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A Real-Options approach to company valuation

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Preface

The idea of this study was born in July 2012. I decided to start as an intern at an M&A boutique and wanted to study the valuation of companies for this master thesis. Thereby, I became enthusiastic about Real-Options theory by my supervisor ir. H. Kroon. Since then, it all went really fast. I explored two new fields for me, the theory and practice of company valuation and Real-Options theory. The challenge of combining these fields started.

I was advised to first start with my six-month internship, gain experience in the practice of “regular” company valuation and discuss remarkable aspects of current methods with my colleagues. Hereby, I gained insight in the advantages and disadvantages of currently used company valuation methods. In concert with S. Ootjers MSc, CFA, my supervisor of PhiDelphi, the subject of this master thesis came about. From there on, I could start digging into Real-Options literature with a clear focus.

In the previous six months, I started with putting my thoughts on paper. The idea of just beginning with my internship to gain experience was really helpful and definitely contributed to the quality of this master thesis. It has enabled me to create a strong theoretical basis and optimally take into account the demands of practitioners.

Reflecting upon this process, I would like to thank some people that were directly and indirectly involved in the completion and contributed to the quality and direction of this master thesis. First of all, I would like to thank ir. H. Kroon from the University of Twente. Giving me all the time and flexibility I requested, being available at the moment I wanted to speed up the process, the flexibility in meeting times and location, sharing a strong vision of Real-Options with me and above all, provide me with outstanding advice. I would also like to thank dr. B. Roorda, who was willing to be a flexible last-minute co-reader.

Of course, I would also like to thank my colleagues from PhiDelphi, I had a wonderful time at your office and I learned a lot. Special thanks go to S. Ootjers, who helped me a lot with the structure of this research and was always prepared to give a critical review about pieces of this master thesis.

Furthermore, I want to thank all the people that indirectly helped me finishing this master thesis, by sparring on important subjects with me or for just being there for me in time I needed distraction.

Management summary

Since Myers (1977) coined the term “Real-Options”, literature in this field has been booming. According to many, Real-Options have the possibility to improve all sorts of capital budgeting decisions, aligning financial analyses with strategic analyses, by taking future flexibility into account. Unfortunately, the current debate is not focused on how Real-Options could improve the overall company valuation, but tends to focus on the shortcomings of either a DCF analysis or a Real-Options approach. However, both approaches could be complementary. This research's objective is to determine when and how Real-Options theory could be applied to improve the valuation of companies and how this information can be used to modify the enterprise DCF model. Thereby, we deliver both a theory and a model for incorporating the value of Real-Options into the valuation of a company.

Basically, the Real-Options literature is divided into two camps, proponents and opponents. By performing an extensive literature search, which started with critically reviewing the fundamentals of Real-Options theory, we attempted to identify the true potential of Real-Options theory. In order to translate this potential to functions that could improve a DCF valuation of a company, we analysed the enterprise DCF model as well. These two analyses led to several functions of Real-Options theory that were worth studying. After an evaluation, we chose to operationalise the bottom-up valuation of short-term strategic Real-Options. A real case, acquired from PhiDelphi, was used to demonstrate our concept and to find out and show to what level of detail we are able to operationalise our (generalised) model.

We found that Real-Options are more than rights on a company's traded assets and that Real-Options theory represent an important tool to value flexibility, not only to value flexibility in operational activities, but also to value strategic opportunities. There are several methods to incorporate Real-Options value, e.g. option-pricing methods, but also decision analysis. Broad recognition of decision analysis can be an important step forward for Real-Options theory. The developed company valuation model shows how the valuation of strategic Real-Options and a DCF valuation of a company's operational activities could be integrated. This study also operationalised a valuation guide to value Real-Options and a specific method to model asset value or other variables through time, driven by both market and private risks.

This study aims to contribute to the academic world in a number of ways. First, it contributes to a better understanding of Real-Options. Our extensive elaboration distinguishes flexibility and strategic Real-Options, Real-Options on project-level and management-level and short-term and distant strategic Real-Options. Second, it addresses and elaborates on several important valuation methods. By combining theory and methods, we obtained many new insights. By looking at the strong and weak points of both Real-Options theory and DCF analysis, we opened the debate into a new direction: combining Real-Options theory with DCF analysis. Future studies could build upon this view. The analysis of the possible functions of Real-Options to improve the valuation of companies also provided insight on the functions that are not suited to improve such a valuation, which is also an important result of this study.

Taking into account the results of this study, we recommend practitioners to make a clear distinction between a company's value based on its (future) operations and a company's value that includes (future) strategic opportunities. To calculate the latter, one needs to identify a company's strategic Real-Options, for which should be determined how they are influenced by market and private risks and how they are correlated. When market and private risks can not be separated from each other and they behave in a normalised way, we recommend the MADD approach, which we operationalised. Further research is needed to the structuring and determination of key variables of several types of strategic Real-Options in order to hand out a practitioner's guide to incorporate strategic Real-Options value.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

The original definition of Real-Options, first stated by Myers (1977), is that Real-Options are opportunities to purchase real assets on possibly favourable terms. It took four years since Black and Scholes (1973) presented their famous option-pricing formula for European financial options to come to the insight that financial option theory could be the basis for valuation of other assets as well.

