into "design of the questionnaire" and "sample data collection".

4.4.1 Design of the questionnaire

We took several steps to design a questionnaire that would allow a maximum of response rate and ask pertinent and clear questions.[414] After carefully studying the existent literature on capital budgeting and real options surveys, we developed a draft survey which we circulated to a group of academics and practitioners. We integrated their suggestions and tips into a revised version. This version was tested in form of a beta-survey by some further selected practitioners in a senior or very senior position. By means of this beta-survey, we learned that the average time to fill out the questionnaire

[414] See appendix A. for an English version of the questionnaire.

was roughly 30 minutes. Again, we adjusted some wording which could have been misunderstood and added some specifying examples based on the feedback of the beta-surveyors. The final version of the questionnaire consisted of twelve pages (nine question pages) and eighteen question groups. Reflecting the different issues to be explored, it was divided into three main parts:

Part 1: Questions about the Valuation of Investment Projects.

Part 2: Questions about the Application of the Real Options Analysis (ROA).

Part 3: Questions about the Relevance of the Valuation of Managerial Flexibility.

The last two pages were added to collect information about the respondent itself and his or her company and to ask for comments on the questionnaire. Part 1 of the questionnaire was intended to find out which capital budgeting methods are used currently in nowadays Swiss practice and to discover whether Swiss companies adjust the standard methods like NPV, IRR or payback ratios for accounting for the value of managerial flexibility. Part 2 had the objective to ascertain whether the ROA was known and if it was applied in Swiss practice. Furthermore, CFOs knowing and/or using the ROA could cross different problems encountered in applying it or reasons why they do not apply it or no longer apply it. An extended space was given to Part 3 as it was aimed at exploring scope number three of the study about the constitutive characteristics of a real option – uncertainty, irreversibility and flexibility - explained in the subchapter 3.2.2. Finally, on the last pages, respondents were asked questions to check for the relevance of their answers, i.e., job title (if, for example, the survey was forwarded to them by the CFO), capital budget responsibility and rough number of assessed projects each year. The answers suggested that the great majority of the respondents were in senior or very senior positions of the company, charged with the responsibility of high or very high capital budgets, and were assessing or co-assessing a large number of investment projects each year.

Like Busby and Pitts (1997), we decided to debar the "real options label" first to avoid a mix-up with financial options for those respondents who did not know the term "real option" and, second, to dismantle a reluctance in responding to all other questions if the subject "ROA" was unknown. Consequently, we used the term "flexibility" or "types of managerial flexibility" when we referred to real options. We distinguished between the six types of real options by Trigeorgis, explained in chapter 3.4.1. We reworded Trigeorgis's options in order to make them as cloesely related to practice as possible. For instance, we changed the "*option to defer*" of Trigeorgis into "*The possibility to defer the starting date of the project in order to wait for supplemental information*". To account for the different language regions in Switzerland (German, French, and Italian) the questionnaire was sent in two languages - German and French. The few Italian-speaking companies could choose to either respond in German or French. The greater part of the questions required responses in form of expressing subjective estimates of quantifiable characteristics (such as the frequency of occurrence of a specific managerial flexibility), or reflecting agreement of assertion (like “rather true” or “rather not true”). Some questions were designed to allow respondents to expand on further items (like other types of managerial flexibility not mentioned in the questionnaire). At the end of the survey, there was the possibility for the respondent to comment on the questions posed as well as on the topic explored.

4.4.2 Sample data collection

We sent the questionnaire in November 2006 to the CFOs of 429 selected Swiss firms; 216 were quoted firms listed in the Swiss Exchange (SWX) and included in the SPI as of November 2006. The second half of the sample was composed of the 213 largest non-SPI Swiss firms.[415] In doing so, we guaranteed a well-balanced sample reflecting the Swiss economic environment. A cover letter, which was personalized and signed, and a pre-stamped return envelope were enclosed to the mailing. The addresses and the names of CFOs were taken from the homepage of the Swiss Exchange,[416] from the Top 2005 list of the Handelszeitung or directly from the different homepages of the companies where available. We gave respondents two week time for the first round of answers. To maximize the response rate, we planned a follow up in advance. We chose to follow up the non-respondents with an e-mail including an electronic questionnaire. Again, we allowed two weeks for answering to the second round. To encourage the participants to return the questionnaire, we offered an advanced copy of the results to the interested parties. The respondents were assured that their answers would only be published in aggregated form and not used to reveal their identity or draw any conclusion on an individual company. Although we will not disclose the individual answers, we collected a number of firm-specific characteristics which allow accurate interpretations of the surveyed data. For checking for possible differences, we divided

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[415] We selected the firms according to the Top 2005 List published online by the Handelszeitung in cooperation with Dun & Bradstreet (Switzerland) as of the end of 2005. We first sorted out the SPI firms as we already had included them in the first half of the sample. Then we chose according to the Top 2005 list the companies with the highest sales. In the case of financials (excluding real estate companies) we ranked them by total assets. Out of these rankings, we chose the remaining 213 companies for the survey. Listed investment funds and investment companies or small insignificant subsidiaries of foreign companies were sorted out of the sample.

[416] http://www.swx.com/market/shares/quotes/swiss/table_en.html (call date: 15th of September 2006).

the sample into six broad industry groups, three sales classes, two total asset classes, three capital expenditure classes[417] and, finally, in SPI and non-SPI firms.[418]

Seven companies could not be reached due to repeatedly incorrect or untraceable addresses. Thirty-two companies responded to have not enough time to participate to the survey, and six that the questions were not suitable for their business or that the answers would have been too confident to reveal. In the end, 83 surveys were returned, which represents a response rate of nearly 20%. Compared to extended capital budgeting surveys to very senior management (like CFOs), this is at the head of the range. Moreover, 83 responses represent in absolute terms the highest return ever reached in a real option-oriented survey. Table 4.1 shows an overview of the respondents' population divided by industry groups, sales classes, total asset classes, capital expenditure classes, and SPI affiliation. Some respondents did not answer all questions, and seldom companies could not be grouped in a specific categorization due to missing data. Furthermore we separated the banks and insurance companies from the others because it makes no sense to compare its sales to the sales of a goods-producing company. Within the financial sector, total assets were used to split the various companies into comparable categories. Therefore, the number of actual respondents for a given question or in a given categorization is not always the same and will be always reported in the tables accompanying the text.

[417] For sales, total assets and capital expenditures we use annual values referring to the current business year.

[418] See Table 4.1 for the exact segmentation.

Table 4.1: Overview of the respondent population.

Selected companies:	429
Reached companies:	422
Refusals:	38
No feedback:	301
Total respondents:	**83**

							Total
spi vs non-spi:	*spi*	*non-spi*					
	42	41					83
industry groups:	*Financials* [1]	*Industrials*	*Utilities*	*Consumer goods and services*	*Chemicals and Materials* [2]	*Technology and Telecom*	
	23	21	13	14	8	4	83
sales classes: [3]	*< 1'000 Mio.*	*≥ 1'000 Mio. and ≤ 5'000 Mio.*	*> 5'000 Mio.*				
	32	18	12				62
total asset classes: [3]	*< 50'000 Mio.*	*≥ 50'000 Mio.*					
	16	5					21
capex classes:	*< 50 Mio.*	*≥ 50 Mio. and ≤ 500 Mio.*	*> 500 Mio.*				
	43	24	12				79

[1] Banks, insurances, real estate industry
[2] Chemicals, health care, basic materials
[3] in CHF

4.5 Results

4.5.1 Techniques used in project valuation

For understanding the importance of the different capital budgeting techniques used by Swiss company, we listed eight different techniques and an empty space for giving respondents the opportunity to add a technique not mentioned in the predefined list. We asked the firms to tick all relevant techniques and to rank their occurrence of application on an ordinal scale with five alternatives from “very frequently” to “never”.[419] Table 4.2 reports the results.

[419] Throughout the complete questionnaire, we used a range of five alternatives when asking about ordinal values. If not otherwise mentioned in the discussion, we always refer to the five-point ordinal scale.

Table 4.2: Frequency of occurrence of different project valuation methods.

	Occurrence of the … … static methods	… payback method	… IRR	… NPV	… DTA	… sensitivity analysis	… Monte Carlo simulation	… ROA
Number of valid responses	82	82	80	81	80	80	78	78
Missing	1	1	3	2	3	3	5	5
Mean[1]	2.06	2.12	2.2	1.96	4.03	2.98	4.58	4.85
Median[1]	2	2	2	1	4	3	5	5

	Occurrence of the …[2] … static methods	… payback method	… IRR	… NPV	… DTA	… sensitivity analysis	… Monte Carlo simulation	… ROA
very frequently	45.1	36.6	42.5	50.6	1.3	17.5	-	-
frequently	25.6	37.8	25	25.9	3.8	16.3	3.8	1.3
occasionally	13.4	7.3	11.3	4.9	26.3	35	9	1.3
seldom	9.8	13.4	12.5	13.6	28.8	13.8	12.8	9
never	6.1	4.9	8.8	4.9	40	17.5	74.4	88.5
Total	100	100	100	100	100	100	100	100

[1]corresponding metric values for response categories:

very frequently	1
frequently	2
occasionally	3
seldom	4
never	5

[2]percentage response

As might be expected, the great majority of the firms use the NPV criterion to value investments. Roughly 75% of the respondents stated they used it “frequently” or “very frequently”. The same held for the IRR method, which is used “frequently” or “very frequently” by about two-thirds of the respondents. It is interesting, however, that the static methods as well as the payback method are ranked with almost the same importance as the NPV by the whole of the sample.[420]

Supposing that firms with larger investments would use the more sophisticated methods, we checked for differences between firms with high capital expenditures and low capital expenditures. We compared the static methods and the payback method (less sophisticated methods) with the NPV and the ROA (more sophisticated methods). We divided the sample into three capital expenditures classes (smaller than CHF 50 Mio., between CHF 50 Mio. and CHF 500 Mio., larger than CHF 500 Mio.). Assuming an ordinal rank value of 1 for “very frequently” and 5 for “never”, we tested for

[420] The static methods were defined as the group of the following three methods in the survey: cost comparison method, profit comparison method, or accounting rate of return.

equality of population medians among the three groups.[421] With a confidence level of 95% the hypothesis of equality of population median could be rejected. Therefore, there is statistical evidence that firms with higher capital expenditures use on average more sophisticated valuation tools. The descriptive statistics and the results of the test are reported in appendix B. in Table A.1. By comparing the medians, it can be seen that in the class of companies with higher capital expenditures, there is a less frequent usage of the static method compared to the class with the lowest capital expenditures. The median frequency of utilization of a static method in the lowest capital expenditure class is "frequently" whereas for the highest class it is "occasionally". By contrast, for the more sophisticated method NPV the median frequency for a low capital expenditure class is "frequently", whereas for the middle and high capital expenditure class it is "very frequently". After several generations of academics pushing the superiority of discounting cash flow measures like the NPV and IRR over accounting-based static methods, that message seems to have been clearly accepted by companies. Only four companies out of the whole sample stated that they never used the NPV criterion. All of these companies are in the class with low capital expenditures. Firms in this class often rely as well on static methods; however, the utilization of the NPV is widely popular among them.

Looking at the statements about the utilization of the ROA in responding to this first general question, we can already observe that ROA is used extremely seldom by Swiss companies. Only nine companies (11.3%) of the whole sample stated that they used ROA, but most of them used it seldom.[422] When analyzing the second part of the survey we will go deeper into this matter. The Kruskall-Wallis H-test for equality of medians between the three capital expenditures classes shows significant results at 95%-level for the different utilization of the payback method and the ROA between classes. For the payback method, we found that it was significantly used with higher frequency by companies in the lower capital expenditures classes; for the ROA the contrary holds. For the other methods, we did not get significant results although the descriptive statistics clearly show that the more sophisticated methods like DTA or the Monte Carlo simulation are used mainly by firms in the high capital expenditures classes. We suppose the weak significance could be mainly due to the low number of observations in some classes rather than to other phenomena. Finally, the category "other methods"

[421] We adopted this value ranking throughout the whole chapter whenever we refer of a median or an average value unless otherwise expressly noted.

[422] In the next section, in which we treat explicitly the ROA application, we will see that ten companies stated that they used ROA. The reason for this apparent inconsistency is that the questions in the next section are formulated as "did you *ever* use the ROA?". In fact, one respondent stated that he tried to apply the ROA but did not use it any longer.

was hardly ticked (only three times) and if, then nobody filled in any response regarding what the "other method" was. Therefore, we omit this category in the discussion.

4.5.2 Valuation of different types of managerial flexibility

In question 2, we asked participants whether they considered the value that could be created through the different types of managerial flexibility described by Trigeorgis. As mentioned in the methodology section, we circumscribed Trigeorgis's option types in order to get a more practically oriented view of the subject. Positive answers to question 2 were followed up in question 3 in the way that those respondents who affirmed to quantify the value of managerial flexibility were asked about the methods used for this purpose. Table 4.3 summarizes the results for question 2 and Table 4.4 for question 3.

Table 4.3: Frequency of consideration of the value of different types of managerial flexibility.

	Consideration of the …					
	… option to wait	... option to change the operating scale	… option to stage	… option to abandon	… option to switch	… option to grow
Number of valid responses	82	81	82	82	82	80
Missing	1	2	1	1	1	3
Mean[1]	3.2	3.25	2.85	3.51	3.71	3.31
Median[1]	3	3	3	4	4	3

	Consideration of the …[2]					
	… option to wait	... option to change the operating scale	… option to stage	… option to abandon	… option to switch	… option to grow
very frequently	2.4	6.2	4.9	-	2.4	2.5
frequently	23.2	22.2	35.4	13.4	11	12.5
occasionally	35.4	29.6	36.6	31.7	24.4	46.3
seldom	30.5	24.7	15.9	45.1	37.8	28.8
never	8.5	17.3	7.3	9.8	24.4	10
Total	100	100	100	100	100	100

[1]corresponding metric values for response categories:

very frequently	1
frequently	2
occasionally	3
seldom	4
never	5

[2]percentage response

In median, the value of all types of managerial flexibility are considered "occasionally" with exception of the "option to abandon" and the "option to switch" whose value is considered only “seldom” by Swiss firms when doing investment valuation. Furthermore, on average there is a greater consideration of the “option to stage an investment”, which is the most considered one, with more than 40% of the respondents stating that they considered it “frequently” or “very frequently”. By contrast, the “option to abandon” and the “option to switch” are the least frequently considered, with roughly 13% responding to consider it “frequently”, and more than 50% considering it “seldom” or “never”.

Moreover we checked for differences between industries. The results are reported in appendix B. in Table A.3. Checking for the equality of the median of the different populations we found significance at more than the 95% level for the “option to wait”, the “option to stage”, and the “option to abandon”. This means that for these three options, the median response given by a specific industry is statistically different from the median response of another industry. For the “option to wait”, for example, we found more consideration within the financials and the chemicals and materials, with a median utilization of “occasionally” and respectively “frequently”, whereas the utilities sector seems to consider it less than other sectors with a median consideration of “seldom”. For the “option to stage” investment, we found again the financials considering this option’s value “frequently”, and the technology and telecom sector considering it even more, namely “frequently” to “very frequently”. Finally, for the “option to abandon”, there seems to be a significant less frequent consideration by the utilities and the industrial sector with a median of “seldom” and, again, the highest consideration by the financials, where the consideration was still quite low with the median of “occasionally”.

Checking for differences within the capital expenditure classes, total sales classes and total assets classes, did not bring up significant results, with exception of the “option to grow”, which seems to be considered more frequently by firms within the high total sales class compared to the others.[423] This could reflect the fact that bigger firms may have more substance to ride out grow investments, which in time might turn out to be of less value than expected. To sum up we found that every industry within our sample considers different types of managerial flexibility. On average, this consideration differs in frequency and industry, but the fact is that the value of flexibility is certainly not neglected by Swiss companies. The way they account for these different types of flexibility will be presented subsequently in the discussion of question 3. Interesting to note is that some practitioners and academics we talked to, suggested excluding the financial sector in the survey about real options arguing that this industry has not real assets to execute the options and most probably a low responding rate was to be

[423] Total sales more than 5'000 Mio CHF.

expected. Nevertheless, we included this sector in our survey because of its relative high importance for Swiss economy and found a surprising high consideration of the value of managerial flexibility within their investment decision process. In fact, with exception to the "option to expand" and the "option to switch" for every other option the financials were in-between the one or two industries with the most frequent consideration of value of the option within the investment decision.

In question 3 we asked participants which methods they used to quantify the mentioned types of managerial flexibility. The five possibilities to tick were an arbitrary surcharge on the calculated project value or an adjustment of the discount rate based on intuition or experience, the DTA, the ROA, or another method. Again, the category "other methods" was ticked extremely seldom. Moreover, some respondents specified to use probability-weighted methods or qualitative approaches like the "value benefit analysis" to consider the value of flexibility.[424] The results for the specified methods are reported in Table 4.4. More than two-thirds of the respondents stated to add a surcharge to the project value based on intuition or experience "occasionally", "frequently", or "very frequently" if they were confronted with a project with high flexibility. A seemingly high percentage of companies adjusted their discount rate, depending on the favorability of a more or less flexible project[425] also at least "occasionally" to "very frequently". The Decision Tree Analysis is brought up in roughly 20% of the cases at least "occasionally" or "frequently", and the ROA is used only by one company "frequently" when valuing investment decisions with inherent flexibility. In general, we can therefore say that as it has been found in the other surveys, it is also the case of Swiss managers to predominantly use their intuition or experience to value managerial flexibility.

Furthermore we found highly significant[426] differences by capital expenditure classes in the utilization of DTA and ROA for the valuation of the different types of managerial flexibility. The results are reported in appendix B. in Table A.2. Whereas the arbitrary methods are used with a similar frequency in all three classes, the more sophisticated methods are used predominantly in the class with the highest capital expenditures, i.e., the biggest amount of invested capital. This leads us to the conclusion that all companies use arbitrary methods when they have to value flexibility; however, when it comes to important outlays of capital, they tend to add other decision metrics to enforce their judgments - a behavior that seems very cautious and wise to us.

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[424] No further explanations were given in regards to the probability-weighted methods.

[425] A higher discount rate is given to less flexible projects and vice versa.

[426] At a more than 95% significance level.

Table 4.4: Frequency of utilization of valuation methods for managerial flexibility.

Utilization of specific methods for flexibility valuation

	Arbitrary adjustment	Capital cost adjustment	DTA	ROA
Number of valid responses	68	68	69	66
Missing	15	15	14	17
Mean[1]	3	3.19	4.23	4.82
Median[1]	3	3	4	5

Utilization of specific methods for flexibility valuation[2]

	Arbitrary adjustment	Capital cost adjustment	DTA	ROA
very frequently	5.9	5.9	-	-
frequently	38.2	26.5	5.8	1.5
occasionally	23.5	27.9	13	1.5
seldom	14.7	22.1	33.3	10.6
never	17.6	17.6	47.8	86.4
Total	100	100	100	100

[1]corresponding metric values for response categories:

very frequently	1
frequently	2
occasionally	3
seldom	4
never	5

[2]percentage response

To check if the quantification of managerial flexibility had also an effect on the managers' real decisions we asked in question 4 how frequently a project was realized even though it seemed to be unprofitable according to the generally used capital budgeting techniques of the firm (e.g., NPV, IRR, or Payback). As can be seen in Table 4.5 we found a very high percentage of companies that answered to realize projects with bad numbers on their originally utilized capital budgeting technique, only because the projects had inherent managerial flexibility. More than 50% stated to do it "occasionally" or "frequently", and only 6 out of 77 respondents reported to never do it. Even if we did not ask which type of managerial flexibility was involved in changing the decisions which were elaborated in the original capital budgeting method we can herewith conclude that although flexibility is mostly accounted only arbitrarily in project evaluation of Swiss companies, it often has an important effect on a manager's decision to undertake a project or not. For the sake of completeness, we also tested the realization of "unprofitable projects" for differences in industry groups and capital expenditures classes; however, we found no statistical significance between the different classes.

Table 4.5: Frequency of realization of project due to managerial flexibility.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	frequently	5	6	6.5	6.5
	occasionally	35	42.2	45.5	51.9
	seldom	31	37.3	40.3	92.2
	never	6	7.2	7.8	100
	Total valid	77	92.8	100	
Missing		6	7.2		
	Total	83	100		
	Mean[1]	3.49			
	Median[1]	3			

[1]corresponding metric values for response categories:

very frequently	1	seldom	4
frequently	2	never	5
occasionally	3		

4.5.3 Application of the Real Options Analysis

Only part two of our questionnaire explicitly mentioned the ROA as the main subject to be explored. We wanted to know following information: first, whether the managers knew the term ROA, although we did not specify what we meant with “know”. We simply wanted to explore whether they had at least heard about it or if it was a completely unknown approach to them. Second, we were interested in ascertaining if they ever applied the ROA. Furthermore, we asked participants who used the ROA about the most important problems in applying it. Finally, participants who never used the ROA even though they knew it were asked why they decided not to use it. An overview of the answers is reported in Table 4.6.

Table 4.6: Knowledge and utilization of the ROA.

Knowledge of the ROA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	32	38.6	40	40
	NO	48	57.8	60	100
	Total valid	80	96.4	100	
Missing		3	3.6		
	Total	83	100		

Utilization of the ROA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	YES	10	12	31.3	31.3
	NO	22	26.5	68.8	100
	Total valid	32	38.6	100	
Missing		51	61.4		
	Total	83	100		

Frequency of utilization of ROA[1]

	Frequency
very frequently	1
occasionally	1
seldom	5
no longer	3
Total	10

[1]corresponding metric values for response categories:

very frequently	1	seldom	4
frequently	2	never	5
occasionally	3		

Thirty two of the responding managers, i.e., roughly 40% of the sample, stated that they knew the term ROA. This is not a level of knowledge we would have reached one decade ago, but it also shows that the term ROA is not known, not even as a term or an idea, to more than the half of the managers in senior positions of Swiss firms.[427] Out of the group of managers who stated to know the term ROA, several declared to have at least touched the subject within the scope of an MBA advanced training course, but to not having furthered their knowledge since.[428] Out of the ROA-knowing participants ten (roughly one third) tried the methodology on a real project, and again from the ROA users, seven are still applying it, and three decided not to pursue further a ROA implementation for the evaluation of their projects. As we already observed in the previous general questions about project valuation techniques, most of the ROA users did not apply it on a regular basis. Only one company reported to use it “very frequently”, and another company not more than “occasionally”. The remaining firms declared that they used it “seldom”.

On question number 5 about the ROA utilization, we cannot draw any conclusion on a broader population as there were only ten respondents. Nevertheless, we reported the frequency table of ROA usage among industry groups, capital expenditure classes, and SPI-affiliation in appendix C. in Table A.4. We expected to find no ROA user or ROA tester in a non-SPI company or in companies with low capital expenditures. From the descriptive statistics, we can see that our expectations were not met. Also non-SPI firms or firms with smaller outlays used or at least tested the possibility of a ROA implementation, even though the sustainability of the ROA implementation seemed to be stronger in the generally more internationally oriented SPI companies. Moreover, before launching the survey, we expected that hardly any company in the financials group would have ever tested a ROA application and that the majority of the ROA users would have been found in chemicals or in the technology sector. Surprisingly, we found many ROA testers or even ROA users in the financial sector, but no one in the technology sector. Although we do not have a representative number of respondents for this question, half of them (five) come from the financial sector. If we consider that we got twenty-one answers from the financial sector, five of twenty-one is a high percentage in comparison to other sectors, especially looking at what we expected.

As this low level of practice application is not a surprising fact in real option surveys, we decided to inquire on problems or hindrances for the ROA application. We tried to include the problems mentioned in chapter 3.6 in the selection list of the questionnaire and hoped to expand the list with new insights from the answers. Unfortunately, few

[427] Busby and Pitts found, for instance, in their survey of UK firms in 1997 that only 6 out of 44 respondents (13.6%) stated that they knew the term “real options”, and most of them did not interpret it as it is used in the literature. See Busby and Pitts (1997), p. 177.

[428] Oral statements of several interview partners.

respondents ticked the field "other reason" or "other problems" and nobody explained what those reasons or problems were, so we stuck to the very comprehensive list presented in chapter 3.6 and accompanied it with some numbers from the practical world. The problems encountered in applying the ROA can be seen in Table 4.7 and the reasons for deciding not to apply the ROA, even if known, are summarized in Table 4.8. For the ROA users, the identification of the real options within a project seems not to be a big difficulty, whereas the determination of the parameters was a problem for most of them.[429] The communication of the calculated results to all involved parties was mainly a problem for the companies that decided not to go further into the ROA application, whereas firms that had implemented the ROA and still used it seem to encounter less difficulty in communicating the resulting values. However, because there were only ten respondents to this question, our sample does not permit drawing general conclusions on this topic.

Table 4.7: Problems in ROA application.

	RO identification	RO modelling	Parameters determination	Communication of RO value
rather true	2	5	7	4
rather false	7	4	2	5
Total	9	9	9	9

(Reporting counts of companies for each specific problem)

For the CFOs knowing the ROA but not using it, we received more answers than in the question before. The three most cited reasons not to use the ROA are, first, the lack of knowledge within the company, second, the difficulty in communication of a ROA value to all involved parties, and, third the one that a real option application is considered to need efforts too strenuous to be implemented. This is in general also what was underlined from our e-mail correspondence or personal interviews with some CFOs in question. A decision about the realization of a project has to be taken in a short time and has to be as communicable as possible. If necessary, a rough NPV calculation can be performed in one or two hours[430] and is easily communicable for the reason that the

[429] Perhaps there is bias in this response that ROA users already started their application having a specific real option in mind. Consequently, the identification was not perceived as a difficult task. However, in general, identifying real options is not that easy as it could appear at first glance.

[430] As stated by an interview partner.

NPV is a widely and well accepted notion in Swiss business life.[431] With a ROA these two important, practical hurdles must first be taken before it can enter into daily valuation business. The insights from this question were, therefore, also a reason why we decided to try to set up a framework which could relatively quickly give a rough estimation of the real option value and which required as little ROA knowledge as possible. This, in turn, would also favor the communicability to other involved parties without needing to study the whole theory in modeling real options in advance.[432] As we learned intuitively from previous questions, the reason that managerial flexibility is not being considered is not a valid reason for not using the real option approach, as most respondents to this question stated explicitly that managerial flexibility was important in their project, and that its value was being taken into consideration with other methods, i.e., mostly qualitatively. The misuse of methodological skills was also declared not to be a big hindrance in applying the ROA. The effect of the "e-bubble" mentioned in chapter 3.6.3 seems to be forgotten by decision makers in Switzerland since it came up in early 2000. Companies inflating values and justifying them with the ROA no longer exist, and consequently the ROA is no longer perceived as a "shady" and incorrect means to an end; at least only four respondents declared that the misuse of ROA skills by ROA experts could be a hindrance to its application in their company.

Table 4.8: Reasons for not considering a ROA application.

	Managerial flexibility value not considered	Managerial flexibility value qualitatively considered	Effort too high	Know-how nonexistent	Initial effort too high
rather true	6	12	17	20	12
rather false	14	8	3	1	7
Total	20	20	20	21	19

	Subordinated importance of managerial flexibility	Difficult parameter appraisal	Difficult communication of the ROA value	Misuse of methodological skills
rather true	6	16	18	4
rather false	13	5	2	14
Total	19	21	20	18

(Reporting counts of companies for each specific problem)

[431] As we also could see from the results of the question regarding the capital budgeting techniques in subchapter 4.5.1.

[432] This framework will be presented in chapter 5.

4.5.4 Constitutive characteristics of real option value

As already described in subchapter 3.2.2 from the theoretical basis of the real option's approach, we learn that there are several characteristics of a project that are indispensable for a real option to be of any value: uncertainty, irreversibility and flexibility. Consequently we wanted to explore the Swiss companies on the perception of uncertainty, irreversibility and the effective occurrence of managerial flexibility. It is obvious that every project in every firm will incorporate to some extent every one of these characteristics. The question in this case is more to ascertain to what extent these characteristics are pronounced and perceived and, especially in the case of flexibility, whether the types of managerial flexibility described by Trigeorgis are actually practiced in real-life or not. If the three characteristics turn out to be less incisive, or, e.g., a specific managerial flexibility is not executable it is obvious that taking up the efforts to conduct a ROA would make less sense, as the results of a NPV calculation would already provide excellent results. This would clearly result in a rational reason for the low application rate of the ROA. This reason, however, is hardly mentioned in theoretical works where the existence of all three constitutive characteristics has always been assumed to the extent of giving importance to a ROA application. In practice it could come out completely different.[433] If a managerial flexibility is not executable - or worse not even perceived as positive - it would obviously represent no real option value in real-life. We will now address every specific constitutive characteristic in a separate subchapter.

4.5.4.1 Uncertainty

As flexibility is only valuable in response to an unforeseen event,[434] i.e., an uncertainty, we asked companies how strongly the strategic relevant projects were exposed to various sources of uncertainty. We did not ask for specific measures, but only for the perception managers had of the specific risks in an ordinal scale from "very strong" to "very weak". Table 4.9 shows the percentage responses for different risk categories with the mean and median risk exposure the companies declared.

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433 Busby and Pitts (1997), for example, found in their survey of UK firms that many managers perceived the option to wait as a negative non-commitment and, by contrast, they stated that committing resources strongly motivates management and employees to achieve the prefixed targets. See Busby and Pitts (1997), p. 179. Another example is the option to abandon, which is also often interpreted as a defeat, not only by the manager, but also by other involved parties such as the employees, the investors, the government, and so on. Therefore, companies are reluctant to plan an abandonment of the project in advance and even more reluctant to fulfill the abandonment when necessary. See Busby and Pitts (1997), p. 180.

434 See Ku (1995), p. 316.

Table 4.9: Risk exposure of strategic relevant projects.

Risk exposure:	Market demand	Technology	Interest rate	Inflation	Currency	Legal/regulatory changes
Number of valid responses	82	83	83	83	83	83
Missing	1	0	0	0	0	0
Mean[1]	2.83	2.87	3.53	3.82	3.59	2.81
Median[1]	3	3	4	4	4	3

Risk exposure:	Geopolitical events	Environment	Demographic changes	Change of social trends	Competition
Number of valid responses	83	83	83	83	83
Missing	0	0	0	0	0
Mean[1]	3.83	3.64	3.87	3.83	2.41
Median[1]	4	4	4	4	2

Risk exposure:[2]	Market demand	Technology	Interest rate	Inflation	Currency	Legal/regulatory changes
very strong	12.2	8.4	4.8	-	1.2	12
strong	31.7	28.9	8.4	6	10.8	28.9
moderate	24.4	37.3	27.7	19.3	36.1	30.1
weak	24.4	18.1	47	61.4	31.3	24.1
very weak	7.3	7.2	12	13.3	20.5	4.8
Total	100	100	100	100	100	100

Risk exposure:[2]	Geopolitical events	Environment	Demographic changes	Change of social trends	Competition
very strong	1.2	1.2	1.2	-	9.6
strong	3.6	13.3	6	7.2	53
moderate	30.1	24.1	22.9	27.7	26.5
weak	41	43.4	44.6	39.8	8.4
very weak	24.1	18.1	25.3	25.3	2.4
Total	100	100	100	100	100

[1]corresponding metric values for response categories:

very strong	1
strong	2
moderate	3
weak	4
very weak	5

[2]percentage response

We found that for the whole of the sample major risk comes from competition followed by risk of legal and regulatory changes, market demand risk, and technology risk.[435] Other risk categories are declared to have less influence on the outcome of strategic

[435] Also for any segmentation in capital expenditure classes, total asset classes, total sales classes or SPI affiliation this risk categories are always the most mentioned by Swiss companies.

projects. High exposure to competition risk could give value to, for example, an "option to stage the investment" or an "option to alter the operating scale", whereas the "option to wait" is of minor value in cases of high competition because the manager's action to wait for more information could be impeded by some competitor preempting the investment. For market demand risk, on the other hand, the "option to wait" could gain value as well as the "option to adjust the operating scale" according to market demand. Furthermore, for high levels of technology risk, an option to "stage investment", an "option to wait", or an "option to grow" could be implemented in the project in order to avoid large failures or profit from resolving technology risk during the project's lifetime. Finally, to deal with the last of the important rated risk categories, i.e., the legal or regulatory risk, a company could decide to implement an "option to switch", e.g. amongst production locations, or an option to switch to another similar product or an "option to abandon" the project in case of changing or very adverse regulations or legislation.

