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Real Options Analysis

-A Study of Implementation Impediments-

Bachelor's Thesis
Industrial and Financial Management

School of Business, Economics and Law
Göteborg University
Spring 2007

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Abstract

In this essay, we study the capital budgeting method called real options analysis. The method is, by many researchers, considered superior to other capital budgeting methods since it is able to value flexibilities within projects. Among practitioners, however, the method has not had a large breakthrough, although it has existed for almost three decades. This indicates that there are problems with the method impeding the implementation and these problems are the interest of this essay. We have conducted a literature study, where we try to create a picture of what the academic world thinks are the largest problems with the method. We have also conducted an interview study, where we interviewed companies, in the Gothenburg region, to get a picture of what they look for in a capital budgeting method and what problems real options analysis would experience in the companies. Our studies have made us identify a number of different problems that we think have to be solved before the method will become more widely used. These problems include both technical problems, concerning valuation of the options, as well as organisational problems, concerning changes in the capital budgeting process, demanded by a real options analysis framework.

Contents

1 Introduction

In this essay, we will study a capital budgeting method called real options analysis. We will look at problems concerning the method and try to see how these problems slow the implementation rate of the method down. In this, the first chapter, we will start by giving an introduction to the area we study and define what we mean by real options analysis. We will then describe the problems we will look at and this will lead us to the end of this chapter, where we present the purpose of this study.

1.1 Background

Since the 1960's, the classical approach to corporate strategy has flourished with its large emphasis on rational planning and financial evaluation techniques (Whittington [45]). Many different methods have been developed to evaluate investments since it is believed that correct valuation and hence correct decisions about financial commitments is crucial to the survival of the company and value creation (Arnold and Hatzopoulos [4], Trigeorgis [44]). However, the prevalent techniques seem incapable to capture all important aspects of an investment. There have been crises in valuation (Boer [6]) where the market values have been difficult to identify, and a theory-practice gap in the area of capital budgeting has also been observed (Graham and Harvey [19], Arnold and Hatzopoulos [4]). Some academics argue that part of this gap comes from problems with the classical approach as such (Whittington [45]), with its reliance on the ability of the managers to predict the future. Others agree on the point that the future is unpredictable, but suggest not that financial valuation should be given up. Instead they have identified shortcomings in the capital budgeting methods themselves.

What had not been accounted for in the methods developed until the late 1970's (and probably also many after that) was the strategic value in having future flexibility to alter the plans made today, which are set up according to uncertain predictions about the future (see for example Copeland and Antikarov [10], Amram and Kulatilaka [2], Trigeorgis [44], Boer [6] or Brach [8]). According to Trigeorgis [44]; "The field of capital budgeting admittedly remained stagnant for several decades until recent developments in real options provided the tools and unlocked the possibilities to revolutionize the field" (p. xiii), this development begun with a breakthrough in the area of financial option pricing.

The breakthrough was an article by Black and Scholes, published in 1973, in which they derived a closed-form equation for valuing financial options. Financial options had been traded for quite a while, but with the provided formulae, it was now possible to find a theoretical price that was the same for everyone (Black and Scholes [5]), and this resulted in a breakthrough for trading options and other derivatives.

In turn, the increased option thinking also affected other areas of the economic society than the pure financial. The most important was the capital budgeting area as researchers, the first example is Myers [31] in 1977, recognised that many projects handled by companies actually

contained *real* options. It could be a research project consisting of several phases where the company only has to proceed into a phase if the preceding phases have been successful, or it could be a project where a new factory is built and depending on the market development, the company can choose to expand the factory or not.

Using option pricing methods in the capital budgeting processes therefore became, if not the most, at least one of the most promising ways to improve the process. Real options analysis (ROA) consequently became a large research area in the decades following Black and Scholes's article. However, there are indications that there might exist different conceptions of what ROA really is (Triantis [41]), and we therefore think it is necessary to define what we mean by the concept:

> With ROA, we do in this essay mean a formal valuation technique for taking future flexibilities into consideration when valuing real-world projects, using option pricing theory.

What seemed so promising with this concept, was that ROA, by including the value of flexibility, would give the true project values. Furthermore, except for showing the true value of a project, using ROA for capital budgeting decisions was also seen as the link that would connect capital budgeting and corporate strategy with each other. This connective property of ROA is due to that when applying ROA, we do not only get a value of the project, we also get instructions on how to act in the future in order to maximise the project's value.

So, in theory, ROA looks like the perfect tool for managers to use. Not only do they find a more correct value of the project, they are also told how to act in the future. Still, ROA has not had a very large breakthrough among practitioners (see for example Graham and Harvey [19] considering the USA and Sandahl and Sjögren [36] for the Swedish case), something that is surprising when considering all the ovations it has received from researchers. In this essay, we will therefore study some of the problems ROA is experiencing and look at how these could impede the implementation of ROA.

1.2 Problem Description

As we mentioned in the previous section, ROA is a method based on financial option pricing theory. The methods used to value real options have been benchmarked from their financial equivalents (Miller and Park [29]), and this is where the problems with the method start. The financial world is less complex than the real world, where the real options are located. Using models from the financial world needs input variables corresponding to financial variables. Therefore, information from real-world projects has to be projected onto the financial world. This results in two problems. First of all, one has to find methods for making these projections and, usually, this calls for some simplifications. Secondly, these simplifications must not be too large since this will mean that the outputs from the models are not trustworthy.

Talking about projections onto the financial world is of course rather abstract. However, this reasoning leads to a structured way of discovering many of the problems with ROA. If we study models for valuing financial options, there are basically six input variables, namely the value of the underlying asset, the exercise prise, the time to maturity, the risk-free rate, the dividends and the volatility. To use ROA, a practitioner has to assign these variables values and the difficulties of doing this may be a reason for the few number of ROA practitioners.

If we look at the first variable, the value of the underlying asset, this corresponds to the value of a project without flexibilities, when studying real options. Borison [7] discusses several different methods, which have been suggested to calculate this project value. Some of these may be accurate but hard to apply, while others may be easier to apply but might result in too many and too crude simplifications. When examining problems with the value of the underlying asset, for example Perlitz et al. [33] list other assumptions made regarding the project value, that may, or may not, hold.

Turning to the exercise price of a real option, this corresponds to the money a company has to pay to go through with a project. There are two main problems with the exercise price for real options. Firstly, the price may not be clearly known on beforehand and may follow a stochastic process, discussed in Miller and Park [29]. Secondly, Leslie and Michaels [23], among others, discuss what happens if the exercise price is divided into several smaller outlays, something that may often be the case.

The time to maturity is the period of time during which a company has the option to choose whether to go through with a project or not. In difference to financial options, the time to maturity of a real option may change due to actions taken by competitors or other actors (Perlitz et al. [33]). Miller and Park [29] mention other circumstances, which may make the interpretation of the time to maturity of a real option harder. For example, for many projects there will be some time after deciding to go through with the project and before starting it.

The risk-free rate is usually the easiest variable to approximate. However, for a real-world project, there may be problems here as well, Miller and Park [29] do for example discuss what happens when there is private, and not only public, risk in a project.

Dividends in financial options can be seen as leakage of the project value as time goes by in the real case. Leakage is partly due to money lost from sales if not exercising immediately, but there are other factors as well. Miller and Park [29] discuss what happens when the leakage depends on external factors and Amram and Kulatilaka [2] describe methods for valuing leakage going to the company holding the option. Including dividends in ROA is harder than for financial options since they are much more difficult to predict and estimate. Leakage is, however, an important factor to consider and not having the possibility to include them in the calculations would be a problem.

Finally, the volatility describes how much the value of a project is likely to change with time. This is a very important variable and hard to estimate for real options. Miller and Park [29] mention three main methods for approximating the volatility; Monte Carlo simulation, historical data and management assumptions, and something called implied volatility. Using these methods results in different problems that have to be solved and assumptions that have to hold. A common assumption discussed by, for example Figlewski [17] and Triantis [41], is that the returns of the projects are log-normally distributed, something that far from always hold.

Now, finding values of these input variables is only one part of a ROA framework. There are other things to do as well and other factors affecting if a company will start using ROA or not. Firstly, calculating the value of the real option is not the end of the story. Afterwards, the development of the project value has to be monitored to see if and when to exercise the option. Copeland and Tufano [11] discuss issues regarding how to make managers of options make the best decisions for the company.

Even if the above problems are solved, there are still other things that may impede companies from implementing a ROA method. First of all, the method is not widely used by companies today and the lack of many previous successful implementations may scare off practitioners considering ROA. The question is also what a successful implementation is. First of all, McCormack in [1] argues that it may be difficult to say whether a company is successful due to usage of a specific capital budgeting method or if it is so that the company uses a specific method because the company is successful. Other researchers, see for example Myers [32] or Borison in [1], mean that the primary success-creating property of ROA is not that it provides a very accurate value of the project, but instead that it connects capital budgeting and financial strategy.

As should be clear now, there are several potential problems with a ROA framework, which may be the explanation to why the method is so sparsely spread. Which these problems are will be the research question of this work and it can formally be stated as:

> *Which are the critical factors that may impede implementation of ROA in real-world companies?*

Some of these factors are probably more severe than others. Finding out which these more severe factors are is important since more effort should be put into solving them. The reason making us think this is important is that we believe that ROA will lead to a better resource allocation by the companies. This will also be important from a societal point of view, which motivates the purpose of this essay and leads us to the next section.

1.3 Purpose

The purpose of this study is to uncover the actual impediments associated with the implementation of a ROA framework in real-world companies.

2 Method

To fulfil our purpose, we will use a method based on a literature study as well as interviews. We will start by describing how the information from these two sources will be used when analysing and discussing what may impede the usage of ROA. This will be described in our analysis model and the model will also explain what information is needed from the literature and interview studies. Therefore, once the analysis model is described, the aims and designs of the two studies will be described separately. Finally, we will discuss the validity and reliability of our studies.

2.1 Analysis Model

Analysing factors that may impede implementation of ROA, or any other capital budgeting method for that matter, is a quite complex task. It will not be possible to make a list of a few different problems and say "Solve these problems, then all companies can use the method." Instead, the problems will probably change from company to company if they are studied carefully. However, on a more general level, the company-specific factors that impede companies from applying a ROA framework are probably possible to group into more common sets of factors.

During the last decades, there has been much research focusing on ROA (Triantis [41]) and important topics regarding the applicability of the method can be found in the literature. Therefore, conducting an extensive literature survey should help us identifying important questions to discuss in the interviews. Furthermore, getting a good picture of what has been written in the literature will also be important when analysing the information received during the interviews. We might be able to identify topics in the literature that are given too much attention with respect to the importance it has for real-world practitioners. Other factors may, on the other hand, seem to have been investigated to a much lesser extent by researchers, but still have a large impact in the real world.

So, knowledge about the problems considered in the academic world will be one part of the information needed for the analysis, the second part is opinions from real-world practitioners. There are different methods one can use to gather these opinions, for example by some sort of survey covering a large number of companies, or by conducting an interview study containing a smaller number of companies. As has already been mentioned, we have chosen the latter of these alternatives, an interview study.

There was one main reason that made us prefer an interview study over a survey, the complexity of the problem. We do not think a survey could have helped us in catching the essence of the factors that may impede implementation of ROA. The questions we wanted to ask were mostly of a rather soft kind in the sense that it usually is not possible to answer them with only a few words or by choosing among a few different alternatives. Furthermore, when conducting an interview, interacting with the interviewee and taking answers to previous

questions into account, can improve the value of the received information to a large extent.

To be able to compare the answers received from the interviews with the information collected in the literature study, we will have to ask many questions related to the topics described in the literature study. Still, we also have to try to ask questions that could reveal problems we have not seen in our literature study. This is of course not easy since we do not know which these problems may be. However, we hope that, by discussing some more general questions about capital budgeting during the interviews, and by having the possibility to ask follow-up questions, we should be able to find other problems as well.

When it comes to the actual analysis of the results from the literature and interview studies, it is hard to really describe the method we will use. We do not have any formal model into which we can plug our results and get an answer. Instead we will analyse the results by discussing them and thinking of what they may say, and from there draw conclusions. This is a very vague description of a method, but we do not think it is possible to describe it in a more clear manner. Instead we will try to describe to the reader why we interpret the results the way we do. To achieve this, we will first try to extensively depict the results we have received from the two studies. As a next step, we will try to make the reader follow how we (the two authors) have discussed the received information between each other and motivate why we make the interpretations of the results that we do. To make the understanding of our interpretations easier, we will categorise the results and analyse the categories separately. Using these interpretations we will then draw conclusions and if we have succeeded in describing to the reader our motivations for the interpretations, the reader will hopefully agree on the conclusions or have the possibility to criticise them.