Due to the usage of financial option theory to capital budgeting problems, managers should finally be able to bridge the gap between strategic and financial analyses. Even if DCF analysis is properly applied, it may fail in strategic applications (Myers, 1984). Under DCF analysis, managers are “allowed” to nurture relatively low-valued NPV projects, instead of higher-valued NPV projects, for strategic reasons. This creates a gap between strategic and financial analyses (Myers, 1984). Strategic plans often encompass investments that, if measured by cash flows alone, appear to have a negative NPV, when in fact they may generate a strategic position to invest in valuable follow-on opportunities (Smit & Trigeorgis, 2004). Financial option theory provides the opportunity to value a company’s strategic options, which – correctly applied – can bridge the gap and align financial and strategic analyses.

A company’s Real-Options are mostly directly related to managerial flexibility, which value DCF analysis fails to incorporate. An example from Amram, Li, and Perkins (2006) describes how Real-Options are correctly applied by Kimberley Clark, a leading American consumer products manufacturer, and shows how Real-Options theory incorporates the value inherent to managerial flexibility. Kimberley Clark was evaluating a joint development agreement with a start-up company, with whom they had the opportunity to invest in technology. In return, Kimberley Clark would gain the exclusive right to license and use the technology in new products. However, the market demand for the lead product was uncertain and the technology was about four years away from full development. Kimberley Clark modelled this investment decision as a Real-Option on a new product in about four years, whereby Kimberley Clark would gain the right, but not the obligation to exit the agreement at any time. Furthermore, Kimberley Clark did not need to commit to the entire investment up front, but (management) could invest in stages as more information would become available. In this situation, the agreement was structured to retain managerial flexibility and to delay spending until sufficient information became available. In their model, the net option value was around $10 million. Therefore, Kimberley Clark invested in the new technology and was going to evaluate at each stage to continue, i.e. whether the project is still worth more than the investment required.

According to Trigeorgis (1993), academics and practitioners have recognised that DCF analysis often undervalues investments. The effect is that many corporate managers overrule passive NPV analysis and use intuition and executive judgement to value future managerial flexibility (Trigeorgis, 1993). Copeland and Antikarov (2001) suggested that Real-Options would replace NPV as the central paradigm for investment decisions in ten years. Dixit and Pindyck (1994) stressed that discounting cash flow techniques do not recognise the interaction between irreversibility, uncertainty and the choice of timing among investment decisions. Students today read in Koller, Goedhart, and Wessels (2010), a highly recommended valuation textbook, that option-pricing methods are superior to traditional DCF approaches. Many others (e.g. Brandão, Dyer, and Hahn (2005), Trigeorgis (1993)) agree that DCF analysis fails to account for managerial flexibility inherent in many types of projects. According to Amram and Kulatilaka (2000), DCF analysis understates the option value attached to growing profitable lines of business. However, DCF analysis is still the most popular capital budgeting method ((Brandão et al., 2005), (Copeland & Antikarov, 2001)). As a possible explanation to the slow adaptation of Real-Options theory, Baker, Dutta, and Saadi (2009) noted that it took decades for DCF analysis to become an integral part in the capital budgeting decision. However, just like DCF analysis, Real-Options theory has its limitations.

Simple capital budgeting decisions that are closely related to the financial markets can be valued by Real-Options using standard option-pricing formulas. However, as complexity and distance from the financial markets increases, customised Real-Option valuation models are necessary (Amram & Kulatilaka, 1999). Some of these models are however subject to heavy criticism (Borison, 2003). It appears that most companies that have shown broad interest in Real-Options theory are engaged in either the energy sector or life sciences, sectors where large investments with uncertain returns are commonplace. Furthermore, these industries seem to be used to sophisticated analytical tools for decision making (Borison & Triantis, 2001). Before Real-Options could breakthrough, practitioners seem to demand a need for it, as seen in both the energy sector and the life sciences industry. Moreover, if practitioners are not familiar with analytical tools, they seem to demand a more friendly application (of Real-Options theory) as capital budgeting technique. This conclusion complies with behavioural scientific research to the acceptance of new technology.

On the one hand, it seems that Real-Options theory is the next step forward in the capital budgeting decision and that large scale application among practitioners is just a question of time. On the other hand, there is still some major critique on the use of Real-Options (Borison, 2003). Most of the critique on the current application of Real-Options theory is grounded, however not insurmountable. Currently, critique is mainly twofold: it is both focused on the wrong application of Real-Options calculation methods and on the use of Real-Options in the wrong situations. However, some critique is more fundamental. Hence, it is not clear that Real-Options theory will replace DCF techniques within the field of capital budgeting, especially not for the more complex capital budgeting challenges as the valuation of companies. It may be that the bundles of assets and opportunities that companies own cannot be practically valued as options, at least not yet (Koller et al., 2010). However with better insights, practitioners could apply Real-Options theory in the right way to the right situations.

1.2 Research goal

Real-Options theory is recognised by both academics and practitioners as a potentially superior capital budgeting model, however the theory is often misunderstood. Furthermore, Real-Options theory could be very difficult to apply as a stand-alone technique to some sorts of capital budgeting problems. Subsequently, in many cases Real-Options theory is either wrongly applied or not applied at all. To overcome shortcomings when using common DCF techniques, managers feel free to accept negative NPV investments for strategic reasons, or they subjectively use discount rates higher than their company's cost of capital to incorporate perceived shortcomings (Dixit & Pindyck, 1995).