Obviously there are differences among industry groups concerning the risk exposure to different risk categories. As can be expected, the technology and telecommunication industry is largely exposed to technological risk and market demand risk, whereas, for instance, banks and utilities are more affected by a changes in regulations or laws. What is worth mentioning is perhaps the fact that competition risk is in highly relevant to all industry groups, a circumstance which could mean for real option theory that future research should concentrate efforts on the development of real options games, i.e., the combinations of real option theory and game theory as proposed in Smit and Trigeorgis (2004). We did not find any other significant insights out from the industry group segmentation and so will not go further on this matter. The interested reader is referred to appendix D. in Table A.5 for an overview of the results.[436]

We based this short discourse on the relation of the different risk categories and their corresponding real option on Trigeorgis's mapping of risks discussed in subchapter 3.2.2.1. We want emphasize that several risk categories which support specific real options are mentioned by Swiss companies as "strongly" or "very strongly" affecting the outcomes of their projects.[437] We conclude, therefore, that from the point of view of the different uncertainties affecting projects, there would be a large potential for real options application. However, without irreversibility and the possibility to exercise

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[436] Only means, standard deviations, and medians are reported because the detailed focus on these results was not the main topic of the dissertation.

[437] For both analyzing it for the total sample, or for the different segmentations (industry groups, capital expenditure classes, total sales, total asset classes, and SPI affiliation).

these options during the life of the project, this application potential obviously vanishes. Consequently, in the following, we investigate also these other two characteristics.

In closing the discourse about risk categories, it should be mentioned that the effect new information can have on the decision of the continuation of the project or the re-scaling of the project's size was explored in the concluding question of this question group.[438] From Table 4.10 it can be seen that for the great majority of Swiss companies, new information frequently means a re-consideration of the decision made. More than 70% of the respondents declared that new information causes changes in decision at least "sometimes", more than one-fifth stated that this occurred even "often".[439] Without inquiring already at this stage if the changes of decision were prevented or induced by major forces, we conclude that the Swiss business environment is extremely dynamic in reacting to volatile information which again gives evidence for great importance of a possible application of the ROA.

Table 4.10: Effect of new information on continuation or re-scaling of the project.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	often	17	20.5	20.5	20.5
	sometimes	42	50.6	50.6	71.1
	rarely	22	26.5	26.5	97.6
	never	2	2.4	2.4	100
	Total valid	83	100	100	
Missing		0	0		
	Total	83	100		
	Mean[1]	3.11			
	Median[1]	3			

[1]corresponding metric values for response categories:

very often	1	rarely	4
often	2	never	5
sometimes	3		

[438] New information arrives obviously continuously to a company. We wanted to know how frequently this information changed decisions about a project.

[439] Again, this statement also holds for any of the segmentations made for the other questions.

4.5.4.2 Irreversibility

Assessing the level of irreversibility of the projects of a company through a questionnaire was a difficult task. We had to move away from exact numbers or measurements which are hardly practicable over so many different companies and tried to get a feeling for the subject by asking the CFOs different types of questions tied to the theoretical basics of irreversibility. First, we asked simply about the perception of difficulty participants had if they wanted to liquidate an investment on an ordinal scale with five alternatives from “very easy” to “very hard”. Additionally, we asked them whether liquidation was associated with high re-conversion cost, again on an ordinal scale from “very high” to “very low”. The results can be seen in Table 4.11A and 4.11B. The great majority of the respondents, namely 86.4% of the respondents, declared that it is at least “hard” or “very hard” to reverse all investment costs. Moreover 71.4% state that the cost associated with re-conversion of an investment would be at least “high” or “very high”.

Table 4.11: Level of irreversibility of strategic relevant projects (A, B, C).

A

Abandonment ease

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	easy	3	3.6	3.7	3.7
	moderate	8	9.6	9.9	13.6
	hard	57	68.7	70.4	84
	very hard	13	15.7	16	100
	Total valid	81	97.6	100	
Missing		2	2.4		
	Total	83	100		

B

Abandonment costs

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very high	10	12	13	13
	high	45	54.2	58.4	71.4
	moderate	22	26.5	28.6	100
	Total valid	77	92.8	100	
Missing		6	7.2		
	Total	83	100		

C

Reasons causing irreversibility[1]

	Costs from industry-specific investments	Costs from intangible assets	High fix costs	Existence of an efficient second hand market	Institutional arrangements	Legal regulations
rather true	81.7	47.6	67.5	5	13.9	11.4
rather false	18.3	52.4	32.5	95	86.1	88.6
Total	100	100	100	100	100	100

[1]percentage response

In the second part of the question group about irreversibility, we returned to the theoretical directions on irreversibility given by Dixit and Pindyck (1994). The authors stated that irreversibility can arise from six different reasons: industry-specific investments, investments in intangible assets, high level of fixed costs, inefficient second-hand markets (i.e., the lemon problem), and institutional arrangements or governmental regulations which hinder the investors from selling assets and reallocating their funds.[440] Consequently, we asked the CFOs whether these reasons

[440] See Dixit and Pindyck (1994), p. 8ff.

would arise also in their companies so that respondents could choose between two alternatives: “rather true” or “rather false”. As reported in Table 4.11C more than 80% declared that the costs for their investments derive predominantly from industry-specific assets. Moreover, more than two-thirds of the respondents specified that their investment costs consisted mainly of a fixed part compared to a variable part, and for 95% of the sample, there was no efficient second-hand market if they wanted to liquidate the investments. In line with the first part of the irreversibility question group, these answers showed an extremely high irreversibility for the whole of the sample. For the question about the proportion invested in know-how or other intangible assets, there was no clear direction. For about the half of the sample, investment costs arose mainly from know-how or other intangible assets; for the other half, this statement is rather false. However, we supposed that this lack of clarity arose because of the differences between industry groups. The financials especially are expected to spend more money on intangible assets. We checked for equality of a central tendency in responses between different industry groups and found a statistical significance at more than the 99% confidence level, supporting our expectations. The financials showed a significantly higher degree of expenditures in intangible assets when undertaking projects compared to all other industry groups. The perceived irreversibility of the financials group could, therefore, arise from investments in intangible assets, whereas the irreversibility of the other groups could derive from the other mentioned reasons. Finally, answers to the last two questions did not add much to our main findings. For both, either the question regarding institutional arrangements or the one about governmental regulations, which both could hinder the resale of assets on the second-hand market, the majority (almost 90%) responded that this was not true for their business. Obviously, this could also come from the fact that having already a high level of inherent irreversibility, there is no need for lawmakers to think about arrangements or regulations for an already very thin second-hand market.

As the sample shows in general a strong tendency for highly irreversible investments, we attach little importance to the task of checking for further differences between our segmentation groups. A strong level of irreversibility can be found all over the sample, whether segmented by industry groups, size of companies, or their capital expenditures. The high uncertainty of some outcome-influencing variables as found in the subchapter above and the high irreversibility ascertained here should favor the organization of different types of managerial flexibility. In the next section, we will explore how often the various types of flexibility effectively occur.

4.5.4.3 Potential of flexible actions

We asked the firms in the first part of the questionnaire how often they took into consideration the specific types of managerial flexibility. If they answered with "often", it still does not mean that this specific managerial flexibility also occurred often, but only that if it did occur, it was often considered into the valuation of the project. The main point of the last question group was therefore aimed at finding whether different types of managerial flexibility are planned in advance and occurred often in Swiss business practice. If they show up seldom in reality, it is understandable from a practical point of view that implementing a new valuation paradigm perceived as being complex and taking too much effort for its application was not regarded as the first task on the agenda of senior management. This circumstance would confine the real option theory in theoretical spheres and would also represent a rational reason why the implementation speed of the ROA in practice is still low. On the other hand, if the different types of managerial flexibility show up often in real business life, the question arises as to why those efforts are not taken up by companies to value the flexibilities as accurately as possible instead of using simply a gut feeling after we assessed an high uncertainty in many risk factors as well as a generally high level of irreversibility.

We asked the companies questions about the occurrence of the types of managerial flexibility as described by Trigeorgis.[441] We asked, first, if the specified type of managerial flexibility occurred and, second, if it was planned deliberately in advance, or if it was simply a reaction on an unplanned event during the life of the project. Obviously, a real option can only be regarded as a valuable action if it is planned in advance and not forced by an accidental event. Note, for example, that neither a delay because a planned machinery is not installed in time nor abandonment because of a lack of financial means are real options. We found a clear and significant relationship between the occurrence and the planning of each of them, the "option to delay", the "option to alter the scale", the "option to abandon" and the "option to switch in- or outputs".[442] Thus, we conclude that in most cases, respondents really understood the managerial flexibility in the right way, i.e., as an option, and not as a "forced reaction"

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[441] As we explained in subchapter 3.4.2, there are several ways to categorize real options. Of the different categorizations, some types of flexibility are not explored in this survey. As the categorization by Trigeorgis is the most common and we wanted to follow a consistent way during the complete dissertation, we decided to also use the options described by Trigeorgis in the survey. Although we are aware that in practice there are also other types of flexibility, we think that the real options by Trigeorgis encompass a large number of managerial actions that describe real business life very well.

[442] In the case of the "option to stage" and the "option to grow", there is no sense in asking whether or not they are planned in advance because they can obviously only occur if they are deliberately planned.

depending on special events. Therefore, in the following we only refer to the "occurrence" of the managerial flexibility, keeping in mind that the specified flexibility is meant as a planned real option, and not as a product of coincidence or of an action induced by external forces. We reported the occurrence of the different types of flexibility in Table 4.12. As this part of the survey is crucial for the dissertation we report a separate table for each of the managerial flexibilities with their respective counts and percentage of occurrence, as well as the cumulated percentage. The most frequently occurring managerial flexibility in our sample is the "option to stage" investments with a median of "often". The least occurring is the "option to abandon" with a median of "rarely". All the other options are in-between, whereas the "option to grow" has a relevant weight compared to others, and the "option to switch in- or output" and the "option to abandon" seem to have the least importance. In general, the majority of the sample is reluctant to abandon projects and focus more on staging investments and growth investments.

Again, we checked for differences in industry groups. Medians and means for industry groups are reported in Table 4.13. The highest mean value of occurrence in a specific industry group for each different option is underlined in the table. Looking at the results in Table 4.13 we see that all real options occur with similar frequency[443] in the different industries, except for the "option to stage" investments which occurs with higher frequency in the financials group. We tested for equality of medians and found statistical significance for the increased occurrence of the "option to stage" in the financial sector.[444] We talked to some of the respondents in the financial group and learned that the staging of investment is regarded as a sort of first step in "risk management" in banking industry[445] and, therefore, it is practiced very frequently.[446] This might be a reason why companies in the financial industry mention the "option to stage" more frequently.[447] For all the other options we found no significant results regarding a different occurrence in a specific industry group. A further noticeable fact in this industry group segmentation is the one that industries with higher exposure to technological and market demand risk (such as chemicals and materials, and technology

[443] Particularly if looking at the medians.

[444] Kruskall-Wallis H-test at the 95% significance level (df 5), Chi Square value: 14.410.

[445] Banks constitute a major fraction of our financials group sample.

[446] According to the statement of some interview partners.

[447] For correctness, we must mention at this point that obviously an "option to stage" represents not only a risk management tool against downside risk, but also the possibility to profit from positive developing events (by doing the next stage). In this sense, staging investments could be interpreted differently by respondents compared to how it was intended in real option theory. Nevertheless, judging from their responses to the whole questionnaire, we are very confident that the participants interpreted the option to stage mostly as a managerial flexibility and not as a risk management tool also in the case of this question.

and telecom) are less reluctant to abandon a project and more favorable to defer investments. This frequent utilization of the "option to defer" is clearly in line with real option theory, which states that the stronger uncertainties affect project outcomes, the less quickly a commitment is made. Furthermore, especially in the chemical and healthcare industries, some clinical tests for medicaments, if not passed, can often cause the abandonment of a project which is therefore seen more like a common research and development process and not as a "defeat" as it is may the case for other industries. Finally, managers dealing with consumer goods and services stated, on average more often than the other groups, that they adjusted the scale of projects. This could come from their direct link to consumer demand. The companies in this industry are directly producing for a great many of consumers. Changing market demand can, therefore, have an immediate influence on project scale.

Table 4.12: Occurrence of different types of managerial flexibility.

	Occurrence of…					
	... project delay	... change of scale	… project staging	… project abandonment	… change of input/output	... growth investments
Number of valid responses	83	80	82	82	81	81
Missing	0	3	1	1	2	2
Mean[1]	3.3	3.39	2.55	3.94	3.77	3.09
Median[1]	3	3	2	4	4	3

Occurrence of project delay

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	often	9	10.8	10.8	10.8
	sometimes	43	51.8	51.8	62.7
	rarely	28	33.7	33.7	96.4
	never	3	3.6	3.6	100
	Total valid	83	100	100	
Missing		0	0		
	Total	83	100	100	

Occurrence of project staging

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very often	10	12	12.2	12.2
	often	33	39.8	40.2	52.4
	sometimes	25	30.1	30.5	82.9
	rarely	12	14.5	14.6	97.6
	never	2	2.4	2.4	100
	Total valid	82	98.8	100	
Missing		1	1.2		
	Total	83	100		

Occurrence of change of input/output

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very often	1	1.2	1.2	1.2
	often	3	3.6	3.7	4.9
	sometimes	23	27.7	28.4	33.3
	rarely	41	49.4	50.6	84
	never	13	15.7	16	100
	Total valid	81	97.6	100	
Missing		2	2.4		
	Total	83	100		

Occurrence of change of scale

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very often	1	1.2	1.3	1.3
	often	9	10.8	11.3	12.5
	sometimes	34	41	42.5	55
	rarely	30	36.1	37.5	92.5
	never	6	7.2	7.5	100
	Total valid	80	96.4	100	
Missing		3	3.6		
	Total	83	100		

Occurrence of project abandonment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very often	1	1.2	1.2	1.2
	often	1	1.2	1.2	2.4
	sometimes	14	16.9	17.1	19.5
	rarely	52	62.7	63.4	82.9
	never	14	16.9	17.1	100
	Total valid	82	98.8	100	
Missing		1	1.2		
	Total	83	100		

Occurrence of growth investments

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very often	1	1.2	1.2	1.2
	often	16	19.3	19.8	21
	sometimes	41	49.4	50.6	71.6
	rarely	21	25.3	25.9	97.5
	never	2	2.4	2.5	100
	Total valid	81	97.6	100	
Missing		2	2.4		
	Total	83	100		

[1]corresponding metric values for response categoı

very often	1
often	2
sometimes	3
rarely	4
never	5

Table 4.13: Occurrence of different types of managerial flexibility by industry groups.

Means and medians for different industry groups

Industry group		Occurrence of …[1] … project delay	… change of scale	… project staging	… project abandonment	… change of input/output	… growth investments
Financials	Mean	3.3	3.43	2.09	3.68	3.77	2.91
	Median	*3*	*3*	*2*	*4*	*4*	*3*
	N	23	21	23	22	22	22
Industrials	Mean	3.29	3.24	2.86	4	3.9	3.5
	Median	*3*	*3*	*3*	*4*	*4*	*3*
	N	21	21	21	21	20	20
Utilities	Mean	3.62	3.85	3.25	4.31	4.15	3.15
	Median	*4*	*4*	*3*	*4*	*4*	*3*
	N	13	13	12	13	13	13
Consumer good and consumer services	Mean	3.36	3.14	2.36	4.07	3.64	3
	Median	*3*	*3*	*2*	*4*	*4*	*3*
	N	14	14	14	14	14	14
Chemicals and materials	Mean	2.88	3.43	2.38	3.88	3.25	2.75
	Median	*3*	*3*	*2*	*4*	*3.5*	*3*
	N	8	7	8	8	8	8
Technology and telecom	Mean	3	3.25	2.5	3.5	3.25	2.75
	Median	*3*	*3.5*	*2.5*	*3.5*	*3.5*	*3*
	N	4	4	4	4	4	4
Total	Mean	3.3	3.39	2.55	3.94	3.77	3.09
	Median	*3*	*3*	*2*	*4*	*4*	*3*
	N	83	80	82	82	81	81

[1]corresponding metric values for response categories:

very often	1
often	2
sometimes	3
rarely	4
never	5

As predicted by real options theory, a higher degree of uncertainty should also favor the creation of specific types of managerial flexibility in presence of irreversibility.[448] We ascertained that the level of irreversibility is perceived as high by the great majority of companies in our sample.[449] Therefore, it is interesting to check whether there are relationships between the mentioned uncertainties and the occurring managerial flexibilities. As highlighted earlier, both types of uncertainties as well as the flexibilities were assessed on an ordinal scale: respondents were asked to assess uncertainties based on an ordinal scale from a "very strong" to a "very weak" and to assess flexibilities based on an ordinal scale from "very often" to "never". To check for a potential link between these two variables, we used the Kendall tau C test, which is a metric which counts the excess number of concordant over discordant pair-ranks between the ranks of two ordinal variables for a n-by-n table (in our case 5 x 5).[450] If the agreements between the two rankings are perfect, i.e., the two rankings are the same, the value of the coefficient is equal to 1. If the disagreement is perfect, i.e., the rankings are completely opposed to one another, the coefficient is -1. For all other cases in-between, the correlation is the higher the nearer the coefficient approaches to 1, respectively -1

[448] See Trigeorgis (1999a), p. 2ff.

[449] As reported above in subchapter 4.5.4.2.

[450] See Janssen and Laatz (2005), p. 269ff.

for disagreement. A coefficient of 0 means, therefore, that the rankings are independent. We ran the tests with the SPSS 14.0 statistic package which reports the Kendall coefficient, the asymptotic standard error, and an approximate T value for the test statistic with a corresponding approximate significance level.[451] Here the null hypothesis to test is the one that the ranking of a specified variable is not correlated to the ranking of another variable, and the alternative hypothesis is consequently that the rankings of both variables are correlated. If the test statistic exceeds the pre-set significance value, the null hypothesis is being falsified and, consequently, there is a certain probability that the two variables are correlated. Setting the significance level at least at 95% (p-value = 0.05), we guarantee that the probability of an error in making the statement that the two specified variables are correlated is very low. Results of the tests for the association of the various uncertainties and types of managerial flexibility are reported in Table 4.14.

Table 4.14: Symmetric measures: Kendall tau C test for equality of ranking monotonicity.

	Kendall coefficient	Asymp. Std. Error[1]	Approx. T[2]	Approx. Sig.
Demand vs. Delay (N=82)	0.183	0.094	1.948	0.051
Demand vs. Scale (N=80)	0.279	0.081	3.438	0.001
Technology vs. Scale (N=80)	0.273	0.079	3.441	0.001
Technology vs. Abandon (N=82)	0.167	0.079	2.096	0.036
Technology vs. Grow (N=81)	0.166	0.068	2.45	0.014
Legal&regulation changes vs. Stage (N=82)	0.204	0.07	2.899	0.004
Legal&regulation changes vs. Grow (N=81)	0.165	0.076	2.172	0.03
Competition vs. Scale (N=80)	0.164	0.079	2.078	0.038
Competition vs. Abandonment (N=82)	0.172	0.071	2.408	0.016

[1]Not assuming the null hypothesis
[2]Using the asymptotic standard error assuming the null hypothesis

[451] SPSS computes the significance of the results on the assumption of an approximate T-distribution. The value shown as „Approx. T“ can therefore be interpreted as roughly equivalent to a common t-test. If the value reaches 1.96, the test results are significant at the 95% level.

We reported only values with high significance level, i.e., according to Table 4.14 the lowest at almost 95% (for demand vs. delay) and the highest at 99% (for demand vs. scale and technology vs. scale). We found weak correlations for all presented combinations of risk categories and types of managerial flexibility. All Kendall coefficients, in line with what is predicted by real options theory, are positive, even though the values are low. In these cases, the hypothesis of an association between the two variables could therefore not be falsified. For example: the higher the perception of demand risk, the more frequent the occurrence of the "option to delay"; or, the higher the perception of demand risk, the more frequent the occurrence of the "option to alter operating scale", as reported in the first row in Table 4.14. Consequently, there is evidence, that planning the flexibility to adjust the scale of a project and defer its start (in order to wait for more favorable information) are managerial actions that could be deployed intentionally in response of market demand risk.

We tried to determine the level of association in the same way also for industry groups.[452] In Table 4.15 we reported the results for those industries where we found evidence to support a positive and significant correlation between a specific pair of "uncertainty vs. managerial flexibility".

[452] For industry groups with a low number of observations (e.g. technology and telecom, N=4) the calculated significance levels should be interpreted with caution as the assumption of a normal-distributed test statistic cannot be taken for granted.

Table 4.15: Symmetric measures: Kendall tau C test for equality of ranking monotonicity in-between industry groups.

	Kendall coefficient	Asymp. Std. Error[1]	Approx. T[2]	Approx. Sig.
Demand vs. Delay				
Consumer goods and services (N=14)	0.612	0.161	3.799	0
Demand vs. Scale				
Consumer goods and services (N=14)	0.673	0.174	3.876	0
Industrials (N=21)	0.369	0.147	2.513	0.012
Technology and telecommunications (N=4)	0.75	0.265	2.828	0.005
Technology risk vs. Scale				
Financials (N=21)	0.351	0.176	1.997	0.046
Industrials (N=21)	0.522	0.079	6.643	0
Technology risk vs. Stage				
Utilities (N=12)	0.593	0.132	4.496	0
Technology risk vs. Grow				
Utilities (N=12)	0.568	0.139	4.1	0

Legal & Regulatory vs. Delay				
Technology and telecommunications (N=4)	0.75	0.265	2.828	0.005
Legal & Regulatory vs. Scale				
Industrials (N=21)	0.454	0.125	3.625	0
Legal & Regulatory vs. Stage				
Financials (N=21)	0.363	0.116	3.126	0.002
Consumer goods and services (N=14)	0.383	0.175	1.163	0.029
Legal & Regulatory vs. Abandon				
Industrials (N=21)	0.456	0.127	3.587	0
Legal & Regulatory vs. Grow				
Utilities (N=12)	0.426	0.195	2.184	0.029
Competition vs. Scale				
Industrials (N=21)	0.272	0.119	2.282	0.022
Technology and telecommunications (N=4)	0.75	0.265	2.828	0.005

[1]Not assuming the null hypothesis

[2]Using the asymptotic standard error assuming the null hypothesis

The relationships are positive: thus, for our sample, the examined types of managerial flexibility seem to be deliberately planned as a response to a specific market uncertainty, although this is not *always* the case.[453] Therefore, we are of the opinion that a systematic analysis of situations when displaying a specific managerial flexibility would be extremely valuable for every project and as a matter of fact for the firm as a whole. The circumstance that for our sample the association between uncertainty and

[453] Many computed correlation coefficients are quite low, although this could also be the case because of the limited testing possibilities with ordinal scaled data.

managerial flexibility is significant, positive but *not perfect*, gives room in the hypothesis that there is still undisclosed potential for organizing and establishing further managerial flexibilities according to the declared uncertainties.[454] We are of the opinion that these potential added values must be systematically unveiled and measured as accurately as possible in order not to destroy or at best overlook relevant firm value.

4.5.4.4 Potential of real option value

Based on the data from the answers regarding uncertainty, irreversibility and flexibility, companies could be filtered to classify them in different groups of "real option's value potential". The probability of a high real option value within a company is per definition higher the more it is exposed to uncertainty, the higher the irreversibility of its investment, and the more different types of managerial flexibility are at disposal of its manager. We, therefore, defined the group of high "real option's value potential" as those companies where there was perceived a high exposure to uncertainty and high irreversibility, and showed many possibilities for managerial actions during the life of their projects.[455] We identified 37 companies where high exposure to uncertainty was perceived. From the 10 declared ROA users (3 of them no longer use ROA), 7 were in this class. Furthermore, in the group of respondents who affirmed having highly irreversible investments, we found 41 firms, whereas 8 of 10 ROA users were part of this group. At this point, we should mention that the level of irreversibility was not a difficult criterion to meet, even if it was set extremely high, as most firms of our sample showed an extensive level of irreversibility. Finally, in the group of companies with a higher number of possible types of managerial flexibility, we identified 24 companies in which we found 3 of the 10 declared ROA users. Only 9 companies of the whole sample were in each of the three groups, i.e., high uncertainty, high irreversibility, and high flexibility, which we defined as the group with the highest real option's value potential. Among these 9 companies, we identified 3 ROA users, 3 respondents who at least know the real option approach, and 3 who had not even knowledge of it. This obviously does not mean that all other companies have no potential for real option value at all.[456] For companies showing up in the high potential group, however, there is a

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[454] This hypothesis could be subject of a further survey research as we did not focus on this issue in the design of the questionnaire and thus did not gather appropriate data to test it.

[455] Appendix E. shows the exact way how we filtered the companies.

[456] In fact, if a company in a specific branch was exposed "highly" only to one risk category (or less than three categories) or perhaps had only one managerial flexibility that occurred "often" (or less than two), it already falls out of our class of high "real option's value potential". This does obviously not mean that doing specific business, undergoing a specific risk, and often displaying the same managerial flexibility cannot create high values in the sense of real options as well. That could also be the reason why some declared RO users do not show up in the highest "real option's potential" category. However, out of the questions in our survey, we cannot assess the exact potential of

higher probability that ignoring the value of flexibility could result in valuation bias when trying to asses the value of an investment project. Applying the ROA could, therefore, be very beneficial in those cases. The fact that we found a major part of the declared ROA users in the classes with high uncertainty, high irreversibility and high flexibility and that a considerable proportion was also found in the class of high "real option's value potential" supports our classification of the companies. We are of the opinion that companies in this class should carefully consider adopting the ROA, even if current ad-hoc methods may seem to satisfy their needs. Not only would ROA be of benefit for the assessment of the value of the single projects, but a systematic application of the method would also create learning effects, experience, and knowledge in valuing managerial flexibility in general. From this point of view, the feared efforts and complexity and the high expenses for the implementation of a ROA could be seen in a very different light. Table 4.16 summarizes the counts of companies within the specific groups. Interesting to note is the fact that "real option's value potential" is not only limited to a specific industry, dimension of capital expenditures or company size, but rather can be found in all different classes of categorization of our sample.

every company and for every project, nor it was the main target at the beginning of the field research; hence we have to carry out our discussion on a more general basis.

Table 4.16: Real option's value potential.

	Total sample[1]	Industry group[1]	Capital expenditure classes[1, 2, 3]	Total sales classes[1, 4, 5]	Total asset classes[1, 6, 7]
Group of high uncertainty	37	12 Financials	14 Capex low	10 Total sales low	6 Total asset low
		2 Chemicals and materials	14 Capex middle	10 Total sales middle	5 Total asset high
		6 Consumer goods and services	7 Capex high	6 Total sales high	
		10 Industrials			
		3 Technology and telecom			
		4 Utilities			
Group of high irreversibility	41	9 Financials	20 Capex low	17 Total sales low	4 Total asset low
		4 Chemicals and materials	12 Capex middle	11 Total sales middle	3 Total asset high
		4 Consumer goods and services	7 Capex high	6 Total sales high	
		14 Industrials			
		2 Technology and telecom			
		8 Utilities			
Group of high flexibility	24	8 Financials	12 Capex low	6 Total sales low	7 Total asset low
		4 Chemicals and materials	7 Capex middle	7 Total sales middle	1 Total asset high
		5 Consumer goods and services	4 Capex high	3 Total sales high	
		3 Industrials			
		2 Technology and telecom			
		2 Utilities			
Group of high REAL OPTION'S VALUE POTENTIAL	**9**	**3 Financials**	**3 Capex low**	**0 Total sales low**	**2 Total asset low**
		0 Chemicals and materials	**4 Capex middle**	**5 Total sales middle**	**1 Total asset high**
		1 Consumer goods and services	**2 Capex high**	**1 Total sales high**	
		2 Industrials			
		1 Technology and telecom			
		1 Utilities			

[1] Counts of companies within a specific group
[2] Number of companies do not sum up to total number within one group because of missing values for capital expenditures
[3] Capex low: < 50 Mio CHF, Capex middle: ≥ 50 Mio CHF, ≤ 500 Mio CHF, Capex high: > 500 Mio CHF
[4] Number of companies do not sum up to total number within one group because of consideration of non-financials and real estate companies only within "Total sales" classes
[5] Total sales low: < 1000 Mio CHF, Total sales middle: ≥ 1000 Mio CHF, ≤ 5000 Mio CHF, Total sales high: > 5000 Mio CHF
[6] Number of companies do not sum up to total number of companies within one group because of missing values for "Total asset" and consideration of financials only within "Total asset" classes
[7] Total asset low: < 50'000 Mio CHF, Total asset high: ≥ 50'000 Mio CHF

4.5.5 Limitations on the interpretation of survey data

Before summarizing our conclusions made through the analysis of the data, we want to spend some words on the limitations of the questionnaire and survey technique we are aware of. First, the comparability of answers like “very often”, “very easy”, or “very strong” are subject to the interpretation of these expressions by the respondents. The results of many answers are sensitive to this point. Second, judgments about the frequency of occurrence of certain events (e.g., deployment of a specific option, utilization of a specific method) are depending on unbiased recall. The quality of judgment of this subjective probability assessment is undoubtedly not free of bias. Further problems could arise from the evident non-response bias.[457] We could not conduct the experiments proposed by Graham and Harvey (2001) to account for non-response bias in survey data because of the limited size of our data set.[458] Even if we are confident that non-response bias is small, there is also the concern about the truthfulness of the respondents’ answers. On the other hand, if a senior manager of an important company took time to fill out a survey, we felt very confident that its intent is not to be untruthful. Another potential problem with survey data is the one that independently from how carefully the questions are produced, they could nevertheless be misunderstood or may not draw out the appropriate information. For answers which seemed implausible to us, we therefore re-contacted the responsible respondent to eliminate further possible sources of error. A last difficulty in interpreting survey data was referred by Graham and Harvey (2001) as “economic Darwinism.”[459] The authors argued that firms that survive must be doing the proper things, even if unintentionally. The authors gave an example of a professional pool player which has the ability to knock the balls into one another just right without being forced to be able of solving a differential equation at every shoot. Consequently, they concluded that it is possible that many managers took appropriate decisions without thinking within the box of an academic model what in turn could elicit some responses in the questionnaire, which cannot be explained within a rational mindset. To conclude this discussion, we are aware that it is impossible to completely decline all the above-mentioned limitations. Nevertheless, we were very careful in designing the questions and did not draw any untouchable conclusion, but only tried to give a picture of the importance of valuing flexibility within a company’s capital budgeting process. We believe that these data are representative and provide important and unique information regarding the matter of

[457] The non-response bias results from limiting the survey analysis to the available data. This bias can arise when those who do not respond have different experiences concerning the issue than those who do respond.
[458] See Graham and Harvey (2001), p. 237.
[459] See Graham and Harvey (2001), p. 239.

"valuing managerial flexibility," even if the analysis we perform and the conclusions we reach must be interpreted without forgetting that our data came from a survey.