From the discussion above, it is clear that the validity and reliability of our conclusions can be questioned since they will be based on the authors' personal interpretations of the results. The validity and reliability will therefore be discussed further in the last section of this chapter. To mention now is that we will never claim that the impediments we identify will occur at every company, or that the impediments are the only or the most important ones. Instead we will describe what *we* think, after finishing our literature and interview studies and after analysing them, are the most important impeding factors. If we have succeeded in describing how we reason and why we reason that way, we hope that the reader at least agrees on that the factors we have found are important and reasonable to consider when studying implementation impediments for ROA.

This discussion explains the need for both the literature and interview studies and how they will be connected when analysing the received information. We will now discuss some issues related to each of these studies.

2.2 Literature Study

In the literature study, we will try to list and describe factors the academic world has identified as impediments to implement a ROA framework. To achieve this, we will conduct what Esaiasson et al. [16] denote a qualitative text analysis, since our intention with the literature study is more to systematise previous research than to criticise it. The information will be gathered by using articles found at electronic databases such as JSTOR, Blackwell Synergy, etc. To select articles to read, we will use the general query "real options analysis" and also specifying it by, for example, adding one of the six input variables mentioned in the problem description. Furthermore, when some suitable articles have been found, we will use their citations to find other articles. We will try to go through much of the literature within the area and do what Esaiasson et al. [16], p. 234 refer to as "elucidate the structure of thought" (the authors' translation). In some sense, we will also classify the information as we will have to separate the problems found into two classes, which we will denote academic problems and real-world problems.

Of course, all problems are real-world problems since they, in one way or another, will affect the ability to implement a ROA framework. However, some problems, take for example the problem to approximate how a price will fluctuate in the future, is easier to discuss with a real-world practitioner than if the returns of a project are log-normally distributed. That the returns are log-normally distributed is a common assumption when deriving models for real option valuation, and if the assumption holds is therefore important to discuss. Still, a real-world practitioner will probably not find the question interesting, he or she will be interested in if ROA can be helpful and what he or she will have to calculate and foresee to use the method. The practitioner will not be able to affect the log-normality of the returns. Therefore, if the returns are not log-normally distributed and log-normality is crucial for the method to work, the practitioner will probably not use the method. From an academic point of view, however, the question of log-normality is interesting. If this assumption is important and it normally does not hold, this could be a reason for a method not being successful and we will therefore consider such problems in our report. We will not ask questions regarding these problems in the interviews, though.

Finally, a word on criticism of the sources. We said above that our intention is not to criticise previous works since we conduct a qualitative text analysis. However, in reviewing the literature, many authors are often recurring. These authors are also often the proponents of ROA and therefore, they do in general talk about the advantages of real options and less about the drawbacks and limitations. Consequently, we have to read the articles critically, even if they are written by prominent academics, because we will try to compare the theories to reality. This comparison will be made with aid of our interview study, which will be the topic of the following section.

2.3 Interview Study

As was mentioned earlier, we have chosen to make an interview study instead of a survey. The reason for this choice is that the questions we want to ask are such that a longer discussion is more important than the shorter answer we would get from a survey. Our choice is supported by Esaiasson et al. [16] who list five areas where conducting interviews is a preferable method. Of these five areas, at least two can be identified in our specific case, namely,

1. One area is when we want to know "how people themselves experience their world", according to Esaiasson et al. [16], p. 281 (the authors' translation). This is indeed one of the purposes of our interviews. We want to find out how people - facing real-world capital budgeting decisions on a daily basis - think about important features of capital budgeting methods, about the possibility to approximate different variables, and so on.

2. Esaiasson et al. say that for theory examination, surveys are more common than interviews. However, when examining complex assumptions, interviews may be more appropriate. As mentioned earlier, the questions studied in this essay are of the more complex kind, where no short answers may be very interesting. So, also for theory examination, the chosen interview study should be suitable.

After having chosen to conduct an interview study, there are decisions and preparations to be made. We have to decide how many persons to interview, which persons to interview and how to formulate the questions. There are also several other, smaller, things to think about when preparing an interview and also during the interview and we used Esaiasson et al. [16] and Eriksson and Wiedersheim-Paul [15] to learn about these things.

So, let us turn to the decisions about the number of interviews and which persons to interview. In our study, we made four interviews with persons involved in capital budgeting decisions in their respective companies. Making four interviews is about the lowest number of interviews Esaiasson et al. [16] recommend. However, after having conducted these four interviews, we felt that we had received enough information. There were also some other companies we were in touch with, who had promised to return to us but who never did. Since we felt that the information received was enough, we did not contact the non-replying companies further. The companies we decided to contact were chosen based on two criteria, the size of the company and if it seemed like the companies could face capital budgeting decisions where ROA could be useful. We did choose large companies since large companies are facing more capital budgeting decisions and should therefore have personnel working with these questions to a larger extent. Since we preferred interviews close to Gothenburg, we used a list with the largest companies in the Gothenburg region when selecting the companies. Based on this list, we tried to identify the companies which could have a need for ROA. Businesses suitable for ROA can be found in the literature, we used Micalizzi and Trigeorgis [28], Miller and Park [29] and Triantis [42] for example, but we also used our own knowledge about real options. To check if the companies seemed to be suitable, we visited the companies' home pages and studied their annual reports to get a better picture of their respective businesses before we contacted them.

Another important task when conducting an interview study is, as we mentioned above, to prepare the questions to ask during the interviews. For our interview study, we prepared an interview guide, which we used during the interviews. The largest part of the guide did look the same for all the interviews, however, some questions were only suitable for some of the companies and some questions had to be formulated in different ways for different companies. In Appendix A, the main structure of the interview guide is shown. When constructing the guide, we worked in the following manner. After conducting the literature study, which is described in Chapter 3, we tried to cover all discovered topics we regard as problems for real-world practitioners. When we were formulating the questions, we of course had to think of, as Esaiasson et al. [16] point out, not making the questions difficult for the interviewees to understand. In our case, the interviewees were familiar to capital budgeting jargon but maybe not to the specific terms used when discussing real options, this complicated the process of turning theoretical concepts into operational indicators. Therefore, we had to try to formulate some of the questions to get answers to real-options questions without using the real-options vocabulary.

Finally, regarding the interview guide, Esaiasson et al. [16] also suggest an introductory part with "warm-up" questions. Our warm-up questions consisted of some general questions about the capital budgeting processes used in the different companies. This was a natural way to start talking about the subject and in some cases, the interviewees had also prepared presentations of their processes.

Before the interviews took place, we also studied the respective companies quite a bit, mainly by reading annual reports and looking at their home pages. Having a decent knowledge about the capital budgeting decisions present in the different companies was important since this gave us the possibility to better connect the questions to the company-specific situations.

2.4 Validity and Reliability

After discussing our choice of method, we can now turn to the issues of the validity and reliability of this study. A discussion of validity is the hardest but also the most important problem in empirical social science, according to Esaiasson et al. [16]. Therefore, the discussion is needed here, but the reader should also try to evaluate the text during the rest of the essay with the complexity of these problems in mind.

First we will discuss the internal validity of the study. The problem with validity starts when the researcher will have to translate the theoretical definitions into operational variables (Esaiasson et al. [16]). In our study, this part will pose differently large problems for the literature study and the interview study. In the literature study, we read books and articles written by academics who consider the theoretical concepts we want to discuss, and the problem of translating theoretical definitions into operational variables will not arise. However, since this is secondary information, of course, the problem that the validity may be lacking in

the studies behind the texts that we are reading, will remain. The academics can have made methodological choices that cause problems with the validity and reliability. We cannot affect the texts themselves, but to deal with the problem we mostly include literature from scientific journals, which will guarantee that the articles have at least been reviewed and approved before publishing, something that should imply a better work with issues like validity and reliability.

In the interview study the problem of translating the theoretical definitions into operational variables will increase considerably. A second aspect of the validity problem will also arise; the problem Esaiasson et al. [16] describe as whether we examine what we say we examine. Since we study companies not using ROA, the translation part will create problems. We have to create some kind of secondary operational indicators that will indicate what impediments could arise if the companies tried to implement ROA. This will increase the distance between the theoretical definitions and operational variables, which, as a rule of thumb, will increase the problem with validity (Esaiasson et al. [16]). With this in mind, we have been careful to not draw too specific conclusions from the interview study about narrow areas of discussion.

Turning to whether or not we are examining what we say we examine, this will hinge on whether or not we have chosen to examine the right aspects of the ROA framework. The problem lies in the fact that the interviewed companies have not tried to implement ROA. The validity will therefore depend on our choice of aspects to study and questions to ask. To minimise this problem, we chose to use the structured way of finding many of the problems with ROA based on the fact that ROA is benchmarked from financial option pricing theory (see Section 1.2). This helps us to not miss any important factors to discuss. Furthermore, we tried to use some open questions about capital budgeting methods to try to discover what aspects the companies find important, but we, or the academics, had missed. With this said, the reader should be aware of that the validity of the interview study somewhat hinge on our choices and problem description. The reader, familiar with ROA, should therefore critically review what aspects of ROA that are being discussed before discarding any aspect as being unimportant since it is not mentioned in the conclusions, it could simply have been missed.

Esaiasson et al. [16] also mention a third definition of high validity as the absence of systematic errors. In the literature study these would arise if we are continuously searching for the wrong factors. We do not believe that this will be a problem since our combined general and systematic way of searching for problems gives us a good coverage that should help us to not miss any important factors. In the interview study the systematic errors can arise with the wrong questions being asked, we have therefore tried to be as structured as possible there as well. The reader can consult Appendix A to evaluate the questions asked, but should remember that some factors were chosen to only be investigated in the literature study because of their technical properties. Once more, the validity of the interview study depends on our choice of questions and can therefore not be said to be perfect. Having discussed these systematic errors, we can now turn to unsystematic errors.

The absence of unsystematic errors is called reliability (Esaiasson et al. [16]) and is the factor that should be dealt with when the problem of systematic errors have been solved. The unsystematic errors mainly arise because of random or careless mistakes during the data collection and analysis. In our literature study this should not be a problem relying on us being thorough. In the interview study we tried to minimise these errors by both authors taking notes during the interviews and recording the interviews so that they could be reviewed afterwards. During the analysis work, we have reviewed our findings many times to minimise these errors. Problems because of misunderstandings and misinterpretations during the interviews can of course still arise and are hard to evaluate afterwards. For this not to have a too large effect, we used more than one question to cover every topic but the problem cannot be said to have been eliminated, it is rather inherent in the case of interview studies.

Finally, we would like to discuss the external validity of this study. This describes to what extent the received results can be generalised to the population of analysis units originally intended (Esaiasson et al. [16]). For the factors mainly treated with in the literature study the generalisations should not be a problem, but the findings from the interview study will pose problems. Of course, we cannot generalise all findings from only four companies to all companies that might try to implement a ROA framework. But, with this in mind we have only chosen to discuss findings that we believe can reoccur in other companies as well, i.e. we have tried to not include too many personal opinions of the interviewees. But these personal opinions are also partly what we are searching for when we try to describe what problems the real-world practitioners will perceive, so there is a difficult balance that we have tried to uphold. Therefore, since we have included an interview study, the external validity of this study cannot be said to be perfect, but we propose to have tried to deal with in a structured way.

This completes the description of our method. As was mentioned, the first part of our work was to make a literature study and that is what follows.

3 Frame of Reference and Literature Study

When discussing our method in the previous chapter, we mentioned that an important part of our work will be to make a literature survey, and that is the topic of this chapter. We will start by looking at some basic real options theory, describing the assumptions usually made when applying real options analysis. The intention with that section is mainly to show what our perception of ROA is, but we will also introduce some of the problems already there.

After this introduction to ROA, we will look at some more specific topics where it seems that academics think that the largest problems, if applying a ROA framework, would occur. This includes both the valuation and management parts of projects as well as the question if the implementation of the framework has been successful or not.

3.1 Basic Real Options Theory

After Myers [31] introduced the real-options concept in 1977, the first years of research focused on what Borison [7] refers to as the classical approach. This approach focused on finding similarities between the returns of the project and the returns of some portfolio with traded investments, called the replicating portfolio. Since the portfolio only contains traded investments, these are given the correct market price and they will subsequently help us find the true value of the project (Amram and Kulatilaka [2]). So, after finding the replicating portfolio, the portfolio is scaled in such a way that the returns of the scaled portfolio is the same as the project's returns. Scaling the portfolio value equally much will then tell the present value of the project.

However, finding the project value this way will become very difficult, if not impossible, once the project becomes a bit complicated. Hence, to make ROA practically applicable, a better way of calculating the project value was needed (Copeland and Antikarov [10]). The solution to this problem was the MAD (Market Asset Disclaimer) assumption used by Copeland and Antikarov. The consequence of this assumption is that, instead of looking at traded investments to find an underlying asset value, we can use the present value of the project found by using a traditional capital budgeting method such as the NPV (Net Present Value) method. The assumption is really, according to Copeland and Antikarov, only that the NPV measure is the best unbiased estimate of the project's market value if the project were a traded asset. Using this assumption, a company wishing to make a ROA calculation can simply expand their usage of NPV and, since recent surveys (see for example Graham and Harvey [19]) have shown that a majority of companies use NPV analysis, this should be a relatively smooth way of applying a ROA framework.