The goal of this research builds upon Myers' (1984) objective: bridge the gap between strategic and financial analysis. This research is going one step further and delves into the application of Real-Options as well. As the field of capital budgeting is very broad and Real-Option models often need to be customised, this research focuses in particular on Real-Options theory to company valuation. With this focus we can deepen our research into the practical application of Real-Options theory and best serve the interests of PhiDelphi Corporate Finance[1], hereinafter "PhiDelphi". At PhiDelphi, the enterprise DCF model is the most applied valuation model. Furthermore, PhiDelphi uses multiples to get an

[1]PhiDelphi Corporate Finance is one of the largest independent merger and acquisition advisers in the Netherlands, engaged in the entire process of an acquisition, divestment, buy-out transaction or financial restructuring. Their client base consists of private companies, private equity groups, listed companies and management teams in almost all sectors of the Dutch economy.

indication of a proper company valuation and to verify their DCF valuation. They do not use Real-Options theory, which could actually give them a tool to cope with some of the limitations of the DCF model. As practitioners prefer to use the enterprise DCF model, this study will analyse how to combine Real-Options theory with the enterprise DCF model.

Basically, their are two methods for using Real-Options theory to value a company. Schwartz and Moon (2000) presented the first stand-alone Real-Options approach to value a company, Amazon.com. They assumed stochastic functions for the company's turnover and its growth rate and estimated other relevant variables. The second company valuation method consists of a DCF component and a Real-Option component. The DCF component captures a base estimate of the company's value, the Real-Option component captures potential growth options. The first method however does not actually value a company's options, it values general flexibility in a company's main functions (e.g. profit or cost functions). Furthermore, such a method will not be generalisable. Therefore, the second method is of interest to this research, as it keeps close to the Real-Option terminology and will be better generalisable.

Smit and Moraitis (2010), Smit and Trigeorgis (2004) and Putten and MacMillan (2004) all suggest to use the method where the Real-Option value is an additional component as well. However, they never became concrete how to apply this regarding a company valuation. Research still tends to focus on the need and the added value of Real-Options theory, on the shortcomings of other capital budgeting approaches and on specific types of Real-Options related to a company's projects. To reduce the effort of practitioners and to gain better insights into the size of the gap between strategic and financial analyses, we want to know for which companies this gap is large and for which it is small enough to ignore. Real-Options literature does unfortunately not answer this question. To be specific, the question for which companies, in which situations, the difference is negligible, is under-addressed in current Real-Options literature.

In case the difference is negligible, the enterprise DCF model is a good stand-alone model to use. In case the difference is not negligible, we will suggest a model, based on the enterprise DCF model, that incorporates Real-Options value. By delivering a theory on when incorporating Real-Options are worthwhile, how Real-Options theory could be applied in different situations regarding a company valuation and how this method can be integrated with the enterprise DCF model, this research both contributes to the current literature and to the usability for practitioners.

This study has two types of deliverables:

- First, this study delivers a theory about incorporating Real-Options value into a company valuation model. This theory should answer the question when Real-Options theory should be applied and subsequently how it could be applied.
- Second, this study will operationalise (a part of this theory) and deliver a company valuation model, that captures the value inherent to managerial flexibility correctly, when such value is not negligible and well understandable by practitioners. This model will integrate Real-Options theory with DCF analysis.

In general, this study focuses on acquiring a *theory* on the application of Real-Options to company valuation and on obtaining a *model* that operationalises this theory. Therefore, the overall research question is:

When and how could Real-Options theory be applied to improve the valuation of companies and how could this information be used to modify the enterprise DCF model?

1.3 Research approach

To reach this research's objective and to answer the overall research question, two research questions are leading. These two research questions should give an answer to the overall research question. Both research questions are again divided into subquestions to come to a comprehensive answer.

The first research question captures the potential of Real-Options theory, its underlying assumptions and how it is currently applied. In order to draw conclusions about how to add Real-Option components to the enterprise DCF model, this model and their interrelations need to be studied as well.

The second research question captures the underlying assumptions of the enterprise DCF model and captures how it is applied in order to understand any relations between this model and Real-Options theory. Furthermore, it addresses the question when valuing the gap between financial and strategical analyses becomes necessary. After this analysis, we will deduct a theory and attempt to build a company valuation model that incorporates Real-Options value, which is based on both the enterprise DCF model and Real-Option components.

The research questions are as follows:

1. Which functions (derived from the different types) of Real-Options could be used to improve the valuation of companies and how could Real-Options be quantified?
   - a What are the different (mathematical) methods of application of Real-Options theory?
   - b How does literature prescribe to use Real-Options as an add-on component to a DCF analysis?
   - c Which functions of Real-Options theory could be used to improve the valuation of companies and how could these functions be quantified by reducing the mathematical complexity as much as possible?
2. How should relevant function(s) of Real-Options be operationalised, when should this/these function(s) be applied to improve the valuation of companies and how could this be integrated in the enterprise DCF model?
   - a How is the enterprise DCF model applied and how are the underlying parameters derived?
   - b Which functions are most relevant to operationalise and how should this/these function(s) be operationalised?
   - c Are their any company/sector specifications or financial parameters that could guide us on the question when to apply the operationalised function(s) in order to improve the valuation of companies?
   - d How could the results of subquestions 1b and 1c be used to expand the enterprise DCF model?