4.6 Conclusion

In this survey we examined the practice of valuing managerial flexibility by Swiss firms. According to our four main research targets, we summarize the findings of our survey as follows:

First, we found that the NPV technique was the most frequently cited capital budgeting method by Swiss firms, followed closely by IRR. Also the static methods (i.e., the cost comparison method, the profit comparison method, or the accounting rate of return) were used frequently in a set of different capital budgeting techniques. However, when it came to value larger investments, the more sophisticated methods were preferred. For instance, we find a more frequent utilization of NPV and IRR for firms with higher capital expenditures. The value of managerial flexibility was considered in valuing investment projects and often influenced managers' decisions in whether to undertake a project or not. However, there were differences in occurrence by industry groups and flexibilities. The most frequently considered flexibility in general was the one to divide a project in different investment tranches (i.e., the "option to stage"). The second most frequent flexibility was the one to wait with the project's start until potential uncertainty is partly resolved (i.e., the "option to wait"). The financial industry reported considering different types of managerial flexibility often, which was not expected. The "option to stage" is considered more frequently by the financials and in the technology and telecommunication industry, the "option to wait" by chemicals and materials and, again, in the financial industry. Firms with high capital expenditures seemed to consider more often growth investments (i.e., the "option to grow") whose success often cannot be supported in advance by numbers deriving from standard capital budgeting techniques. Even if the value of managerial flexibility found so much consideration among companies, the methods to assess its value remain quite rudimentary. Our survey revealed that most companies still valued flexibility based on intuition, e.g., by adjusting the discount rate or by adding an arbitrary surcharge on the project value. Only a few respondents declared that they used more sophisticated methods such as the DTA, the Monte Carlo simulation, or the ROA. However, there is a significant difference between smaller firms and bigger firms, which seem to be more likely to use more sophisticated methods.

The Real Option Analysis as a term seems to slowly take hold in senior management spheres of Swiss companies; 40% state to know the real options approach to value investment projects. However, only roughly 14% stated that it had ever been applied to value their investments, and only few applied it on a regular basis (more than "seldom"). What was again surprising was that many RO users stem from the financials group. The main problems in applying it were declared to be the parameter identification, whereas the main hindrances not to use it (or to no longer use it) were the lack of knowledge, the large perceived efforts (compared to commonly used techniques), and the expenses to implement the new method. Finally, also the difficulty in communicating the calculated real option's value to all involved parties was stated to be an important hindrance in applying the ROA.

From the three constitutive characteristics driving the importance of the valuation of managerial flexibility, we get the following results. Companies stated that they perceived their exposure to many different types of uncertainty as strong. The responses were obviously very heterogeneous as the sample incorporated many different industries; however, every industry seem to be exposed to an important extent to uncertainty that much, so that in many cases, new information could induce managers to change important project decisions in an ongoing project. Competition risk is the most cited risk. This could mean for the real option theory developing further into the direction of real option games, i.e., game theory and real option analysis combined. Further important risk categories were risk deriving from legal and regulatory changes, market-demand risk, and technology risk. Irreversibility was perceived as very high by the whole of the sample independently of industry group, capital expenditures, total assets, or total sales classes. In comparison to the consideration of the value of the different types of managerial flexibility, we checked also their occurrence and planning. Both, occurrence and planning of all types of managerial flexibility occurred "occasionally" or more in average. The most frequently occurring managerial flexibility in our sample was stated to be the "option to stage", followed by the "option to grow". Least cited are the "option to switch" and the "option to abandon". The "option to stage" was found to occur significantly more frequently in the financial industry, which matches the consideration of the value of the option to stage made by the financial group in the precedent questions, i.e., not only the option to stage occurred more frequently in the financial industry, but also it was considered more frequently. Furthermore, we found evidence for a highly significant, moderate to strong relationship between the planning and the occurrence of managerial flexibility, which shows that the real options are with high probability not "reactive" (accidental or forced by external events) but rather "proactive" (studied and planned in advance as potential response to unforeseen changes). Also between the consideration of the value of managerial flexibility and its occurrence, we found evidence for a highly positive association. That is, if they occur they were also considered. However, this association was low in its degree. This means that there was a certain probability that there were real options whose value might not be considered (either with the ROA or anyhow else), whether because they were categorized as less valuable a priori, or because they were simply neglected by companies. With our data, it is not possible to further answer this question. An indication could be the segmentation of companies into high uncertainty, high irreversibility, and high flexibility categories. We defined the firms that can be found in all of these three categories as "high potential real option value" firms. These firms should have, per definition, higher potential for showing value coming from managerial flexibility and, thus, they should also consider this value more often. Indeed, we found that many of the companies that do apply the ROA actually belong to this category. At the same time, there were many other companies that belonged to this category but did not apply the ROA or did not even know it. Interestingly, this group of potential ROA users was not limited to specific cases, but was rather found to consist of companies of different industries, different capital expenditure classes, and different sizes.

We conclude that the value of different types of managerial flexibility, i.e., real options, plays an important role for Swiss companies. Depending on industries and size of the companies, many different types of valuable managerial flexibility occurred. However, they were not always considered and, if they were, then this happened mostly by intuition and seldom within the frame of an academic model like the ROA. The major problems of this new paradigm seem to lie in how companies perceived the efforts to learn and implement it and in the communication of the calculated results to involved parties. Of course, this low level of real option application does not imply that managers make bad decisions,[460] but nor does it rule out the possibility that a more systematic analysis of the value of managerial flexibility could improve the understanding and communication of the value of investment projects, and in this way, create the premises to consider also good investment opportunities which would have been missed without putting a value to flexibility.

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[460] As we pointed out already above, there are a lot of appropriate decisions which are made without academic rule sets: „A professional pool billiard player does not have to solve a differential equation at every shoot".

5 Assessing the Relevance of the Real Options Analysis

5.1 Introduction

So far we have seen that firms that want to be successful in a volatile environment have to be flexible and adapt to changes. This adaptability is undoubtedly of value. However, the actual value arising from flexibility is not easy to determine. This statement applies not only when using the ROA but also for other methods for flexibility valuation.[461] The complexity and the material efforts arise not only from the mathematical applicability of the various models proposed, but also from the construct of flexibility itself. Koornhof (1998) states, e.g., that placing a value on flexibility is often a paradox:

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[461] As we have seen in the results of the survey in chapter 4.5, even if many firms showed potential for inherent flexibility value, only the minority of them reported applying the ROA, the DTA, or another method for assessing the value of flexibility mentioned in the survey.

the more one tries to value it, the more it loses some of its attributes.[462] In other words, if a decision maker plans in advance an action to execute at a specific point when a specific change in business environment requires it, this action gets fixed and, thus, the flexibility of the manager has been lost to some degree. On the other hand, not measuring flexibility at all would not make the value visible to decision makers and the basis for decision would be somehow distorted respectively. Barnett (2005) concluded that there is nothing else to do but continuously monitor the opportunities of the company as well as keeping up with the latest development of the business environment to maximize the rewards coming from a flexibility valuation and the odds of success of a ROA application.[463] This, in turn, requires a great deal of attention. As attentional resources are limited, the firm should carefully choose the real options to which to devote these limited resources. For this reason, we propose a framework which should permit the separation of relevant real options from those that are not required or that show a limited value potential and, according to our definition, are irrelevant for a ROA application. Collecting the information to decide about the relevance of the ROA application will also lead to other beneficial "by-products" which help bridge the gap between theory and practice of real option valuation. Applying the framework will result in a preliminary step of the ROA, which is intended to detect valuable real options within a specific project and expose them to further monitoring and closer examination. A clear and rigorous selection of valuable real options will thus be of help in structuring and simplifying real options problems, communicating externally and internally the flexibility values of the firm, and supporting decision makers in allocating financial as well as monitoring resources. Moreover, while the argument that many investments have valuable strategic or expansion options embedded in them is obvious, there is the danger that in basing the statements on purely intuitive judgments, this argument will only be used to justify poor investments.[464] In applying a more structured and rigorous process for detecting the value of real options, even in giving only rough estimations of their value, the ROA will be prevented from falling into the same black hole of associating unjustifiable flexibility value to mediocre investment opportunities.

Before starting with the explanations of the framework, it should be clarified what we mean by *"relevance"* of the application of the ROA. In our opinion it is relevant to consider the application of an accurate and explicit ROA if…

[462] See Koornhof (1998), p. 199 ff.

[463] See Barnett (2005), p. 67.

[464] As we explained in chapter 3.6.3, many firms adopted the real option approach to explain the gigantic rise of value in the new economy during the late 1990s and early in the year 2000. In this way negative or poor accounting values could be associated to potential high future value, which were in most cases not justifiable as could be seen ex post.

1. … the prerequisites for the option analogy are given.[465]
2. … the flexible actions are explicitly planned, could be implemented for real and are thus not simply "ideas".
3. … the estimated values of the detected real options are high enough to make a change of decision about a given investment likely.

In the cases where we can find the above-mentioned requirements, we believe that there is real, assessable flexibility value inherent in the project and that the probability to miss a part of the project's value in not accounting for real options is high. Consequently, the chance to make a wrong decision and misallocate limited financial resources is high and, thus, the implementation of a ROA is relevant.

But how can these three requirements be assessed in an efficient and structured way without getting trivial? We will explain our idea in more detail in the following subchapters. At this point, we want only to briefly highlight the connections between the three requirements and the theories discussed in this study so far, in order to provide the reader with a further foothold in understanding the framework.

The first requirement refers to the "prerequisites for the option analogy". With this, we mean the constitutive characteristics of a real option as explained in chapter 3.2.2. High uncertainty will give higher value to the flexibility inherent in the project, but only in the case when there is also high irreversibility associated with the investment and action flexibilities to adapt to the changing environment are realistic. Consequently, we propose how the level of irreversibility can be assessed and show how the relevant types of managerial flexibilities can be systematically detected to respond to relevant uncertainties that affect the project. We already stated that actions of competitors can erode flexibility value. Thus, it is also important to estimate to what extent a company is exposed to the risk of preemption by a competitor. Otherwise, the flexibility values calculated solely through an option pricing model will be far away from representing real material value.[466]

The second requirement refers to the feasibility of the real options. It should be checked whether the real options are only remote ideas or realistic plans that can be implemented. For instance, probably every firm will consider a possible expansion into

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[465] By prerequisites we mean the constitutive characteristics of a real option and of an investment project, as explained in chapter 3.2.2.

[466] There is the possibility to use game theoretic approaches to adjust the real option value for competitors' preemption risk. See, for example, Smit and Trigeorgis (2004). However, these solutions are not very practicable for now and we thus want to refrain from implementing them in our model as we want to stay on a practice-oriented level as much as it is possible.

a greater market if its product turns out to be a success. The question is, however, is this expansion really possible? This should be examined not only from the perspective of the monitored uncertainty, e.g., market demand uncertainty, but also in regard to the organization of the company, the required financial means or any types of regulatory or governmental restrictions that could prevent the action from being implemented. Will any of these grounds hinder the execution of the real options when the strike signals are favorable (e.g. high market demand), then the expansion will remain a dream instead of a real value and consequently this real option to expand will be of no value for the firm. Garud *et al.* (1998) concluded that if the option falls short of successful exercise the firm will find that it holds "fool's gold" instead of the real possibility to adapt to changes of the environment and thus its long-term prosperity remains under peril.[467] Similarly Robinson (2003) stated that *"Actions, not calculations, capture option value"*.[468] Thus, only if real options represent concrete action possibilities do they materialize as value in the project and their valuation is relevant for the firm. We will base our discussion on the question of realizability of the different types of managerial flexibility primarily on the flexibility indicators of Ku as presented in subchapter 3.2.2.3.

Given requirements one and two, the question about the value of the option arises. Of course, the value of the real option will result from the calculations of the complete ROA. However in practice there is no sense to devote too much further attention to real options with low or potentially insignificant value, which will not change the investment decision. For this reason, we suggest making a simple model to get a rough estimation of real options value, using data which are in great part already available from standard NPV calculations. Damodaran (2001) noted that it is not simple to value real options because inputs are difficult to obtain and often "noisy." However, he concluded that noisy estimates are better than no estimates at all.[469] In this point, we totally agree and, therefore, think that a rough estimation of the real option value will match our needs for assessing whether further attention should be dedicated to a given available or potential real option. For this purpose, we adapt the model of Luehrman (1998b), which will be explained in chapter 5.3.[470] The higher the probability that the estimated potential value of the real option will change the investment decision, the more relevant is a further and more accurate analysis of its value and, consequently, the more relevant is an application of the ROA.

[467] See Garud *et al.* (1998), p. 212ff.
[468] Robinson (2003), p. 39.
[469] See Damodaran (2001), p. 397.
[470] See Luehrman (1998b).

Finally the information gathered must be communicated in a way that can be understood above all by internal parties (senior management, co-workers, and employees), but also by external ones (e.g., shareholders and stakeholders). Some information on managerial flexibility cannot be communicated because of its complexity, and also because of its strategic confidentiality or its effect on employees. For instance, the option to abandon a production plant could have negative effects on the commitment of the employees in this plant and also lead to discouragement of other workers within the company, who might expect to share the same destiny.[471] Another example is the announcement of an expansion into another region. This could alert competitors to prepare efficient countermoves and is, therefore, also sensible to communicate. The differentiation between internal and external communicability is, therefore, extremely important. According to Koornhof (1998), we show which parts of our framework may be communicated and the means of communication which could be used.[472] We believe that the better the communicability of the created value of flexibility is warranted, the more the ROA will be accepted as a means to judge investment projects. This is also the reason why we show in chapter 5.4 a possible way to present the above-mentioned information on flexibility in what we call a "flexibility appropriation request", which we devise as an add-on of a standard appropriation request of a firm. As Barnett (2005) and earlier Kester (1984) argued, getting a project through a corporate capital appropriation committee is not an easy task.[473] We think that adding clear and structured information on flexibility value could be a further argument to convince upper-level management about the merits of a given project. Figure 5.1 represents the three main parts of our framework, which sum up the relevant information on the decision about the application of a ROA.

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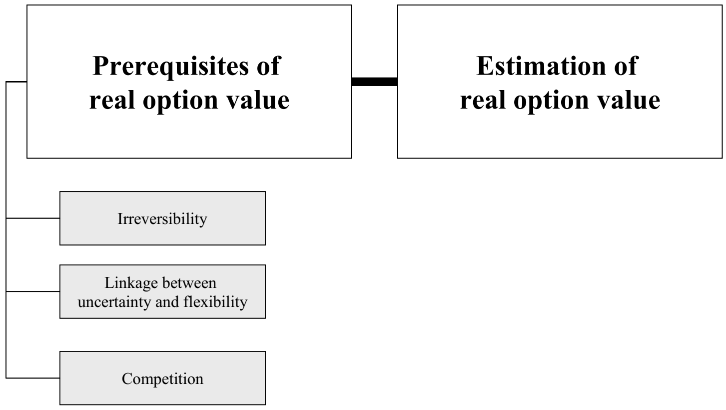
[471] For instance, Busby and Pitts (1997) found in a survey that real options are not always seen as beneficial in practice as they reduce organizational commitment to a planned outcome or event. See Busby and Pitts (1997), p. 170.

[472] See Koornhof (1998), p. 193ff.

[473] See Barnett (2005), p. 66 and Kester (1984), p. 153.

Figure 5.1: Relevant information for deciding about a ROA application.



Before we explain the individual parts of the framework, we want to discuss what we do not want to treat or cannot treat in the model. The reason why we take these critical issues in advance is that we do not want the reader to expect a finished cookbook-solution, which is universally applicable to every possible valuation problem. In fact, there is no universal "option-value potentiality measure" that allows comparing one-to-one every single project in different industries or different companies. Every firm is unique and has an ever-changing stock of potential flexibility value. As we conduct the discussion on a very broad base, we cannot treat every single industry, company, or project-type, even if the mindset of our framework is intended to analyze and draw conclusions for the real options inherent in every project. The specific application of our guidelines to a particular industry or project-type could, therefore, be an objective of further research. Moreover, our assessment of the relevance of the ROA application is based not only on quantitative measures, but also on ordinal-scaling factors, which are thus not measurable quantitatively. This obviously makes a comparison between companies difficult or at least questionable. However, in business administration, there are many models that rely heavily on qualitative statements of the decision maker but which lead, nevertheless, to improved decisions.[474] This is the reason why we think that it is legitimate to ground the framework for the very first step of a ROA (i.e., when managers have to decided whether to incur the costs of a more extensive ROA) on qualitative statements of experienced managers.

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474 Some well-known and widely used business administration tools based on quantitative assessment are, for example, the "value benefit analysis" or the "B.C.G. growth-share matrix".

According to the objectives stated in this introduction, we will first describe how we assess the prerequisites of real option value. Then the quick estimation of the real option value based on Luehrman is explained. Further, we show how the information gathered could be presented in a structured, clear manner. Finally, we apply our ideas to an example to show how the framework is intended to function and draw some final conclusions.

5.2 Prerequisites of real option value

Academic research focused mainly on the single project characteristics that influence real option value, i.e. irreversibility, uncertainty, flexibility or competition. A combination and representation in a framework has not been treated as yet. Moreover, these prerequisites are mostly taken as given in real options literature, whereas in practice this is not always the case. Consequently, we study how these various aspects could be assessed in a real case and how they could be combined into a confined framework. We call this framework the "Real Option Value Grid" (ROVG). We start with explaining how to assess the level of irreversibility. Then we address the question about competition which, as we learned in the previous sections of this study, can erode flexibility value in case in which it is highly pronounced. Furthermore, we show in detail how to examine the linkage between uncertainty and flexibility.[475] This linkage is crucial for explaining why flexibility should be valuable for a given investment project and will thus build the backbone of our framework. Finally, we will show how to synthesize and represent the most relevant information in the ROVG.

5.2.1 Level of irreversibility

Economic irreversibility refers to the impossibility to reverse or correct an investment decision with no cost.[476] Managerial flexibility does not have any value if the decision would be fully reversible. However this situation is very unlikely in reality.[477] Empirical studies found a positive correlation between irreversibility and the influence uncertainty

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[475] We use this order of discussion of the single components because it helps underlying our train of thoughts for constructing the ROVG presented at the end of this section.

[476] See also subchapter 3.2.2.2.

[477] See, for example, also the results of our survey in subchapter 4.5.4.2. Most respondents state that their projects are highly irreversible.

has on the delay of an investment.[478] This means that the higher the degree of irreversibility is, the longer an investment will be delayed for a given level of uncertainty. Consequently, higher levels of irreversibility necessitate a disciplined analysis of managerial flexibilities to respond to changing market conditions. Thus, in our opinion, a determination of their value and consequently an application of the ROA appear to be more relevant in cases of investments which are substantially irreversible.

We already specified some causes which can make an investment irreversible earlier in this thesis. To recall them briefly, these causes were:

1. The *operating leverage* of a firm: the higher the operating leverage, the higher the degree of irreversibility of the investment.
2. The *inefficiency of the second-hand market*: the higher the inefficiency of the second-hand market, the higher the degree of irreversibility of the investment.
3. The *degree of specificity* of the investment goods: the more specific an investment good, the higher the degree of irreversibility of the investment.
4. The *transaction costs* incurred in liquidating the investment: The higher the transaction costs when reversing an investment, the higher the degree of irreversibility of the investment.
5. *Governmental regulations* or *institutional arrangements* hindering the re-sale of the investment goods. The more severe governmental regulations and/or institutional arrangements, the higher the degree of irreversibility of the investment.

In analyzing the cumulated impact that the forces listed above will have on the irreversibility of the investment, the user will have a comprehensive view of the degree of irreversibility of the committed resources. Consequently, if the degree of irreversibility is found to be high, a first argument is gained as to why to apply the ROA. In the following we show how to proceed to get a hold of the overall level of irreversibility of an investment in analyzing the single causes of irreversibility. The theoretical arguments have already been touched before, so at this point we try to render them more practicable.

Damodaran (2001) stated that the operating leverage of a firm is measured by the fixed costs versus the variable costs, and argued that the higher the proportion of fixed cost, the more volatile the earning will be due to changing market conditions and, thus, the

[478] See, for example, Folta *et al.* (2001), p. 23.

higher the operating leverage.[479] Trigeorgis (2000b) noted that a high proportion of fixed costs over variable costs tend to render corporate decisions irreversible.[480] Therefore, in examining the ratio between fixed costs and variable costs and finding a high proportion of fixed costs will be a first indication of considerable irreversibility.

The second factor that could signalize irreversibility of investments is the inefficiency of the second-hand market.[481] The existence or the access to second-hand market is not given for every firm. Even if the second-hand market exists and the access is given, due to adverse selection problems, sellers of high quality investment goods will be reluctant to re-sell their equipment and, thus, only medium and low quality investment goods will stay in the market. This causes monitoring costs for screening the second-hand market for the quality of an asset and its corresponding re-selling prices. These costs can go so far that the market collapses because on the part of the owners, nobody wants to sell used goods under their prices and, on the part of the buyer, it is hard to check quality and assess the price one wants to pay. Taking the point of view of the owner, in these cases, he will get rid of this investment good fallen into disuse only at a high discount of the original purchase price. Thus the more inefficient the second-hand market for his investment, i.e., the harder the information gathering for re-selling prices and quality of the goods, the more likely is the chance that a large discount will have to be conceded to the new buyer and, thus, the higher the degree of irreversibility.

The third point to examine is the specificity of the investment good. A specific asset is characterized by a low (if any at all) redeployment possibility for alternative uses or by alternative users, unless a loss of productive value is accepted.[482] If a good is highly firm-specific or industry-specific, its second-best use for another renter may not pay much. This circumstance augments the difficulty of selling the asset for the first-owner, what consequently also heightens the irreversibility of the asset. The difference between the first-best use and its second-best use quantifies the above-mentioned loss in productive value and can be employed to measure the degree of specificity of the investment good to be sold. This difference is also called the quasi-rent of an asset.[483] Consequently, the lower the second-best utilization value of an asset, the higher its irreversibility, and vice-versa. Estimating the value of the second-best use can be done over its liquidation value. Hence, the lower the potential liquidation value of the

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[479] See Damodaran (2001), p. 75.

[480] See Trigeorgis (2000b), p. 2.

[481] We explained what we mean with inefficient second-hand market in section 3.2.2.2 through the theory of the „lemon-market effect“ of Akerlof (1970).

[482] See Williamson (1996), p. 377.

[483] See Klein *et al.* (1978), p. 298.

investments done, the more irreversible are those investments. Brand- or product-specific investments, investments in knowledge of human capital, investments in selling efforts, or specific R&D investments are indicators of forces that lower the liquidation value and consequently heighten the irreversibility of the project's overall investments.

The fourth factor to look at is the transaction costs which the firm is subject to if it wants to liquidate its investment goods.[484] These costs cannot be regained and, therefore, augment the irreversibility of the undertaken investment. Some examples of such transaction costs might be the cost for the execution of the sale, the search costs for finding an acquirer, the cost for sale negotiation, the set-up cost for the sale contract, and additional legal work which must be done to assure the working of the sale. Having analyzed these costs before undertaking the investment and finding them high relative to the whole amount invested would be another signal of higher irreversibility and thus ROA application usefulness.

The last factors that can cause irreversibility are regulations. In fact, whether legal regulations or institutional arrangements, both can hinder the re-sale of acquired investment goods when bad market conditions require it and, thus, render the investment irreversible. Pindyck (1991) gave as an example capital controls[485] of the government which could make impossible for investors to sell assets and relocate their funds.[486] A further example may be working law regulations or arrangements induced by the trading power of labor unions, which can make investments in human capital also irreversible.[487] If there is a clear regulation, there is little reason to discuss about the "level" of irreversibility. In case of a strict law, the occurrence of irreversibility is dichotomous. For instance, either a firm is allowed to sell pollution-control equipment, or it is not. In the second case, the pollution-control investment was fully irreversible; otherwise, the company that wants to asses the irreversibility of the investments has to analyze to which extendt the law will hinder the liquidation of the investment.

To assess the overall level of irreversibility of a given investment we advise decision makers to systematically check all the listed factors. Finding a high overall degree of irreversibility would mean that committing to investment without having a flexibility to adapt to unforeseen changes would create high opportunity costs. Thus, for highly irreversible investments assessing and valuing different possible types of managerial

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[484] See Damisch (2002), p. 72.

[485] Capital control is an instrument used in monetary policy. It can be introduced by a country's government to regulate the flow of investment-oriented money into and out of a country or currency.

[486] See Pindyck (1991), p. 1110.

[487] See Dixit and Pindyck (1994), p. 8.

flexibilities, i.e. real options, is highly valuable and represents a first valid argument for the importance of the application of the ROA.

5.2.2 Competition

Already in early studies on real options theory, many authors agreed that in contrary to a financial option, the possibility of competitive preemption can erode the value of shared real option and, thus, can force its early exercise.[488] To decide whether a firm should use ROA, it is thus important to examine the state of market competition. When finding strong competition which cannot be efficiently antagonized or avoided, a company may be forced to exercise its investment opportunities as quickly as possible and, thus, cannot profit from the timing value of delaying the investment. Consequently, an application of the ROA makes little sense in such circumstances. By contrast, if a monopolistic situation prevails for a specific investment, a company can wait for more information and delay its investment without being pushed to invest by competitors. In these cases, a real option is more valuable, and the utilization of the ROA is relevant.

In practice, the situations are often more complex, and so it is difficult to come up with a clear-cut direction whether the competitive dynamics will make a ROA useless or not. Kester (1984) suggested reflecting about a competitive situation based on two characteristics: the competitive rivalry and the exclusiveness of the right to exercise.[489] Figure 5.2, based on Kester, visualizes the aspects to be examined for analyzing the competitor's activity influencing the real option value. Proprietary real options are highly valuable and cannot be duplicated by competitors; they are located in the upper right corner indicated by "MONOPOLISTIC."[490] In those cases, the risk of preemption is low, the dominant firm can appropriate the full option value for itself, and an application of the ROA can be highly beneficial in detecting the flexibility's value. In contrary, for the shared real options in the lower left corner indicated by "PERFECT COMPETITION," there is a high risk of preemption by competitors and, thus, the firm cannot fully appropriate the value of the real options.[491] An application of the ROA can be of less value, or even superfluous, as there is no possibility to act in a flexible way, but rather the company must act rapidly in order not to lose the investment opportunity. The other two quadrants are less straightforward. In the quadrant indicated by

[488] See, for example, Kester (1984), p. 158ff. and Smit and Ankum (1993), p. 249.

[489] See Kester (1984), p. 158-159.

[490] Proprietary options may arise through unique knowledge or patents held by the company, or through natural barriers such as control of the resources, supply lines, markets, or land.

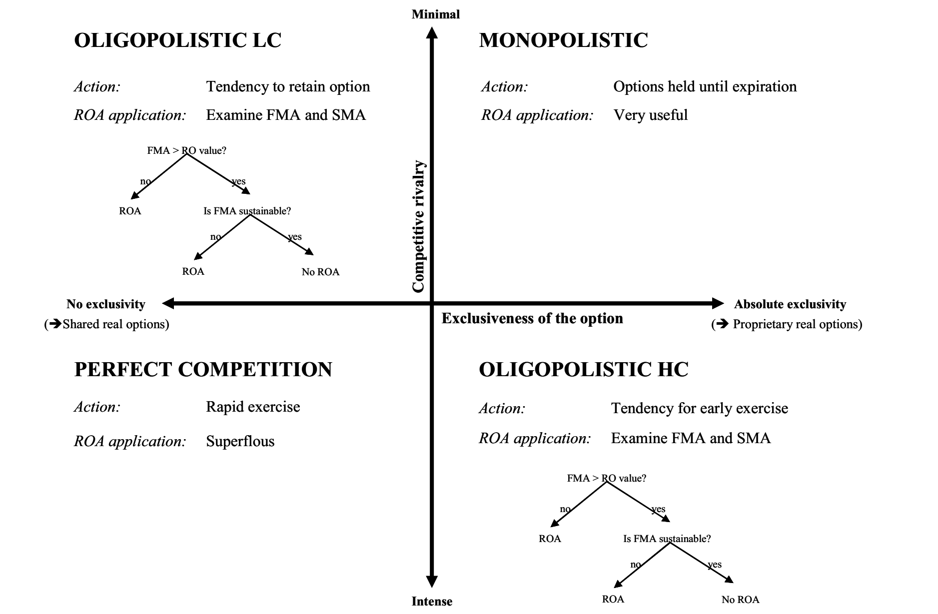
[491] Examples for shared real options may be cost-cutting projects or the entry into a new, unprotected market.

"OLIGOPOLISTIC HC" (HC = high competition), the real options are, in fact, proprietary and, thus, there is a low risk of preemption by competitors; however, there is a higher threat of value erosion through competitive activities. Thus, an earlier exercise would preclude the erosion of value. However, this will also lower the chance to profit from flexible actions and, thus, a ROA is not always advisable. Finally the upper left quadrant, indicated by "OLIGOPOLISTC LC" (LC = low competition), is characterized by shared real options but a low competitive rivalry, i.e., the firm can defend its investment opportunities through its strong market position. Consequently, there is though the risk of a preemption of a competitor, but even in case of preemption, the firm can appropriate a big part of the real option's value through its dominant position and will further also profit from preempting competitors providing useful market information. Under these circumstances the value of flexibility does not loose value and thus assessing investments with a ROA would be beneficial.

Weeds (2006) suggested further ways to examine these more complicated cases with shared real options in putting them into the context of game theory. She distinguished between situations where there is a first mover advantage (FMA) and such with a second mover advantage (SMA).[492] If there is a SMA, delaying investment clearly pays and, thus, applying ROA and assessing the value generated from delaying actions is important. In cases with a FMA it should be examined whether this FMA outweighs the real option value of the investment and, if so, whether the FMA is sustainable or not. In cases where the FMA does not outweigh the real option value, waiting is of value and, again, applying ROA is relevant. In cases where the FMA outweighs the real option value, it is advantageous to invest immediately and profit from the FMA. Applying ROA would therefore be less useful. This holds especially if the FMA is sustainable, i.e. the company profits for long time from this FMA. In cases where the FMA is not sustainable (and thus not very large), delaying investments is possible and, thus, an application of ROA would be expedient.

[492] Whereby examples for first mover advantages could be first-to-patent races or entries into natural monopolies. An example for a second mover advantages is the case of IBM which had enough capital resources to develop a PC. In doing this, they created the demand and the awareness about PCs. Follower firms, i.e., second movers, cloned the product and profited from IBMs first move.

Figure 5.2: Competitive situation and the timing of the commitment of capital.



Source: Based on Kester (1984), p. 159.

In summary, the relevance of ROA depends on the competitive situation. For the two extreme cases, the message is clear. In monopolistic cases with proprietary real options and low competitive rivalry, it is clearly relevant to utilize ROA. In cases with shared real options and high rivalry in contrary (i.e., in perfect competition), there is no sense to assess the value of a flexible action because the decision maker is no longer flexible. A ROA is thus not relevant. In-between these extreme cases (if there are shared real options and for oligopolistic cases), ROA is more relevant the larger a SMA and the smaller and less sustainable a FMA.

5.2.3 Linkage between uncertainty and flexibility

After having explained how the level of irreversibility and competition can influence the value of a real option and, thus, the relevance of a ROA application the next step is to assess the two central constitutive characteristics of real option value – namely uncertainty and flexibility. Given uncertainty and available flexibility will represent further indications for potential real option value and, thus, for the relevance of the application of the ROA. Many authors noticed the close relationship between uncertainty and flexibility. Merkhofer (1975), for example, stated that if learning is expected through resolution of uncertainty or acquisition of new information, then flexibility allows its holder to take advantage of that learning or new information.[493] Bräutigam *et al.* (2003) observed that since flexibility represents the option to react to a state of resolved uncertainty, this uncertainty is the key to the presence of options. Thus, identifying uncertainties permits to identify also the reactions to the given uncertainty, i.e. real options, in a systematic way.[494] Moreover we already presented our uncertainty-flexibility mapping based on Trigeorgis in subchapter 3.2.2.1 and showed what we mean by mapping uncertainties and flexibilities, i.e., finding a matching type of managerial flexibility which could respond to a given uncertainty that affects the project's outcome. This relationship between flexibility and uncertainty suggests merely that 1) flexibility is valuable when there is uncertainty, and 2) flexibility is a way of coping with uncertainty. Therefore, their importance cannot be assessed completely detached from the other. This led us to examine their presence within a project in a combined way and represent them in a construct we call the Real Option Value Grid (ROVG).