According to Borison [7], in recent years a couple of other theories for pricing the underlying asset have been developed as well. Many of these focus on how to take care about projects consisting of not only public, or market, risk but also of private risk. The private risk is not considered in financial markets and a large amount of private risk will at least make

the classical approach inappropriate. However, for now, we will not pay more attention to how to calculate the value of the project without flexibilities. There are different methods to use, some are in some cases more appropriate in theory, others, e.g. the MAD assumption, are more practically suitable.

The remaining part of this section will show how to value a real option if we know the value of the project without flexibilities, the techniques are taken from the textbooks written by Copeland et al. [12] and Mun [30]. So, let us assume that we know the present value of the project without flexibilities and denote it S. In the ROA approach, we ask ourselves something like; "Depending on how this project value changes in the future, what sorts of actions can we take, what are our options?". The answer to this question will vary from project to project, an example could be something like this: "We are considering investing in a factory today to be able to produce a certain amount of a product. However, if the market development turns out better than expected, we would like to produce more of the product." We could then have a contract saying that in T years (the time to maturity) we have the possibility, but not the obligation, to invest a certain amount, X (the exercise price), to expand the factory with $p\%$. This is an example of an expansion option and we will choose to exercise it if the market development is good enough. Clearly, having the option to expand the factory is something good since we would only exercise it if the market development is good enough. This means that we will only make better or equally well compared to if we did not have the option. We will never get worse since the option will not be exercised after a bad market development, i.e. if exercising does not benefit the company.

The question is then how much the option is worth. This depends on the probability of earning something by having the option. In the case of the expansion option, having the option will be beneficial if the project value increases enough. The probability of a large increase is measured by the volatility of the project value, denoted σ. The volatility is a measure of the variance of the project value and if the volatility is large, the project value is more likely to increase much and subsequently, the value of the option will increase. To note is also that a high volatility increases the probability of lower project values as well. However, since we will not exercise the option for low project values, this will not lessen the option value and having the option will not bother us. Something that will bother us, on the other hand, is if there is any leakage in the project value during the time we wait to exercise. Leakage, denoted δ, occurs when we loose money due to the fact that we have not exercised yet. In the example with the expansion option before, a leakage could be the possible money lost compared to if we were able to expand earlier. Finally, since the cash flows resulting from an exercised option will arrive in the future but we are interested in the present value of the cash flows, we have to discount the cash flows. Since the replicating portfolio is risk-free, the discount rate will be the risk-free rate r_f.

Knowing all these variables, it is possible to calculate the value of the real option. However, depending on how complicated the option is, different valuation models will be possible

to use. In the simple example with the expansion option we will be able to use the formula for valuing a European call option derived by Black and Scholes in their 1973 article [5], adjusted to take leakage into account, saying that the value of the option c is

$$c = Se^{-\delta T}\Phi(d_1) - Xe^{-r_f T}\Phi(d_2) \tag{1}$$

where

$$d_1 = \frac{\ln(S/X) + (r_f - \delta)T}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2} \tag{2}$$

and

$$d_2 = d_1 - \sigma\sqrt{T}. \tag{3}$$

In (1), Φ denotes the cumulative standard-normal distribution. Equation 1 is an example of a closed-form expression giving a single number as an answer. Closed-form expressions do only work for very specific options and if any conditions change, the expressions are no longer valid. The expressions have been derived for many sorts of financial options, however, a real-world ROA application is generally too complex to be valued in this way and other valuation methods have to be used. Of these methods, the most important is the binomial lattice model and we will discuss this model now.

The binomial lattice model has the advantage of being flexible and it is therefore suitable for real options valuation since it can be adjusted to the specific conditions of a project. The main drawback is that it may take a lot of computational power to find an accurate result. When using a binomial lattice model, we start with one or several options with times to maturity of less than or equal to T years. These T years are divided into a finite number of time periods of length Δt and the next step is to create a binomial tree with project values at these time periods. In the binomial lattice model, during each period, we model that the project value can either go up with a factor u or down with a factor d. If σ is the project's volatility, u and d are calculated as

$$u = e^{\sigma \cdot \Delta t} \text{ and } d = 1/u. \tag{4}$$

The binomial tree starts with one node for $t = 0$ where the project value without flexibilities, S, has been calculated using any of the methods discussed in the beginning of this section. After the time Δt we model the project value as either $S_u = Su$ or $S_d = Sd$, after another time period there will be three project values $S_{uu} = Su^2$, $S_{ud} = Sud = S_{du} = S$ and $S_{dd} = Sd^2$. We continue in this manner until we have added $T/\Delta t$ time periods and our binomial tree is ready and will look like in Figure 1. This tree will represent the possible values of the project without flexibility at different times and we will use these values to calculate the option value.

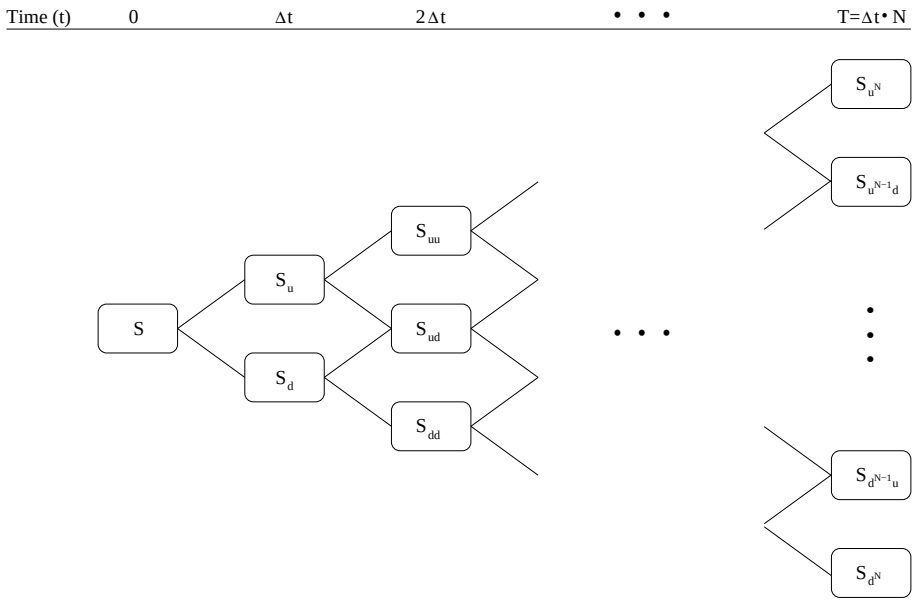

Figure 1: Example of a binomial tree

To value the project with flexibility, we start by looking at the end nodes of the tree, at time $t = T$. For each such node we will have, say, n options and the option to exercise will depend on the project value. For some end nodes we may not want to exercise any option but merely continue as we used to. We will choose the option maximising the value of the project with flexibilities, c, due to the formula

$$c_{\text{node } i} = \max[\text{Value of option 1 when } S = S_i, ..., \text{Value of option } n \text{ when } S = S_i, S_i]. \quad (5)$$

When these values are calculated, we can continue to calculate the values of the nodes for $t = T - \Delta t$. At these nodes we may also have some options possible to exercise (not necessarily the same options as before), and we can choose to exercise any of these, or to continue without exercising. If we choose to exercise an option the value of the project with flexibilities is calculated using the value of the project without flexibilities in the same node and the extra value added by exercising the option. However, if we choose to continue without exercising, we will end up in any of the two nodes at $t = T$ having edges to the node we are looking at and the value of continuing will depend on the values in these two nodes. We cannot, though, simply average the two values and discount the average back a time Δt to find the correct value, what we have to do is to find a risk-neutral probability and use a weighted average before discounting.

The idea of the risk-neutral probability is as follows. We have \$x at time $t = 0$ and we can invest them either in a one-time-period bond with risk-free rate r_f or in an investment that can either go up with a factor u or down with a factor d during this time. We now ask, how large should the probability, p of an upwards movement be in order to make us neutral to either investing the money in the bond or in the other investment? If we buy the bond, we

will have $\$x(1 + r_f)$ at the end of the period. If we choose the other investment we will get $p \cdot ux + (1 - p) \cdot dx$ dollars on average. Setting these two equations equal to one another and solving for the risk-neutral probability then gives that

$$p = \frac{(1 + r_f) - d}{u - d}. \tag{6}$$

Going back to the binomial tree, we see that the situation is the same when we are calculating the value of not exercising any option in a non-end node. We calculate the risk-neutral weighted average of the two following nodes and we discount it with the risk-free rate. This value is then compared to the values we would get if exercising any of the options and since we will do what is value maximising, we will choose the action with the highest value. In this manner we can construct the entire binomial tree of project values with flexibilities. We will complete the tree at $t = 0$ where we find the present value of the project with flexibilities, which was the ultimate goal.

This was a short description of how to value real options using the binomial lattice model. As the description has showed, the input variables to the model are the same as to the B-S model in equations 1-3 except for the leakage. Leakage can of course be implemented in the binomial lattice model as well, hence the inputs will be the same. The output of the two models are not the same, though. The B-S model only gives the value of the project with flexibility. From the binomial lattice model, we also get a value of the project, however, if we record the choices we made at the different nodes when constructing the second tree we will also get a decision tree. This tree can then be used to identify important parts of the project and it will be a tool when connecting capital budgeting with corporate strategy. In the next section, we will look at problems connected to approximating the different input variables.

3.2 Input Variables

If we look at the Black-Scholes model in equations 1-3, we see that there are six input variables affecting the value of the option; the value of the underlying asset, the time to maturity, the exercise price, the volatility, the risk-free rate and the dividends or leakage. Although the B-S model only holds for very simple option types, more advanced types will have the same variables as inputs. So, when using ROA, calculating and approximating these six variables is a very important part. Two of these variables, the leakage and the volatility are, in general, the hardest and most important variables to estimate (Davis [13]). We will therefore treat these two variables in separate sections; the other four variables will be discussed here.

3.2.1 Value of the Underlying Asset

In Section 3.1 we discussed how to find the value of the underlying asset, or the present value of the expected cash flows. In the classical approach the valuation was done by finding a replicating portfolio with the same returns as the project. The other approach discussed was the MAD assumption, making it possible to use the NPV of the project as the underlying asset. It was also mentioned that sometimes none of these methods may apply and that this

was due to the existence of private risk in projects.

Perlitz et al. [33] discuss other factors that can make methods used for valuing real options inappropriate. Many of these factors mostly seem to affect methods assuming continuous time, like the B-S model and other closed-form expressions. If these models are used, the assumption is that the value of the underlying asset changes like a diffusion process. If the value moves like a diffusion process there never occur any jumps in the value and according to Perlitz et al. this is not always the case. Furthermore, a diffusion process also tends to move too far away from the starting point compared to the real world where the prices tend to move back towards the original price. This is called a mean-reverting process and telling if the price-movement is such a process or not is hard (Perlitz et al.). But if the process is mean-reverting, this will make some evaluation methods unsuitable.

The above discussion shows that valuing the underlying asset is indeed not trivial, to make sure that the right models are used, a lot of investigation is needed. However, if a company applies a ROA framework, its managers will probably not have the time, nor the knowledge, to analyse if the assumptions are fulfilled or not. To make ROA applicable for practitioners, and that has to be the ultimate goal, easier methods have to be used. Therefore, the possibility to use the project NPV as the underlying asset value is almost necessary and this is, according to Perlitz et al., the standard method used by practitioners. On top of that, if the alternative to ROA is using only a traditional NPV analysis, it is reasonable to assume that we will come closer to the truth if using ROA than if we do not consider flexibilities at all.

Finally, we also want to mention that in what is written above, as well as in most other texts about ROA, one gets the feeling that finding the NPV of a project is a piece of cake. However, this is not the case. Although a majority of (the large) companies use the NPV method or some other DCF (Discounted Cash Flow) technique, it took quite some time before the methods got widespread. There are probably problems still occurring when using these methods (Graham and Harvey [19]) and this could be a reason for companies not having started to use ROA.

3.2.2 Exercise Price

In financial option pricing, the exercise price is well-known and stated in the option contract. This is not the case with real options. Sometimes the exercise price will be known, e.g. if stipulated in a contract with a construction firm. But often it might be less well-defined and/or divided into several outlays. For uncertain, stochastic exercise prices there have been developed closed-form equations (Miller and Park [29]), but then you also need to be able to determine which stochastic process the exercise price, $X(t)$, will follow and what are the parameters of the process. See for example Fischer [18] who values a call option when the exercise price follows a diffusion process. Assigning an uncertain exercise price a stochastic process will of course induce yet another, partly subjective, assumption to the real options valuation.

A stochastic behaviour is not the only problem with the exercise price in ROA. A real option's exercise price (in the case of a call option) consists of the present value of all the fixed costs during the asset's remaining lifetime (Leslie and Michaels [23], Perlitz et al. [33]). These, of course, do not all have to occur at the same time but can be spread out over time. This calls for techniques where the option can be valued using some kind of aggregated exercise price, but this has not clearly been solved yet (Miller and Park [29]).