1.4 Structure of thesis

This thesis consists of six chapters, where each chapter is divided into sections. In order to fully understand all the topics addressed in this thesis, the reader should be familiar with financial option theory and basic finance theory. In case some terms are unclear, a list of explanations of important financial terms could be found in appendix A at the end of this thesis. With the exception of this and the final chapter, each chapter will end with a conclusion about the most important findings in order to build upon previous findings.

In this first chapter, we have introduced the importance of our research, stated our research goals and the deliverables we pursue. The objective is to improve the current knowledge in the field of application of Real-Options analysis, in order to improve the valuation of companies.

In chapter 2, we will conduct a research to the fundamentals of Real-Options theory, in which we include a section about how to use Real-Options theory as an add-on component. We will conclude this chapter with an analysis of the possible functions for Real-Options theory to improve a company valuation. This chapter will answer all of the subquestions of research question 1.

In chapter 3, we will analyse the enterprise DCF model and other DCF valuation techniques which can possibly be used in combination with Real-Options theory. This chapter will answer research question 2a.

In the subsequent chapter, chapter 4, we will analyse which functions of Real-Options theory to improve the valuation of companies should be operationalised. Furthermore, we will review literature to verify when Real-Options theory is important with respect to the functions we want to operationalise. This chapter will answer research questions 2b and 2c.

In chapter 5, we will try to operationalise our deducted theory about including Real-Options value in a company valuation model. A real case that is acquired from PhiDelphi will help us demonstrate the concept of our model and serves as support to find out to what level of detail we are able to operationalise our (generalised) model. This chapter will answer subquestion 2d.

In the final chapter, chapter 6, our overall research question will be answered. Furthermore, we will evaluate our findings and our approach, discuss our assumptions, discuss the limitations and recommend areas for further research.

Chapter 2

Real-Options – Functions and quantification

The objective of this chapter is to get a grip on which functions of Real-Options theory can be used to improve the valuation of companies. Therefore, we give a comprehensive overview of Real-Options literature. There seems to be several types of Real-Options and each of them is applicable in a different situation and has a different function. This chapter will also deepen into how these Real-Options can be used as an add-on to the enterprise DCF model. Furthermore, this chapter deals with the challenge of quantifying Real-Options. There are different quantification methods in general and in particular there are different quantification methods for different types of Real-Options.

2.1 The basics of Real-Options

In this section a broad review of the Real-Options literature will be given. By reviewing the types of Real-Options and the methods of quantifying these, a holistic view is provided.

2.1.1 Literature

As of 1977, when Myers (1977) first coined the term “Real-Options”, literature within the field of Real-Options theory has expanded quickly. Triantis (2005) estimated in 2005 that there were approximately 1,000 research papers about Real-Options theory. Reviewing this literature learns us that there are several very important contributors to the Real-Options theory:

- Stewart C. Myers
- Avinash K. Dixit and Robert S. Pindyck
- Thomas E. Copeland
- Alexander J. Triantis
- Lenos Trigeorgis
- Timothy A. Luehrman
- Martha Amram

The people mentioned above can be called gurus on the topic of Real-Options theory. Stewart Myers is the creator of this field of interest and has done several follow-up studies. Avinash Dixit and Robert Pindyck have done a lot of research together to investment under uncertainty and are the authors of the also so-called book: “Investment under Uncertainty”, where the Real-Options value is an important topic of interest. Thomas Copeland is an expert in financial decision-making, with a lot of work-related experience. Next to his all his research, he wrote: "Real-Options: A Practioner's Guide". In this book he elaborates on several valuation methods of different types of Real-Options. Alexander Triantis has published articles as of 1990 to date, of which several are published in the Journal of Applied Corporate Finance. Lenos Trigeorgis is also a great contributor to the Real-Options theory, with research to Real-Options and strategy, using game-theory, and research to the simplification of Real-Options valuation methods. Timothy A. Luehrman conceived the idea of treating a business strategy as a series of options and published two widely quoted articles in the Harvard Business Review. Finally, Martha Amram has wrote some important articles published in the Harvard Business Review and the Journal of Applied Corporate Finance and as well published a highly recommended book called Real-Options: Managing Strategic Investments in an Uncertain World. Despite there are several other important contributors to the Real-Options literature, this research will use mainly literature from these so-declared gurus and articles they refer to.

Furthermore, we will use specific search terms to search for literature to answer research subquestion 1b, Real-Options as an independent add-on component to DCF analysis. Search terms will be:

- "Expanded NPV" + "Real-Options"
- "Passive NPV" + "Real-Options"
- "Static PV" + "Real-Options"
- "Strategic NPV"

2.1.2 Definition

Myers (1977) first stated that a Real-Option is a decision opportunity for a corporation or an individual. It is a right, rather than an obligation, whose value is contingent on the uncertain price(s) of some underlying asset(s).

Dixit and Pindyck (1994) define Real-Options as opportunities to acquire real assets. Real-Option investments are characterised by sequential, irreversible investments made under conditions of uncertainty. Dixit and Pindyck (1995) further explain that Real-Options are based on an important analogy with financial options. A company with an opportunity to invest is holding something much like a financial call option: it has the right but not the obligation to buy an asset at a future time of its choosing.