Figure 5.3 shows the basic form of the ROVG. On the upper side of the bold framed square, we find the uncertainties already explained in the uncertainty-flexibility mapping in subchapter 3.2.2.1. Although we think that the categories of uncertainty discussed in this study cover a wide range of cases arising in different industries and different projects, we are aware that there are many other uncertainties which can arise in specific industries or projects as well. We chose to deal with this confined number of exemplary uncertainties to guarantee a simpler representation and a better understanding of the ROVG. Obviously, when taking the framework into a specific, or, by contrast, into a more general perspective, the risk categories can be easily changed. On the left side of the bold-framed square, different types of managerial flexibility are listed according to their chronological occurrence during the lifetime of a project - hence, first, the recognition/initial stage of the project, then the building stage, the operational stage, and finally the stage for follow-up opportunities. The different types of managerial flexibility are the usual ones encountered through this thesis and based on Trigeorgis. We chose to avoid the option label and split up the different categories to render the framework as practicable as possible. Thus, for instance, the "option to switch" by Trigeorgis has been split and modified into "switch input", "switch output", and "switch modus operandi".

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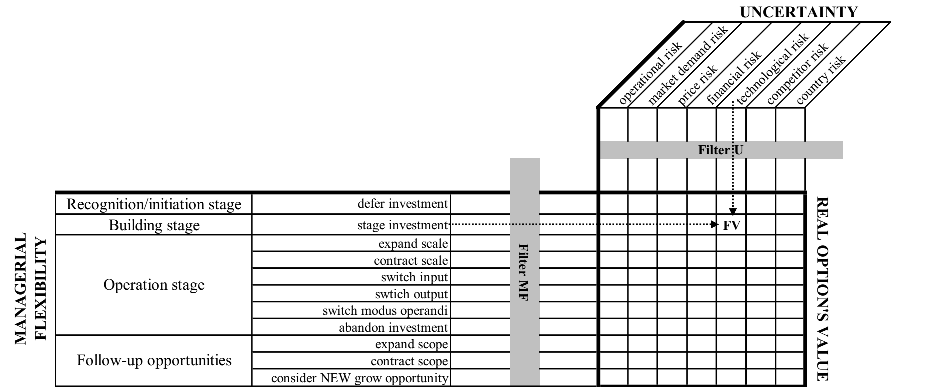
[493] See Merkhofer (1975) in Ku (1995), p. 311.

[494] See Bräutigam *et al.* (2003), p. 1.

Figure 5.3: The basic form of the Real Option Value Grid (ROVG).



The basic instructions for using the ROVG are quite straightforward. An example is given in Figure 5.3 within the representation of the basic ROVG. The application of ROVG is divided in three steps. First, scan the environment for relevant uncertainties. In the example, this is represented by the technological risk that could be attached, e.g., to the development of a medicament. If some required clinical tests fail, the government will deny authorization for bringing the product to market and, thus, the development costs are lost. Second, scan the project for relevant inherent flexibilities that will permit a company to react and adapt to the new conditions once the uncertainty is resolved. In our example, this is indicated by the "option to stage," i.e. "stage investment." In splitting the total investment into different stages, the company can learn if the pharmaceutical will pass the different test phases and be finally authorized by the government. If it will not pass the first test phase, the company can decide to drop the development and concentrate on other products. In doing so, a great part of the total investment could be saved compared to investing the whole amount at once at the beginning of the project. This "option to stage" investments (if possible) is clearly of worth for the company and, thus, is represented by a bold **FV** (flexibility value) in the corresponding quadrant of the ROVG. This is also the third and final step of taking a project into the ROVG. Obviously, finding many FVs in the ROVG would imply that the probability is high that value arising from flexibility can be materialized, i.e., is real. As we have already seen in the former chapter of this study, neglecting this value could lead to large valuation errors. Thus, applying the ROA in these cases is highly relevant.

So far, we have spoken of "relevant uncertainties" and "relevant flexibilities" mapped in the ROVG. However, we have not yet explained what we mean by *relevant*. As stated by Ku (1995), flexibility is not a free good. Consequently, there is no point of having, or even worse, creating flexibility when it is not needed. Only when uncertainty is important or costly enough should flexibility be considered.[495] For instance, a risk of armed conflicts is quite negligible in Switzerland and can, thus, be neglected for projects running on Swiss soil and aimed at Swiss customers. Dropping irrelevant uncertainties and useless flexibility choices is, therefore, important for deciding where to allocate the companies' limited resources. As yet we have symbolized the drop of uncertainties and flexibilities in the basic ROVG in Figure 5.3 with the two gray beams, namely the uncertainty filter (Filter U) and the filter for managerial flexibilities (Filter MF). In the following subchapter, we explain how the two filters are constructed and, thus, how to decide which uncertainties and which different types of managerial flexibility can be omitted due to their irrelevance. Finally, we will present the complete ROVG with the deployed filters, clarify how the framework can be interpreted, and explain which extra-information or supplemental utilization can be won by applying the ROVG, besides to our main objective to assess the relevance of a ROA.

5.2.3.1 Relevant uncertainties

Trying to encompass the whole real world within a model will result in an overload of information, inertia and, finally, real inflexibility. A model is constructed to enable reasoning on a specific real-world observation, simplifying the real world in making explicit assumptions that are known to be incomplete or false, but that will still allow accurate answers on the matter to be analyzed. For our case, considering all possible uncertainties and all corresponding flexibilities would result in an inconceivable modeling of the real world, even before starting with the mathematics on it. Fortunately, as we mentioned above, not every uncertainty is relevant for a given project and, thus, the first step is to decide on the uncertainties to be considered for the current situation. For assessing the added value of considering a specific uncertainty in a ROA, five properties of the uncertain factor must be examined:

1. The measurability of the uncertainty should be given.
2. The uncertainty should be residual.
3. The uncertainty about the underlying risk factor should be high.
4. The impact on the project value should be high.

[495] See Ku (1995), p. 314.

5. The likeliness of resolution of the uncertainty through new information should be high.

First, in situations where the uncertainty cannot be quantified in a meaningful sense (be it objectively or subjectively), i.e., where no basis exists to forecast the future, for instance, in a project to build a vacation resort on the surface of Mars. In those cases, a ROA would be as misleading and inappropriate as any other commonly used analytical tool. Thus uncertainty must be at least subjectively *measurable*.[496]

Second, a ROA is not a substitute for research and analysis to measure knowable uncertainty. Thus only *residual* uncertainties which cannot be assessed through reasonable efforts in doing e.g. analysis of demand trends, performance of existing technologies, competitor's activity, and so on should enter a ROA.[497]

Third, the *uncertainty about the underlying risk factor* should be high. If, as an example, the market demand of sugar is fairly stable for 10 years, it does not make sense to assess its influence on the project opening of a new sugar factory. Moreover, as we explained in chapter 3.3.1, it is a common notion of option pricing theory that a higher uncertainty will also augment the value of an option because its holder will profit from good development of the option's underlying asset, although he has no obligation to act in case of a bad development.

Furthermore, the *impact of the uncertainty on the project* should be high. Obviously, only uncertainties that will have an incisive impact on the value of the specific project will be of interest when deciding flexible actions to respond to uncertain events.

Finally, there must be a reasonable likelihood that new and material information will be received over time, and that this *information resolves* some of the *uncertainty*. There is no point in waiting to invest or design further flexible actions to exercise during the lifetime of the project if there is no process of information discovery, which will provide the basis for decision whether to exercise these options or not.[498]

The first two discussed points can simply be answered by yes or no. Either the uncertainty is measurable or not, and either it is resolvable through a reasonable effort in research and analysis or it is not. Having assessed that the uncertainty is measurable and residual, for the three other properties we propose a rating based on guess estimation, where 1 means low, 2 medium and 3 high. We can thus distribute points for the amplitude of the uncertainty, for its impact on the project's value and for the

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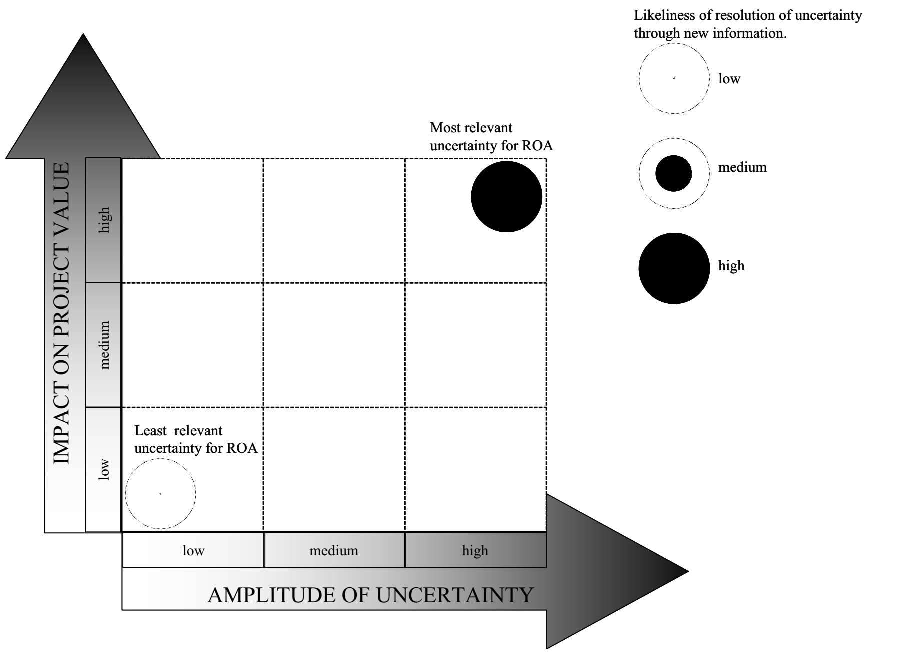
[496] See Robinson (2003), p. 37-38.
[497] See Robinson (2003), p. 37.
[498] See Robinson (2003), p. 37.

likelihood of resolution through information. Those uncertainties scoring the maximum points will essentially be the one that is relevant for a ROA. We represent these statements in the two-dimensional diagram in Figure 5.4, adapted from Dey (2002).[499] On the horizontal axis, we plot the amplitude of the uncertainty, beginning with low and ending with high. The same scale applies for the vertical axis where it is used to plot the impact the uncertainty will have on the project. Finally, the probability of resolution of the uncertainty through information is conveyed by the different sizes of the circles. A small circle means a low likeliness, a medium one means a medium likeliness, and a large circle means that there is a high likeliness of resolution. Thus, in brief, in comparing the different uncertainties a company may think apply to a specific investment case, only the uncertainties represented by large circles and situated in the upper right corner will score the maximum of points and, therefore, are the most relevant uncertainties for the ROA. By contrast, uncertainties represented by small circles and situated in the lower left corner of the diagram will score a minimum of points and are, thus, irrelevant when performing the ROA.

[499] See Dey (2002), p. 18.

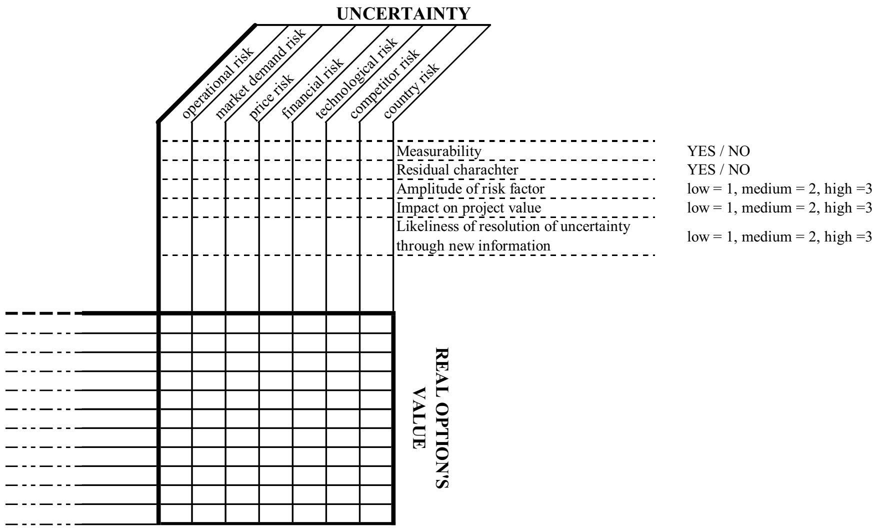
Figure 5.4: Uncertainty relevance matrix.



Source: Based on Dey (2002), p. 18.

Returning to our primary question about the filter in the ROVG, we now can say that the more an uncertainty is situated towards the right upper corner of the uncertainty relevance matrix, and the bigger the circle is plotted, the more likely will this uncertainty pass the filter and enter into the ROA. Finding many relevant uncertainties will also mean that for the given project an application of the ROA would be relevant. The complete graphical representation shown above cannot be drawn into the ROVG due to its size. Therefore, we propose to insert the uncertainty relevance filter into the ROVG as depicted in Figure 5.5, using only the scoring of points resulting from above. The more points an uncertainty collects, the higher the probability that it passes the filter, and that it will be taken to the further step of analyzing potential flexibilities that could be of help in coping with this specific uncertainty.

Figure 5.5: Filter for relevant uncertainties.



5.2.3.2 Relevant types of managerial flexibilities

As it was the case with the uncertainties before, also for the different types of managerial flexibility the maxim holds: "Less is more." What we mean with this oxymoron is that to remain transparent and give a clear message about the value arising through flexibility, a user of the ROA must decide which managerial flexibility is more relevant for an actual investment case. Besides the augmented clarity in communication of flexibility's value, there are also other reasons which enforce the correctness of the choice of limiting the number of flexibilities to be examined in the application of a ROA to project. Barnett (2005), for example, stated that looking for strike signals for exercising the real options is costly and resources are limited. Thus, deciding which real option is the one on which the additional resources should be concentrated is extremely important.[500] Busby and Pitts (1997) noticed that having flexibility can also have negative effects in as far the commitment of the organization to a proposed plan can be undermined.[501] Thus, it is important that only relevant flexibilities will be considered which can outweigh these costs of reduced commitment. Also Ku (1995) pointed out

[500] See Barnett (2005), p. 68.

[501] See Busby and Pitts (1997), p. 184.

that too much flexibility, i.e., too many options, may be harmful in as far as they can complicate the analysis and confuse the decision maker. Moreover, she puts forward the hypothesis that the value of flexibility may follow the rule of the diminishing marginal return and states that the marginal benefit of an additional option may decrease as the number of flexibilities increases.[502] This is confirmed by Trigeorgis (1996c), who calculated a numerical example and showed that even if a few particular options may have been neglected in the treatment of his exemplified project, the valuation results may still represent a close approximation to the true value of the project due to the diminishing marginal option-value effect.[503] The limitation of the number of real options to be examined will, therefore, still produce a valid valuation result and, moreover, it will also take care of the fact that attentional resources are limited and scanning the environment for strike signals could get extremely costly. Therefore, we follow that choosing the relevant real options to examine in a ROA is important and propose to limit their number to maximal three options in order not to create confusion in the decision maker's mind and, above all, channel the limited attentional resources only on feasible and highly valuable flexibilities. This suggestion is represented in Figure 5.3 through the filter for managerial flexibility, i.e., "Filter MF", which we will explain in the following.

The choice of the relevant options to examine will be taken amongst the classical types of managerial flexibility as reported in Figure 5.3. The user of our framework should be aware that we can also imagine expanding this list in case of a specific managerial flexibility which is not comprehended in our selection. However, as a matter of consequence, we will proceed in explaining our thoughts by applying the classical types of real options used throughout the whole study. We will base the selection of the relevant flexibilities on the indicators of flexibility by Ku explained in chapter 3.2.2.3. The better these indicators are met, the more relevant the specific real option will be for the given investment case and, thus, the more relevant will be the application of the ROA. This is a stronger argument than simply saying that a gap may exists between option potential and option realization for a specific real option. The indicators of flexibility were treated with a relative high level of abstraction in the further part of thesis. At this point, we want to recall and explain them as practicable as possible and show how they can be used within our ROVG. Following indicators are important for a managerial flexibility to be relevant:

1.) The *purposefulness* of the flexibility action must be given, i.e., it must be a response to a stimulus (e.g., an uncertainty) and not be accidentally.

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[502] See Ku (1995), p. 315-316.

[503] See Trigeorgis (1996c), p. 252.

2.) The *capability of change* must be given, and it should be possible to fulfill the change easily. Organizational barriers and regulatory constraints must be as low as possible and capital resources for the action should be available in a sufficient amount.

3.) Among the purposeful and possible choices the *size of choice* set must be abridged by leaving out undesirable or similar alternatives.

4.) The cost to provide the flexibility, i.e., the *enablers* must be as low as possible.

5.) The cost to fulfill the flexible action must be as low as possible, and the lead time to implement the action must be as short as possible. These two aspects are subsumed under the term *disablers*.

6.) The benefits or payoffs associated with the flexibility, i.e. the *motivators*, must be as high as possible.

If all the indicators are met to the best extent the probability that a firm holds a realizable and valuable real option for the given project is high. In those cases a valuation of this real option is relevant and thus the application of the ROA is relevant as well.

The *purposefulness* of a specific flexibility is easily ascertained in applying the ROVG. The flexible action should be a response to an uncertain event, called a "trigger" event in the former section of this thesis when we explained the theoretical basics. Thus, only flexibilities are relevant that can respond to the uncertainties that passed the uncertainty filter and made it through into the ROVG core. A valid response to an uncertain increase of market demand of the produced good would be for example an expansion of the production scale. Furthermore, in examining if the uncertainty will make it through the filter, additional important information has been assessed, namely, if it is likely that the uncertain factor will reach a specific state that will lead to the flexibility's execution. In the theoretical basics, we called this state the "trigger state", and for the mentioned example this would be a "high market demand". Thus identifying a "trigger event" (e.g., the market demand uncertainty) and defining a "trigger state" (e.g., a high market demand) will make a flexible action (for this example a production-scale expansion) purposeful.

Second, the *capability of change* must be ascertained. There is no point in considering flexibilities, which cannot be implemented in reality, as they will only stay on the "what-if" idea level without giving the company the possibility to really materialize the potential value. The capability of change depends mainly on three different aspects. First, the organizational aspects of decision taking in a company, then on the regulatory constraints, which could hinder the implementation of specific flexibilities and, last, from the capital resources available to the firm, which in case they are not given will obviously make it impossible to exercise a planned real option. The two latter aspects are quite straightforward. If, of course, the regulatory body will prohibit abandoning an investment once it becomes operational, then the option to abandon is obviously completely valueless. The same clarity holds also for the capital-resource availability. Take, for instance, our example from above. If the market demand turns out to be high, the "option to expand" the production scale comes to its execution. However, if there is not enough budget to buy new machines, or to hire additional sales personnel, establish new selling points or, in general, to market the produced goods, then this option to expand is also completely valueless. A real option is, thus, only valuable if possible regulatory constraints are checked in advance, and if enough capital resources can be provided in case of execution. The question about the organizational aspect turns out to be more complicated. The more authorities are involved in taking a decision about a project, the harder to find a consensus. The real option approach is only valuable if options are exercised effectively.[504] If decisions are caught up in formal processes or red tape, the opportunity to act may pass away and, thus, ends valueless.[505] Furthermore, some respondents in a survey by Busby and Pitts (1997) stated that not every technically possible option will be feasible also from an organizational point of view. The authors concluded that, as the available real option models did not reflect either organizational or behavioral aspects, this could result in a general limitation of the normative theory of real option value.[506] The most obvious solution to this problem could be found in assigning the responsibility of the decision to exercise the flexibility to the one who values the project (and therefore sets up the real options). Obviously, this is somewhat unrealistic, especially in big companies with many projects, centralized controlling divisions, and multi-staged decision approval processes. Therefore, Koornhof (1998) suggested the establishment of organizational structures that foster flexibility, for example, in coaching and training management in creating flexibility, habituating employees to be flexible, and creating a corporate culture that supports changes and adaptations. She furthermore notes that this development of flexibility in an organization is rather a process than a goal.[507] In our opinion, this is the biggest hurdle in adopting the real option approach for valuing projects as it does not only depend on the will of one person, but rather demands the change of a whole organization in some cases. Returning to our scope of selecting relevant real options for

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[504] See Coff and Laverty (2001), p. 74.
[505] See McDonald (1989) in Robinson (2003), p. 39.
[506] See Busby and Pitts (1997), p. 179-180.
[507] See Koornhof (1998), p. 234 and 237.

a ROA, we can, therefore, say that only flexibilities which pass all three criteria, i.e., there is no regulatory constraint on it, there is enough capital budget to exercise the option, and there are no or only passable organizational hurdles to their execution, should be considered. Only in finding such a managerial flexibility can the ROA user be sure that the real option will really be a valuable opportunity to adapt to changing business environment and not only a nice theoretical exercise for the brain.

Once the purposefulness of the flexibility and its capability of change are given, the third aspect to examine is the *size of the choice set*. This goes to some degree into the previously mentioned capability of change but differs from it in as far as it abridges the number of purposeful and technically and organizationally feasible real options by the trivial or undesirable ones, which are unlikely to be chosen. By trivial choices we mean choices that are not evidently different from one another. For instance, a scale down of the production by 20% would be similar to a scale down of the project of 22%. Calculating both real option values in this case would be quite redundant. Furthermore, there are feasible choices which, regardless of the reason, are undesirable. These choices must also obviously be removed from the choice set of real option which should enter the ROA. Only if the commitment to execute the flexibility is completely reached in the mind of the ROA user does the real option get really valuable.

The fourth point mentioned in our list of aspects which must be examined to separate valuable real options from the simply theoretical ones are the so-called *enablers*. Enablers are those costs incurred for providing flexibility. For instance, take a transportation company that keeps its trucks running on ordinary gasoline. The company learns that a hydrogen motor could be built in into the trucks. According to the relative fluctuation of hydrogen prices against gasoline prices, the managers will choose to switch the energy input from one to the other. Obviously, for providing this flexibility, the costs of installing the hydrogen-gasoline hybrid motor must be incurred. These costs represent the enablers. Logically, the lower the cost of the enablers, the higher will be the probability that this switching option will actually be considered and, thus, will be valuable for the firm.

Beside enablers, there are other costs to be considered when analyzing real options, namely the costs of implementing the planned flexibility. These costs are only incurred when the changes occur. Obviously, the lower they are, the higher is the probability that the change will effectively occur. Further frictional elements which go into this category we call the *disablers* are the lead time and the response time.[508] Reducing them

[508] The lead time is the time between the initiation of a process and its completion. For the case of implementing a real option, it represents the time between the start of the adaptation and the point when changes become operative. Response time, on the other hand, is the time between the moment when a system gets a stimulus and the point the

both will make it faster to change. Therefore, real options with low implementation costs and short lead time and response time will be more likely to be exercised if the strike signals require it, and it will be consequently more likely that they can materialize their theoretical value. Such options will be thus relevant for a ROA.

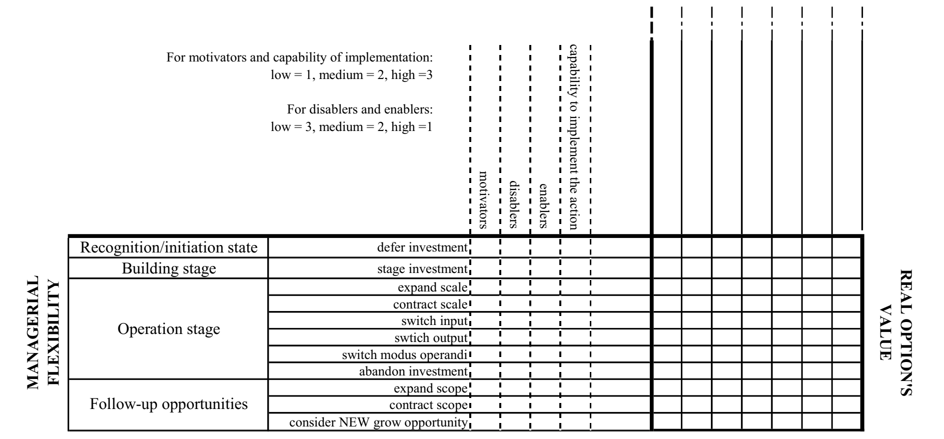
The last aspect to examine in removing practically valueless real options from those which have the potential of truly creating value for the firm are the so-called *motivators*. The motivators are all the benefits or payoffs associated with the flexibility to be implemented. Without calculating the exact value of a real option an experienced manager can already state by means of intuition if a given flexibility is likely to generate large benefits or not. Logically, if the benefits are expected to be high, i.e., motivators are high, it is more likely that the real option will represent real value for the firm and should therefore be considered when undertaking a ROA.

Coming back to our initial aim to create a filter for the ROVG which permits us to separate valuable real options from the valueless ones, we can say that the real option to be considered must exhibit following characteristics. First, they must be purposeful in the sense that they will be a response to an uncertain event. Furthermore, managers must be capable of fulfilling the change once it comes to exercise, whether from an organizational, a regulatory, or a budgeting point of view. The choice of the flexibility must be nontrivial and desirable, i.e., no mental hindrances should prevent the exercise from taking place once the time is come. Finally, the enablers and the disablers must be low and the motivators high. Such an option will result in a real value for a company, and it is thus relevant to examine its value. Finding such options would, therefore, imply that a ROA is of relevance. We resumed the left part of Figure 5.3 and inserted the filter for flexibilities in Figure 5.6. The purposefulness of the flexibility, its desirability and state of triviality is represented in the concrete choice of a specific flexibility. The other aspects like the capability of implementation, the enablers, disablers, and the motivators are represented by the vertical insertion into the ROVG. Again, as it was the case for the uncertainties, we suggest that distributing values from low to high and associating them with numbers from 1 to 3. The numerical order must be inverted for the enablers and disablers as for those a low value means a higher probability of relevant real option value. In applying this scoring system and getting managerial flexibility with a high score will mean that this flexibility will pass the filter, is a real instrument for adapting to unforeseen changes of the specified risk factors and will, thus, be of value for the firm. Such values should be assessed through the application of a ROA. The disablers as well as the capability to implement the flexible

system begins to react to the input. For the case of implementing a real option, this is the time between the flexible actions having been implemented and the point when the results of the change are effective.

action could have been split up in the figure into the different aspects mentioned in the text, e.g., for the disablers into lead time, response time, and costs for implementing the action. However, for a purpose of clarity, we kept the figure simple. The adaptation of the managerial flexibility filter for a specific case may be, for instance, splitting up the disablers or the capability to change into different sub-aspects, which could be of major importance for the investment in question; this will be left to the interested user.

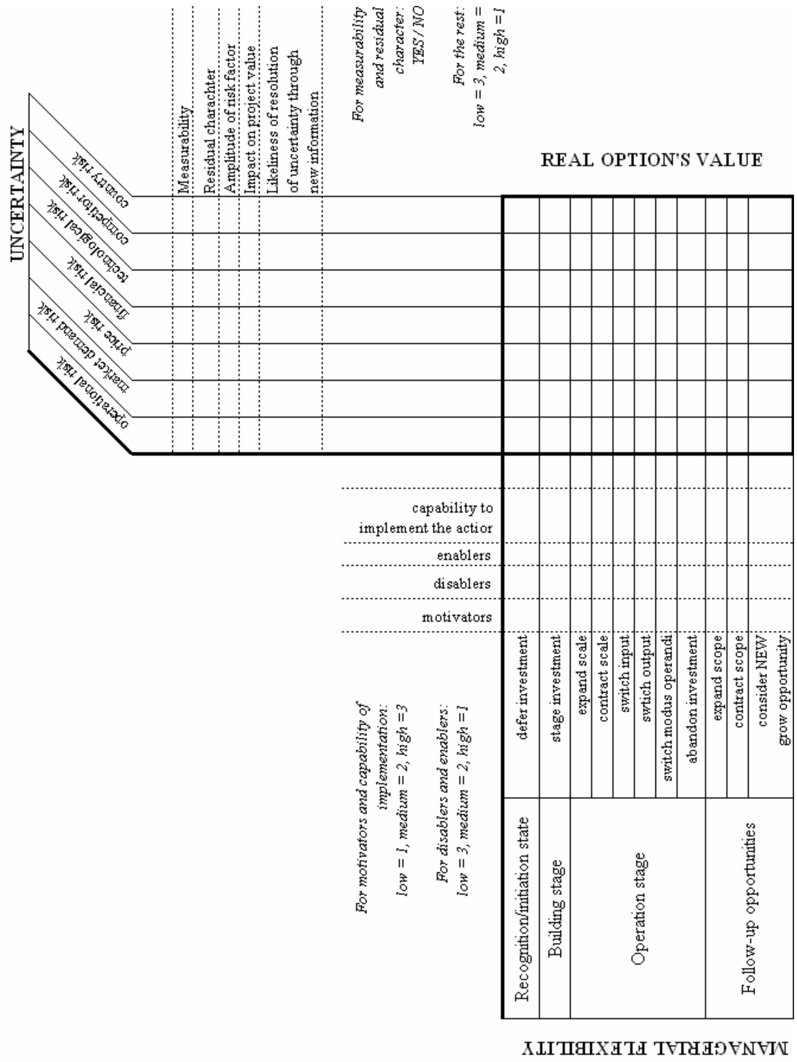
Figure 5.6: Filter for relevant types of managerial flexibility.



5.2.3.3 The Real Option Value Grid (ROVG)

After having explained the basic functions of the ROVG and shown how we construct the filters to decide which uncertainty is relevant for the ROA of a specific project and which types of managerial flexibility should be considered, we can portray the complete ROVG in a single recapitulatory figure, and laying some features and special properties of it. The complete ROVG is represented in Figure 5.7.

Figure 5.7: The complete ROVG.



The process to apply the ROVG on an investment project is similarly straightforward, either with a filter or without a filter. Begin in the upper right part of the ROVG to identify uncertainties which could affect the project. Analyze the uncertainties concerning their relevance for the application of a ROA. The relevant uncertainties will pass the uncertainty filter, i.e. will be measurable, residual, large in amplitude, their impact on the project value will be high, and the likeliness that a new information will resolve the uncertainty over time will be high as well. Then, for the resulting uncertainty (or the resulting uncertainties), check whether one of different types of managerial flexibility listed could help in case the project has to be adapted due to new information concerning the uncertainty factor - either to avoid further losses or to profit from new opportunities. The flexibilities in question must then be further examined on their practicability, because only a real option which is effectively implementable when it comes to strike will result in real value. Therefore, for passing the filter, the managerial flexibility must be taken into operation with low organizational decision barriers; there must be enough capital budget reserved for the strike; and no regulation should hinder the implementation. Furthermore, the enablers and disablers must be low as they are a hindrance to the implementation of the real option and the motivators must be high. In following this clockwise process in the ROVG, there may result in one or several cross points in the bold grid in the center of the ROVG. These cross points represent valuable real options for a given project with a high likeliness of implementation if changing business conditions require it. These added values should be considered and assessed in order to have a comprehensive view concerning the value of the specific project. If several cross points should result in the ROVG, we suggest limiting the number for a complete ROA to a maximum of three of them for, first, not compromising the clarity and communicability of the analysis and, second, because the marginal benefit of real options' value is decreasing with a higher number of real option taken into consideration.[509]

Our principal scope was to assess if the ROA is of relevance for a given investment project. Detecting managerial flexibility that could result in real value for the firm automatically suggests that this value must be considered as accurately as possible in order not to incur in valuation errors and maybe even in wrong investment decisions. The application of the ROA is thus relevant. Beside this primary scope there are many features of the ROVG which could be of advantage in analyzing an investment decision. The modularity of the ROVG makes it adaptable to different investment decisions, different project types or different industries. In fact, the spine of the

[509] To rule out further less valuable real option form the complete ROA we suggest a rough estimation of their value as suggested by Luehrman (1998a). We will explain his model in chapter 5.3.