3.2.3 Time to Maturity

The time to maturity may be hard to assess. Sometimes the company has a license with a clearly set expiration date and it will be no problem to set the time to maturity, but this will not always be the case. For example, Kemna [22] states that when valuing the option to wait, theoretically, the time to maturity could be infinite, but in reality it is often determined by the time it takes for competitors to enter the market. This would call for a competitor analysis and perhaps alterations in the ROA when further information about the competitors' moves uncovers itself. Perlitz et al. [33] distinguish between "exclusive" and "common" real options. In the first case, only the holder has the right to exercise the option, this can be, for example, in the case of the existence of a patent, exclusive rights or competitive advantages which are hard to mimic because of imperfect resource mobility, as described by Peteraf [34], which will make the resources bound to the firm. The common real options can be exercised by competitors as well, which makes the valuation more complicated (and very unlike the financial option valuation from which the valuation tools are benchmarked). The actions taken by competitors in this case are often treated as dividends but these are hard to model as well and will be treated in Section 3.3.

Miller and Park [29] list a few more factors that can affect the time to maturity and take up factors like; private/market risk resolution, competition, changes in technology and macroeconomic factors. These can be exogenous and hard to define. Furthermore, they comment that the exercise date often is much longer in duration than in the financial contracts that the normal option pricing techniques were developed for. Last, but not least, Miller and Park comment that real options perhaps might not be exercised immediately, there might take some time to construct a facility or to train a new labour force. All these dissimilarities in the exercise date compared to the financial options will affect how correctly the financial option techniques can be applied to, and value, the real options.

3.2.4 Risk-Free Rate

The risk-free rate is usually the easiest input variable to estimate when making financial options calculations. What one does is really only to look at the rate of treasury bonds or similar securities with time to maturity equalling the project length. However, when looking at longer time periods, as one often does in the case of real options, the risk-free rate can be unknown or stochastic, which makes the estimation of the risk-free rate more difficult (Perlitz et al. [33]). Furthermore, using the risk-free rate in the calculations may not always

be appropriate. In Section 3.1 we mentioned that having private risk in a project will change the conditions and which methods plausible to use. Miller and Park [29] discuss how private risk may affect the option value and methods dealing with the private risk. Many models are designed for only market risk and this is due to the fact that in financial options, the private risk is diversified away. For a non-traded asset, like a project, this diversification is generally not possible.

If there is private risk in a project, a company should, according to Miller and Park, use a discount rate higher than the risk-free rate to take this risk into account or use some other technique. Techniques adjusting for private risk are discussed by Miller and Park, and examples of such are letting the option value depend on the ratio of private and market risk or by modifying some differential equations used for valuing the option and thereby take the private risk into account. Now, we once again see that, when looking deep into the properties of real options, the models quickly become more advanced and hard to grasp. To make the models applicable, one therefore has to make some simplifying assumptions and this goes for the risk as well. Examples of such assumptions are discussed in Trigeorgis [43] and the consequence is usually that real options can be considered as financial options. Therefore, with these assumptions, the risk-free rate can be used when calculating the value of a real option.

3.3 Leakage in Value

In financial option pricing, dividends lower the call option value and increase the put option value. The original Black-Scholes equations can be adjusted to take a single dividend or a constant rate of leakage into account (see for example Hull [21]). When valuing projects, leakage in value might manifest itself as, e.g. rental income, cash flows, convenience yields or loss of market shares to competitors. The first two examples represent cash flows to the holder of the underlying asset (the third an implicit cash flow), with real options the holder of the underlying asset is most often also the holder of the option. When the dividends are payable to the holder of the option and not the holder of the underlying asset, this will make the valuation more complicated, since it is not considered in financial option pricing theory (Amram and Kulatilaka [2], Perlitz et al. [33]). Further, the leakage in value in a real option is not as easy to model as the dividends of a financial underlying asset. The amount and timing will be dependent on exogenous influences (Miller and Park [29]). The financial option pricing techniques may be used but they need to be further developed to account for the uncertainty in the dividend yield.

Davis [13] considers the dividend yield for a real asset to be more difficult to calculate than that of a financial asset since the asset is not openly traded. Because of the difficulties in estimating the dividend yield, many real options analysts assume it to be zero, set it equal to the convenience yield of the output good or use an arbitrary value and test the option value's sensitivity to it. According to Davis, many of the techniques developed are *ad hoc* in nature but he manages to derive equations for two cases that can be refined for other, similar projects. These two cases are; the option to invest in a project with no operating flexibility

and the option to abandon an operating project, however, many approximations have to be made, e.g. that the price of the output good follows a geometric Brownian motion.

When developing techniques for real options valuation, there is a need to consider the trade-off between accuracy and applicability [1]. Many believe that the problem with the cold reception of real options is that the techniques are hard to comprehend and apply. If the holders cannot fully comprehend a more complex (and therefore supposed to be more precise) ROA process, they will not be able to act according to it and the option valuation will be incorrect anyway. Amram and Kulatilaka [2] say that a simplified treatment of the convenience yield may give "capacity" for other asset features in the model, or frequent cash flows might be approximated with a constant rate. This is said to be due to overmodelling when trying to achieve more precision in details, which might introduce modelling errors instead. A less sophisticated model with large assumptions can be suggested if the result is tested for sensitivity. For example, Kemna [22] approximates the pay-out rate of an oil-drilling project as constant so he can use the formula for a financial option on an underlying asset paying out a constant dividend yield, the sensitivity of the value to the assumed rate is then tested.

3.4 Volatility

The volatility is often the variable that has the greatest impact on the option value, but unfortunately, it is also one of the hardest variables to estimate. In financial option pricing, the volatility is normally calculated using historical data or an implied volatility. However, it is often the case that no historical data or comparable companies exist when valuing real options (Miller and Park [29], Davis [13]). According to Miller and Park, three different approaches to estimate the volatility can be found in the literature; twin security information, Monte Carlo simulation and closed-form expressions. Twin security information can be used if you can find a traded security with the same characteristics as the project. Luehrman [25] suggests somewhat similar techniques; you can either guess it from your knowledge about the volatility of associated stocks or you can gather data on historical returns in the same or related industries, however, finding such historical returns is often hard (Davis [13]). If there is a traded option on a similar underlying asset, you can derive an implied volatility since you have the price and all other inputs for the option. Last, but not least, you can use the projected cash flows for the project and make a Monte Carlo simulation of the probability distribution of the project returns.

3.4.1 Monte Carlo Simulation

Copeland and Antikarov [10] describe how Monte Carlo simulation can be used to estimate the volatility of the project. First, you need a model of the project and a decomposition of the future expected cash flows into price, quantity and so on, this should not be a problem since without a financial model, you cannot begin your ROA. By assigning mean values, probability distributions and standard deviations to the variables and running a simulation with an appropriate software, you can acquire a simulated distribution of percent changes in the value of the project. The computer program can then easily calculate the simulated

volatility. The process as such is really easy, the hard part is to set the parameters for the variables in the model. The technique has the advantage that you do not have to find data on an exactly similar project, but you still have to assess the volatility of the variables that are part of the model. Important is also to not forget that the variables can be correlated, either autocorrelated (correlated with themselves) or correlated with each other. Take for example price and quantity, these are most often negatively correlated and should be treated as such with an appropriate correlation coefficient in the simulation. Positive correlations can lead to increased option values while negative or independent correlations could lower the value according to Miller and Park [29]. To estimate the parameters of the variables, Copeland and Antikarov suggest that you either use historical data or subjective estimates from the management.

3.4.2 Historical Data or Management Assumptions

When is it more appropriate to use historical data and when is it more appropriate to use management assumptions? If we can assume that the future will resemble the past, we can use historical data. For example, when valuing replacement investments or the option to expand or shut down an existing project, we can use historical data. The project will still be exposed to the same market risk for price, quantity and the like. For these variables we can use historical data to estimate the volatility and correlations. But for the parts that will not look like the past, e.g. if the alteration in the project will come from a new process that has never been used before, the price and quantity will be exposed to the same (market) risk but the variable cost will perhaps be exposed to a private risk that you have not observed before (Copeland and Antikarov [10]). For this and other new uncertainties we have to turn to the management assumptions for help. This is not so bad though, there is often no one who knows the business better then the management. The problem lies in transforming their intuition into mathematical parameters. By assuming a reasonable stochastic process, setting a time frame and letting the management estimate values for the mean, and worst/best case scenarios that will only occur for a given percent of all cases, you can translate the management's intuition into a volatility by using backward calculation.

3.4.3 Implied Volatility

A popular method of assessing the volatility of an asset is, if you have found a similar traded option, using an implied volatility. The volatility is one of six parameters in the Black-Scholes formula, but the only one that it is not directly observable for financial options. Using the other five parameters that can be be readily observed, plus the market-set option price, you can derive an implied volatility. One of the foremost advantages of using an implied volatility on an option, instead of using historical returns, is that the option's theoretical value depends on the expected future volatility during the option's remaining lifetime and is therefore not backward looking (Figlewski [17]). If you can find an option on an underlying asset that should behave much like your project, many argue that the implied volatility of the option will be a good estimate of the project's future volatility. The argumentation behind this is that, using the implied volatility, you can capture the market's expectations about the volatility. However

Figlewski, in his effort to find the optimal technique to estimate volatility for option pricing, found that there seems to be a theory-practice gap in how the traders act. Figlewski says [17];

> *In theory, the implied volatility is the options market's well-informed prediction of the underlying asset's future volatility. Academic researchers typically treat it as such. In practice, however, the arbitrage trading that is supposed to force option prices into conformance with the market's volatility expectations may not be done very actively at all. [...] Thus the implied volatility derived from market option prices need not be a good proxy for the market's best forecast of future volatility of the underlying asset.*

3.4.4 Log-Normal Returns?

A common assumption is that the returns will be log-normally distributed. The random variable X is log-normally distributed if $\log(X)$ is normally distributed (Limpert et al. [24]), therefore, negative values of the variable is not possible since you cannot take the logarithm of a negative number. The assumption of log-normal distribution often holds for stock returns and it is therefore often used when estimating volatility on stock returns. It can also be used to estimate the volatility of other variables in the financial model. For example, even when Kemna [22] uses the simple margin between the output proceeds and the supply costs for a crude-oil distiller, he has to make the assumption that both of these will be log-normally distributed in order to use standard option pricing models. However, assumptions like these always have to be tested in some way, for example by using sensitivity analysis. In cases like the one Kemna describes, with crude-oil and other natural resources, the assumptions often hold. For other variables the assumptions will be less motivated, Figlewski [17] maintains that empirical evidence shows that the behaviour of asset returns differs substantially from the properties of the log-normal distribution. For example, there are so called "fat tails", i.e. there are more large changes and less small changes than in a log-normal distribution. Triantis comments the problem in the following way [41]:

> *First, and I believe foremost, we need to be careful about specifying the distribution for each of the underlying assets in our model, whether that be a specific commodity price or demand, or a "bundled" uncertainty in the form of the underlying project value. In many of the applications in which real options analysis is used, the distributions of the uncertainties differ significantly from the standard lognormal distribution that is assumed in Black-Scholes and other related models.*

As mentioned above, sometimes the need for simplicity and applicability is often more important than precision. However, one has to be careful so that the ROA will not give misleading results when the assumptions and simplifications become too large and many, this is the so important trade-off between applicability and precision.

3.5 Managing Real Options

As the review of the basic real-options-analysis methods in Section 3.1 showed, when an analysis is finished we will end up with a project value. If we use some lattice model like the binomial lattice model we will also have a decision tree telling us how to react when the true development of the project is revealed in the future. Furthermore we should also have done a sensitivity analysis telling us the parameters that will affect the project value the most if they change.

However, doing the analysis is merely the start of a process and if it tells a manager to go on with a project, what is the next step for her or him? If the manager has created a decision tree, he or she might think it says that "in one year the value will be $x, $y or $z and depending on which we will make different decisions, but that is nothing to worry about now." Looking at the created information in this way is not very constructive, it should be possible to do something during this year to increase the possibility for a good project performance or at least for avoiding spending more money on a on beforehand doomed project. Although acting like this probably is not optimal, and it should be possible to affect the project value actively, there might be managers acting in this way. When the manager thinks that the value of the project cannot be affected further, he or she is only waiting whether to exercise any of the existing options or not. These options are referred to as *reactive* flexibilities by Leslie and Michaels [23]. Instead, if the manager is actively trying to find information and improve the option, he or she is utilising what Leslie and Michaels refer to as *proactive* flexibilities.