Copeland and Antikarov (2001) define Real-Options as the right, but not the obligation, to take an action (e.g. deferring, expanding, contracting, or abandoning) at a predetermined cost called the exercise price, for a predetermined period of time, which is the life of the option.

According to Triantis (2000), Real-Options are opportunities to delay and adjust investment and operating decisions over time in response to the resolution of uncertainty. Another research performed by Borison and Triantis (2001), gives us the valuable insight that under practitioners there are different interpretations of the term Real-Options. They come up with three categories of interpretations, (1) Real-Options as a way of thinking, (2) Real-Options as an analytical tool and (3) Real-Options as an organisational process. In each category however, corporate decision-making is improved by a better understanding of the role of uncertainty on investments.

Panayi and Trigeorgis (1998) explain that Real-Options involve discretionary decisions or rights, with no obligation, to acquire or exchange the value of one asset for a specified value or price. Trigeorgis (1993) explicitly states that managerial flexibility is a set of Real-Options, as he suggest the use of option-based techniques to value the managerial flexibility implicit in investment opportunities.

In an explanation of Real-Options, Timothy A. Luehrman describe Real-Options as follows: "Real-Options capture the value of managerial flexibility to adapt strategic decisions in response to unexpected market developments. Companies create shareholder value by identifying, managing and exercising Real-Options associated with their investment portfolio. The Real-Options method applies financial options theory to quantify the value of management flexibility and leverage uncertainty in a changing world".

Thereby, he is the first who explicitly states that Real-Options theory could be used for valuing strategic decision-making.

Amram and Kulatilaka (2000) use two definitions: "Viewed narrowly, the Real-Options approach is the extension of financial option-pricing models to the valuation of options on real (that is, non-financial) assets. More broadly, the Real-Options approach is a way of thinking that helps managers formulate their strategic options, the future opportunities that are created by todays investments".

The definition of Martha Amram shows us the development of the term "Real-Options". Real-Options are based on an important analogy with financial options, Real-Options are rights and not obligations related to company's assets. However, Real-Options are also a way of thinking that help managers formulate their strategic options, the future opportunities that are created by todays investments. This study will use the definition of Martha Amram, as her broad definition reflects the current development of Real-Options theory. First, it emphasises that Real-Options theory could be used to value strategic options and second, it lets go of the requisite to use financial option-pricing methods to value Real-Options. This definition reflects also that Real-Options are more than options on tradeable assets, where the vast majority of the literature assumes the underlying asset is traded in a complete or partially complete market (Alexander & Chen, 2012). This gives us the opportunity and the challenge to make use of Real-Options on non-tradeable assets.

2.1.3 Value drivers

To understand what drives option value, it is first important to understand the structure of an option. There are two basic types of options:

Call option A call option gives the option holder the right to buy an asset in the future.

Put option A put option gives the option holder the right to sell an asset in the future.

Options could be further distinguished as either European or American. European options can be exercised only on their expiration date and American options can be exercised at any time up to the expiration date. As American options grant the option holder more rights, they are at least worth the same as their European counterparts.

Regardless of the structure of the option, or the quantification method, the value of a Real-Option depends on the variables listed below (Copeland & Antikarov, 2001). These variables could also be of importance to the valuation method (e.g. the pay out of dividend), these option-characteristics should then be mentioned together with the option structure.

1 Value of the underlying asset (S)
2 Exercise price (K)
3 Time to expiration (T)
4 Volatility of the underlying asset (σ)
5 Risk free rate of interest (r_f)
6 Dividend (δ)

Value of the underlying asset

This is today's value of a project, investment, acquisition or any real asset that is under consideration. Considering a financial option, this value is derivable from the financial markets. For a Real-Option, today's value of the underlying asset is often much more difficult to retrieve. There are basically two methods to estimate this value:

- The financial markets
- The Market Asset Disclaimer (MAD)

When the underlying asset is traded in the market, the value is publicly available. When the underlying asset is not traded in the market, but other kind of similar assets are, a replicating portfolio could be composed. For this replicating portfolio, a so-called "twin security" has to be found. A twin security has cash flows that are perfectly correlated with those of the original real asset. After finding such a replicating portfolio, the portfolio is scaled in such a way that the returns of the scaled portfolio will match the original real asset's returns.

"The frustrated part of the twin security is that it is practically impossible to find a priced security whose cash payouts in every state of nature over the life of the project are perfectly correlated with those of the underlying asset (Copeland & Antikarov, 2001)". Copeland and Antikarov (2001) suggest to use the present value of the underlying asset, without flexibility. They make the assumption that the present value of the cash flows of the project without flexibility is the best unbiased estimate of the market value of the asset. This assumption is called the Market Asset Disclaimer (MAD).

Exercise price

The amount of money one needs to invests in case one wants to execute their Real-Option, for example starting an investment or finalise an acquisition. It could also be the amount of money one is likely to receive in case of abandoning a project for example, in general this is the case for put options. In financial option pricing, the exercise price is well-known and is stated in the option contract. This might be as simple as well for Real-Options, in case the investment amount or salvage value is already fixed or stated in a contract. However, the exercise price can be a lot more difficult to determine. In case of an investment under consideration, it is reasonably to assume that the exercise price is equal to the present value of future investments. Another solution could be an increase in the number of decision points, creating a "compound Real-Option". However, these future investments can also be uncertain. Exercise prices for Real-Options are therefore in reality stochastic.