ROVG's functionality is only its clockwise application process and the linkage between an uncertain factor and a managerial flexibility that could respond to this uncertain factor. All other features could be easily changed and adapted to a specific investment case. For instance, new uncertainties could be inserted or industry-specific flexibilities could be taken into consideration. Also, the filters could be removed and replaced by project-specific filter layers. Moreover, if a specific filter layer is considered to be extremely important for a given uncertainty or managerial flexibility it could be weighted with a specified factor to reflect the importance of the aspect to be considered. For instance, if the budget to provide the flexibility, i.e., the enablers, are seen to be difficult to provide but central to the implementation of the flexibility one can multiply the estimation (e.g., high = 3) with a factor of 2 getting consequently 2 times 3 = 6. In doing so, a double importance is given to the enablers compared to the disablers, motivators or to the capability to implement the action.

A further interesting property of the ROVG is its ability to distinguish between available, potential and required flexibilities and systematically lay open the available ones and indicate the potential and required ones. As yet for our scope of examining whether the ROA is relevant for a given project we have only highlighted the available opportunities, i.e., those that passed the filter. However, in applying the ROVG, some flexibilities could be detected which indeed would be a response to a specific uncertainty and are might also desirable and nontrivial, but, on the other hand miss some other aspects like e.g. low enablers, low disablers or the ease of implementation. This would signalize that these potential options may be realizable and valuable in working on the aspect on which a lack has been observed. Interesting results may arise on a company-wide perspective, if, for instance, several ROVG applications on different projects of the company signal systematically a lack of capability to implement potential valuable real options due to extended authorization processes. In these cases the company may get an indication that the time is come to revise this process in order to endow the leader of a project with the appropriate power to act to generate the full value of the investment opportunity. Finally, in applying the ROVG, there could be also disclosed important risk factors for which flexible action would be indispensable and, in doing so, generate the awareness that a specific real option is needed to make the project work. These required real options may induce management to modify the project set-up and work on the aspects that render their implementation possible and their value real. The ROVG can, therefore, help to manage the real options inherent in a project in as far as it helps to determine and select the available real options; it shows how to develop and maintain the potential real options, and indicates where real options are required in order to consolidate the success of a project.

In conclusion, the ROVG could therefore not only be used to decide whether the application of a ROA is relevant, but also as a preliminary step of ROA in systematically discovering and selecting available real options and clarifying the process needed to develop and maintain the potentiality of the real option value within a project. Furthermore, because of its relative simplicity and quick communicability, even in leaving out the exact numbers and ROA calculations as a start, it leads to an improved understanding and communication of the value that can arise through flexibility in the whole company. This would support the formation of organizational structures that foster flexibility and augment the company's shareholders' overall value.

5.3 Quick estimation of real option value

So far we have discussed the prerequisites of real option value. If these prerequisites are given for a specified project, there is the high probability that this project incorporates realizable flexibility value. Obviously, the higher the values of these real options, the more likely a decision for or against a project can be changed. Thus, the more it will pay to asses their exact value with an accurate ROA, to champion the acceptance of the project to senior management and within the entire company. What we need at this point is a methodology that allows us to quickly estimate the value of the real options arising through the application of the ROVG before going into a deeper and complete ROA. For this purpose, we will adopt the "option space" proposed by Luehrman (1998a) and Luehrman (1998b).[510] Luehrman's main proposition is that most real options problems can be discouraging to solve and will thus remain the domain of real option specialists. For the ROA to gain use by general management who have a business to run and simply want to do better, i.e., get closer to the "right" answer - setting aside the analytical work for the first is better than doing nothing. As stated by Luehrman: *"…for many projects in many companies, a 'good enough' number is not only good enough but considerably better than the number a plain DCF analysis would generate. In such cases, forgoing some precision in exchange for simplicity, versatility, and explicability is a worthwhile trade."*[511] This is exactly what will help us in deciding if a real option is worth further investigation or, for the time being, should be left to a

[510] The following explanations in this chapter will be based on these two articles where not otherwise explicitly mentioned.
[511] Luehrman (1998a), p. 51.

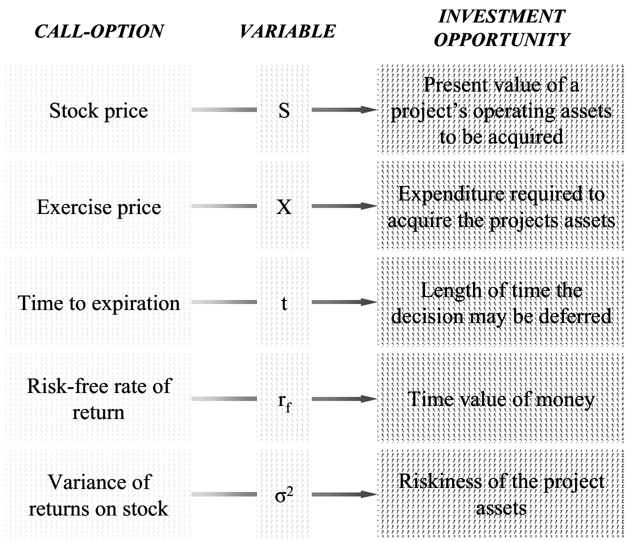
semi-quantitatively analysis of its value.[512] We will first explain the two metrics Luehrman based his model on. Then we will show how to plot the real options into the option space and for which real options a closer look may be useful. Finally, we will present briefly some interesting insights which can be gained in applying Luehrman's model that will help decide about the question of whether to devote additional attentional resources to the given real options apart from their exact valuation.

5.3.1 Linking NPV and option value

Luehrman based his framework on the Black-Scholes model presented in subchapter 3.3.2.2 and the NPV explained in chapter 2.3.1. Assuming that the NPV technique is a common tool used in project valuation and thus its data basis should be easily available and its interpretations understandable to a manager who wants to analyze its project, Luehrman proposed how to link the NPV parameters to option valuation. How the parameters of an investment opportunity can be mapped to the Black-Scholes option formula was shown in chapter 3.3.3 and therefore we will only briefly recall it in Figure 5.8, this time based on Luehrman's notation.

[512] We use here the expression semi-quantitatively because as yet we followed mainly qualitative aspects to examine flexibility value. In adopting Luehrman's model we will introduce first real numbers (even if rough estimations) based on the NPV which will make our analysis for a certain extend quantitative.

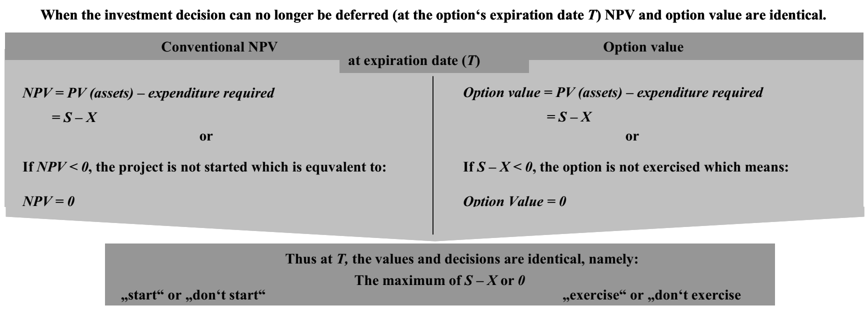
Figure 5.8: Mapping an investment opportunity onto a call option.



Source: Based on Luehrman (1998a), p. 52.

According to the NPV rule, a project will be accepted when the present values of the cash flows from the operating assets (S) will be higher than the costs to acquire them (X), thus if S > X. Otherwise it will be declined. The same holds for a call option at expiration. That is, when there is no more time for waiting and profiting from evolving events the call option will only be exercised if S>X, otherwise it will expire as worthless. This commonality between NPV and option value is illustrated in Figure 5.9 and has great practical significance. Three of the five option pricing parameters, S, X, and r_f can easily be found in the spreadsheets used to compute conventional NPV.

Figure 5.9: Equality between NPV and real option value.



Source: Based on Luehrman (1998a), p. 52.

However, before expiration, the investment decision made following the NPV rule is different than the one derived from option valuation models. The reason is that in waiting for the optimal time to invest, two sources of value are captured by option valuation models, which are overlooked by the NPV rule. These are: first, the ability to react to a changing environment and, second, the time value of money of the investment outlays.[513] In order to capture these additional sources of value, two new metrics were defined by Luehrman: the *volatility metric* $\sigma\sqrt{(t)}$ and the *value-to-cost metric*, $NPVq_c$.

The volatility metric represents the value deriving from the potential upwards movements of the underlying which will affect the investment for the better. This metric cannot be measured directly. Luehrman proposed to measure the uncertainty about the changes of the underlying in terms of the standard deviation of project returns per unit of time - the cumulative volatility $\sigma\sqrt{(t)}$. The Black-Scholes option pricing model will then quantify the value associated with that specific amount of uncertainty. Cumulative volatility $\sigma\sqrt{(t)}$ is simply the square root of the cumulative variance $\sigma^2 t$, which is the variance of project values per period of time σ^2 multiplied by the time t. Luehrman argued that cumulative variance $\sigma^2 t$ is a good way to measure the uncertainty associated with business investments, whereas cumulative volatility $\sigma\sqrt{(t)}$ is simply a modification of $\sigma^2 t$ for mathematical convenience.

For the value-to-cost metric Luehrman explained that by waiting to invest, a project manager will need less money today to fund an expenditure required in the future, because interest is earned on that money. Thus, only the present value of the investment

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[513] What is understood by the ability to react to unforeseen changes has been explained several times through the dissertation. What is meant by capturing the time value of money of the investment outlay is reflected by the following idea: In not investing yet, the investment outlay can be momentarily restrained and, thus, the risk-free rate of return can be gained on the investment costs until the time is right to carry out the investment.

outlay is needed today, $PV(X) = \dfrac{X}{(1+r_f)^t}$, to carry out the investment in the future.[514] In this formulation, the NPV can be modified to

$$NPV_{\text{mod}} = S - PV(X) \qquad \textbf{(5.1)}$$

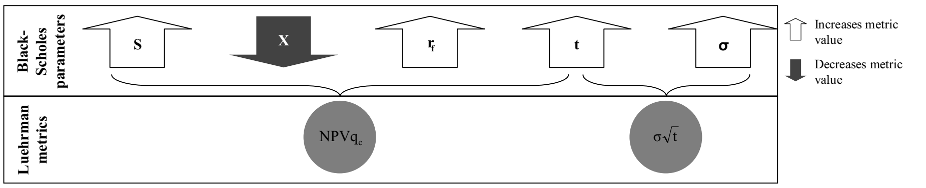
which represents the present value between the value of the assets S and the present value of the required investments PV(X). To ease the plotting in a two-dimensional diagram Luehrman created a new metric out of the NPV_{mod} in simply dividing the first term through the second and calling it the NPV quotient:

$$NPVq_c = \frac{S}{PV(X)} \qquad \textbf{(5.2)}$$

The q stands for quotient and the c means that this quotient is used to price a project which is equaled to a European call option. The quotient can never be zero or negative and, although they are not equivalent, there is a perfect correspondence between the $NPVq_c$ and the NPV_{mod}: if NPV_{mod} is zero than $NPVq_c$ is one, and if NPV_{mod} is positive (negative) than $NPVq_c$ is greater (smaller) than 1.

Thus $NPVq_c$ and $\sigma\sqrt{(t)}$ permit to represent the additional value of waiting to invest using the five parameter of the Black-Scholes model and combining them in only two metrics. This is summarized in the Figure 5.10.

Figure 5.10: Linking the Luehrman's metrics to the Black-Scholes model.



Source: Based on Luehrman (1998a), p. 55.

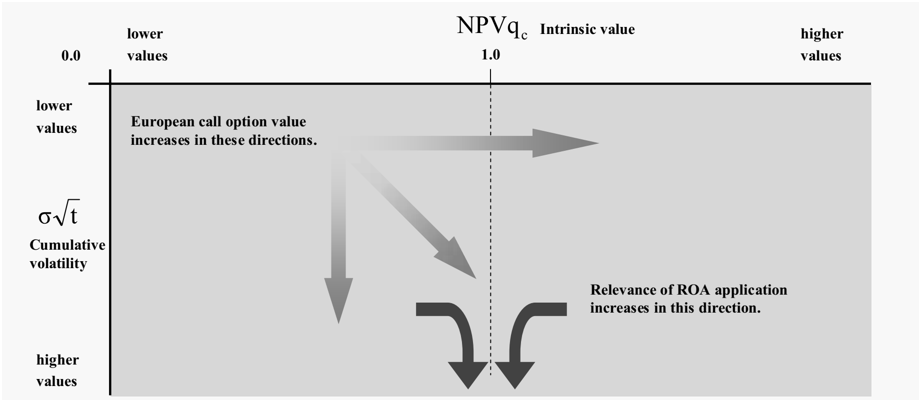
Luehrman stated that seeing investments in a two-parametric framework has several advantages. First, it is easier for the management to grasp compared to a full ROA. In

[514] Throughout the dissertation and especially in explaining the Black-Scholes formula, we used continuous compounding to discount values, i.e. e^{-rf*t}. At this point, to stay in line with Luehrman, we applied simple periodic discounting, i.e. $1/(1+r_f)^t$. The results will obviously only change slightly but, in using the same notation as Luehrman, the understanding will be much better for the interested reader who wants to deepen his knowledge of the Luehrman model in the original papers.

fact, both metrics have natural business interpretations, and $NPVq_c$ can even be derived from standard NPV calculations. Second, it fits together tightly with the NPV rule, even if separating the value that comes from waiting and uncertainty in an intuitive way from the value derived by the classical NPV methodology. Third, and perhaps most importantly, the options can be plotted in a two-dimensional diagram, which provides an excellent visual tool for managing the real option values of investment projects or for illustrating and communicating them in a simple manner. Figure 5.11 showed how to represent the option value in the two-dimensional space which he called option space. On the horizontal axis $NPVq_c$ is plotted, whereas the volatility metric $\sigma\sqrt{(t)}$ is graphed on the vertical axis. Recalling the function of the Black-Scholes parameter, the intuition of the option space is straightforward. For $NPVq_c < 1$ the NPV of a project is out of the money, at $NPVq_{c\,=}\,0$ it is at the money and for $NPVq_c > 1$ the project is in the money and its exercise will be valuable if the time to exercise is come. Thus, the higher the $NPVq_{c,}$ the more valuable the investment project seen as a European call option. Similarly, for higher $\sigma\sqrt{(t)}$, i.e., the more uncertain the outcome of the project and the longer this uncertainty lasts, the probability is higher that the project's outcome will evolve to be better.[515] Therefore the option value will increase. The directions in which the real option value will be greater are summarized and represented by the bold arrows with augmenting color gradient depicted in Figure 5.11. As options move towards their expiry date, i.e., their time value diminishes, they drift to the left and up, and lose overall value.

[515] Remember that if chance is not favorable and the outcome of the project's outcome turns out to be worse we do not have to act and just let the investment option expire worthless without loosing any money.

Figure 5.11: The option space by Luehrman.



Source: Based on Luehrman (1998a), p. 55.

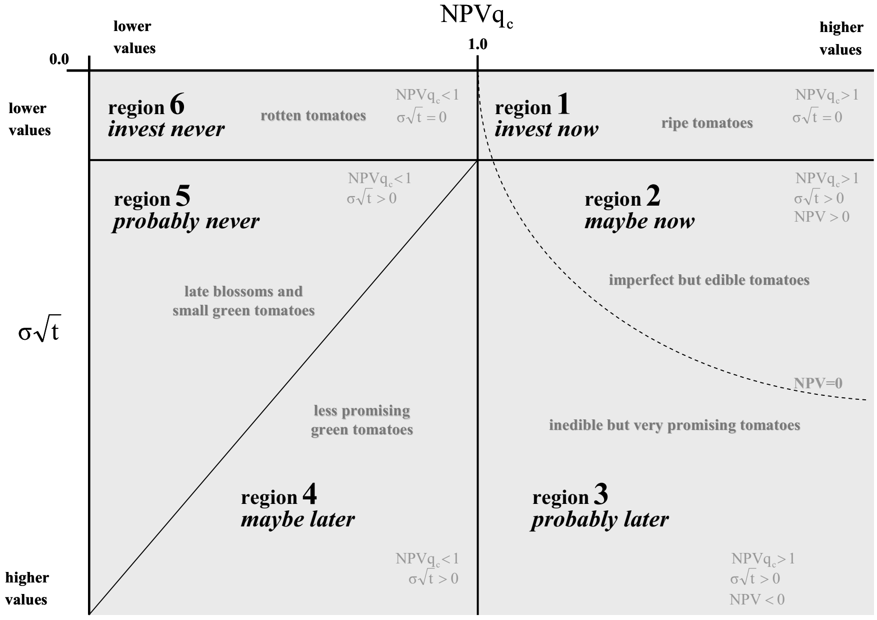
Locating options in the option space shows their relative value to each other. Besides many interesting implications, which we will explain in the next subchapter, for our primary task to separate projects for which a ROA is meaningful from those on which it is not, we can say that projects located in the upper part of the diagram will have, in general, little inherent option value and thus a common NPV computation will do a good job. The lower the option will drift down in the option space, the more important will be a comprehensive analysis of the project's inherent option value. Especially for those options in the lower part of the graph and on (or near by) the $NPVq_c = 1$ line an inaccurate assessment of the option value and, thus, of the project value can lead to a completely wrong investment decision.[516] For options being far out of the money ($NPVq_c << 1$) or deep in the money ($NPVq_c >> 1$), the application of the ROA is in as far questionable as the former will expire worthless with high probability, and the latter will probably turn out to be good investments in any case. Thus, accomplishing an exhaustive and expensive ROA seems to be of minor meaning in those cases and the semi-qualitative assessment of the importance of the real options will be sufficient. The directions for the relevance of the application of the ROA are represented by the bold black arrows in Figure 5.11.

[516] This is intuitive in as far as options that are near at the money will show a higher sensitivity of change of the exercise decision to movements of the underlying assets. The way until the option will be in or out of the money is very short at this point, and the decision whether to exercise the option or not changes drastically if it is in the money (the option will be exercised) or out of the money (the option will expire as worthless).

5.3.2 A gardening metaphor: options as tomatoes

Considering real option value through the option space diagram in terms of intrinsic value (value to cost metric) and cumulative variance (volatility metric) suggests a number of strategic prescriptions that can help decision makers in timing and execution of investment projects. For this purpose, Luehrman compared his option space to a tomato garden and a portfolio of projects to the different tomatoes growing in this garden. The tomato garden is pictured in Figure 5.12 and mapped into the option space using the same metrics as in Figure 5.11. When a gardener examines his tomatoes at mid-season, he will find different kinds of tomatoes. Luehrman subdivided his option space diagram into six different predefined regions representing the different kinds of tomatoes, or, away from the metaphorical representation, the different kinds of investment projects. Experienced gardeners can tell when their tomatoes are at the right stage of ripeness (and thus to the right option space region) at any time and also understand how the vines change over time. Whereas early in the season all fruits can make it, by the end of the season they all fall into the “now” or the “never” region, although along the way active gardening is necessary in order to get more of the in-between tomatoes to grow and ripen before the time ends. An active gardener cultivates the vines regularly and waters and fertilizes the tomatoes and, in doing so, the chances of a good harvest are increased. In option terminology, active managers do not just make exercise decisions between good and bad. Rather, they monitor the options and try to enhance their value by influencing their underlying parameters during the lifetime of the real options. Option pricing allows one to estimate the value of each different tomato (and thus of the whole crop) at any given time in the season. This helps to determine which tomatoes to pick and which to leave in the garden. Finally, option pricing can indicate how to cultivate those in-between tomatoes so that they become ripe and edible.

Figure 5.12: The tomato garden.



Source: Based on Luehrman (1998b), p. 92ff.

This analogy between a tomato garden and the project portfolio of a company, joint to the knowledge about conventional NPV, $NPVq_c$ and $\sigma\sqrt{(t)}$ permits to draw interesting conclusions and make important prescriptions about the strategy to pursue according to the location of the project in the option space. For this Luehrman divides the option space into three broad areas; the top of the space and the two spaces to the right and left side of $NPVq_c = 1$, whereby every area contains two regions numbered from 1 to 6. In the following, we will explain the implications of finding an option placed in a specific area or corresponding region.

The *top of the space* is divided into *region 1* and *region 6*. The very top of the space $\sigma\sqrt{(t)}$ is equal to zero because of either the uncertainty's being completely resolved (σ=0), or the time for waiting has run out (t=0). As there is no uncertainty to respond on and/or no time to wait, the decision is straightforward and falls back to the simple NPV criteria. Projects in region 1 where $NPVq_c$ is greater than 1, which indicates that these projects are in the money, are thus ready for immediate exercise. The investment instructions will be a clear "*invest now*". In this region, we will find all red and ripe tomatoes ready to be harvested. By contrast, projects in region 6 are out of the money as

$NPVq_c < 1$. As there is no time and/or no chance left that they will ever come in the money ($\sigma\sqrt{(t)} = 0$), they are clearly worthless, and the investment decision will turn out to be "*invest never*". Region 6 contains all the rotten tomatoes unworthy of harvest.

Projects with $NPVq_c > 1$ and $\sigma\sqrt{(t)} > 0$ fall in the *right side of the space*.[517] These projects are very promising as the underlying asset is worth more than the present value of the required expenditures ($NPVq_c > 1$). Nevertheless, time has not run out yet, and uncertainty can still change the outcome of the projects ($\sigma\sqrt{(t)} > 0$). In order to get further directions about the investment behavior to apply to the single projects of the right side of the space, the right side can be divided into two regions through the dashed NPV = 0 curve. Attention should be paid to the fact that with NPV = 0, we mean this time the conventional NPV and not Luehrman's $NPVq_c$ metric.[518] Projects in *region 2*, with $NPVq_c > 1$, $\sigma\sqrt{(t)} > 0$ and NPV > 0, an immediate exercise must be considered as their NPV is positive. The investment direction results in invest "*maybe now*". This region contains all the imperfect but edible tomatoes. The chance for these tomatoes to get better is still intact. For an investment project, this means: if there is still potential for better development, why this value should be forgone by investing immediately. Just as a stock option holder may miss dividend payments by deferring the exercise of the option, any predictable loss of value or cost associated with deferring the investment (e.g., preemption by a competitor, predictable loss of market share) reduces real option value and can thus cause an early exercise of the option.[519] Using the tomato analogy, we might consider picking orange but already edible tomatoes a bit earlier than optimal if we can predict that the chance is high that thieves or birds will come and eat them otherwise. For *region 3* in contrary $NPVq_c > 1$, $\sigma\sqrt{(t)} > 0$ and NPV < 0 holds and thus the conventional NPV is still negative even if Luehrman's metrics show a promising state of the option. All the very promising tomatoes which, however, are still inedible fall into this region. These projects are thus out of the money and should not be exercised early. However, there is still the probability that chance will turn them in the money and eventually it will be worthwhile to invest later, thus this investment region is denoted by invest "*probably later*".

Finally the third broad area is the one to the *left of the option space* with value-to-cost metrics for the options that are smaller then one. Conventional NPV is everywhere

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[517] We have already discussed the projects with a very low $\sigma\sqrt{(t)}$ and will thus concentrate our discussion here on projects with higher or highest $\sigma\sqrt{(t)}$, which are located below the top of the space.

[518] The NPV = 0 curve can be derived from the Black-Scholes equation by e.g. holding r_f and σ constant as t varies. Then solving for the $NPVq_c$ which corresponds to NPV = 0, one gets a point of the curve for every t. If for example $r_f = 0$, the curve will be a vertical line corresponding to the $NPVq_c = 1$ line. With increasing r_f the slope of the curve decreases, bending to the right.

[519] For instance, we explained in section 5.2.2 how competition may lower the value of waiting to invest.

negative in this area, and even the value to cost metric signals that these projects will be less promising despite their value of waiting being positive, $\sigma\sqrt{(t)} > 0$. Even so, the area can be divided into two regions. For both regions, obviously both Luehrman metrics are equal in sign, namely $NPVq_c < 1$ and $\sigma\sqrt{(t)} > 0$ and, moreover, their conventional NPV is negative. However, for options in *region 4*, one metric is reasonably high, whether the value-to-cost metric or the volatility metric. This means that there is still some chance, even if it is not very high, that the project will fall in the money at expiration and, thus, its exercise is valuable. Finding options in this region will lead to invest "*maybe later*". All less promising green tomatoes, but for whose there is still a chance to ripe before the end of the season, will fall into this region. Finally, *region 5* comprises all the options with low values for both metrics. Luehrman called this region the "*probably never*" region. These projects are unlikely to turn out to be valuable, and there is no sense of spending much attention on them even if there is a remote chance to find them lucrative when the time to invest comes. In tomato-language: Region 5 contains the late blossoms and small green tomatoes that are unlikely to ripen early enough.

Luehrman's approach is dynamic in as far as the tomato or option cultivation is a continuous process; new project opportunities come into the garden and old ones are exercised or fall out. As reported in Figure 5.11 options become more valuable if they move either to the right, downward, or both together. However, over time, options tend to move exactly in the other direction as desired if no action is taken on them, namely upward and to the left. Upward, because $\sigma\sqrt{(t)}$ decreases with decreasing t, and to the left because the time value of money incorporated in $NPVq_c$ decreases as well, as time passes. The only two forces to push the options downward or to the right are good luck and active management. In taking actions to increase the option-value metrics active managers can cultivate their project portfolio and increase the firms' overall value. Trying to push options to the down right corner of the option space before they will float all the way to the top as time runs out will generate with high likeliness a larger number of valuable projects out of that which was only an investment opportunity at the time of its recognition. Examples for moving the option into the right direction of the option space are the reduction of costs, thus increasing $NPVq_c$ and pushing the option to the right, or, an increase of $\sigma\sqrt{(t)}$ by changing the operating leverage and thus pushing the option downward. The effects of managerial actions might interact or have an impact on both Luehrman metrics and consequently have to be analyzed carefully. But the framework provides a good way to organize, visualize them and disclose what drives their value. In a further development of his model, Luehrman even demonstrated how to represent nested options and better understand their interdependencies, which, for instance, can be very helpful in valuing staged investments. As it is beyond the scope of this dissertation we refer the interested reader to Luehrman's original paper.[520]

Concluding we can say that adopting Luehrman's option space for managing investment opportunities will not only serve for our primary target to disclose those projects where the application of a ROA will pay more, but it will also allow a rough estimation of the option value, a deeper knowledge, and sound communication of its drivers and an encouragement of strategic thinking in an options framework providing interesting insights that can change investment decisions. This is why we espouse Luehrman's idea and promote its application in combination with the ROVG for the assessment of the value of managerial flexibility in real-life projects.

5.4 Communication of the flexibility value

We have emphasized throughout this study that flexibility is central to the success of an organization in uncertain times. However, when the information about flexibility cannot be communicated in an efficient and clear way to all interest groups, it will neither be useful for the decision-making process, nor for the external information process about the company's value creation. The communication of flexibility should allow to...

1. … provide information about available, potential, and required flexibility.
2. … provide guidance for decision-making to management.
3. … support championing the project through the internal appropriation request process.
4. … support and sustain flexibility in the organization in general.
5. … provide discriminatory information for stakeholders to enable them to choose between flexible and inflexible organizations.

Even so, the communication of the value of flexibility is difficult mainly because of three aspects. First, the abstraction level of the construction of flexibility is, per se, very high and flexibility is thus difficult to grasp. Developing flexibility and assessing its value is a continuous process more than a goal because of the permanently changing business environment and the corresponding actions to take.[521] This fact would imply a perpetual flow of information disclosure. Second, the valuation of flexibility can be

[520] See Luehrman (1998b).

[521] See Koornhof (1998), p. 237.

complex and specific depending on the situation and the model used. Third, real options are sensitive strategic information about the company's investment behavior. This sensitivity holds not only for external parties but also for internal ones. The benefit of disclosing managerial flexibility must be therefore balanced against the cost that might arise from the reactions of the employees or competitors.[522] All three aspects can hinder an efficient and intuitive communication of the value arising through managerial flexibility, and this, in turn, results in a reluctance to value it accurately.[523] Thus, it is important to find an efficient framework for disclosing satisfactory information on real options. Internal or external reports should include adequate information about the firm's real options and define the necessary information to call into the appropriate place. Furthermore, information should be limited to prevent an overload which could result in an impracticability of the given directions. For this purpose, we propose to use the *ROVG* in combination with the *option space* of Luehrman. Using them together will help in achieving many of the different requirements for a simple and sound standing communication of flexibility value which can help in guiding limited financial resources to the appropriate investments. In the following, we will explain to what extent this information disclosing is possible and where we think this information could be best placed.

The principle aim why we proposed the combined utilization of the two models is the one of determine investment cases where further efforts for a comprehensive and detailed ROA were most beneficial, i.e., where the application of ROA was relevant. This is also the first important information which is useful for the internal purposes of devoting the right attentional resources to single specific investments. In disclosing the relevant real options in a structured way and comparing them with their ability to pass the ROVG filter for managerial flexibility, an intuitive and easy communicable picture of the value coming from flexibility will be given. Understanding why a specific managerial flexibility is of value can be enforced through the antecedent analysis of the irreversibility and competitive situation. In cases with a highly irreversible investment and low competition, the possibility to prevent unforeseen changes through managerial flexibility is of extreme value should be easy to understand for everyone even without knowing the real options approach. Moreover, through the application of the ROVG, the information is laid open about which type of managerial flexibility is *available*, which is only *potential* and which may is *required*. In having this information management can decide where to spend additional financial and attentional resources as

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522 See Chen *et al.* (2005), p. 2.

523 This was also found in our survey in the previous chapter. Many managers stated that the communication was one of the main hindrances in applying the ROA on a regular basis and that a flexibility assertion based on intuition was therefore preferred. See chapter 4.5.

efficiently as. For the *available* real options, e.g., the most important actions will be to wait for strike signals and to work on the value drivers of the real option, i.e., the volatility, the time to expiration, the cash inflows and the costs of the project. This second job could be supported by the Luehrman's framework in analyzing the position the given real option will take in the option space and moving them through the space in changing their option metrics. Instead *potential* real options (out of the ROVG analysis) are options that could be of value, but are still practicably unavailable because of hurdles hindering their passing of the ROVG filter, e.g., organizational structure in the company that prevents an efficient exercise of the real options or insufficient budget to implement it. Clearly, the ROVG signals in these cases that the option could be of worth if more work has done on the hindrances, e.g. endowing the manager with the authorization of quick exercise or provide enough capital budget to profit from the opportunity when strike signals are positive. Also in the cases of potential real options, the Luehrman option space can be applied to sustain the decision to pursue a specific real option; for example, in finding the real option positioned in the right upper or middle region its further development is might more advisable and beneficial than finding it in the left lower part of the diagram. Finally in applying the ROVG and unveiling important uncertainties that could affect the success of the project heavily and, on the other side, not having managerial flexibility to act on it would suggest that either the project has to be cancelled, or a specific *required* flexibility should be generated.[524]

This information about available, potential and required managerial flexibility detected with the ROVG and enforced by the option space could be thus very helpful in providing information for decision-making to the managers. Moreover, because of its simplicity and facility of inspection, it could be communicated internally quickly and efficiently. It would not take long, in fact, to explain the ROVG's result and the accompanying elucidation based on the option space in order to champion the given project towards senior management. In achieving this aim successfully the culture of flexibility will automatically be supported and sustained throughout the whole company, and unnecessary organizational hindrances against flexibility could be systematically removed. The summarized information on flexibility for a company's internal purposes could be added to a standard investment appropriation request of a company as a supplement for assessing the additional value coming from flexibility.