We think that when studying factors impeding the implementation of ROA, the reactive flexibilities are the most important since these flexibilities have to be properly managed in order to make the project value calculated with ROA valid at all. The proactive flexibilities will, on the other hand, probably only be interesting when a company has a working ROA framework, they can then be used to improve the value of the project further, after the project has been approved. Therefore, we do not think the proactive flexibilities will pose any problems for the implementation of ROA and a discussion regarding these flexibilities is not necessary for the purpose of this essay. However, if ROA becomes a widespread method, the managers will also have to be able to manage the proactive flexibilities and a description of the proactive flexibilities can be found in Appendix B for the interested reader. A description of their reactive counterparts will follow in the next section.

3.5.1 Reactive Flexibilities

When managers are not actively trying to affect the value of the project after deciding to go through with it, they get into a similar situation as someone holding a financial option. The problem is then when to exercise the option or if it should be exercised at all. Finding the optimal point for exercising is critical since it decides the payoff of the project (Leslie and Michaels [23]).

If we start by looking at the problem of exercising the option at all, the big issue is how to make the decision-maker making the right decision. Even if the decision-maker knows what the right decision is, that decision may not be what is eventually chosen. A very important thing for the company is therefore to assign managers the responsibility for the exercise decisions and make sure that they are properly motivated (Copeland and Tufano [11]). A common source for lack of motivation is if the manager responsible for exercising is the same manager as the one who decided to start with the project. If this manager comes into a situation where it is optimal, for example, to abandon a project, feelings like prestige can result in that the optimal decision is not made. Instead, the manager hopes for an unlikely development that would make the project look good.

If the company succeeds in properly motivating the decision-makers to make the appropriate exercise decisions, the results of the company will be good, *on average*. The problem is though, that there may be a manager responsible for only one project. If this project turns out bad, and this could happen merely by accident, the manager will face more negative effects than the company in general, even if he or she acts the way the ROA tells her or him to. If the option is a contraction option for example, the manager will have to dismiss some staff. To avoid this, the manager may hope for an unlikely, good development in the future and not exercise the contraction option. This example shows that if a manager by making an exercise decision will loose more than the company in general, there is a probability that he or she will not make the optimal decision according to the ROA. A good way to deal with this problem is to let one manager be responsible for several projects so that the manager can feel the effects of averaging more personally [1]. Furthermore, it is also important to evaluate a manager's performance on if he or she is making optimal decisions and not on if he or she is being lucky or not.

The first part of the discussion about reactive flexibilities has focused on the problem of making managers want to make the optimal decision. Even if a company succeeds in making their managers willing to make optimal decisions, this might not be enough. The managers must also have the *ability* to make the optimal decisions. This is a problem that also occurs when looking at financial options, some options are exercised too early and some are exercised too late (Copeland and Tufano [11]). To solve this problem Copeland and Tufano suggest that the company should create trigger points that the value has to pass before an option is exercised. The value of this trigger point will change with time since there are different criteria for exercising at different times. Furthermore, Copeland and Tufano argue that the trigger point actually should be more of an interval than a specific point and that when to exercise within this interval should be discussed. The reason for that the optimal decision for a given project value could have changed since the trigger point was calculated, is that some assumptions, used when deriving the optimal decision, may have changed.

3.6 Successful Implementations?

When looking for examples of successful implementations, it may be hard to decide on an indicator on a successful implementation. Mainly, one can argue that if a company has tested real options and continued using it, they ought to have found the method useful and as a help in the capital budgeting process. But in assessing whether the companies using real options get a competitive advantage, you get the problem of inferring causality. In certain industries, the ones where ROA is most common, such as the oil and gas, mining and pharmaceuticals industries, there seems to be a correlation between success and ROA. However, it is hard to say if these companies are the best because they use ROA or if they use real options partly because they have more money to spend on it, says McCormack in [1]. This causality will have to be addressed; if one finds a company that is successfully implementing a ROA framework, one will have to conclude whether it is the framework as such that is the source of the success. The generated success could equally well be due to the company having more money and managerial capital to put into the project.

From another perspective, some academics argue that the power of ROA may not be that it will give a precise value but that it can bridge the gap between the strategic analysis and financial analysis in capital budgeting (see for example Myers [32] or Borison in [1]). In other words, when studying companies using real options, you have to take on a broad perspective and not only look at the numbers; in which way has the capital budgeting process changed since the introduction of real options? As an example, Amram et al. [3] describe the successful implementation of real options at Kimberly-Clark and compare it with the other companies which they have worked with on real options implementation. They argue that the reason for Kimberly-Clark doing better than others in implementing ROA is such factors as that the company had projects that needed ROA and not the other way around, (that they wanted to use ROA and searched for projects to use it on), and that the implementation process was allowed to take long time. At Kimberly-Clark the real options added value by changing the way that project analysis are framed and by changing the order in how risks are investigated and resolved.

This concludes our literature study, and it can be seen that there are many possible problems that could occur if using ROA in real-world companies. Some of these problems will also be considered in the next chapter where we will describe our findings from the interview study. Later, in Chapter 5, we will compare the findings from the two studies.

4 Empirical Findings

In Section 2.3 we described how we chose which companies to contact for interviews and that we ended up conducting four interviews. The interviews lasted between 60 and 140 minutes and were carried out at the interviewees respective offices. We will begin this chapter by giving short presentations of the four companies we interviewed, which were Eka Chemicals AB, Port of Göteborg AB, Ringhals AB and Stena Finans. In the sections following the company presentations, we will describe and analyse our findings from the interviews.

4.1 Company Presentations

Eka Chemicals is a supplier of chemicals to the pulp and paper industry. Their two largest product groups are bleaching chemicals (54% of sales) and paper chemicals (30%), the remaining 16% of sales come from different specialty products according to [14]. During 2006, the sales were €963 million and their investments were €46 million. The company has sites in Europe, North America, South America, Asia and Australia and their headquarters is situated in Gothenburg. At Eka Chemicals we interviewed Gijsberth de Ruiter, responsible for Control and Finance.

Port of Göteborg is a company owned entirely by the municipal of Gothenburg and runs, as the company name indicates, the port of Gothenburg, the largest port in Scandinavia. The company offers services in areas of containers, ro/ro, oil, cars, passengers, logistics and railways and is aiming to become a hub for sea transports in the future. During 2006, the sales were SEK1,503 million and they made investments for SEK321 million, according to [20]. At Port of Göteborg we interviewed their CFO, Ingela Thörnkvist.

Ringhals AB is the company owning the nuclear power plant in Ringhals, situated about 80 km south of Gothenburg. Ringhals is, in turn, owned by the state owned energy company, Vattenfall. During 2006, the market value of the produced energy at Ringhals was about SEK7.5 billion [35]. Presently, a number of large investment programs are being carried out at Ringhals. The programs will involve outlays of SEK13.5 billion and are mainly intended to increase efficiency, safety and lifetime of the power plant. At Ringhals we interviewed Erika Schönborg, one of three persons responsible for capital budgeting valuation in the central administration of Ringhals.

Stena Finans is one of several companies within the Stena sphere owned by the private company Stena AB. One of Stena Finans' responsibilities is project financing in the other companies in the Stena sphere. These companies work within the areas of shipping, passenger ferries, oil drilling, real estate and recycling. Together the group of companies in the Stena sphere had a turnover of SEK22,895 million in 2006 according to [38]. At Stena Finans we interviewed the CFO, Rolf Mählqvist and the Business controller, Henrik Hallin.

4.2 The Capital Budgeting Methods Presently Used by the Companies

If we start by looking at the questions in the general part of our interview guide in Appendix A, our interviews indicated that DCF methods are the most commonly used capital budgeting methods. Three of the companies used DCF techniques, in the fourth company, the true nature of the technique was not completely uncovered. This fourth company was Port of Göteborg and when we asked if they used a method based on the NPV, we did not get a very clear answer. We found out that they do look at the profitability of the project and this is calculated by considering changes in the cash flow due to the project. However, we were not told how future money is valued today, if they are discounted or not. Since Port of Göteborg is owned by the municipal of Gothenburg, they may have a harder time to approximate a discount rate. This may, as a consequence, make DCF techniques less applicable for this company.

Of the companies using DCF techniques, two of the companies used other techniques as well. One company used multiple calculations on some occasions and, when possible, they also looked at market values of the assets. Another company used several other criteria when making capital budgeting decisions, they considered payback period, IRR and EVA^{TM} as well as NPV. The third company was, mainly, only focusing on the NPV of investments. They used a software for the NPV calculations and this software had, as an output, a measure denoted CVA, Cash Value Added. The CVA measure is the ratio of the NPV of the incomes created by the project and the NPV of the project's outlays. Having a demand for a CVA larger than one is therefore the same as demanding a positive NPV when summing all the considered cash flows of the project.

Another topic we discussed in the introductory part of the interviews was the impact the results of the capital budgeting methods had. The answers we received can be summarised as follows. When making capital budgeting decisions that involve costs over certain limits (these limits will be described further in the next section of this chapter), a calculation using the companies' respective methods should always be conducted. However, there will be many occasions where the outputs from the methods will be negative. An example of such an occasion is when some fundamental part of a plant has to be replaced. The alternative to replacement is closure of the plant and this alternative is usually not valued since it will, in general, mean a larger cost for certain. However, there are still at least two reasons for making calculations for replacements. Firstly, the calculation will show how much the replacement will cost and give information about how much money that has to be allocated. Secondly, the results from the calculations can be used if the company has different replacement alternatives to choose from.

Another occasion when projects are approved, although they do not show a positive value according to the capital budgeting method, is when the project is seen as strategically important. The companies think that such projects are hard to value mathematically, there are future possibilities and options that their present models are not able to value, and knowing of these things make them make decisions that may seem bad on paper. This is the situation Myers [32], among others, describes and, as has been mentioned earlier, this is an area

where ROA is supposed to be helpful. Therefore, that all our interviewees indicate that such decisions occur and that they find them hard to value might indicate a positive future for ROA.

So, when is a positive value from the respective capital budgeting methods a strict criteria? In the interviewed companies, this was the case when the project was either a rationalisation or an expansion that was not of large strategic importance. In these cases, being able to show that an investment will be profitable becomes more important and subsequently does the importance of the outputs from the methods increase. However, also in these situations, one of the companies said that they were able to stretch the limits and allow projects not passing all criteria. This was the company using, among others, IRR and payback, and there could be situations where a project had a short payback period but an IRR slightly lower than the formal limit, but the project could still be approved. This company motivated not having too strict limits with a factor we will consider more in the next section, namely making the employees make, for the company, optimal decisions. If the employees know that a project may be approved, although it does not fulfil all criteria completely, this should be an incentive to not modify the numbers.

4.3 Decision-Making Processes and Incentives for Making Optimal Decisions

If we turn to how decisions regarding capital budgeting are made, we are able to identify similarities between the companies, and their decision processes can in general be described as follows. The organisations were divided into a number of levels, and depending on the cost of an investment, different levels were allowed to make the decision whether to go through with a project or not. The largest investments could only be approved by the companies' boards of directors. Somewhat smaller outlays could be approved by the CEO, even smaller by managers of different business units, and so on. For projects with outlays that the companies regarded as very small, projects were not regarded as investments and were not evaluated as formally as larger projects.

The above description of the capital budgeting process differs from the picture we got from our literature study. We got the picture that, also the large, decisions are made by people deep in the organisation and made by them alone. This will only work as long as the companies have unlimited amounts of money to spend on different projects, given that the projects are profitable. In reality, according to our interviews, this is not the case, and for larger capital budgeting decisions, the board of directors, or at least the CEO will have to be involved. Therefore, the question whether the decision-makers are properly motivated or not is not as large worry in practice as it is in theory.

However, before top management make decisions, they will be provided numbers from persons deeper down in the organisation. Making sure that these numbers are not modified may therefore have been a larger concern for the companies. When asking if this was a problem, none of the companies thought it was. There were several reasons making them think they

were provided the correct numbers; first of all, many mentioned the company culture. The interviewees meant that there was a culture in the companies making persons provide the correct information. Also, since projects are evaluated after they have been accomplished, providing wrong numbers would be a drawback for the provider in the future. Finally, as we mentioned in the previous section, one of the companies also told us that they use somewhat loose criteria so that employees know that projects may be approved although not all criteria are fulfilled.

4.4 Input Variables

Discussing the input variables of a model with someone not using the model is naturally not easy. With the questions in our interview guide, we tried to get a glimpse of the possibility to determine the input variables without going too deep into real options theory.

As we mentioned in Section 4.2, DCF techniques were the prevalent techniques among the companies. Therefore, using the MAD approach discussed in Section 3.1 should be possible for the companies. Based on the NPV of the project, the next question is if it is possible to approximate how the value of the underlying asset will change in the future. Closely related to this question is consequently how to estimate the volatility of the project value. For the different interviewed companies, the project values did of course depend on different variables, however, the interviewees said that many of the most important factors affecting the project value were possible to observe on different markets (e.g. commodity exchanges and financial markets). They therefore believed that it would be possible to make approximations of how the project values may vary in the future and also to come up with probabilities for different developments.