Time to expiration

The amount of time between the moment the opportunity arises and the latest moment this opportunity will be accessible. In case of financial options – both European and American – the time to expiration is easy to establish. It is simply the difference between the moment the option contract is signed and the moment the option contract expires, regardless if the option is exercised early. For Real-Options the time to expiration could be either easy to establish or rather vague. It is easy to establish if the company holds a licence to investment with a clear expiration date, or has an ultimatum for investment. However, in some cases the time to expiration can theoretically be infinite, for example for the option to defer an investment. In reality, the time to expiration is often dependent on the competition, changes in technology and macroeconomic factors and is therefore not explicitly fixed. As with financial option theory, an increase in the time to expiration leads to an increase in the option value. A longer time to expiration will also lead to an increase in the value of a Real-Option, as it will allow us to learn more about the uncertainty.

Because the time to expiration could be unfixed and even approximate infinity, it will be a challenge to prevent a huge, undesirable, upside effect to the value of a Real-Option. A possible solution will be to introduce a penalty for deferring the Real-Option from a certain point in time, which can be realised via the variables "exercise price" or "dividends". According to Triantis (1999), it is reasonable to assume that the exercise price for many investment projects will rise with the risk free rate of interest, this will neutralise the benefit of a longer time to expiration. Second, if there is an expected "leakage" in the present value of the underlying asset or opportunity (which can be modelled with a dividend payout), due to for example the competition catches on, then the longer the time to expiration, the larger the decrease in the present value of the underlying asset (the larger the value of all related dividend payouts amounts to).

Volatility of the underlying asset

The volatility indicates the sensitivity to price fluctuations of the underlying asset, the uncertainty about the future value of the project's cash flows. In case of a Real-Option, managerial flexibility leads to uncertainty in the price of the underlying asset, which will increase its volatility. An increase in the volatility will also increase the option's value. In fact, the volatility is often the variable that has the greatest impact on the option value. Because financial options and their underlying assets are traded in the financial markets, either the historical volatility or the implied volatility could easily be derived. For Real-Options on non-traded assets, the volatility of the underlying asset needs to be established otherwise.

Volatility is measured as the standard deviation of the rate of return of the underlying asset. It is common to express the volatility as an annual figure, e.g. when the volatility is 25%, it is usually meant that the volatility is 25% per annum. To understand how the volatility could be derived for the purpose of Real-Options theory, example 1 will provide a clear explanation of the volatility with respect to a stock.

Example 1 *The standard deviation shows how much variation there exists from the mean. When z is normally distributed, with its mean $\mu = 0$ and variance $\sigma^2 = 1$, its probability density function is described by $f(z) = \frac{1}{\sqrt{2\pi}} e^{\frac{1}{2}z^2}$. The probability mass between $-\sigma$ and σ, which is the expectation that z will not deviate more from the mean than 1 times the standard deviation in either positive or negative direction, is equal to $\int_{-\sigma}^{\sigma} \frac{1}{\sqrt{2\pi}} e^{\frac{1}{2}z^2}\, dz$, or could be expressed as:*

$$P(-\sigma \leq z \leq \sigma) = \int_{-\sigma}^{\sigma} f(z)\, dz = \int_{-\sigma}^{\sigma} \frac{1}{\sqrt{2\pi}} e^{\frac{1}{2}z^2}\, dz \approxeq 0.683$$

In the same way:

$$\begin{aligned} P(-2\sigma \leq z \leq 2\sigma) &\approxeq 0.954 \\ P(-3\sigma \leq z \leq 3\sigma) &\approxeq 0.997 \\ P(-5\sigma \leq z \leq 5\sigma) &\approxeq 1.000 \end{aligned}$$

Calculating the probability mass for other normally distributed functions, i.e. with another μ and σ^2, yields the same result in terms for σ. In other words, when a stock's value is \$100 and the stock has an annual implied volatility of 25%, it means that over a year, its value is expected to be between \$75 and \$125, with a probability of 68.3%, or is expected to be between \$50 and \$150, with a probability of 95.4%, etc..

For Real-Options, the underlying asset is usually not traded in the market. Furthermore, historical data about the real asset's market value is seldom available. In general, the volatility could be estimated through an educated guess, through a twin security or historical data, or through a simulation model (Luehrman, 1998a). A generally accepted method for an estimated guess starts with isolating the primary source of uncertainty (Hevert, 2001). Through an estimation of the asset's value up (u) and down movements (d), the volatility could be derived from the following set of equations, where an underlying normal distribution is assumed:

$$u = e^{\sigma} \tag{2.1}$$

$$d = 1/u \tag{2.2}$$

According to Davis (1998), it may be possible to estimate the volatility from a historical series of unlevered company values of listed companies with identical projects. However, note that most projects within companies can be expected to have a higher volatility. Copeland and Antikarov (2001) describe a method where the projected cash flows for the project are used to make a Monte Carlo simulation of the project's returns, which could be used to estimate the project's volatility. The hard part of such a simulation is to determine the right parameters for the relevant variables and the right correlation coefficients.