[524] At this point, this may looks like a risk management tool against an unforeseen risk striking down on the project. However, this is clearly not the case. Imagine a project with a low NPV, whereby an expansion of the scale could increase its NPV tenfold in year 2. Unfortunately, the market demand is still unclear today. Consequently, the *required* real option in this case would be the "option to expand the scale." If we do not have such an option, the project is still valuable, but the resources invested in earning the low NPV may be deployed more efficiently elsewhere.

Our proposition for this supplemental flexibility appropriation request is presented in appendix F. and is composed of three parts:

1. the *ROVG*
2. the *option space*
3. the *additional information* on…
    a. irreversibility
    b. competition
    c. the uncertainty filter
    d. the managerial flexibility filter
    e. and the specification on the function of the real option.

In six pages the flexibility appropriation request will deliver through the *ROVG* much information about how to avoid risks and catch opportunities, on what is needed to get ready and execute the flexible managerial actions, on which organizational structure could hinder a fast reaction and whether the given real options should be further developed or not. Moreover, the accompanying *option space* of Luehrman could give further directions on which value drivers more emphasis has to be dedicated, what the rough value of the given flexibility could be, and how it interacts relatively to other valuable real options in the project. Most information can easily be made comprehensible by graphical representation. Other important information which could not be represented entirely in the diagram is subsumed in the *additional information*. After this preliminary flexibility analysis has been done and the flexibility appropriation request has run through the various controlling processes of a company, management can still decide whether a deeper and more accurate ROA is necessary and more resources have to be devoted to it, or if the gathered information at that time is already satisfactory for improved decision-making. As we have already noticed when explaining the ROVG, the risk categories, different types of managerial flexibility as well as both filters are exemplified from broad observation of business life. For a specific company or a specific investment case, the ROVG can be easily adapted by changing filters or adding risk categories and additional specific types of managerial flexibility.

As with any framework or model, only a repetitive utilization will make it possible to learn how to master its full functionalities. Moreover, even if we have suggested in the early explanation of the ROVG to limit the number of real option to be examined for a project to a maximum of three options, the interactions between the different real options can be challenging for a novice ROVG or option space user. Thus, in the beginning, to avoid confusion, we suggest filling out the flexibility appropriation request for every single real option alone. Even if it will slightly augment paperwork, it will nevertheless be of help in clarifying the flexibility value for those who receive the information.

As yet we have only treated the company's internal communication. However, flexibility value, as a part of the complete investment value and thus of the overall company's value, should also be communicated to external parties if possible. This will allow investors and other stakeholders to discriminate between flexible and less flexible organizations and so have more accurate information whether the company is endowed with the appropriate managerial flexibilities to profit from upcoming opportunities or secure itself from unforeseen events with negative impact. The information for external interest groups could be extracted from the previously described flexibility appropriation request and could be disclosed in, e.g., the notes of the company's financial report. As already mentioned information on flexibility can be highly confidential the more it is of strategic relevance and, thus, it must be decided in each single case carefully what to disclose and what not. Obviously, real options that are already *available* and could immediately be put in action if necessary, and where a low competitive activity prevails in the market for the given option, are predestinated to be disclosed also to external parties, as there is a low chance of competitors' preemption. Nevertheless, we cannot foresee conditions for every single investment case and therefore we leave the decision about the disclosure of the single real options to the judgment of the company that wants to assess the flexibility's value of its project.

Finally, to make all explanations in this chapter better understandable we will show as next how the flexibility appropriation request will work on a concrete case and calculate thereafter the real option's value for a hypothetical project.

5.5 Application example

In this section we will show how a ROA works from the preliminary step, i.e. the application of the proposed flexibility appropriation request, through to its calculations and decision rules based on the results. We keep the mathematics behind the example as simple as possible in order to make it easy to follow; because, for our scope, it is more important to highlight the valuation process itself instead of the mathematical and modeling background.

5.5.1 Setup of the problem and NPV calculation

In 2005, a certificate system was launched in Europe to regulate the CO2 emissions of European companies according to the Kyoto protocol.[525] The basic principle of this system is that only companies in possession of the appropriate certificates may generate CO2 emissions. The target is to change the perception of CO2 emission rights from a "hidden tax" towards a tradable commodity like steel or petrol. These European emission certificates (EUA) can be traded like stocks.[526] As a result, companies are motivated to reduce greenhouse gas emissions not by government regulation but by market forces. Thus, it is evident that CO2 emissions represent a direct cost for the company, and emission trading will affect its investment decision.

MotorPS is a motorbike manufacturing company in Italy facing an opportunity to invest in equipment to reduce CO2 emission. Today, in year 2007, it would have to pay € 4.5 Mio to buy a CO2 filtration facility for its factory that will reduce CO2 emissions by 48'000 tons each year. The facility needs one year to install and will thus be operative in 2008. The filtration equipment has already been tested in other companies that produce transportation equipment, and its optimal function is well recognized. A constant emission reduction is thus expected for a period of 20 years, after which the facility has to be replaced. Even though the standard functionality of the filters is known, some changes have to be made to adapt them to the particular situation of MotorPS. This renders the investment highly firm specific and difficult to re-sell. The revenues from the filter installation are manifold. First, it can represent avoidance costs of buying emission rights under specific emission regulation. Second, if the company meets its emission target, it can sell emission rights to other companies, generating direct revenues. Third, it can be a combination of both. These revenues will, however, be highly dependent on the price of the emission rights. The price for the emission of one ton of CO2 as of January 2007 is € 5.30.[527] This price, in turn, is highly volatile as the markets of CO2 emission rights are not seemingly efficient as common stock markets and, moreover, the prices are highly dependent on the reports coming up at the

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[525] In 1997, a UN convention on climate change was held in Kyoto, Japan. The Kyoto protocol established during this convention is an agreement made between the participating countries which ratified the protocol to reduce their emissions of carbon dioxide (and five other greenhouse gases), or engage in emission trading if the level of emission is maintained or increased. The Kyoto Protocol requires that, by 2012, the signatory nations reduce emissions of greenhouse gases to an average of 5% below 1990 levels. January 2008 is the starting date fixed by the Kyoto Protocol to show average reductions in emission. The compliance period will last 5 years. In 2013, the next compliance period will start.

[526] See http://www.europeanclimateexchange.com .

[527] According to the prices published by the European climate exchange in Amsterdam, see http://www.europeanclimateexchange.com/ .

end of the Kyoto compliance period in 2012.[528] The price is expected to grow at the risk-free rate of 4% by the company, with exception of the year 2013. As the prospects of betterment of global warming do not look bright despite of the combined efforts of the countries' prices of CO2 certificates are expected to jump to € 8.00 in 2013. The general information about the investment is summed up in Table 5.1.

Table 5.1: Investment data for CO2 reduction equipment project.

Investment costs in 2007:	€ 4'500'000.00							
Price for one CO2 certificate: *(allows to emit 1 ton of CO2)*	€ 5.30							
Expected price jump in 2013: *(due to Kyoto compliance period)*	€ 8.00							
		2007	2008	2009	2010	2011	2012	2013
Expected prices for the first 7 years of investment: *(from 2008 price grows at risk free unless in 2013)*		€ 5.30	€ 5.30	€ 5.52	€ 5.74	€ 5.98	€ 6.22	€ 8.00
CO2 emission pro year:	48000 t							
Time period of effectivenes of CO2 reduction equipment:	20 years *(from 2008-2027)*							
WACC:	6.9%							
risk free rate:	4%							

In evaluating the investment opportunity using the NPV, continuous compounding and a WACC of 6.9%[529] we get following numbers:[530]

$$NPV = -4'500'000 + \sum_{t=1}^{20} \frac{P_t * Q_t}{e^{0.069*t}} = -4'500'000 + \frac{5.30*48'000}{e^{0.069*1}} + \frac{5.52*48'000}{e^{0.069*2}} + ... + \frac{14*48'000}{e^{0.069*20}} = \underline{\underline{-246'641}}$$

Because the NPV is negative, the investment in 2007 does not pay and will consequently not be initiated according to the forecast data. The project initiator of the emission reduction project is, however, convinced that CO2 emission rights, seen as a raw material for future production, will have important impacts on the revenues of every good producing company with augmenting global business growth. Even if the

[528] Obviously the reports of the compliance committee in 2012 will have an effect on national regulations in 2013 and, therefore, also on the demand of CO2 emission rights. This can have an incisive effect on prices.

[529] The WACC faced by the MotorPS for this case study is derived from similar business in Italy. The DUCATI Motorholding S.p.A., which produces motorbikes in Italy reports for example a WACC of 6.9% in their online annual report, see http://www.ducati.com/company/fd_ita_923_0_report_annuale_31_12_06.pdf , p.28.

[530] The revenue in one specific year corresponds to the quantity of saved CO2 in tons Q_t, times the price of the given year P_t, whereby prices and revenues are in euros.

uncertainty associated with this emission reduction investment is quite fuzzy at first glance, the manager is sure that flexibility to adapt to changes of ecological regulation could become extremely important for the future of MotorPS. As an appropriation request with a negative NPV will hardly be accepted by the controlling department and senior management, the manager decides to check if there is the possibility to determine or even quantify the potential value coming from managerial flexibility and to represent this value as intuitively as possible. He, therefore, decides to check the relevance of a ROA application using the flexibility appropriation request. If he gets satisfactory results, he is convinced that including these results in the company's standard appropriation request will help him getting through the proposed investment in emission reduction.

5.5.2 Checking the relevance of a Real Options Analysis

In the following subchapter, we show how the flexibility appropriation request can be worked through to examine the relevance of a ROA application using the case of to the MotorPS as example. We refer to the proposed application request in appendix F. and go through each part and each point separately. This comprises first of all the application of the ROVG, then the one of the option space, followed by the analysis of the irreversibility and competition, and finally a summary of the found results, and the proposition whether to undertake a ROA.

5.5.2.1 The CO2 emission reduction project in the ROVG

Part 1 of the application request consists of the ROVG and the analysis of the uncertainties and potential managerial flexibilities. Starting with the upper section of the ROVG, first the uncertainties that have a material importance for the project must be determined. Of the listed uncertainties in the ROVG, there is one main risk that will have a great impact on project value: the price risk of CO2 certificates. Technological risk could also affect the implementation of the filter and, thus, the revenues of the project to some extent. However, as it is a well known, well functional technology, big surprises are not expected. Country risk could apply given that Italian government could set up completely different rules for CO2 emission compared to other European Kyoto protocol signers. However, this is not seen as a big risk factor as most industrialized European nations follow the same line in trying to reduce global warming. It is thus fair to focus on the price uncertainty of CO2 certificates. This risk is residual because the product manager cannot assess the exact price of the certificates from 2008 (when the filters are expected to work) until 2027 (when the filters are exhausted) through more research or better analysis. The prices of the certificates can be observed in the European Climate Exchange (ECX), which trades future and option contracts on CO2 certificates. Thus, the uncertainty about expected future prices seems at least measurable through trading prices on this exchange. According to this data, price volatility of CO2 certificates in 2007 is 27%.[531] Due to the results of the Kyoto compliance period, (especially the one in 2013 which is still far away), and the subsequent revisions of governmental regulations, price changes could even get higher. Moreover, the impact on the project value is straightforward. The yearly revenues of the project consist of the amount of money saved from not needing to buy CO2 certificates, thus the price of the certificates times the quantity of reduced emission P_t*Q_t. The yearly emission reduction achieved through the installation of the new equipment is known to be 48’000 tons per year. Also the cost of capital of MotorPS was fairly stable over time and is assumed to remain 6.9% p.a. The price risk of the CO2 certificate is the most important uncertain value driver of the emission reduction investment. However, there is a high likelihood that this uncertainty can be resolved as new information on global warming, CO2 emission levels and consequent regulations will become available over time and will have an immediate impact on certificate prices.

After determining the relevant uncertainty, in our case the price uncertainty of the CO2 emission certificates, the next step is to find a relevant managerial flexibility to play out when new information about certificate prices comes forth. Going through the listed flexibilities in the ROVG, the project manager of MotorPS can immediately remove the growth option as the project is not a firm’s growth project into another business or country. In the same line, the expansion, shrinking, or staging options can be removed from the possible actions as the CO2 filtration equipment can either be installed or not, and any staging or scale-altering possibilities will not change its acquisition price of € 4.5 Mio. Moreover, switching fuel or the operating mode to reduce CO2 emission does not represent a meaningful option as the entire machinery of the facility is designed to run on combustion of carbonaceous fuel. The last viable flexibility in possession of the manager is the one to delay the investment. The manager has the possibility to invest either immediately in 2007 or in every successive year until 2012, according to the evolving certificate prices.[532] The option to invest later than 2012 is not feasible as the

[531] This is the average value of the volatility of price changes for future contracts on CO2 certificates from December 2008 until December 2010, taking into consideration daily price changes from January 2007 until March 2007. In the past, the volatilities were by far higher according to the different environmental reports on the global warming effect and the following regulations. As we do not want to overestimate the option, we used daily prices near to the time window of the start of the investment.

[532] Obviously also in the case of investing later the filtration equipment will take one year after investment to get operative and it will stay running for 20 years after the investment. So, for instance, by investing in 2012, it will be functioning from 2013 through 2032.

technology for the available emission filter will become outdated, and the selling firm will launch new technologies and suspend the sale of the current equipment, only guaranteeing its maintenance for the next 20 years.[533] Thus, using the theoretical notion from chapter 0 we can say that the trigger event that can make the option to wait valuable is the price uncertainty for CO2 certificates and its trigger state, which can provoke the execution of the investment option is represented by a high price. Motivators for this option could clearly be important as prices fluctuate strongly. According to the volatility estimated in advance prices might turn up to be for instance at roughly € 40 at the beginning of year 2013 which is equal to five times the expected price used for the NPV calculation of investing immediately in 2007.[534] Clearly, in this case, the NPV of the project would substantially change to make it highly profitable. Even that this highest possible price is an extreme case, there are many other cases in-between that could also render the project profitable. Thus, without yet calculating any exact numbers on the value of the option, it can already be seen that the motivators to keep the option to wait open are high. Next, the enablers and disablers should be examined. The enablers to get the option are low. With the exception of losing revenues for one year, until the filtration equipment gets operative (remember, it takes one year to get the equipment working), there is no cost to be incurred by waiting.[535] The disablers, i.e. the investment costs for the execution of the option, are set to € 4.5 Mio. The manager is confident that given the firm's overall yearly investment volume of roughly € 100 Mio, the budget for his project is acceptable and realistic if revenues turn out to be satisfactory. Other disablers like the lead time (to implement the filters) and the response time (when the first impact on revenues will be recognizable) are also low. In fact, it will take just one year to make the CO2 filters operative, and the revenues from reduced CO2 emission will be received as soon as the filters are functional. Finally, for assessing the importance of the option to wait for the investment project, its feasibility must also be determined. We called it in the theoretical basics the "capability to change" and proposed to divide it into internal organizational hindrances, possible regulatory constraints, and other hindrances due to unavailable resources. There are no regulatory constraints against installing filters to reduce CO2 emission. Thus, only the other two possibilities that could prevent the option to be exercised must be analyzed. The organizational hindrances in decision-making and execution of the option do not to apply. In fact, the decision-making process can clearly be set up in advance, and there

[533] In this case, a new investment project with new numbers and new options must be analyzed. As we want to keep the case study clearly laid out, we do not expand the investment horizon on newer technology in later periods.

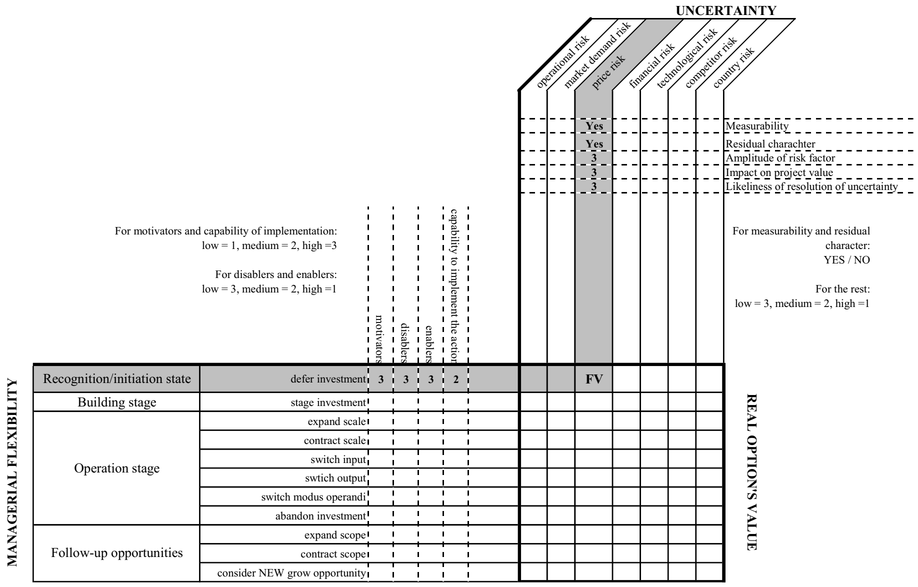
[534] How to model the price process for the CO2 certificates is presented later in Table 5.3. At this point, we only want to highlight how much the price in 2013 can differ from the price 2007.

[535] These costs are small and are thus neglected in the followings of the case study for clarity's sake. Moreover, also a possible price increase of the filtration equipment is ignored as the prices for the CO2 filters are regarded to be stable.

is enough time for senior management to approve an execution of the investment by the project manager when a specified CO2 price has been reached. The available budget for a given year must be available; otherwise, the filter equipment cannot be bought. Being flexible on a budget of € 4.5 Mio over 5 years (from 2007 until 2012) seems to be the biggest stumbling block for the project manager, but he is convinced that the upward price changes to make the project profitable will be attained more likely in the latter period of the waiting period, and so he will put more emphasis on making the budget available at the end of the waiting period. This may limits flexibility to a certain extent but, on the other hand, it augments the probability that senior management could be committed to guarantee the budget for the disposal of the project manager once the trigger state to execute the option has been reached. The project manager should thus make clear in his flexibility appropriation request that the competence to execute the option should be approved and guaranteed in advance, and the budget should be available over the whole five year period, but especially in the last year before expiration of the option in order to make the value of the option real.

Finally the assessed relevant uncertainty, i.e. the price uncertainty of the CO2 emission certificates, and its linkage with the relevant managerial flexibility, i.e., the option to wait, show clearly that there is a potential viable option value inherent in the project of installing CO2 emission filters in the facility of the MotorPS, if the action to install the filters is seen as an option to gain revenues from reduced emissions. Without considering this value, a decision to go or not go for this project would stand on a weak decision basis. All the information is summarized for a quick overview in the ROVG in Figure 5.13. The importance that is given by the manager to flexibility inherent in the project can be seen at a glance before going into further details. The ROVG is filled out as follows: the price uncertainty of CO2 certificates is identified as measurable (YES), residual (YES) and with a high volatility (3) and high impact on project value (3). Moreover, the likeliness that important new information which will change the project's value will become available over time is expected to be high (3). The only viable real option to profit from these high fluctuating prices is identified to be the option to wait. Motivators are expected to be high (3) and the enablers to be low (3). The disablers should also not represent an important hindrance to the execution of the option (3). The capability to change is highlighted to be an important key factor when it comes to make the investment opportunity real and, thus, to obtain real revenues from the investment. The capability to change is annotated only with a value of (2) in the ROVG box. Some narrative explanations should, therefore, be added to explain this lower value. This information should make clear that the project manager should be given the appropriate decision power and a sufficient budget when the time to exercise comes.

Figure 5.13: The ROVG for the CO2 emission reduction project.



After finding that the project comprises a potential valuable managerial flexibility, the next step would be to provide a rough estimation of its value and the corresponding implication for the project's decision. This will be done with the second part of the flexibility appropriation request and shown in the next subchapter.

5.5.2.2 The CO2 emission reduction project in the option space

Part 2 of the flexibility appropriation request deals with the rough valuation of the detected real option and its graphic representation into the option space of Luehrman. For this purpose, three numbers are needed. First, the NPV of the project, which was calculated in advance and, second, the two Luehrman metrics described in chapter 5.3, namely the value to cost metric and the volatility metric. The obtained NPV from investing immediately was found to be € -246'641 and, thus, taking the NPV criterion as a decision rule, the CO2 reduction equipment should not be installed. The value to cost metric is derived by summing the present value of the revenues and dividing them with the present value of the investment costs.[536] As we have the possibility to invest in any year between 2007 and 2012, we must calculate six different values to cost metrics (and also six different NPVs) as if it were six different mutually exclusive investment opportunities. For instance, either we invest in 2008 or 2009, but obviously not in both. Moreover, the volatility metric is calculated by multiplying the volatility, which was estimated with 27% by the square root of the time left for the investment opportunity, i.e., 0 until 5 year depending on which year the investment opportunity is considered. The results for the NPV value in each year and the different option space metrics are reported in Table 5.2. Moreover, the relative positions of the different option values if taking into consideration of investing in a specific year from 2007 until 2012 are represented in Figure 5.14.

Table 5.2: NPV, option space metrics and approximate Black-Scholes option values for the CO2 emission reduction project.

NPV IF INVESTED IN YEAR…

2007	2008	2009	2010	2011	2012
-€ 246'641	*-€ 143'350*	*-€ 44'887*	€ 48'960	€ 138'393	€ 223'607

$NPVq_c$ IF INVESTED IN YEAR…

2007	2008	2009	2010	2011	2012
0.95	0.97	0.99	1.01	1.04	1.06

VOLATILITY METRIC IF INVESTED IN YEAR…

2007	2008	2009	2010	2011	2012
0.60	0.54	0.47	0.38	0.27	0.00

BLACK-SCHOLES OPTION VALUE IF INVESTED IN YEAR…

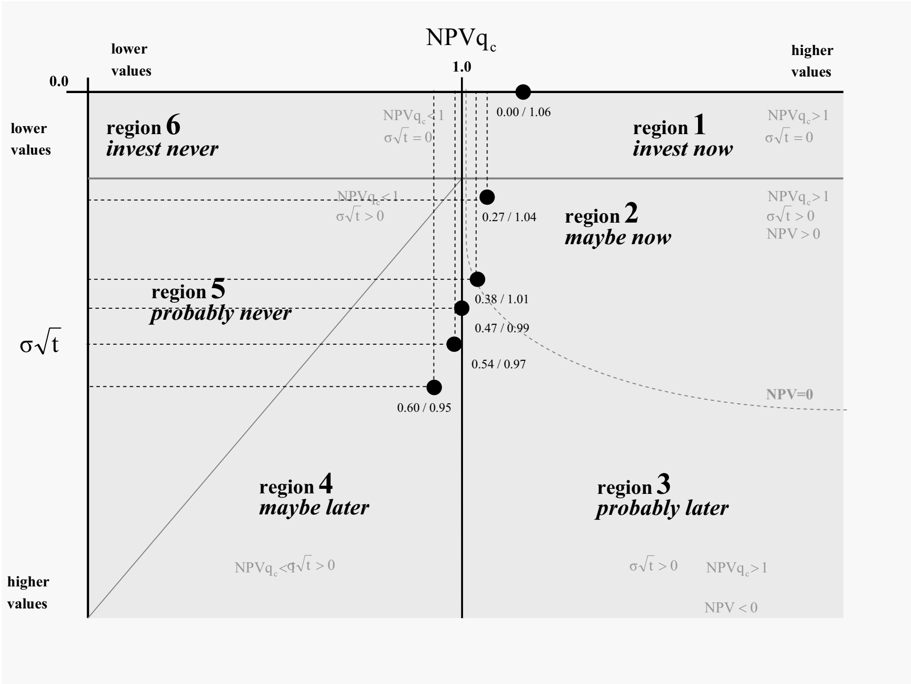
2007	2008	2009	2010	2011	2012
€ 1'251'788	€ 690'756	€ 691'247	€ 678'971	€ 642'174	€ 0

It can be seen from the resulting numbers and from the relative position within the option space that considering an investment in early years, e.g. 2007 or 2008, will get a high option value (the option metrics are higher the higher the time left to invest),

[536] The amount of money for the investment costs grows with the risk-free rate of return until the date of investment if the investment is not initiated immediately. Thus, if we want to not invest until 2012, we have to put aside an amount of money equal to the investment cost in 2012 (4’500’000), discounted by the risk-free rate of return.

whereas investments near to the end of the investment opportunity will show a low option value. The extreme case is the year 2012 when the final decision must be taken because the investment opportunity will vanish forever afterwards. This is clearly in line with standard option pricing theory where a longer time to expiration will result in a higher value for the option. Moreover, comparing earlier investment starting dates to latter ones shows that the value to cost metric will get higher and higher, starting in the “maybe later” region of the option space ($NPVq_c$<0), crossing the $NPVq_c$=1 value and ending in the “probably later” region of the option space ($NPVq_c$<0). This shows that if the project manager can fix the investment costs (as assumed in the case study set-up), then waiting works in his favor because he will need a lower present value of the investment costs if investing, e.g., in 5 years instead of doing it immediately. The results from the option space show clearly that the project could become valuable over time if regarded as an option to wait. There is an evident time value (because of the high volatile prices), which should not be underestimated. Calculating the Black-Scholes option value gives the approximation for the real option values of the projects if waiting for the various starting dates from 2007 through 2012 is considered. The results are reported in Table 5.2. Obviously, in the last year (2012), the option value equals zero because a further year of delay is not possible and, thus, the investment will only be made if the NPV is positive at this moment. For the other years, however, using the Black-Scholes formula to value the option, signals a relevant value that could give rise to the decision to wait instead of investing immediately or turning down the investment opportunity. To sum up, after having detected and presented a potential managerial flexibility which applies to the project, i.e., the real option to wait, the manager of the MotorPS who wants to champion his emission reduction project has found another straightforward argument to complete his flexibility appropriation request and, thus, for getting through is investment proposal. The results of the option space analysis indicate that the emission reduction project seen as a real option to invest later shows a high value and, therefore, much attention should be given to it as it could represent high potential gains for the company. The investment opportunities (for every year from 2007 through 2012) are located near to the value of 1 for the $NPVq_c$ metric, which signals that a more accurate real option analysis could be highly relevant as the option to invest has a intrinsic value close to zero and, thus, a neglected or wrongly calculated real option value could have great effects on the decision whether to undertake the project. Note that the depicted trajectory in the option space which lands in the positive NPV area for the last investment opportunity in 2012 represents one possible way for the investment to end up (to be more precise, the expected one). However, there are many other possibilities to move for the investment opportunity according to the changing prices of the CO2 emission certificates. For this reason and to get more precise investment advices for the various possible resulting certificates, the project manager of MotorPS recommends an accurate real option analysis for this project.

Figure 5.14: The CO2 emission reduction project represented in the option space.



5.5.2.3 Additional information and summary of the flexibility analysis

Part 3 of the flexibility appropriation request analyzes the irreversibility and the competitive situation of the projection under discussion. The irreversibility regarding the project is done quite fast in our case. In the problem set up, we stated that the CO2 filters have to be adapted to the specific case of MotorPS's machinery. The good news is that the seller of the filtration equipment includes these customization costs in the price of the equipment.[537] The bad news from a flexibility point of view is that once the

[537] MotorPS has its core competencies in designing and construing motorbikes, not in adapting CO2 filters to plant machinery.

machinery has been installed, it is difficult to uninstall and sell it to other possible acquirers. The cost involved would be simply too high to make it a viable opportunity. Thus the CO2 emission reduction project is highly irreversible, and this fact augments the importance of being in possession of the flexibility to wait for further information as described in the ROVG analysis above.

The analysis of the competitive situation does hardly apply to this project. Competitor's actions do not erode the option value of this investment opportunity. MotorPS is an outrider what concerns CO2 reduction investments and, even if all direct competitors take steps to reduce emission and the regulation of CO2 emissions in Italy gets looser MotorPS can sell CO2 emission rights through climate exchanges to other companies in other countries around the world.

Finally, the project manager summarizes his findings from the flexibility appropriation request. Seen as an option to wait, the emission reduction project seems to be very profitable, unlike the case if the investment should be carried out immediately. A high volatility in the prices of CO2 emission certificates was observed in the European certificates markets. This price could make the project of MotorPS profitable. Thus, waiting for further information about the development of global warming, legal regulation on CO2 emission, and the subsequent price changes for CO2 certificates would be highly relevant for making any decision of whether to install the CO2 filters. This is also because of the high irreversibility of the investment which could not be resold once adapted to the production facility of MotorPS. The waiting period for the investment opportunity is estimated at five years from today. The investment can be done at the beginning of each year and will be effective from the beginning of the next year. After the five-year period, the filter equipment becomes obsolete. An analysis of the option space and rough estimations of the option value with the Black-Scholes formula gives a high value to the managerial flexibility to wait. Moreover, as the value to cost metric and the traditional NPV are near around zero (thus, the intrinsic value is small) and the volatility metric is high compared to the value to cost metric (thus, the time value is high), a more accurate ROA is highly recommended. The ROA would also deliver possible investment advice on what to do if CO2 emission certificate prices reach specific levels for the given years. In fact, the analysis done so far does not specify what to do, for instance, in year three if the price of the certificates reaches € 23. An accurate ROA could thus help "cultivate" the investment and make it as profitable as possible, deciding year by year what to do. By no means is a project stop suggested only because of the negative NPV of investing immediately. If the levels of CO2 certificate prices are high enough after 2007, then the investment opportunity becomes profitable. The appropriate investment execution competencies and enough capital budget would be requested for this time.

Finishing the appropriation request in this manner will give a succinct and clear overview about the importance that an accurate ROA could have for the project in cause. The combination of the ROVG, the option space, and the additional information about the competition and irreversibility of the project convinces the controlling instance of MotorPS that a detailed ROA is necessary before taking a decision on definitively dismissing it or accepting it. This ROA will be presented in the next subchapter of the thesis.

5.5.3 Applying the ROA to the CO2 emission reduction project

The analysis of the flexibility applying to the project has been taken a step further. A real option valuation consultant gets the mandate to perform the ROA for the emission reduction project. For this purpose, he decides to use the binomial option model described in subchapter 3.3.2.1. The product manager told him that the waiting period is five years from today, what means that the investment opportunity is considered again in every year from 2008 until 2012. The analysis done so far shows clear evidence that in seeing the project through the option lens, there is a value which can be attached to waiting for further price information of the CO2 certificates. However, the interesting information to know would be, if specific levels of certificate prices can make waiting in vain and, thus, the decision to invest immediately could be a superior choice at this moment. Moreover, it would be interesting to know if there is also the possibility that prices attain such low levels that the project will never turn back into the profitable zone and, thus, attentional and financial resources should be better made available to other projects of the company. Applying the binomial option pricing model, the consultant can provide investment advice for every year and for every possible price of the CO2 certificates. For this purpose, he decides to proceed as follows:

1. Setting up the binomial tree for the possible prices of the CO2 certificates.
2. Calculate the respective probabilities of up and down movement of the prices.
3. Calculate the NPV of the revenues obtained in each year for the different prices.
4. Compare the option value of waiting to the NPV of investing immediately and recommend the decision to go or not to go on this basis.