At present, at least some of the companies make scenario analyses when calculating project values, but mostly, they only look at a worst-case scenario. Usually they do not calculate the probability of this scenario, it should only not be completely unlikely. Therefore, assessing some probabilities for both increases and decreases in project value will be something the companies are unknown to and it will probably be quite hard, although the interviewees believed it may be possible. Furthermore, looking only at a worst case scenario points to a risk-averse behaviour. This kind of risk-averse behaviour might impede the implementation of ROA, since if implementing ROA, you really need to embrace risk, i.e. volatility, rather than shying away from it.

Turning to the exercise price of options, or the cost of future investments, having the ability to determine these varied from company to company and usually also between different projects within the same company. If the cost of the investment was similar to that of an investment the company had made before, it was believed that it would be easier than if this was not the case. In some of the companies, the approximation of these prices was made in a preproject phase where someone in the organisation studied the value of the project. In this phase, different alternatives were also studied and for the chosen alternatives of the

project, a deeper analysis was conducted. To mention also, is that the interviews confirmed one of the topics described in the literature study, namely that the costs comprising the exercise price often are spread out in time. Sometimes, it is even necessary for the companies to place orders many years in advance, which can be accompanied by an advance payment. This phenomenon will also affect the next input variable to be discussed, the time to maturity.

When looking at the time horizon of a capital budgeting decision, it varies with the type of investment. For a replacement investment when something is broken, in practice, the time horizon is short since this may actually stop an entire plant, production line or similar. Other investments, and these investments are the more interesting ones, like an expansion or the introduction of a new product, will have longer time horizons. When discussing the time horizons of such investments with the interviewees, it turned out that they were different for the different firms. Some of the companies were part of markets where, if they did not act, someone else would. Therefore, their time horizon was limited and they had to act before it was too late, however, setting a precise time to maturity was considered difficult. These companies also seemed to find options to wait more valuable than the other companies. Those other companies, who were not affected that much by competitors' actions, had much longer time horizons and they did not have to consider to start projects before they became profitable. These companies only lost money due to the decreased sales during the time until the project was started. For the other companies, this loss may have been larger and this is the last input variable we discussed, namely the leakage.

So, we have already mentioned that the leakage varied between the different companies. For the companies acting on competitive markets, the loss of acting too late became larger than the direct incomes lost due to waiting. A competitor may have taken market shares, which would take a long time, if possible at all, to win back. This means that the leakage for these companies was larger and also harder to approximate. This may impede the implementation of ROA if the model cannot take this leakage into account. On the other hand, it is situations like these which make ROA most usable, and having good methods for modelling leakage is therefore important.

After discussing possibilities to approximate the input variables, we now turn to the discussion about whether ROA seems applicable in the interviewed companies or not.

4.5 Applicability of ROA

When discussing the applicability of a ROA framework in the studied companies, many aspects are interesting since it is not enough if the company's business is identified as suitable for the use of ROA. The company also needs to be able to adopt the whole process of ROA, all the way from valuation and information gathering to implementation and execution of the option.

In general, all companies observed flexibility in at least some of their investments. Looking at the investments with the longer time horizons, the flexibility increased. To note is still

that, in some cases, most of the investment costs occur in the beginning. Furthermore, the case can often be that parts of the future investments that one might consider optional at first glance really had to be ordered many years ahead and are therefore already fixed. In general, there is left more flexibility in the larger investments, of course this can be because larger investments are more likely to have a larger time frame, but also because of that the decision-makers have limited time to work with the investments and therefore will only revise the larger ones. For the smaller investments, most decisions are made at one point in time.

The question might come to if the companies are willing to use different methods for different investments, depending on which are the characteristics of the investment. The use of different methods would be due to that the ROA might only add further insights in some special cases and will be superfluous in others. A problem with this may arise; one company mentioned that they wanted to use the same method for evaluation of all investments to make it possible to compare them. Here the issue will be how exact the methods are and if they are comparable. If different methods give very different results, the possibility to compare different alternatives will be lost. When using the same methods for all investments, even though it is not the optimal one, the possibility for fair comparison increases. However, Copeland and Antikarov [10] point out that, for example, NPV "systematically undervalues every investment opportunity", this is because it fails to take flexibility into account. The question will be when most of the comparability is lost, it could either be when we use different methods for different investments or when we use the same method but it undervalues the investments with more flexibility. The observant reader might here ask why the investments should be compared, should not all investments that will add to shareholders' value be carried through? Yes, in theory, but the companies also described that in the real world, they have limited resources and abilities to take on new investments, as will be further discussed later (the case can of course also be that you are comparing two alternatives for one investment, here one of the companies admitted that their current method was insufficient).

We go on to further discuss the possibility to revise the investment plans during the project's life time. It is clear that large parts of the plans for an investment can be revised in many cases, not all decisions have to be made in the beginning of the projects, as one of the interviewees made clear:

> *In year 0 you have a plan [...], some parts of the plan are relatively open, that depends on if there exists a contract from the beginning or not. The initial investment is of course rather fixed from the start. After that; that you develop the investment under the course of the project might happen.* (The authors' translation)

This statement increases the possibility of ROA being applicable, as does that the companies described how they build in real options in their investments, for example by creating over-capacity to be able to meet a future larger demand. However, this was presently hard to value and they had to turn to more strategic decision analysis for evaluating those kind of investments today.

An important issue will be how important the financial valuation is in the capital budgeting process. Today, as mentioned in Section 4.2, the financial valuation is not always key, sometimes other factors are more important, e.g. strategic planning. A question will be if the companies will be willing revise their current decision processes and let a tool like ROA value the strategic flexibility instead. For example, Myers [32] described the situation as "low net present value projects are nurtured 'for strategic reasons,' the strategic analysis overrides measures of financial value. Conversely, projects with apparently high net present values are passed by if they don't fit in with the firm's strategic objectives. When financial and strategic analyses give conflicting answers, the conflict is treated as a fact of life, not as an anomaly demanding reconciliation." This was already in 1984 and he then hoped that the gap between the finance theory and strategic planning could be bridged by applying existing finance theory correctly and add the option thinking. The question will be if the companies are willing to try to close this gap or not and rely on financial models to describe strategic value.

As parts of this section have shown, ROA seems to be applicable, at least to some extent, but are the companies looking for something like ROA? Do they feel a need for a method that can value the flexibility? What would make them interested in using it?

4.6 Need for ROA

For the companies to implement a new capital budgeting method, they need at least feel that they have a use for the new features it can add. We asked the companies about what features in a capital budgeting method they value high and if they are missing properties that ROA could add.

First of all, transparency in the capital budgeting methods proved very important. There is a need to be able to discuss the calculations and understand what goes into the calculations in order to be able to discuss the results and understand how your own estimations and assumptions affect the results. If this is not the case, it will be hard to assess the robustness of the results and how reliable the model is. As one interviewee expressed it:

> *Every model is garbage-in, garbage-out, so you need to have good information going into the model to get something good out of it.* (The authors' translation)

This leads to the discussion about whether or not the managers will be able to trust the information they put into the model. Therefore, we started using follow-up questions about whether or not they would trust a model where they had to give more input data and if that input data was something they would trust, or if they would feel that it would be "garbage-in". In the interviewed companies, we found that, for example, the volatility would probably have to be estimated using the management assumptions approach described in Section 3.4.2. When asked if they would feel comfortable in having to estimate some kind of confidence interval as well, they said that this often would be hard to estimate. One respondent although commented that of course it could be better to try to do it than neglecting that the estimated numbers will not be exact and that they could be more or less uncertain.

So, the transparency was important, the companies asked for a model that they could understand since it did not matter how theoretically correct the model was if the companies gave it the wrong input data. The companies wanted to understand what they were doing in order to do it in a more correct way. But this was not the only reason, the companies also wanted to be able to discuss the calculations between the different offices. If there is a need for more than one office (like sales, top management, production etc.) to contribute with input data, they need to have the same conception about the investment and if they are to discuss it in terms of input data to a capital budgeting method, the method needs to be transparent. Furthermore, the decision-makers are often not the same persons who conduct the financial calculations but they still need to be able to grasp the calculations as well.

If possible, a way to communicate and better discuss the calculations was welcomed at the companies, but did they feel any need for new methods for the valuation of investments? When asked if they felt any pressure from the competition that called for better capital budgeting techniques, the answer was no. Probably, companies in other businesses can be found that have a need to more exactly evaluate projects, but at least the situation is not as pressing for all companies as described, in Section 1.1, by Arnold and Hatzopoulos [4] and Trigeorgis [44]. As many companies do not really have the ability to undertake all projects that will add to the shareholders' wealth, they will not have the same need to accurately value the investments to see exactly which one will be the last to pass the required hurdles. If the academics are right about the ability of ROA to more correctly value investments, imperfect markets can perhaps instead explain why the companies have not been forced to apply a ROA framework. However, the companies still expressed a desire to value the investments as correctly as possible although the pressure from the markets was not there. Some cases were described in which the companies felt that their current methods were sometimes not sufficient to properly choose between possible investments. For example, in one company their DCF method would only show that one investment alternative was the best although they knew that there was a chance that the other (more costly) alternative could be needed in the future, rendering the first completely useless. The possibility that the other alternative could be needed in the future could not be incorporated in the model.

We also asked how the companies evaluated their capital budgeting methods. The companies revised their methods, if they were not satisfied with them they would make some corrections, but they did not often replace their methods. When asked how they would evaluate the methods, there was a tendency that methods mostly got revised when the methods had overvalued the investment and not when it had undervalued it. This tendency will impede the implementation of ROA since ROA will help to take overlooked value into account. As described by Mun [30] there is a worry that ROA will only "bump up and incorrectly increase the value of a project to get it justified". If the companies show these tendencies to rather use a method that undervalues investments than take the risk that some projects get overvalued, they will probably be more reluctant to welcome a method that will give at least as high value

as their current methods and for some investments an even higher value.

As described in Section 3.6, a problem has been observed in that the proponents of ROA cannot point to a large enough number of successful implementations of the method. The companies expressed a will that some other company (preferably in the same business) had successfully tested the method before they would try it. This will considerably slow down the adaption process, especially since the companies also waited a really long time before they would replace their methods. One can hope for the "trickle down" effect, described by Sangster [37], where, when the larger companies have adopted a method, the smaller will follow. However, if the companies all want to see examples of the methods used in the same business as well, it will take an even longer time. However, when asked if the companies believed that there is a causal relationship between which methods companies use and their results the answer was a clear no. It was at least as important that they were good at using the model and that everyone understood it. This will probably also slow down the process of the companies adopting more sophisticated methods as predicted by the academics, since their arguments about that the companies using the right methods will be most successful, will not be listened to.

5 Analysis and Interpretation of Results

By conducting the literature and interview studies, we have received much information and in this chapter, we will discuss and compare the information from the two studies. These studies have shown that there seems to be two different sorts of problems, which may impede implementation of a ROA framework. We will denote the first sort of problems technical problems. These are problems that complicate the valuation of a project using real options. A subset of these problems are those we referred to in Section 2.2 as academic problems. The real-world problems described in the same section can, on the other hand, belong to both problems considered in this chapter. Many of the real-world problems are namely practical problems, the second sort of problems we will discuss here. The practical problems are such that, even if a company has the possibility to calculate good approximations to the real option values of its projects, the practical problems will still impede an implementation.

5.1 Technical Problems

Turning to the technical problems, we can roughly divide them into two categories; problems concerning the underlying assumptions and problems with approximating the different input data. The problems with the underlying assumptions are such that the practitioners will not encounter. These problems will question the validity of the method and even if it will work at all. The approximation problems are those that the practitioners will encounter, since even though the model would be valid in theory, it can be hard to apply. We call these approximation problems since the practitioners will be demanded to approximate real-world properties into numbers, which is not always easy, although it can theoretically be done.

5.1.1 Underlying Assumptions

As described above, the problems discussed in this section will not be encountered by the practitioners, they are mainly academic and if they are too large, the practitioners should not even be recommended to test the method. Because of this, these problems have mainly been discussed in Chapter 3 where we conducted our literature study. Many of the underlying assumptions show to not hold. The question is whether the assumptions are too bold for the ROA method to be valid at all. In this essay we have described a number of these problems, and the most important ones will be discussed in this section. Many of these problems stem from the fact that ROA is benchmarked from financial option theory.

Firstly, assumptions about the underlying asset are made. The classical approach have received much criticism in that it will be nearly impossible to find a replicating portfolio and if it could be found, the assumptions about no arbitrage will not hold in the markets of today. The MAD approach solves the part of finding a replicating portfolio, but both of the approaches assume that the underlying asset will follow a geometric Brownian motion, which will probably not hold (Borison [7]).

The exercise price and time to maturity are not fixed nor stated in a document like in the case of financial options. Instead, these may be stochastic and spread out in time. Perhaps these problems can be solved using probability distributions and the like, but this has not been clearly solved and will induce further questions about the validity of ROA. Although this section should mainly be connected to the literature study, we did, in our empirical study, find another problem. Often some parts of the investments (larger ones) need to be ordered in advance. The order does sometimes even need to be placed years in advance and can then be accompanied with an advance payment. Although it will be known when the payments are due, how they can be modelled into an aggregated exercise price has not been clearly solved yet, as was mentioned in Section 3.2.2.