According to Pindyck and Majd (1987), it may be impossible to estimate the volatility correctly. Dixit and Pindyck (1994) usually take the volatility to be equal to the average percentage standard deviation of stock market equity, about 20% to 30%. Note that the methods described to estimate volatility may only be appropriate for flexibility Real-Options[1]. For strategic Real-Options, these particular methods could be inappropriate. Intuition in estimating volatility seems important, example 1 should contribute to such intuition.

Risk free rate of interest

The risk free rate of interest is the theoretical rate of return of an investment with zero risk. For financial options the risk free rate of interest is easy to determine, as it is natural to assume that the rates on Treasury bills and Treasury bonds are the correct benchmark (Hull, 2008). An increase in the risk free rate of interest will increase the value of an investment option, since it will increase the time value of money advantage in deferring the investment cost. For Real-Options, when making use of risk-neutral probabilities, the risk free rate of interest can be derived in the same way as for financial options. However, for Real-Options with an unfixed time to expiration, the risk free rate of interest is stochastic.

Dividend

Dividend is a return to the shareholders for providing capital to the company. Because not all the companies pay dividend, this variable is not always relevant in financial option pricing. Despite real assets do not pay dividends, this variable is still important for Real-Options. In Real-Options literature, a dividend is a cash outflow from the real asset, in other words it decreases the value of the asset. For Real-Options, this could be useful to take into account cash flow losses due to for example competition. However, such leakage in value is difficult to model, as the amount and timing are dependent on exogenous influences.

2.1.4 Types of Real-Options

We have found Real-Options with and without strategic value. Strategic value, or growth option value, is not specifically defined in the Real-Options literature, but is mentioned often. Basically, strategic value is value locked inside a company, that cannot yet be converted into cash, but can possibly be converted into cash at some time in the future. Real-Options with strategic value are related to possible future projects that do not derive their value primarily from cash inflows. Real-Options literature is mostly concerned with Real-Options without strategic value. These Real-Options are closer related to financial option theory and are concerned with the current business. These Real-Options are also described as "cash-generating" options by (Trigeorgis, 1988), or as flexibility options by (Triantis, 1999). Real-Options without strategic value mostly have a clear payoff (exercising leads to a clear and measurable cash inflow) and are typically related to operating decisions. Our definition of Real-Options gives us the tools to use Real-Options theory for Real-Options with and without strategic value. We will first discuss the differences.

The classification of Real-Options by Trigeorgis (1988), is depicted in figure 2.1. This classification uses similarities between Real-Options and financial options. Trigeorgis (1988) concluded that Real-Options without strategic value, which are cash-generating, are (usually) structured as so-called simple options. Real-Options with strategic value, which are not cash-generating, are (usually) structured as so-called compound options.

In the second layer of figure 2.1, Trigeorgis (1988) shows that both Real-Options with and without strategic value can be divided into proprietary or shared Real-Options. In contradiction to proprietary

[1]Flexibility and strategic Real-Options will be defined in section 2.1.4

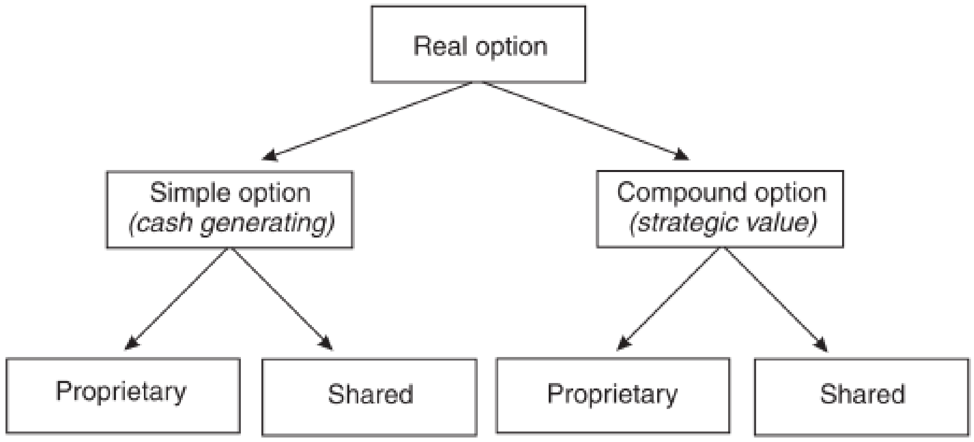


Figure 2.1: Classification for Real-Options

Real-Options, shared Real-Options are opportunities that are jointly held by a number of competing firms, or even by an entire industry, and can be exercised by anyone of the collective owners. A competitive strategy for executing these Real-Options should according to Smit and Trigeorgis (2004) be found with game-theory. Examples of Real-Options in each category are:

Simple proprietary Real-Option	E.g. a government concession to develop natural resources or a potential expansion of capacity to produce a unique product protected by patents.
Simple shared Real-Option	E.g. many expansion decisions in competitive industries.
Compound proprietary Real-Option	E.g. exploration investments protected by government licenses.
Compound shared Real-Option	E.g. a pilot project proving the market and creating customer acceptance.