Recall that the important input parameters are given in Table 5.1 and through the discussion of the ROVG. Beside the numbers summarized in the table, the only additional important information we need is the fact that we will be able to invest immediately or delay the investment from one to five years, and that the volatility of the prices of CO2 emission certificates is equal to 27%. We stated above that the price of the certificates today in 2007 is € 5.30. For the second year (2008), the expected price is not anticipated to change. However, this is only the expected price. The real price can move up or down according to the given volatility of 27%. For the ensuing year (and for any given year later), the expected price is supposed to grow with the risk-free rate of return of 4%. Again, these are only average expectations of the management and, obviously, from the volatility of 27%, a completely different real price for a given year can rise. The up-state and the down-state prices for the binomial tree can be derived from the price in the previous period as follows:

$$P_{up,t+1} = P_t * e^{\mu_t + \sigma}$$

$$P_{down,t+1} = P_t * e^{\mu_t - \sigma}$$

Whereby μ_t stands for the expected percentage growth of the certificate prices for the specific year t and σ denotes the volatility of the prices. At this place, it should be mentioned that for the ease of explanation, we take large time steps of one year for the up and down movements of the certificate's price. Obviously, time steps and thus price changes could be applied yearly, monthly, weekly, or daily, depending on the accuracy of the calculations. Table 5.3 shows how the price process is modeled on a spreadsheet program based on the given assumptions.[538]

Table 5.3: Binomial tree price process for the CO2 emission certificates.

(for the first 6 years)

	2007	2008	2009	2010	2011	2012
	€ 5.30	€ 6.94	€ 9.47	€ 12.91	€ 17.60	€ 23.99
		€ 4.05	€ 5.52	€ 7.52	€ 10.25	€ 13.98
			€ 3.21	€ 4.38	€ 5.98	€ 8.15
				€ 2.55	€ 3.48	€ 4.75
					€ 2.03	€ 2.77
	€ 5.30	€ 5.30	€ 5.52	€ 5.74	€ 5.98	€ 6.22

The interpretation of the table is straightforward. The price starts in 2007 at € 5.30. In 2008 it can either move up to € 6.94 or down to € 4.05. What results again in an

538 At this place we show only an excerpt of the complete binomial price tree; the actual model spans the entire time period from 2007 to 2032.

expected price of € 5.30 (reported in the lowest row). For 2009, the price can take up the three mentioned values in the table, whereby the expected value this time is € 5.52 (as we stated above, the expected price grows at the risk-free rate of return of 4%). This goes along for every year equally, with exception of year 2013 (not shown in the table above) where the price jumps to € 8.00, due to the start of the new Kyoto compliance period, which is expected to cause tighter measures to fight global warming. After that price jump, the expected prices continue to grow at the risk-free rate again. The expected prices are obtained as a weighted average of the possible prices in that year using the formula $q = \frac{e^{\sigma} - 1}{e^{2\sigma} - 1}$ for the probability of an up-tick in price and (1-q) for the probability of a down-tick. This will result in the probability tree for future prices represented in Table 5.4.[539]

Table 5.4: Probabilities of future price movements of CO2 emission certificates.

(for the first 6 years)

2007	2008	2009	2010	2011	2012
100.00%	43.29%	18.74%	8.11%	3.51%	1.52%
	56.71%	49.10%	31.88%	18.40%	9.96%
		32.16%	41.77%	36.16%	26.09%
			18.24%	31.58%	34.18%
				10.34%	22.39%
100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

The yearly revenues equal the prevailing emission prices times the saved CO2 emission for the specified year. The second is constant at 48’000 tons per year. So for example if the price goes up for two consecutive years and reaches € 9.47 in 2009, the revenues for this state will result in € 9.47 * 48’000 = € 454’368. The revenues for the first five years and the different possible price outcomes are reported in Table 5.5. Note that for the given year, when investing, the price level is no longer uncertain in this time since it can be observed in the market. This is concretely shows the advantage of waiting to invest.

539 It is important to keep in mind that most of the obtained prices can be reached in several different ways and must therefore be weighted with the according binomial factor. For example, for year 2009 the middle price could be reached in two different ways (either up and down, or down and up).

Table 5.5: Yearly revenues from saved CO2 emission.

(for the first 6 years)

	2007	2008	2009	2010	2011	2012
	€ 0	€ 333'255	€ 454'368	€ 619'497	€ 844'638	€ 1'151'600
		€ 194'204	€ 264'782	€ 361'011	€ 492'211	€ 671'093
			€ 154'301	€ 210'378	€ 286'835	€ 391'078
				€ 122'598	€ 167'153	€ 227'900
					€ 97'408	€ 132'808
	€ 0	€ 254'400	€ 264'782	€ 275'588	€ 286'835	€ 298'541

With these intermediate results the expected present value received in a given year can be calculated. The expected present values of the different years depend on the length of time when the revenues can be gained, on the price of CO2 at the point we started obtaining revenues, and on the possible subsequent resulting prices. Revenues can be gained from the year after investment until 20 years later. Thus, investing, e.g., in 2009, will generate revenues from 2010 through 2029. Moreover, if starting gaining revenues in 2010 with a high price of € 12.91, the revenues will be not only higher for this first revenue in 2010, but also for all the other expected revenues thereafter due to the higher expected prices in the following years. On the other hand, starting for the same year with the lowest price of € 2.55 will make it harder to climb up the ladder. The results for the expected present value are reported in Table 5.6. Note that these present values are not discounted back to today (i.e., 2007), but only to the first year when the revenue is received.

Table 5.6: Expected present value for first year of revenue.

(if investment is done in year t revenues are gained from year t+1 till t+20)

	2007	2008	2009	2010	2011	2012	2013
	€ 0	€ 5'969'774	€ 8'234'722	€ 11'361'300	€ 15'678'178	€ 21'639'743	€ 29'874'313
		€ 3'478'876	€ 4'798'770	€ 6'620'778	€ 9'136'431	€ 12'610'522	€ 17'409'203
			€ 2'796'475	€ 3'858'247	€ 5'324'239	€ 7'348'760	€ 10'145'183
				€ 2'248'387	€ 3'102'691	€ 4'282'477	€ 5'912'088
					€ 1'808'088	€ 2'495'606	€ 3'445'259
						€ 1'454'310	€ 2'007'718
							€ 1'169'994

The NPV of the investment for a given year is now obtained by taking the expected present value calculated above, discounting back to the year when invested and subtracting the investment cost of € 4.5 Mio. For instance, the NPV for 2007 is obtained by discounting back the expected revenues in 2008 to 2007 with 6.9% (the defined WACC for MotorPS) and subtracting the investment costs of € 4.5 Mio. The expected revenues for 2008, in turn, are derived from adding the revenues obtained from a high price of € 6.94 (from the price tree) with a probability of 43.29% (from the probability tree) and the revenues obtained from a low price of € 4.05 in 2008 with a probability of 56.71%. For 2007, the NPV thus results in a value of € -246'641, which is obviously in line with the calculated NPV of investing immediately (as shown in the first section of this case study). The other NPVs for the respective years of investment are derived likewise and reported in Table 5.7.

Table 5.7: NPV when invested in year 2007-2012.

(NPV going back to year of investment, e.g. if invested in 2010 revenues are discounted back to 2010)

2007	2008	2009	2010	2011	2012
-€ 246'641	€ 1'367'095	€ 3'594'727	€ 6'670'427	€ 10'917'937	€ 16'784'923
	-€ 1'080'961	€ 217'188	€ 2'009'547	€ 4'484'776	€ 7'903'752
		-€ 1'751'067	-€ 706'573	€ 735'862	€ 2'728'265
			-€ 2'289'387	-€ 1'448'810	-€ 287'741
				-€ 2'721'925	-€ 2'045'314
					-€ 3'069'536

The NPVs in Table 5.7 are values from direct investment in the given year. Next we have to compare these values with the values of the option to invest. If the NPV turns out to be greater than the option value, then the optimal choice will be to invest. If the option value is greater than the NPV value, then waiting is valuable and recommended. If the option value is zero and greater than the NPV (i.e. a negative NPV results with no time value), then the investment should be canceled, as there is no further possibility that it would make it into the profit zone.[540] In 2012, we set the restriction that it is the last year of deciding about the investment because thereafter the investment opportunity vanishes. Consequently, in 2012, the option value equals zero irrespective of the resulting certificate price. This is reported in Table 5.8 in the last column. If we can

[540] In reality there could always be a very small chance to return in the profit zone. As we start from the assumption that the price model, as well as the volatility and the price estimates are fair, a return in the profit zone is not possible for some very low CO2 prices in our example.

choose whether to invest at this moment, we would clearly only invest if the resulting NPV of immediate investment is greater than zero as there is no remaining value from the option to wait. This is the case for the three highest possible prices in 2012 of our investment example, i.e. € 23.99, € 13.98, and € 8.15, for which we get a positive NPV if investing in 2012. Thus the decision will be to initiate the project and install the filters in those cases. In the other three cases, we let the investment opportunity expire, and the budget can be used for other projects. To calculate the other option values in Table 5.8 we apply the backward valuation. We need to work backwards as the previous values are dependent on later decisions. As we know that our first decision in 2012 is optimal (invest if NPV positive, otherwise let option expire), we can now calculate the option values for 2011, basing the calculation on the optimal decision of 2012 and likewise for the other years. For 2011, for instance, we have to weight the optimal values in 2012 (which turned out to be for the highest three prices a positive NPV from investing immediately and for the lowest three prices 0) with the probability of an up-tick or down-tick and discount them back to 2011. In 2011, for example, the certificate prices of € 17.60 (the highest possible price) this would give:

€ 16’784’923 * 43.29% + € 7’903’752 * 56.71% = € 10’965’164

Table 5.8: Value of the option to wait for a given year.

2007	2008	2009	2010	2011	2012
€ 1'242'327	€ 2'299'709	€ 4'082'372	€ 6'884'948	€ 10'965'164	€ 0
	€ 591'638	€ 1'228'553	€ 2'457'196	€ 4'637'485	€ 0
		€ 179'958	€ 445'393	€ 1'102'338	€ 0
			€ 0	€ 0	€ 0
				€ 0	€ 0
					€ 0

Comparing the option value of Table 5.8 with the NPVs of immediate investing in Table 5.7 we can observe that the NPV are only higher in three cases, namely in year 2012 for the three highest possible prices. In this situation, it would be optimal to invest immediately. For six other cases, we see a negative NPV and an option value of € 0. In these cases it is not possible that the project makes it back into the profit zone and, thus, it should be definitively canceled. For every other price development the option value is greater than the NPV value of a direct investment, thus waiting clearly pays and represents the superior decision. The numbers of an optimal investing decision and the optimal decisions itself are summarized in Table 5.9. The option value to wait for today

(2007) is € 1’242’327 which signals that the project could turn out to be very valuable in future and it should be therefore abstained from canceling the project definitively only because of its actual negative NPV of € -246’641. It should be noted that this value is quite close to the Black-Scholes value calculated in the rough approximation of the flexibility appropriation request. This, however, is not always the case. We constructed the example in a most possible straightforward manner simplifying many characteristic. In doing so, the Black-Scholes calculation resulted very near to the binomial option pricing model. If we had introduced higher prices jumps, stochastic costs, stochastic volatility, or dividends stemming from missed revenues, the differences and especially the investment decision in a given year could have turned out to be substantially different from the Black-Scholes calculation.[541] Thus, accurately modeling the price process of the underlying asset (in our case the revenues from saved CO2 emissions) and properly evaluating the real option valuation tool for the specific situation clearly pays. Additionally, for our case study, it solves the black box aspect of applying simply the Black-Scholes model and getting a value with difficult decision advice to interpret. Furthermore, the nearer the intrinsic value will move around zero, i.e., the nearer the NPV is near to zero, the more a miscalculated option value can lead to a wrong decision.

Table 5.9: Maximum between NPV value of direct investment and option value to wait.

NET PRESENT VALUE WITH OPTIMAL CHOICE

(The influence of the option to defer is included. Thus, the value in the cell equals the maximum between NPV and the value of the option.The value of the option today (2007) is reported in bold.

2007	2008	2009	2010	2011	2012
€ 1'242'327	€ 2'299'709	€ 4'082'372	€ 6'884'948	€ 10'965'164	€ 16'784'923
	€ 591'638	€ 1'228'553	€ 2'457'196	€ 4'637'485	€ 7'903'752
		€ 179'958	€ 445'393	€ 1'102'338	€ 2'728'265
			€ 0	€ 0	€ 0
				€ 0	€ 0
					€ 0

[541] As already noted in chapter 3.6.1 when discussing the theoretical critiques towards the ROA.

OPTIMAL DECISION INCLUDING THE OPTION TO WAIT

2007	2008	2009	2010	2011	2012
WAIT	WAIT	WAIT	WAIT	WAIT	INVEST
	WAIT	WAIT	WAIT	WAIT	INVEST
		WAIT	WAIT	WAIT	INVEST
			CANCEL	CANCEL	CANCEL
				CANCEL	CANCEL
					CANCEL

To conclude our case study, the ROA consultant suggests to the project manager to wait till the very end of his investment opportunity in 2012, and to invest at this time if the NPV is greater than zero. An earlier investment would kill some time value still inherent in the project and is, thus, not optimal. Should the price fall to or below the level of € 2.55 in 2010, then the project cannot make it back in the profit zone, and the investment opportunity should be rejected immediately. In this case, it is advisable to withdraw any attention or capital resources from the CO2 equipment filter project and to buy emission certificates to keep the facility running.

5.6 Conclusions and critical discussion of the framework

The organizational aspect emphasized through this thesis spreads the different aspects of the valuation of a project over different people and specializations of the company. Consequently, we suggest a clear cut between determining the appropriate managerial flexibility applying to a project and valuing them with mathematical models. Both tasks are not trivial, and both need experts in their fields. Experienced project managers can judge well which possible managerial flexibility comes into play for a specific project and which is unrealistic. On the other hand, a specialist in ROA will be able to construct the right valuation model based on the inputs of the project manager. In this chapter, we focused on the first step of determining the potential real option inherent in a project, because we think that not much work has been done on this crucial preliminary step of real option valuation. The great majority of academic articles do not treat the detection and choice of valuable real options but, instead, real options to be valued are always taken as given a priori. We believe that this assumption does not properly reflect all challenges of the ROA in practice, where the exercise to systematically unveil the realistic flexibilities of a project it is not a trivial task. Our main target was to determine for a given project whether taking the further step for an accurate and elaborate ROA would be relevant. For deciding this question, we concluded that the project must be examined in three aspects. First, it must be examined on the prerequisites for the option analogy. Then it has to be checked whether the implementation of the determined real options is realistic. Third, a rough and quick approximation of the option value should be done. We, therefore, presented a framework based on the ROVG and the option space of Luehrman, which offers a structured approach to detect valuable real options inherent in a project and helps to assign a rough value to the available option. Being based on the relationship between uncertainties and different types of managerial flexibility to respond to them, the ROVG may be subject to critical discussion with respect to the different categories of real options and uncertainties. Also the filters to eliminate irrelevant real options or uncertainties can get specific for a given industry or project type, and a generalization of them could lead to questionable conclusions. Nevertheless, the basic idea still holds, and other option types, uncertainties, and filter characteristics could easily be integrated into the ROVG. We think that applying the ROVG allows for an intuitive discovery process of real options closer to managerial thinking compared to very complex real option valuation models with stochastic calculus and differential equation which will hardly be practicable in real life. Furthermore, augmented intuition facilitates communication and eases the appropriation request process. The communication problem was stated to be one of the major hindrances in implementing ROA for project valuation in our survey carried out through Swiss firms.[542] For this reason, we proposed a flexibility appropriation request that could be used to communicate real option values. Applying the ROVG and the option space in combination would not only deliver worthwhile information on the relevance of the ROA application to a project, but it is also a sort of “down payment” for a potential following more accurate ROA. The efforts of filling out the flexibility appropriation request are thus by no means wasted time. Inputs coming from it will help the ROA specialist set up a more accurate valuation model if it comes to a definitive ROA of the project. If, on the other hand, it is found that a more detailed ROA is not relevant or unneeded for the given project, the manager will at least remain with important information about the flexibility aspects of the examined project and with an approximate estimation of this value. This will help to discriminate between flexible and inflexible investment opportunities and enhance the investment decisions without using demanding mathematical models. We, therefore,

[542] See chapter 4.5.3.

think that applying the flexibility appropriation request will be an aid in determining the most accurate project value as possible and help managers in exposing and justifying them as intuitively as possible.

6 Summary and Conclusions

The focus of this work is on the valuation of managerial flexibility inherent to investment projects. We have examined the possible role which Real Option Analysis can play in practice to assess the value of managerial flexibility in investment projects. According to the main objectives of the dissertation we summarize following aspects:

- The reason why valuing managerial flexibility is important
- The available alternatives to value managerial flexibility in practice
- The theoretical and practical critiques of the ROA for investment valuation
- The main application areas of the ROA treated in academic literature
- The treatment of the value of flexibility by Swiss firms
- The framework to analyze the relevance of the ROA for an investment valuation

The reason why valuing managerial flexibility is important

Managerial flexibility in this study is defined as the ability of management to alter its operating strategy or the course of a single project rapidly and with low cost, by acting in response to the resolution of market uncertainty over time, in order to capitalize on favorable future opportunities or mitigate losses. We adopted the six different types of managerial flexibility by Trigeorgis (also called real option types) to develop our ideas. The real option types are:

1. the *option to defer* an investment,
2. the *option to alter the operating scale or scope* of the investment (expand/shrink)
3. the *option to stage* an investment (time-to-build option),
4. the *option to abandon* an investment,
5. the *option to switch* the input, the output or the operating mode of an investment
6. and the *growth option*, which represents investments which are seen as growth opportunities for the firm.

An investment project with one ore more of the above-mentioned flexibilities has a different value than an investment without these flexibilities. As all these flexibilities are rights but not obligations, an investment with flexibility is always worth more (or at least equal) to an investment without flexibility. Failing to assign the right value to flexibility can lead a firm to misvalue a project, to reject investment opportunities that would be worth doing and, thus, to lose revenues. We demonstrated what could happen in chapter 2.2 by means of an example. Thus giving the right value to managerial flexibility is highly important. Moreover, the more volatile business environment is, the more likely will it be that unforeseen events can change the outcome of a project (either positively or negatively). Managerial flexibility will be more valuable in those cases as it allows, per definition, to profit from upcoming unforeseen positive events and to protect from negative ones.

The available alternatives to value managerial flexibility in practice

Recognizing the value of managerial flexibility and trying to attach a value to it is nothing new to business practice. The currently most common investment valuation technique, the net present value (NPV), neglects the managerial flexibility associated with investments. Therefore several alternatives have been developed which complement the NPV in this sense. These alternatives are:

1. *Rules of thumb*, which are arbitrary changes of the project parameters (e.g. a lower discount-rate, a higher cash flow, etc.) to account for the added value of managerial flexibility.
2. *Sensitivity and scenario testing*, which account for flexibility in as far as they unveil sensible project parameters to which more attention has to be dedicated. In doing so, a decision maker will be forced to reveal the valuable flexibilities the project set-up provides to him or elaborate some new flexible actions to deploy in case of unexpected developments.
3. *Monte Carlo simulation*, which extends sensitivity and scenario testing by replacing single parameters with probability distributions, whereas it accounts in the same manner as sensitivity or scenario testing for flexibility.
4. *Decision Tree Analysis (DTA)*, which, in contrast to the three afore-mentioned methods, accounts directly for the fact that decision makers operate in a dynamic world and need therefore to capture the value of their flexibility to respond to unfolding events. This is done in representing investment opportunities as trees and assigning probabilities to different actions (flexibilities) which can be undertaken in case of a given state of nature that is not clear yet at the beginning of the investment.

All four alternatives are helpful in complementing the NPV in its flaw of accounting for the value of managerial flexibility. However, every methodology suffers some disadvantages which make it necessary to look for another flexibility valuation approach. This has been identified in the *Real Options Analysis (ROA)*, which at least from a theoretical point of view is the most sophisticated methodology to value managerial flexibility. In the ROA, an investment opportunity (i.e., a real option) is regarded as analogous to a financial option because of their similar payoff structure. A real option represents the right, but not the obligation, to take an action on an asset in place (one or more of the managerial flexibilities mentioned above) at a predetermined cost, called the exercise price, during a predetermined period of time, that is, the life of the option. Thus, according to its similarity to a financial option (which is also a right, but not an obligation) in a ROA, the value of an investment opportunity is determined in the same way as the value of a financial option. The ROA ties the value of the investment opportunity to six parameters analogous to the valuation of financial options, namely:

1. the present value of the cash flows deriving from the project‘s operating assets to be acquired,
2. the expenditure required to acquire the project’s assets,
3. the length of time during the investment decision is available,
4. the risk-free rate of return, and
5. the volatility of the present value of the cash flows of the project’s operating assets.
6. the dividends, i.e. the forgoing free cash flows if the investment opportunity is not started immediately (or not started at all).

This is in line with financial stock option valuation, which in its standard form uses the stock price, the strike price (to acquire the stock), the time to expiration (of the financial option), the risk-free rate of return, and the volatility of the stock’s return to determine the value of a financial option on a company’s stock.

The theoretical and practical critiques of the ROA for investment valuation

The analogy between financial options and real option, however, is limited to some extent. Therefore, several critiques arise which we discussed extensively in chapter 3.6. These theoretical critiques derive from:

1. the market completeness, which is not given for investment projects,
2. the complexity of the valuation of interacting multiple real options,
3. the influence a decision maker can have on certain valuation parameters which for financial options are exogenously and thus not influenceable (e.g., volatility, price of the underlying),
4. the distribution of the underlying’s price, which is assumed to be normal in financial option valuation, whereas it is not for investment projects, and
5. the counterparty risk which is minimal for financial options and ambiguous for investment projects.

Beside this cutups deriving from the option analogy of the ROA, there are two other major issues in practice, which must be addressed: first, the difficulty of recognizing the “realistic” real options and, second, the complexity of the mathematical modeling of the real option valuation problem. For this reason, we propose to strictly separate the two tasks. The project leader, who is a specialist in his business but not necessarily familiar with mathematical models, knows the uncertainties of the project and recognizes the potential action flexibilities at his disposal. The manager should deliver the appropriate information to model the valuation problem. Real option specialists, either organized as an internal department of a company or externally mandated, could subsequently build the valuation model and suggest estimation methods for input parameters tailored on the specific situation of the project. To guarantee a maximum of efficiency within this process, a sound and simple communication must be guaranteed. In chapter 3.5 we, therefore, provide an overview of real options valuation approaches to support the ROA user to get an idea of what is possible and what is not with a specific valuation approach in regards to the valuation for his project. These approaches do not represent closed-end solutions for specific investment problems, but rather stand for different ways to see the real option valuation process, to get input parameters for the valuation itself and to interpret the results of a ROA.

The main application areas of the ROA treated in academic literature

The end of chapter 3 represents the passage from the more theoretical aspects to more praxis-relevant aspects. For this reason, we introduced the most frequently cited practical application areas in the real option literature. Not surprisingly, research and development projects or projects in natural resources have been diligently researched as these types of projects exhibit both great uncertainty about future outcomes as well as the potential of flexible action to adapt to this uncertainty. For this reason, the ROA is mostly regarded to be closely related to this two application areas. However, this is not true. We sketched many other application areas where ROA has been implemented and produced interesting results. To cite some examples, the ROA has been applied in flexible manufacturing, in corporate events (mergers and acquisitions, initial public offerings), in land development, in deciding about business contracts (with, e.g., suppliers), in large and irreversible infrastructure investments or for expansion strategies to foreign countries. We found application examples for switching tax regimes, valuing film projects, or introducing a new sort of beer. This illustrates that the ROA is not limited to research and development or natural resources. All reviewed application areas share three important characteristics at a considerable level for their relevant investment projects: first, they face a high degree of uncertainty; second, they include irreversible decision and investments; and, third, they leave room for managerial flexibility. These are the conditions which have to be met to make a ROA meaningful for an investment project.

The treatment of the value of flexibility by Swiss firms

As we wanted to enrich our statements with information from the business world, we examined the practice of valuing managerial flexibility by Swiss firms. We surveyed 429 Swiss companies and got a response rate of roughly 20%, which is at the head of the range for surveys of this dimension (12 pages and 18 questions), targeted at very senior management of the company (the questionnaire was sent to the CFOs). We found that the value of different types of managerial flexibility, i.e., real options play an important role in the Swiss business community. Depending on industries and size of the companies, many different types of valuable managerial flexibility occur, which are stated to be potential reasons to change investment decisions. However, their valuation is not always considered and, if it is, then this happens mostly by intuition and very seldom with the ROA. The major hindrances to applying ROA are the perception that it would take significant efforts to learn and implement and that it is difficult to communicate the calculated results to all involved parties. Of course, this low level of ROA application does not necessarily imply that managers make bad decisions, nor does it rule out the possibility that a more systematic analysis of the appropriate value of managerial flexibility could improve the selection of investment opportunities. In using the ROA, premises would be created to consider also good investment opportunities which would have been missed without putting a value to flexibility.

We divided the companies in two different pools: the one whose officers stated to perceive great uncertainty, irreversibility, and have great potential for implementing flexible managerial actions; and the one that did not show these characteristics. Whereas the latter are of minor interest for a ROA application, the former should at least show a high consideration of the value of managerial flexibility (either by means of the ROA or with another method). We found many companies in the former group that stated to not consider the value coming from flexibility and if, then only in an arbitrary way. From a theoretical point of view in these cases there should be great potential for a ROA application with beneficial effects for the company's decision-making. Surprisingly, our survey revealed that companies in the financial industry were among the ones that stated to consider the different types of managerial flexibility more often. Especially the option to stage investment and the option to defer investments seem to be two managerial actions that are often considered in financials. Moreover, we found that companies in the financial industry not only consider the value of managerial flexibility, but also were found among the rare companies that tried to apply the ROA for their valuation needs. This was not expected as the real option approach has the reputation of being tied above all to good-producing firms undertaking R&D projects or investment in natural investments. We decided to survey the financial sector as well in our sample because of its importance for the Swiss economy and were positively surprised. The reason for this more frequent utilization of the ROA in financials could be that option theory in general applies as well to other business activities of the industry. Consequently, dealing with volatility, intrinsic value and time value is more common in the financial industry. This lowers the entry barriers into the new investment valuation method, and the step from the financial option to the real option valuation could result less challenging as in other industries. However, we have no evidence for this statement, and it remains only a hypothesis unless examined in future surveys.

The framework to analyze the relevance of the ROA for an investment valuation

The suggested separation between the assessment of potential real options inherent in a project and the subsequent valuation has the following implications:

1. The complete valuation process can get expensive. Especially the modeling of the valuation problem can get very elaborate. Thus, for a company it is only meaningful to undergo these efforts if the ROA will yield relevantly different results from the commonly used valuation methods.
2. A structured and simple mean of information is needed which allows gathering the appropriate information about the relevant real options inherent in a project and refer it from the ROA end-user to the ROA modeler.

To address these two issues, we propose a framework that consists of a combination of two models – the Real Option Value Grid (ROVG) and the option space by Luehrman. The ROVG allows a systematic examination of an investment project with respect to inherent valuable real options. This analysis is based on the assessment of the three constitutive characteristics of real option value, namely irreversibility, uncertainty, and flexibility. Thus, finding a high level of irreversibility, uncertainty, and flexibility in an investment opportunity would mean that it is highly likely that the investment opportunity incorporates valuable real option value, i.e. valuable managerial flexibility. The more likely an investment will incorporate real options, the more relevant will be a ROA. The second part of the framework is represented by the Luehrman option space, which allows to quickly generate a rough approximation of the real option value based on readily available data from standard investment proposals and on some estimates of the remaining option parameters. In this way, a ROA user will get an intuitive picture about the development potentialities and the crucial flexibility value drivers of the analyzed project. The more likely the approximated real option's value could change the investment decision, the more relevant an accurate ROA will be. In Luehrman's option space, this is the case for investments with a high volatility metric and a value to cost metric of roughly 1. The advantage of this combined analysis consisting of, first, the assessment of the real option's value prerequisites and, second, the approximation of the real option value, are straightforward in regards to the above-mentioned implications:

1. The costly and elaborate part of the valuation process will only be started if the project demonstrates to incorporate relevant and valuable real option value. Only in these cases is an accurate ROA relevant and will reward the decision maker with a maximum of additional decision-relevant information.
2. The ROVG and the option space allow gathering useful information on flexibility valuation in a structured way. This information can be summarized and presented in what we call a "flexibility appropriation request". This flexibility appropriation request could be used as an information medium and make the way from the project manager, through the controlling department of the company, until a ROA modeler (if an accurate ROA is found to be relevant for the given project).

The ROVG and the option space application is simple, intuitive, and more easily communicable than complex real option valuation models with stochastic calculus and differential equation, which are hardly understood in everyday business life. The information required to complete the ROVG and the option space is based on well-known concepts and available data, and the clear structure of the process should be helpful to establish routine procedures, which are of great advantage in a fast moving environment like today's business world. The structured information (at least the less sensible one) could furthermore be used in communication with external parties to reveal valuable information that could help investors or analysts discriminate between inflexible and flexible companies (which are more valuable).[543] We think that in this sense, the ROVG and the option space could be of great help. Obviously, to set up the framework, a trade-off between completeness and complexity was necessary. The transparency and understanding of the value of managerial flexibility deteriorates quickly when the user is confronted with more complex models. We think that with the ROVG and the option space, we achieved a well-balanced solution that is simple enough to be quickly understood and familiar enough that the need for further

[543] The lack of communicability of a ROA was stated to be one of the major hindrances by Swiss companies in implementing the ROA in practice.

explanations is limited. On the other side, however, it is neither superficial nor trivial and stresses the important aspects of the value of managerial flexibility inherent to an investment project. Using the framework as a preliminary step for a valuation of managerial flexibility could, therefore, be of support in both, understanding and explaining intuitively where the flexibility value comes from and preparing the important information for a more accurate and detailed ROA.

Our overall scope of the dissertation was to analyze the challenges and opportunities of the application of the real option theory for the valuation of managerial flexibility in practice. We are convinced that applying the ROA for valuing managerial flexibility inherent in an investment project can be highly beneficial in order to undertake a founded investment decision. However, the real-life application of the real option theory is still prevented by many challenges which must be taken. Propagating the ROA in practice requires more than only a mechanical application of a set of valuation techniques. The real option approach should be shaped as a tool for framing and thinking about investment problems. This encompasses information gathering, data capture and analysis, model building, and assumption setting, but also report writing and communication. We think that our proposed separation of real option detection and real option valuation can be of help to tackle the challenges in assigning the specific tasks to the experts in their fields. Additionally, the ROVG and the option space can represent a substantial support for framing an investment problem within a dynamic flexibility set-up, before going further to an accurate ROA. We are of the opinion that applying this flexibility thinking within a rigorous and structured framework will help to propagate its utilization for different project valuation problems of different industries and companies. Only if additional experience and confidence in the ROA could be gained, a "critical mass" of knowledge will be accumulated which, in turn, will accelerate its practice. We hope that this dissertation, by placing the ROA in a broader context, will stimulate the interest of researchers as well as practitioners to further developments and additional applications of what has come to be known as the real option theory.

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Appendices

Appendix A.: Survey questionnaire - English version

Please note: the questionnaire has exclusively been sent to the respondents in German and French. The questionnaire has been translated into English for the convenience of the reader as this dissertation is written in English.

VALUATION OF MANAGERIAL FLEXIBILITY WITHIN THE INVESTMENT PROJECT APPRAISAL PROCESS

A SURVEY OF SWISS COMPANIES

University of Zurich
Swiss Banking Institute

Prof. Dr. Rudolf Volkart
lic. oec. publ. Pietro Scialdone

INSTRUCTIONS FOR THE QUESTIONNAIRE

Notes:

- It will take you roughly **30 min** to answer this questionnaire.
- The results of the survey will be presented in the dissertation exclusively in **aggregated form**.
- In the questionnaire the term „project" will always be understood as **„investment project"**. Please exclude projects of minor economic importance for your company (i.e. low project risk, small project size).
- Please consider for your responses only the experience of the last **three business years**.
- Please return the questionnaire with the pre-stamped, self-addressed envelope up to **November, the first 2006**.