The risk-free rate and modelling of leakage in value leave question marks already in financial option pricing and these problems get more severe in the case of ROA. Allotting the underlying value with a volatility will be more difficult than in the highly liquid and transparent financial markets. Will this volatility be constant and attributable to a random walk process? Finally, we want to mention that the assumption of log-normal returns have been shown to not hold in the real-world, since there are phenomena like fat tails.

So, many of the underlying assumptions can be shown to not hold. But will this completely hinder the applicability of ROA? What we have to bear in mind, is that all methods used in the real world have underlying assumptions that are not fulfilled. Even the financial option pricing theory has assumptions. When trying to apply a method to the real world it will not be able to describe it perfectly, and the assumptions will not be followed, that is why they are called assumptions. However, we need to assess how severe the assumptions are and how large errors they will induce in the model. This has not been done yet, although Borison [7] describes how many of the early proponents of the ROA models, that are more closely benchmarked from financial options, gradually have turned over to the softer models where more assumptions have been relaxed. However, no one has yet tried to quantify the degree of error introduced by the models. For example, Borison comments the works by Luehrman [25] and Amram and Kulatilaka [2] that have been used in this essay with the words: "As is the case with Amram and Kulatilaka (1999), no information is provided to quantify the degree of error introduced when the assumptions are less than perfect." A final word in this discussion, to enlighten that the problems may not stop the applicability, can be left to Copeland and Antikarov [9]: "the assumption underlying the MAD approach is the same one that corporate executives routinely make when using the NPV of projects as estimates of the market price of projects", a very similar statement gathered from Copeland and Antikarov [10] is also cited in Borison [7]: "MAD makes assumptions no stronger than those used to estimate the project NPV in the first place."

5.1.2 Approximation Problems

Now we will instead discuss the problems that the practitioners may run into when trying to implement a ROA framework in their companies. Assuming that Copeland and Antikarov [9] are right in the above statement and ROA should be as valid as for example NPV, the question is still if it will be applicable. Later, in Section 5.2, we will discuss if ROA will be a useful and desired tool, but here we will discuss if it will be a possible tool to apply. It is not enough if, for example, an assumption about the exercise price will hold in theory, the practitioners will also have to be able to estimate the exercise price in their respective situations.

The underlying asset value according to the MAD assumption can of course be estimated by the companies presently using NPV techniques to value their investments. Using the replicating portfolio approach seems more difficult since it is hard to find another asset that is correlated with the project (even if there might be one according to theory). So, the MAD approach can be used but a problem with this and the accompanying volatility will follow:

The volatility can be estimated, although it will, in many cases, be quite difficult. The question comes to if the management will be able to trust the estimations made, and our interview study indicated that they would. In some cases, the input variables can be observed through time-series data, old data from the company and in some cases information gathered from external organisations. However, the data used will most often be subjective, based on hunches and experience. Therefore, we can partly agree on the statement of Borison [7];

> *[...] the value of the underlying investment [...] should be assessed entirely subjectively. This assumption appears to ignore the possibility that there might be a replicating portfolio for the corporate investment in question, or at least that important elements of the investment in question, such as input or output commodity prices, might have market equivalents. As a result, market information on the value of the corporate investment or important elements of that investment is completely ignored.*

We do not agree on that all market data will be ignored, though. As mentioned, the companies could find some market data, like commodity prices and sales volumes. The problem of subjectivity will, however, still remain.

The variables that further need to be approximated, when looking at the technical side of using ROA, are the risk-free rate, the exercise price, the time to maturity and dividends. The risk-free rate will of course not be difficult for the practitioners to find, the problems with that is more an academic issue. However, the other three will cause some problems. The time to maturity will differ between companies, that much can be seen, putting a value to it will be difficult, though. Different times to maturity can sometimes give large differences in option value depending on the other option parameters. The exercise price can sometimes be quite well estimated if a contract can be written from the start or a similar investment has been

made earlier. Problems can arise where the exercise price is harder to estimate (like when valuing an expansion not done before) and it can also be spread out in time. The practitioners will also meet difficulties in the situation described in the previous section where the orders need be put in advance with an advance payment. How they can translate this into an exercise price and time to maturity is still unclear. Finally, a word on leakage in value, this can be approximated and already has to be in the case of rents from the projects. Putting a number to leakage in value when considering options to wait, that is loosing market shares to competitors, will be much more difficult.

Most technical problems discussed can perhaps be overcome. What has to be further investigated is how large evaluation errors the necessary assumptions and simplifications will induce. The method will be more complicated than the ones used today though, and this will impede the implementation of ROA. But if some academics are right, the practitioners will have to implement it anyway since they cannot do without the superior treatment of flexibility (see for example Copeland and Antikarov [10]). If this argument will really hold will be discussed as a part of the next section.

5.2 Practical Problems

As mentioned earlier, being able to approximate the real-option value of a project in a reasonable way may not be enough. Both the literature study and, foremost, the interviews, showed that there are other properties of a capital budgeting method, which are also important when deciding which method to use. In this section, we will discuss the nature of these properties for a ROA framework and how these properties may impede the implementation of the method.

5.2.1 The Organisational Culture in Companies of Today

In the literature study, we described the problem of motivating the managers, discussed in Copeland and Tufano [11]. They think that there is a risk that the optimal exercise decisions will not be made if the manager, in some sense, will loose prestige, or similar, when making the decisions. During the interviews, when asking about this topic, the interviewees did not think this was a problem and they mainly referred to the culture in the companies. We think there are two reasons for why this problem cannot be discarded that simply.

First of all, as suggested by McCormack in [1], it will be important to move some decisions to the operational level where the important variables can be observed and linked to some exercise criteria (what Copeland and Tufano [11] called trigger points). Today, in the studied companies, the decision processes do not look like the process we feel is usually described in the text books, where there is no problem to observe the development of and exercise the options. In the interviewed companies, the board of directors or the top management are presented with the financial valuation of an investment along with other information and these are the ones who make the decision. This means that major decisions will only be made at discrete moments in time and that only smaller, additional decisions are delegated down the chain of authority. This results in two consequences; firstly, this would imply using the

binomial lattice model for valuation since the decisions cannot be taken continuously. Secondly, for a ROA framework to add anything to the company, it will be important that the ones best suited to evaluate the progress of the investment should also be responsible for the exercise of the option. Who is best suited to exercise the option can of course be discussed; is it the top management or board of directors (with overview and knowledge of many factors) or someone at operational level (with expertise in the area)? This cannot be said in general, but the companies need at least be more open to new mandate structures. McCormack addresses this issue for the case of the oil business; "The problem, however, is that allowing their operating managers to deviate sharply from marching orders issued six months ago would be a transforming event for most oil companies of any size" [1]. We can probably expect similar problems in most companies if they were to start using ROA and they would have to change their organisational structure. Changing the structure would, in turn, probably change the culture. Subsequently, the main reason for the interviewed persons to not believe that making suboptimal decisions is an issue, would not hold.

Secondly, when we conducted the interviews, we were interviewing part of the management, and the interviewees might, to some extent, be the persons Copeland and Tufano [11] refer to when discussing the problem of suboptimal decisions. If the interviewees actually are the problem, we should probably not expect that they will see the problem or at least not say that it exists. Still, from all interviewees, there were several more steps to go down the chain of authority and this is where we think the problem Copeland and Tufano describe will mainly occur.

The discussion above regarding suboptimal decisions is based on that the decision-maker knows what the optimal decision is and that he or she, still, makes the wrong decision. If the consequence of implementing a ROA framework is that more decisions have to be made further down the chain of authority, the really big problem might instead be to make these persons know which the optimal decisions are. This is part of what we will discuss in the next section.

5.2.2 Transparency

Something that became very clear when conducting the interviews was that the transparency of a financial model is very important to the practitioners. We think this is a topic that the academic world may have paid too little attention to. Some literature, like Myers [32] or Eapen in [1], do discuss how ROA can connect capital budgeting and strategic planning and that ROA might make it easier for these sides of companies to communicate with each other. This was, however, not what the interviewed companies primarily were looking for. The practitioners instead indicated that it is important for much broader parts of the companies to be able to discuss the valuation of projects.

First of all, when calculating project values, there are persons from several parts of the companies who provide numbers for the input variables. It was mentioned that it was important

that these persons understand the capital budgeting method being used in order to get their opinions on the different input variables. If the method used becomes too complicated, it was believed that getting these opinions would be harder and that valuable knowledge from experienced employees could be lost. Subsequently, a more complex model may loose in accuracy.

Furthermore, not only the input, but also the output is discussed in several parts of the companies. For example, one interviewee described an important situation in the interviewee's company as:

> *[...] we only have a limited amount of money to spend on projects and therefore, there is a sort of managerial council with representatives from all parts of the company. [...], the representatives know that there is a limited amount of money and they all have to agree on which projects to choose.* (The authors' translation)

In order to come to an agreement on which projects to choose, it will of course be important that everybody understands the criteria that are used to rank the projects. Therefore, transparency of the method used to rank the projects will be a necessity.

We think that demanding transparency of a model is reasonable, a manager will have a hard time to motivate her or his choices if only the manager understands the reason for the choice. The decisions will be especially hard to explain to someone whose project has been turned down. If this person cannot understand why another project is preferred, it will be hard to accept the decision made.

Now, transparency will only impede the implementation of ROA if the method is regarded as a black box instead of being transparent. If this will be the case or not can of course be discussed, however, we believe that a ROA implementation will be fairly complex and we think this may be an important factor that could impede implementation of ROA in real-world companies. We do not think that all persons being part of the decisions have to be experts on ROA, but we think that a decent understanding of the basic concepts of the method will be crucial. Since our interviews indicated that there are several persons in each company who would have to learn about the method before it can be implemented, this is probably not something that happens over a day.

On the other hand, we have the discussion put forward by, for example, Myers [31] or Eapen in [1], that ROA can help to combine strategic thinking with financial valuation and therefore help the cooperation between different actors in the capital budgeting process. If they are right, it is presently hard to communicate hunches and experience, but ROA can help quantify it, which will help communication between the different actors. Eapen expresses this as "intuition is not always reliable, and it's valuable to have a more rigorous process for framing and quantifying that intuition", Triantis [41] also has a similar apprehension of managers using real options; "managers also generally develop an options-based, shorthand vocabulary that does a better job of communicating strategic objectives". So, we come to the trade-off between accuracy and applicability discussed in [1] and Section 3.3. On the one hand, we

need transparent and applicable models that the users understand. On the other hand, we also want the more accurate and sophisticated models that can value all of the information that the users can put in with their knowledge and experience. In the next section, we will discuss whether ROA seems to be something the companies are looking for or not.

5.2.3 Is ROA What the Companies are Looking for?

As we have seen in the previous sections, there are reasons which may impede the implementation, even if the possibility to evaluate projects using ROA exists. In the literature, it is usually pointed out that the superior capital budgeting methods have to be used by all companies after a while. If a company does not use the best methods, other companies, using the best methods, will outperform it and the company will have to face bankruptcy. That some researchers believe that this will happen to companies not starting to use ROA is confirmed in Copeland and Antikarov [10], where it is believed that ROA will replace NPV within a decade due to its superior treatment of flexibility.

On the other hand, the interviewed companies do not seem to think that using "the wrong" methods is a very large problem. When asking if they think there is a connection between the capital budgeting methods used and the success of the company, the answer is no. On the other hand, they say that it is important for them to use a method giving them the correct project values. However, when they want a method giving correct values, what they really seem to be looking for is a method not overvaluing the projects. Since the NPV method "systematically undervalues every investment opportunity" (Copeland and Antikarov [10]), and it sometimes still overvalues the projects for the interviewees, using ROA giving even higher project values is probably not what they are looking for. Now, arguing like this is not fair, the intention with ROA is not to overvalue projects, although the values will be higher than the NPV. The intention is instead to value the flexibilities the companies have and to better compare the projects, something that the interviewees felt would be a feature they sometimes lack at present. Furthermore, if the development of a project is worse than expected, using ROA will hopefully give suggestions for how to limit the losses while the NPV does not.

What we want to point out with the above discussion is that companies may be looking for other properties of capital budgeting methods than the ones ROA offer. Or at least that they do not think that the offered properties of ROA are as important as many researchers argue. We think that, since this is the case, many companies will avoid implementing a ROA framework since they may think that the benefits are not worth more than the cost of implementation.

As the discussions in the different sections of this chapter have shown, we have been able to identify different kinds of factors that may impede the implementation of ROA in real-world companies. Therefore, we feel that we are ready to turn to the last part of this essay, our conclusions.

6 Conclusions

In this, the last, chapter we will reconnect to the purpose of our study, which was:

> *The purpose of this study is to uncover the actual impediments associated with the implementation of a ROA framework in real-world companies.*

We will list the factors that we have found to impede the implementation of ROA the most.