Structure: The questionnaire consists of **18 questions** subdivided in 3 parts:

Part 1 Questions about the Valuation of Investment Projects
Part 2 Questions about the Applications of the Real Option Analysis (ROA)
Part 3 Questions on the Relevance of the Valuation of Managerial Flexibility

Type of question: **Selection type**: Please mark only **ONE** out of two or more choices.

Mark in this way: ☐ ☐ ☐ ☐ ☒
Correct: ☐ ☒ ☐ ☐ ■

Statement type: Fill in **ONE** response (number, statement, etc.). Please write in **block letters**.

Contact: In case of questions you can reach me under the contact details mentioned below:
Pietro Scialdone, **scialdon@isb.unizh.ch**, **+41 76 XXX XX XX**

Part 1 Questions about the Valuation of Investment Projects

1. How frequently do you use the following methods to evaluate investment projects?

	Very frequently	Frequently	Occasionally	Seldom	Never
Cost comparison method, profit comparison method or accounting rate of return	☐	☐	☐	☐	☐
Payback method	☐	☐	☐	☐	☐
Internal Rate of Return (IRR)	☐	☐	☐	☐	☐
Net Present Value (NPV)	☐	☐	☐	☐	☐
Decision Tree Analysis (DTA)	☐	☐	☐	☐	☐
Sensitivity Analysis	☐	☐	☐	☐	☐
Monte Carlo Simulation	☐	☐	☐	☐	☐
Real Option Analysis (ROA)	☐	☐	☐	☐	☐
Other: ______________________	☐	☐	☐	☐	☐

2. How frequently do you consider the value which could be generated by the following types of managerial flexibility when evaluating investment projects?

	Very frequently	Frequently	Occasionally	Seldom	Never
The possibility to defer the starting date of the project in order to wait for supplemental information.	☐	☐	☐	☐	☐
The possibility to alter the operating scale (shrink/expand) during a projects lifetime according to the changing market conditions.	☐	☐	☐	☐	☐
The possibility to stage the investment of a project as a series of outlays.	☐	☐	☐	☐	☐
The possibility to abandon a current project if market conditions worsen severely.	☐	☐	☐	☐	☐
The possibility to change the output mix of a project or to produce the same outputs using different types of inputs according to changing market conditions (e.g. input: replace labor forces through capital; e.g. output: produce umbrellas instead of sunshades).	☐	☐	☐	☐	☐
The possibility to realize projects independently from their direct value just because they could open up future investment opportunities (e.g. in order to generate knowledge or collect information for potential business areas or new regions).	☐	☐	☐	☐	☐
Other: ______________________	☐	☐	☐	☐	☐

If all your answers to the questions in this block are „**Never**", please proceed to question 8.

3. If you quantify any type of managerial flexibility mentioned in question 2, how frequently do you use the following methods?

	Very frequently	Frequently	Occasionally	Seldom	Never
Surcharge on the project value determined by intuition/experience	☐	☐	☐	☐	☐
Adjustment of the discount rate determined by intuition/experience	☐	☐	☐	☐	☐
Decision Tree Analysis (DTA)	☐	☐	☐	☐	☐
Real Option Analysis (ROA)	☐	☐	☐	☐	☐
Other: ____________	☐	☐	☐	☐	☐

4. How frequently does it happen that you realize a project due to any type of managerial flexibility mentioned in question 2, even if according to your standard capital budgeting techniques (e.g. NPV, IRR or Payback rate) it should not be accepted.

Very frequently	Frequently	Occasionally	Seldom	Never
☐	☐	☐	☐	☐

Survey on the Valuation of Flexibility in Investment Projects 4 / 12

Part 2 Questions about the Application of the Real Option Analysis (ROA)

5. Application of the real option method for investment valuation

	YES	NO	
Do you know the Real Option Analysis (ROA) to value investment projects?	☐	☐	If no, please proceed to question 8.
Have you ever applied the Real Option Analysis to value investment projects?	☐	☐	If no, please proceed to question 7.

	Very frequently	Frequently	Occasionally	Seldom	Never
If Yes, how frequently do you still apply the Real Option Analysis?	☐	☐	☐	☐	☐

6. Which are/were the biggest problems in applying the Real Option Analysis?

	Rather true	Rather false
Identification of the real options within the project	☐	☐
Mathematical modeling of the real options	☐	☐
Assessment of the parameters like volatility, underlying, time to maturity etc.	☐	☐
Communication of the obtained values to all involved parties and pressure groups	☐	☐
Other: ______________________		Please proceed to 8.

7. Why did you never apply the real option method even if you know it?

	Rather true	Rather false
The value of the managerial flexibility is not being taken in consideration.	☐	☐
The value of the managerial flexibility is being taken in consideration only qualitatively.	☐	☐
The application of the Real Option Analysis is too costly or complicated.	☐	☐
At the moment we do not have the know-how for an adequate application of the real option method.	☐	☐
The initial effort to acquire real options know-how is considered to be too high.	☐	☐
Managerial flexibility plays a subordinate role within our projects.	☐	☐
The input parameters for real option models are difficult to specify/estimate.	☐	☐
The project value obtained by Real Option Analysis is difficult to communicate. (e.g. to shareholders/stakeholders).	☐	☐
There is a risk of abuse of methodological skills by ROA-specialist.	☐	☐

Other: ______________________

Part 3 Questions on the Relevance of the Valuation of Managerial Flexibility

If you should have any difficulties in responding to one of the following questions (especially starting from question 10) because the projects supervised by you are very heterogeneous, please consider the last industry-specific project for answering to the questions. Please describe it shortly in few words (e.g. the development of a new medicament, the implementation of a new IT infrastructure, the launch of new financial products, etc.)

8. How strongly are the strategic relevant projects of your firm exposed to following risk categories?

	Very strong	strong	moderate	weak	Very weak
Market demand risk	☐	☐	☐	☐	☐
Technology risk	☐	☐	☐	☐	☐
Interest rate risk	☐	☐	☐	☐	☐
Inflation risk	☐	☐	☐	☐	☐
Exchange rate risk	☐	☐	☐	☐	☐
Risks from legal/regulatory changes	☐	☐	☐	☐	☐
Geopolitical risk	☐	☐	☐	☐	☐
Environment risk	☐	☐	☐	☐	☐
Demographic risk	☐	☐	☐	☐	☐
Risk from changes of social trends	☐	☐	☐	☐	☐
competition risk	☐	☐	☐	☐	☐

9. Does it occur often that new information alters the project outcome that strongly in order to change the decision about the scale of the project or even its continuation?

Very often	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

10. If you have to suspend a project and want to *reverse* all investment costs, ...

	Very easy	easy	Moderately	hard	Very hard
... how easily can you do this?	☐	☐	☐	☐	☐
	Very high	high	Moderate	Low	Very low
... how high were the incurred costs in reversing the decision?	☐	☐	☐	☐	☐
... how many % of the initial investment costs can you roughly recover in average?	approx. ________	%			

11. Please judge the following statements:

	Rather true	Rather false
The investment costs arise mainly from industry-specific assets.	☐	☐
The investment costs arise mainly from know-how or other intangible assets (e.g. consultancy, marketing, training, etc.)	☐	☐
The main part of your investment costs consists mainly of fixed costs.	☐	☐
There is an efficient second-hand market if you want to liquidate the executed investments.	☐	☐
There are often institutional arrangements which hinder a divestiture on the second-hand market.	☐	☐
There are often governmental regulations which hinder a divestiture on the second-hand market.	☐	☐
Your industry is characterized by strong competition.	☐	☐
There are high entry barriers if someone wants to start a project in your industry.	☐	☐
There are legal requirements which could get you competitive advantages (e.g. bank license).	☐	☐
Your company is in possession of exclusive rights which could get you competitive advantages (e.g. Patents, mining rights etc).	☐	☐

In the following questions the point is to find out if specified, potentially valuable managerial actions (like e.g. the delay of the start of the project or the adjustment of the project's scale during its lifetime) are planned in advance, respectively are executed during the project's life.

12. Delay of the start of the project

	Very often	Often	Sometimes	Rarely	Never
How often does it occur that you delay the start of the project to wait for more value-creating information?	☐	☐	☐	☐	☐
How often do you consider a possible delay of the start of the project already in the planning phase of the project?	☐	☐	☐	☐	☐

If a planned delay of the start occurs **rarely** or **never**, what are the reasons? (Otherwise please proceed to question 13)	Rather true	Rather false
There is the peril that you will be anticipated by competitors.	☐	☐
The possibility to wait would change the value of the projects only marginally.	☐	☐
Waiting would be too costly.	☐	☐

Other: ______________________________

13. Adjustment of the production capacity

	Very often	Often	Sometimes	Rarely	Never
How often does it occur that the project scale is being expanded or shrunk due to new decision-relevant information arriving with ongoing operations?	☐	☐	☐	☐	☐
How often do you consider a possible adjustment of the project scale already in the planning phase of the project?	☐	☐	☐	☐	☐

If an adjustment of the project scale occurs **rarely** or **never**, what are the reasons? (Otherwise please proceed to question 14)	Rather true	Rather false
The possibility to adjust the scale with ongoing operations would change the value of the projects only marginally.	☐	☐
The conversion to a new project scale would take too long time to profit from the new information.	☐	☐
Adjusting the project scale would be too costly.	☐	☐

Other: ______________________________

Survey on the Valuation of Flexibility in Investment Projects 8 / 12

14. Segmentation of the project in multiple stages					
	Very often	Often	Sometimes	Rarely	Never
How often does it occur that a large project is split up in different stages and that the investments are done sequentially (from milestone to milestone)?	☐	☐	☐	☐	☐

If a segmentation of the project occurs **rarely** or **never**, what are the reasons? (Otherwise please proceed to question 15)	Rather true	Rather false
The possibility to split up the project would change its value only marginally.	☐	☐
The segmentation of the project would be too costly.	☐	☐
The projects' size are mostly too small or the projects' length are too short to split them up.	☐	☐
Other: ______		

15. Abandonment of the project					
	Very often	Often	Sometimes	Rarely	Never
How often does it occur that because of very bad market-conditions a project is being immediately abandoned?	☐	☐	☐	☐	☐
How often do you consider a possible project abandonment already in the planning phase of the project?	☐	☐	☐	☐	☐

If a project abandonment occurs **rarely** or **never**, what are the reasons? (Otherwise please proceed to question 16)	Rather true	Rather false
The possibility to abandon the project would change its value only marginally.	☐	☐
A project abandonment would be interpreted extremely negatively by your shareholders and stakeholders.	☐	☐
An abandonment of the project would be too costly.	☐	☐
Other: ______		

16. Change of input- and/or output products during ongoing project
(Example input: replace labor forces through capital; example output: produce umbrellas instead of sunshades)

	Very often	Often	Sometimes	Rarely	Never
How often does it occur that, according to varying market-conditions, the original input and/or output product is being changed with ongoing operations?	☐	☐	☐	☐	☐
How often do you consider a change of input and/or output products already in the planning phase of the project?	☐	☐	☐	☐	☐

If a change of input and/or output products occurs **rarely** or **never**, what are the reasons? (Otherwise please proceed to question 17)	Rather true	Rather false
The conversion to a new input and/or output product would take too long time to profit from the new information.	☐	☐
The conversion to a new input and/or output product with ongoing projects would be too costly.	☐	☐
The conversion to a new input and/or output product would be a too drastic action from a strategic point of view to implement with ongoing operations.	☐	☐

Other: ______________________________

17. Projects for originating new, value-creating investment opportunities

	Very often	Often	Sometimes	Rarely	Never
How often does it occur that projects are being deliberately realized independently from their direct value, just because they could generate the basis for future investment opportunities (e.g. knowledge, information, relationship etc.)?	☐	☐	☐	☐	☐

If such types of project occur **rarely** or **never**, what are the reasons? (Otherwise please proceed to question 18)	Rather true	Rather false
This action would be too costly.	☐	☐

Other: ______________________________

18. For the evaluation of your answers we need the following information:

Your company:

The name of your company: ____________

Number of the employees of your company: ____________

To your person:

How many investment projects do you appraise each year (included the rejected projects)? ____________

Which amount invested are you roughly responsible for each year? ____________

Industry of your company:

- ☐ Banks
- ☐ Construction & Materials
- ☐ Chemicals
- ☐ Retail
- ☐ Utilities
- ☐ Financial Services
- ☐ Health Care
- ☐ Basic Resources
- ☐ Industrial Goods & Services
- ☐ Media
- ☐ Food & Beverage
- ☐ Noncyclical Goods and Services
- ☐ Technology
- ☐ Telecommunications
- ☐ Insurances
- ☐ Cyclical Goods and Services
- ☐ Other

Do you have any commentaries to the questionnaire?

____

____

____

____

____

Thank you very much for having completed the questionnaire!

If you are interested in the results of the survey please fill in the address field below.

Contact person:

Name/Surname ____________________

____

Function ____________________

Street ____________________

Zip code/city ____________________

Phone number ____________________

E-Mail address ____________________

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Appendix B.: Test results for equality of population median

For testing the hypothesis of equality of population median, we used the Kruskall-Wallis H-test, which is a one-way analysis of variance by ranks. As it is a non-parametric test, it does not assume a normal population. The null hypothesis to test is the one that the medians of a distribution stem from equal populations, and the alternative hypothesis consequently that the medians are derived from populations which are not equal. The test value is approximated with a chi-square distribution. We run the test with SPSS 14.0, which reports the test statistic as "Asymptotic Significance". If the pre-set critical value is exceeded, then the null hypothesis can be falsified, and the probability of making an error in stating that the medians are from different population is very small, as we take the 95% level (p-value = 0.05) as our critical value where not otherwise mentioned. The detailed results can be seen in the tables below for:

Table A.1: Differences in occurrence of valuation methods by capital expenditures classes.

Table A.2: Differences in utilization of adjustment methods for flexibility valuation by capital expenditures classes.

Table A.3: Differences in consideration of specific types of managerial flexibility by industry group.

Table A.1: Differences in occurrence of valuation methods by capital expenditures classes.

Testing for equality of population medians grouping companies by capital expenditures classes

Means, standard deviations and medians for different capital expenditures classes

Capital expenditures class		Occurrence of …[1] ... static methods	… payback method	… NPV	... ROA
< 50	Mean	2	2.4	2.21	4.95
	Median	*2*	*2*	*2*	*5*
	N	43	43	42	41
>= 50 < 500	Mean	2	1.48	1.7	4.86
	Median	*2*	*1*	*1*	*5*
	N	23	23	23	21
>= 500	Mean	2.5	2.08	1.33	4.42
	Median	2.5	2	1	5
	N	12	12	12	12
Total	Mean	2.08	2.08	1.92	4.84
	Median	*2*	*2*	*1*	*5*
	N	78	78	77	74

Test statistics[2,3]

	Occurrence of … ... static methods	… payback method	… NPV	... ROA
Chi-Square	1.578	6.927	5.402	7.627
df	2	2	2	2
Asymp. Sig.	0.454	0.031	0.067	0.022

[1]corresponding metric values for response categories:

very frequently	1
frequently	2
occasionally	3
seldom	4
never	5

[2]Kruskall Wallis H-test

[3]Grouping variable: capital expenditures class

Table A.2: Differences in utilization of adjustment methods for flexibility valuation by capital expenditures classes.

Testing for equality of population medians grouping companies by capital expenditures classes

Means, standard deviations and medians for different capital expenditures classes

Capital expenditures class		Utilization of …[1] arbitrary adjustment	capital cost adjustment	DTA	ROA
< 50	Mean	2.89	3.05	4.45	4.95
	Median	*2.5*	*3*	*5*	*5*
	N	38	38	38	37
>= 50 < 500	Mean	3.17	3.28	4.21	4.83
	Median	*3*	*3.5*	*4*	*5*
	N	18	18	19	18
>= 500	Mean	3	3.56	3.44	4.22
	Median	3	4	4	5
	N	9	9	9	9
Total	Mean	2.98	3.18	4.24	4.81
	Median	*3*	*3*	*4.5*	*5*
	N	65	65	66	64

Test statistics[2,3]

	Utilization of … arbitrary adjustment	capital cost adjustment	DTA	ROA
Chi-Square	0.683	1.781	6.53	9.934
df	2	2	2	2
Asymp. Sig.	0.711	0.41	0.038	0.007

[1]corresponding metric values for response categories:

very frequently	1
frequently	2
occasionally	3
seldom	4
never	5

[2]Kruskall Wallis H-test

[3]Grouping variable: capital expenditures class

Table A.3: Differences in consideration of specific types of managerial flexibility by industry group.

Testing for equality of population medians grouping companies by industry group

Means and medians for different industry groups

Industry group		Consideration of the…[1] ... option to wait	... option to alter operating scale	... option to stage	... option to abandon	... option to switch	... option to grow
Financials	Mean	3	3.41	2.5	3.09	3.68	3.05
	Median	*3*	*3.5*	*2*	*3*	*4*	*3*
	N	22	22	22	22	22	22
Industrials	Mean	3.43	3.45	3.05	3.86	4	3.5
	Median	*4*	*3*	*3*	*4*	*4*	*3.5*
	N	21	20	21	21	21	20
Utilities	Mean	3.77	3.69	3.54	4	3.69	3.46
	Median	*4*	*4*	*3*	*4*	*4*	*3*
	N	13	13	13	13	13	13
Consumer good and consumer services	Mean	3.14	2.93	2.79	3.36	3.64	3.38
	Median	*3*	*3*	*2.5*	*4*	*4*	*3*
	N	14	14	14	14	14	13
Chemicals and materials	Mean	2.25	2.38	2.75	3.38	3.13	3.13
	Median	*2*	*2.5*	*3*	*3*	*2.5*	*3*
	N	8	8	8	8	8	8
Technology and telecom	Mean	3.25	2.75	2	3.25	3.75	3.5
	Median	*3.5*	*2*	*1.5*	*3*	*3.5*	*3.5*
	N	4	4	4	4	4	4
Total	Mean	3.2	3.25	2.85	3.51	3.71	3.31
	Median	*3*	*3*	*3*	*4*	*4*	*3*
	N	82	81	82	82	82	80

Test statistics[2,3]

	Consideration of the… ... option to wait	... option to alter operating scale	... option to stage	... option to abandon	... option to switch	... option to grow
Chi-Square	11.938	8.292	11.644	14.643	4.498	4.355
df	5	5	5	5	5	5
Asymp. Sig.	0.036	0.141	0.04	0.012	0.48	0.5

[1]corresponding metric values for response categories:

very frequently	1
frequently	2
occasionally	3
seldom	4
never	5

[2]Kruskall Wallis H-test

[3]Grouping variable: industry group

Appendix C.: Differences in ROA utilization

Table A.4: Differences in ROA utilization.

Frequency of utilization of ROA by …
(Reporting number of companies in specific category)

… industry groups

	Financials	Industrials	Utilities	Consumer goods and consumer services	Chemicals and Materials	Technology and Telecom
very frequently	-	-	-	-	1	-
occasionally	1	-	-	-	-	-
seldom	3	1	-	-	1	-
no longer	1	1	1	-	-	-
Total	5	2	1	-	2	-

… capital expenditures[1]

	< 50	>=50 < 500	>= 500
very frequently	-	-	1
occasionally	-	-	1
seldom	2	2	1
no longer	1	1	1
Total	3	3	4

… SPI affiliation

	SPI	Non SPI
very frequently	-	1
occasionally	-	1
seldom	1	4
no longer	2	1
Total	3	7

[1]in Mio CHF

Appendix D.: Exposure of specific industry to specific risk category

Table A.5: Risk exposure by industry.

Industry groups		Risk exposure: Market demand	Technology	Interest rate	Inflation	Currency	Legal/regulatory changes	Geopolitical events	Environment	Demographic changes	Change of social trends	Competition
Financials	Mean	3.35	**2.74**	3	3.7	3.96	**2.43**	4.04	*4.09*	3.48	3.52	**2.35**
	Std. Deviation	1.027	0.864	1.168	0.765	1.065	0.896	0.928	0.848	0.898	0.947	0.885
	Median	3	3	3	4	4	2	4	4	3	3	2
Industrials	Mean	**2.29**	**2.81**	3.71	3.76	3.19	3.48	3.52	3.67	4.1	*4.24*	**2.19**
	Std. Deviation	1.102	1.123	0.845	0.7	0.75	1.123	0.873	0.856	0.995	0.768	0.602
	Median	2	3	4	4	3	4	3	4	4	4	2
Utilities	Mean	3.62	3.38	3.62	4.15	3.85	**2.31**	3.62	**2.46**	*4.31*	4.15	3.31
	Std. Deviation	1.044	1.044	0.961	0.899	0.987	0.855	0.87	0.776	0.751	0.689	1.032
	Median	4	3	3	4	4	2	3	2	4	4	3
Consumer good and consumer services	Mean	**2.5**	3.07	3.79	3.79	3.71	3.21	*4*	*4*	3.64	3.21	**2**
	Std. Deviation	0.941	0.917	0.893	0.579	0.914	0.975	0.784	0.392	0.745	0.802	0.555
	Median	2.5	3	4	4	3	3.5	4	4	4	3	2
Chemicals and materials	Mean	**2.43**	3	3.75	3.63	3.13	**2.5**	*4.13*	3.5	3.88	*4.13*	**2.63**
	Std. Deviation	1.134	1.069	0.463	0.744	1.126	1.195	0.641	1.069	0.991	0.991	0.744
	Median	2	3	4	4	3	2.5	4	4	4	4	2.5
Technology and telecom	Mean	**2**	**1.25**	4	*4.25*	3.25	2.25	3.75	3.75	*4.25*	4	**2**
	Std. Deviation	0.816	0.5	0.816	0.5	0.5	0.957	1.258	1.258	0.5	0	0.816
	Median	2	1	4	4	3	2.5	4	4	4	4	2
Total	Mean	2.83	2.87	3.53	3.82	3.59	2.81	3.83	3.64	3.87	3.83	2.41
	Std. Deviation	1.153	1.045	0.98	0.735	0.976	1.087	0.881	0.97	0.908	0.895	0.87
	Median	3	3	4	4	4	3	4	4	4	4	2

More important for this industry group (bold)

Less important for this industry group (italic)

Appendix E.: Filtering companies with high "real option's value potential"

For defining the group of high "real option's value potential," we analyzed the answers of question 8 through 17. First, we selected all companies that stated to perceive at least for three of our eleven risk categories a "high" or "very high" risk exposure. This group of high uncertainty exposure was comprised of thirty-seven companies from our sample. For the group of companies with high irreversibility, we proceeded as follows: we first selected all companies that responded with "hard or "very hard" to the question about how difficult it would be to reverse an investment and with "high" and "very high" to the question about the cost involved in a possible investment reversal action. Additionally, we separated all companies that had answered in at least two of the three following questions with "rather true". The questions were, first, whether the costs were coming from industry-specific assets; second, if costs were derived mostly from intangible assets; and, third, if investments consisted mainly of fixed costs. Finally, we selected all firms that had answered with "rather false" to the question about the existence of an efficient second-hand market. Filtering in this way, we ensured having a group of companies that perceived a high level of irreversibility for their investments. This group comprised forty-one companies. Finally, we set the benchmark for firms with a high occurrence of different types of managerial flexibility in selecting all firms which stated at least for two out of six flexibilities that they occurred "often or "very often". This group was comprised of twenty-four companies. Obviously, the benchmarks for each of the three characteristics are set very subjectively without having any empirical values to support them. We, therefore, set them conservatively to be sure to capture only firms that really demonstrated high parameter values of any of the mentioned characteristics. If a company was in each of the three mentioned groups, i.e. the one that was highly exposed to uncertainty, the one which had highly irreversible investments, and the one which had many types of managerial flexibilities occurring, we defined it as a company with a high probability of real option's value arising from its investments, i.e. a high "real option's value potential". We did not segment the sample for the other extreme that had no "real option's value potential," as we were only interested in the firms where a real option's application would show the highest benefit. Also, all companies in-between the two extreme values of "real option's value potential" show obviously a certain tendency of developing real option's value and are consequently candidates that might capitalize on an application of the ROA. However, as we are conducting the discussion on subjective ordinal data, we prefer to adopt the black-and-white view of regarding only the extreme values to avoid any pretensions of ordering companies in the grey area according to their "real option's value potential".

Appendix F.: The flexibility appropriation request

FLEXIBILITY APPROPRIATION REQUEST

(SUPPLEMENT TO STANDARD APPROPRIATION REQUEST)

INTRODUCTION:

This appropriation request template serves as a guide to determine valuable real options inherent in the project. Please read the instructions on how to assess the prerequisites for real option value and how to estimate the available and potential real option value before completing the request.

The completed request should reflect a concise overview on the real options inherent in the project and the reasons why those real options should be valuable. It is therefore divided in four parts:

Part 1: **Real option value grid (ROVG)**

Part 2: **Option space**

Part 3: **Additional information on irreversibility and competition**

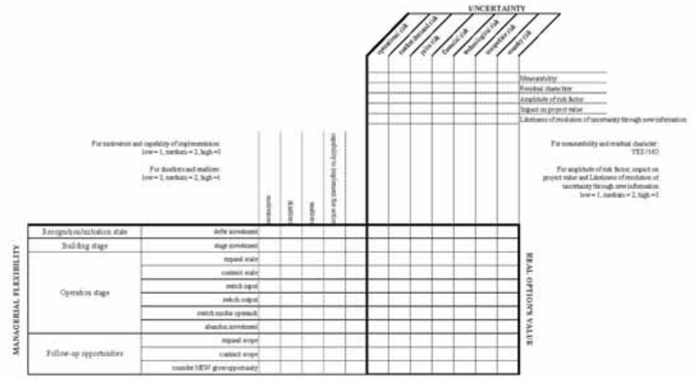
Part 4:Narrative description of the function of the real option and proposition regarding further analysis

Where a judgment is requested to differentiate between LOW, MEDIUM, HIGH, please accompany the judgment with a short description.

In some cases, it may not be necessary to provide information for every heading. Only complete the sections that you think apply. Cross reference information you think has been asked twice. Provide as concise descriptions as possible. Information that you think is important to the assessment and review of the appropriation request, but is not covered by the headings, can be provided as an attachment to the main document.

Flexibility Appropriation Request 2

PART 1: REAL OPTION VALUE GRID (ROVG)



A Narrative details on the uncertainty filter

Explain for every uncertainty if several apply.

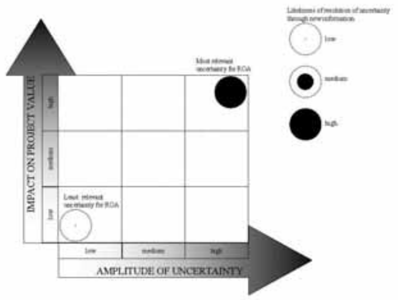
[Is the uncertainty measurable?]

[Is the uncertainty residual?]

[Is the amplitude of the uncertainty: LOW, MEDIUM, HIGH?]

[Is the impact on project value: LOW, MEDIUM, HIGH?]

[Is the likeliness of resolution of the uncertainty: LOW, MEDIUM, HIGH?]



Flexibility Appropriation Request 3

B ***Narrative details on the filter for managerial flexibility***

Explain for every managerial flexibility if several apply.

[Are the motivators: LOW, MEDIUM, HIGH?]

[Are the disablers: LOW, MEDIUM, HIGH?]

[Are the enablers: LOW, MEDIUM, HIGH?]

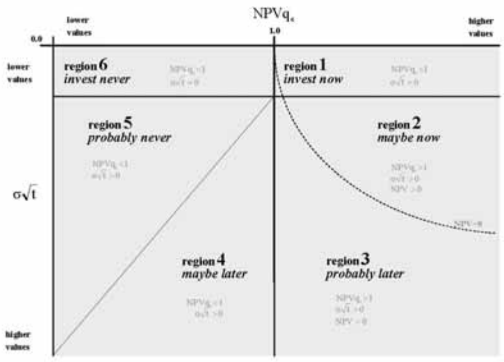
[Is the capability to implement the action given?]

[Possible organizational hindrances?]

[Possible regulatory constraints?]

[Possible hindrances due to unavailable resources?]

PART 2: OPTION SPACE



A	***Value-to-cost metric - NPVq$_c$***

[Present value of the cash flow of acquired assets, S]

[Present value of the required investments, PV(X)]

[Riskfree rate, r_f]

B	***Volatility metric - $\sigma\sqrt{(t)}$***

[Volatility of the cash flows of the acquired assets, σ]

[Time till the real option will be implemented, t]

C	***Standard NPV***

[]

D	***Narrative on the position of the option***

[]

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PART 3: INFORMATION ON IRREVERSIBILITY AND COMPETITION

A Irreversibility of the investment

[Is the operating leverage: LOW, MEDIUM, HIGH?]

[Is the efficiency of the second-hand market for the acquired assets: LOW, MEDIUM, HIGH?]

[Is the degree of specificity of the acquired asset: LOW, MEDIUM, HIGH?]

[Are the transaction cost for re-selling the acquired asset: LOW, MEDIUM, HIGH?]

[Are there any regulations or institutional arrangements which hinder a selling of the acquired asset?]

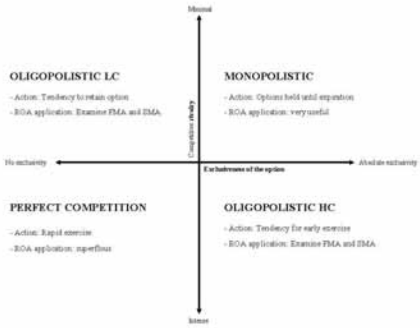
B Competitive situation regarding the real option to be implemented

[Is the competitive rivalry: LOW, MEDIUM, HIGH?]

[Is the exclusivity of the real option: LOW, MEDIUM, HIGH?]

[Are first mover advantages: LOW, MEDIUM, HIGH?]

[Are second mover advantages: LOW, MEDIUM, HIGH?]



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PART 4: NARRATIVE DESCRIPTION OF THE FUNCTION OF THE REAL OPTION AND PROPOSITION REGARDING FURTHER ANALYSIS

A Narrative description

[e.g. number of stages, if investment should be staged]

[e.g. switching modi, if option to switch]

[e.g. expansion/shrinking scale, if option to expand/shrink]

[etc.]

B Recommendation about further steps to be undertaken

Please, summarize the information gathered till now.

[Is the real option relevant for the project?]

[Are the prerequisites of real option value given?]

[Could some relevant uncertainties be detected? Which?]

[Could some relevant real options be detected? Which?]

[How is the degree of irreversibility of the project high?]

[How is the degree of competition?]

[How much amounts the rough estimation of the real option value?]

[In what region of the option space is the real option positioned?]

[Would you like to have a further more accurate analysis for the found real options?]

C Additional Attachments

Please, provide further information on supplemental sheets if needed and cross reference it at this place.

Curriculum Vitae

Pietro Scialdone (1973) studied Economics and Business Administration (major subject "Finance") at the University of Zurich, Switzerland. Upon successfully graduating in June 2000 he worked for Translink Corporate Finance advising companies in cross-boarder Mergers & Acquisitions deals. In autumn 2001 he came back to his academic path in taking up a position as research assistant and doctoral student at the Swiss Banking Institute of the University of Zurich. There he was a member of Prof. Dr. Rudolf Volkart's team and besides his teaching activities at undergraduate, graduate and executive education program levels he participated in several research projects. Parts of his doctoral studies were spent at the Kelley School of Business, Indiana University in Bloomington (USA). Pietro Scialdone completed his doctoral studies with the present dissertation in June 2007.