The first factor is that, presently, there does not seem to be a common opinion on which assumptions that can be made when applying ROA. Furthermore, it has not been quantified how large the errors will be when different assumptions are made. Without knowing these things, a real-world practitioner will have a hard time when constructing a model. Even worse, since some assumptions can make the method invalid and therefore not even applicable, using the method will be quite risky.

The second factor is that it is not clear how to model some frequently occurring properties of projects in a ROA framework. For example, it is not clear how to model an uncertain exercise price or time to maturity. This will make it very hard for the practitioner if implementing the framework and when approximations have to be made, this leads back to the first factor.

A third factor is that the present organisational culture may not be suitable for a ROA framework. A company with a centralised organisation, where all important decisions are made by top management, will have to decentralise in order to be able to properly exercise the options. If it is not possible to exercise in a correct manner, the valuation with the method will also be incorrect.

The fourth factor is that companies demand models that are easy to understand. The reason for this demand is twofold. Firstly, many persons in the organisations provide input data to the model and it is important that there is a consensus among these persons on what to put into the model. Secondly, the outputs from the model will be discussed among several persons in the organisations and if these persons do not understand the model, the discussion will be affected. This means that several persons within the organisations will have to learn about ROA before it is implemented and this will slow down the implementation rate.

The fifth and final factor is that the companies may not be searching for a method able to value flexibility to such a large extent as many researchers propose. Flexibility is already considered by companies today, however, usually only informally. As long as the methods used today do not prove to be insufficient, there will not be incentives strong enough to make the companies change their entire capital budgeting processes.

6.1 Concluding Comments and Suggestions for Further Research

In this section we will consider how the factors mentioned above may be overcome and we will also give suggestions for further research that we think would be interesting and important to do.

For the factors to be overcome, the first measure we think have to be taken is that the academic world has to reach a common agreement on which assumptions that can be made and how large errors these incur. We do not expect that this is something that can be done very easily, several attempts have already been made, but for ROA to become widely applicable, it is important that this happens.

We also think that, to create a boom for ROA among practitioners, someone has to start making direct money on the implementations. We are thinking of, for example, consulting firms offering services where they help companies implementing a ROA framework. The reasons we think will make this necessary are:

- It takes a lot of time and effort for the companies to construct a working framework on their own.
- Learning by doing is too costly and risky and the companies cannot afford making all the mistakes.
- The consulting firm will gather knowledge from several implementations and can subsequently offer a solution where the two above reasons can be avoided.

The five impeding factors and the two suggested measures lead us to our suggestions for further research, which will conclude this essay.

As has been described above, the organisational culture showed to be an important factor that can affect the applicability of ROA in companies. Many previous studies have pointed out businesses where ROA may be suitable, however, we suggest another perspective. Instead of focusing on the company's surroundings, one also has to study the company's organisational culture and the factors in the culture being important for ROA to be implementable. In organisation theory, the theoretical term for an implementation process is institutionalisation and a good introduction to this subject can be found in Tolbert and Zucker [40].

Another topic to study is what consulting firms, especially in Sweden, think about ROA and if they have tried to make the companies start using the method. Since our opinion is that the consulting firms' efforts will be necessary for a wider implementation of ROA, knowing if they think there are problems with the method and which they are, could explain why ROA is not more widely implemented.

The last suggested topic is a study of how capital budgeting methods really are used, taking a process perspective. Our study indicates that the capital budgeting methods are not merely

used as a tool to value projects. Instead, it also has to be possible to use the methods for discussion and communication between different parts of the companies during the process of evaluating an investment. Further knowledge about this area is something we believe will be important to get a better understanding of what is needed from capital budgeting methods like ROA.

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A Interview Guide

As an example we present our interview guide from the interview with Gijsberth de Ruiter at Eka Chemicals AB. The other interview guides followed the same pattern with only slightly differing questions, adjusted to the companies in question. Since the interviews were conducted in Swedish, the presented interview guide is a translated version.

Real options area: General questions

- Which financial capital budgeting methods are you currently using?
- How large impact on the investment decisions do these financial calculations have?

Real options area: Volatility

- Which methods do you use to estimate future exchange rates, energy prices, raw material prices and demand?
- Do you receive any confidence intervals for these estimations or perhaps "worst and best case scenarios"?
- How subjective are these estimations, would you feel comfortable in using them as input data in a mathematical model for capital budgeting decisions?
- How exact do you think that one can be in making assessments of risks (i.e. how much the mentioned parameters will fluctuate)?

Real options area: Leakage in value

- Do you miss out on many future incomes when waiting to invest until later?

Real options area: Input variables

- What kind of input data do you use to calculate the net present value of investments?
- Can any of these input data be observed on a commodity exchange or can you in some other way observe time series on those data?
- Can you fixate the future cost of an investment, e.g., an expansion that will occur far into the future?
- How sure can you be that the costs estimated in tenders and the like will agree with the actual cost of the investment?
- Does it generally take a long time between the decision about an investment has been made and that the work is started and finished?
- Can you estimate how long time you have to act before you loose a market to the competitors?

- Are the fixed costs for an investment widely spread out in time or can they be related to a specific date?

Real options area: Industry applicability

- Can you observe any possible real options in your investments?
- Do you invest in extra capacity to be able to meet a possible future demand that is higher than the most probable?
- Do you try to value the benefits of this extra capacity (provided it is followed by a higher cost)?
- Do all the decisions concerning issues during an investment's life time have to be made at the beginning or do you have much flexibility during the course of the project?
- Where in the organisation is it decided which capital budgeting methods are to be used?

Real options area: Successful implementations

- How important is it that one can demonstrate that a method like ROA have been successfully implemented in another company before you would consider using it?
- If important, how close to your business would that company have to be?

Real options area: Important qualities of capital budgeting methods

- How would you say that you can assess whether a capital budgeting method worked well after the implementation, what are the important qualities?
- Would you say that there is a causal relationship between which methods a company use and how successful it is?
- Concerning capital budgeting methods; how large and important is the trade-off between transparency and precision?

Real options area: Managing real options

- Who has the authority to make investment decisions and how is the decision process carried out at Eka?
- During the course, of the project who has the authority to revise the decisions and plans?
- Do you think that other goals than purely financial can be sought?
- How do you create incentives for the decision-makers to always act in the company's best interest (financial interest)?

B Proactive Flexibilities

When managing real options, the manager has an opportunity to actively affect the option values. This possibility is not present for financial options and the difference between the two types of options that creates this possibility for real options, is the limited number of players on the market (Leslie and Michaels [23]). This limitation makes the actions of each player important and if a company can outperform the other, this will create higher values of its options. Leslie and Michaels analyse the different ways a manager can influence the option value by studying the closed-form option-valuation Equation 1 provided by Black and Scholes. Although this equation only applies for a very limited number of options, the six input variables to the equation is the same as to most other options. These input variables are what the manager can influence and Leslie and Michaels visualise them as levers the managers can pull. These levers are described in Figure 2. Some of these levers are pulled easier than others and those that should be focused on will change from project to project. To mention is that the risk-free rate is not possible to change by a single company, however, trying to anticipate the future development of the risk-free rate is important since the value of the option changes with it. Higher risk-free rates means higher option values. The other variables may be possible to influence, the question is then when it is beneficial to try to influence them. Many factors affect the answer to this question, e.g. how much it costs to be able to pull a lever and how much the project value changes when a lever is pulled. Leslie and Michaels divide options into three categories depending on how easy it is to change the option value, these categories are; High-priority options where the value is very sensitive to changes in a variable that the company easily can affect, Medium-priority options whose values are possible to influence by some other companies and these options are therefore advantageously sold to these companies, Low-priority options not being sensitive to changes in any of the variables that some player can affect.

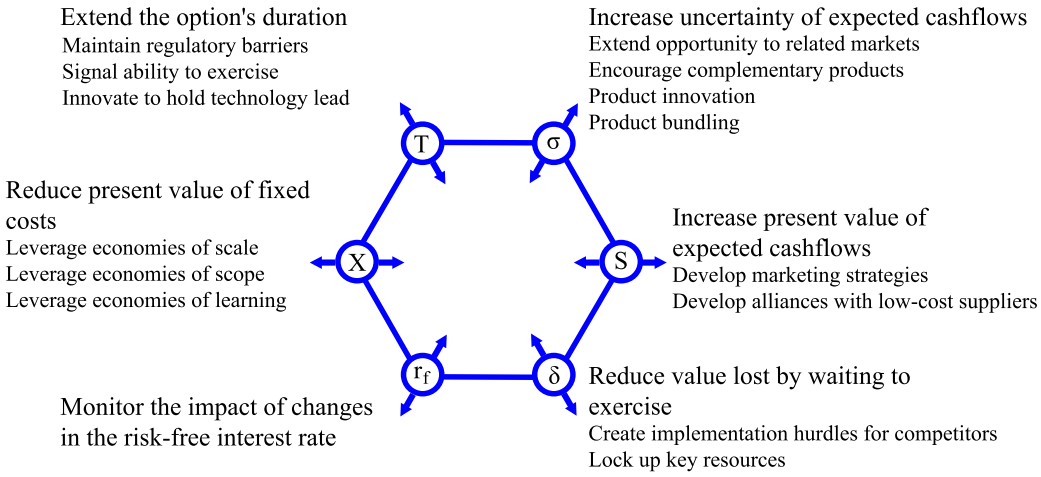

Figure 2: Different measures that can be taken to actively affect the value of an option. (From Leslie and Michaels [23])

Among the proactive flexibilities, a central part is what is often referred to as options to learn. This part of the flexibilities has in turn two main subunits; learning by reducing noise and learning by increasing the probability of success (Brach [8]).

Starting with the noise-reduction part, the first thing is to realise what the noise is. The noise is a measure of how uncertain the value of a project is when a manager is trying to estimate it, according to Brach [8] and Mayor et al. [26]. One might now ask; if we really want to reduce this uncertainty, is not uncertainty good for the project value when using ROA and does not Figure 2 say that we shall try to increase the uncertainty? The answer to this question is that there are two kinds of uncertainty: The uncertainty we want to increase is the market uncertainty i.e. the uncertainty in the future development of the market. The measure uncertainty we observe when we try to calculate the project value is what we want to minimise. That we really do want to reduce the latter of these uncertainties is clear since if there is a lot of noise when calculating the actual project value, we will not be able to tell what the value is. Since decisions are made depending on this value, detecting a wrong value can be fatal. If the value is very uncertain we may go through with a project that should have been abandoned or vice versa. So, the questions are how to reduce this noise and when it is worth making this reduction.

If we start by looking at the second of these questions, a company will of course not pay more for learning than they can gain on having this extra knowledge. The value of the extra knowledge will, when we are considering noise reduction, almost completely depend on if the noise reduction will change the decision made. Even if a company cannot limit the project value but into a wide interval this will not be a problem if the decision made is the same within the entire interval. In that case, paying for learning more about the project value will not make any difference and it will only be a waste of money. On the other hand, even if the company knows the project value fairly well, this is not enough if there are at least two possible decisions within this interval. In this case, the company will probably be willing to pay something for learning, however, it depends on how much learning costs. The company will pay for learning as long as the cost for learning is less than the amount it will gain from reducing the probable loss if the wrong decision is made. So, how can a company work to reduce the noise? This will vary from project to project. Examples on measures that can reduce the noise are different sorts of marketing research like consumer surveys or product introductions to smaller markets, or extra phases in the R&D process where the potential of a project can be revealed.

If we turn to learning for increasing the probability of success, this is also something that can be achieved by measures in either marketing or R&D, or combinations of these. Examples on measures is making marketing research to find features that customers would appreciate and then try to implement these features, or in drug development where an extra development phase can reveal necessary properties of a drug to be successful. If we consider the value of learning in this case, the company will invest in possible learning as long as the cost of learn-

ing is lower than the increase in the average gain due to the increased probability of success. To mention is also that several researchers have developed theories for how valuable learning initiatives are. See for example Sullivan et al. [39] and McCardle [27].

Many of the activities connected to learning for increasing the probability of success has the consequence of delaying product introductions. If we wait with the introduction of a product in a competitive market, a competitor starting earlier can take larger market shares. There are still occasions when waiting can be beneficial (Brach [8]). If the company, while waiting, improves the product this can result in a better result in the end. This is what Brach refers to as active learning. Furthermore, if a competitor takes the first step into a new market, a company can observe the success of the competitor and choose not to enter the market if the development is bad. In this case, the company has an option to defer. By studying its competitors' entrances, the company can also learn of features that customers are demanding. Adding these features to the product, before introducing it on the market, will be an advantage and can overcompensate the lost market share. In such a case, the option to wait, or learning passively as Brach refers to it, will have a positive value.

The above examples of proactive flexibilities show that, with a ROA framework, questions traditionally treated within market planning can be connected to capital budgeting decisions. This means that a good implementation of ROA in a company may, as a consequence, bring units of a company together that classically have been separated.