Triantis (1999) describes Real-Options with strategic value as growth options, which he distinguishes from Real-Options without strategic value, namely flexibility options. “By acquiring growth options, firms can *position themselves* to potentially exercise profitable growth options in the future, by investing in research and development, IT expertise, brand name recognition and other sources of competitive advantage”. Taking a favourable position and thereby nurturing the Real-Option will appear to be the only right decision and the distinctive aspect of a strategic Real-Option. Flexibility options are related to a firm’s ability to revise investment and operating decisions over time as uncertainty is resolved. Examples of typical growth and flexibility options are given by Triantis (1999) and are listed in table 2.1

The insights from Trigeorgis (1988) and Triantis (1999) are complementary. From these insights we established definitions for flexibility and strategic Real-Options. These definitions will be used to classify the types of Real-Options derived from the literature in this section:

1. *Flexibility Real-Options*, i.e. all-Real-Options without strategic value. These Real-Options are only concerned with one project, can not initiate new projects and are related to a company’s current activities / assets in place. More technically, these Real-Options are generally simple options with a clear payoff (exercising leads to a clear and measurable cash inflow). Over time, as uncertainty resolves, it becomes clear whether these Real-Options should be executed or not.

Industry	Growth option	Flexibility option
Pharmaceuticals	Research and development	Outsource production or sales
Oil & gas	Lease blocks	Delay production
Power	Global expansion	Peak generating plants
Computer hardware	New model under brand name	Assembly configuration
Financial services	IT infrastructure	Abandon service or divest
Airline	Aircraft delivery options	Contingency rights
Real estate	Undeveloped land	Redevelop with adjusted mix
Telecommunications	Mergers and acquisitions	Re-deploy assets
Internet	Marketing investments	Outsource services

Table 2.1: Examples of growth and flexibility options in different industries

2. *Strategic Real-Options*, i.e. all Real-Options with strategic value. These Real-Options can initiate new projects. These new projects can be either related to one or more projects currently undertaken, or may be strategic opportunities not related to any project/assets in place at all. These Real-Options are growth options, where companies position themselves favourably to potentially exercise profitable growth options in the future, by for example investing in research and development, IT expertise, brand name recognition and other sources of competitive advantages. More technically, these Real-options are generally compound options, where potential future payoff (future cash inflows) is unclear at the time of execution.

Types from literature

Copeland and Antikarov (2001) indicate that Real-Options are primarily classified by their type of flexibility, they indicate five types of Real-Options:

1. *Option to defer*, e.g. the option to defer a project. Could be structured as an American call option where one has the right to delay the start of the project. The exercise price is the amount of money that should be invested in order to start the project.
2. *Option to abandon*, e.g. the option to sell or close down a project. Could be structured as an American put where one has the right to exit a project. The exercise price is the amount payable for abandoning the project.
3. *Option to contract (scale back)*, e.g. the option to reduce the scale of a project's operation. Could be structured as an American put where one has the right to sell a fraction of the project's activities for a fixed price. This fixed price is the exercise price, which is thus the amount of potential cost savings.
4. *Option to expand*, e.g. the option to make further investments and increase the output if conditions are favourable. Could be structured as an American call, where one has the right to scale up the project's activities for a fixed price. This fixed price is the exercise price, which is thus the amount payable for expanding a project.
5. *Option to extend*, e.g. the option to extend the life of an asset. Could be structured as an American call, where one has the right to extend the life of a project. The exercise price is the direct cost involved with extending the life of the project.

In many real-life situations, there is not just one type of Real-Option related to a project. Besides the classification by type of flexibility, Copeland and Antikarov (2001) add some more Real-Options categories to the list, which are classified by type of combination of options. These sorts of Real-Options are primarily concerned with the modelling structure.

1. *Switching options*, e.g. a portfolio of American call or put options that allow their owner to switch at a fixed cost between to modes of operation.

2. *Compound options*, i.e. options on options, e.g. phased investments or sequential investments. A classic example of a compound option comes from Brealey, Myers, and Allen (2011), where they consider an investment in a computer model called the "Mark I". When evaluating the option to build the Mark I, one could also take into account the option to build his successor in the future, the "Mark II". This latest option could be structured as a compound American call option, where one has the right to build the Mark II, the successor of the Mark I.
3. *Rainbow options*, i.e. options driven by multiple sources of uncertainty, where the option value is dependent on two or more underlying variables, e.g. price of a unit of output and the quantity that might be sold.

Of course, their could be a mixture of the Real-Options classified by combination as well. Many real-world applications are in fact compound rainbow options (Copeland & Antikarov, 2001).

Amram and Kulatilaka (1999) identified the timing, exit, operating, growth, flexibility, staging and learning options. In this order, these options could be translated to the options Copeland and Antikarov (2001) identified, with exception of the rainbow option, as listed above. Avinash K. Dixit and Robert S. Pindyck, Alexander J. Triantis and Lenos Trigeorgis all use the same terminology as either Thomas E. Copeland or Martha Amram.

However, Trigeorgis (2005) identifies one additional type of Real-Option, namely:

1. *Corporate growth options*, i.e. another version of the option to expand, with considerable strategic importance, which set the path for future opportunities. More generally, many early investments (e.g. R&D, a lease on undeveloped land or a tract with potential oil reserves, a strategic acquisition, or an information technology network) can be seen as prerequisites or links in a chain of interrelated projects. The value of these projects may derive not so much from their expected directly measurable cash flows, but rather from unlocking future growth opportunities.

By our definition of flexibility and strategic Real-Options, we can categorise the first types of Real-Options mentioned (i.e. the option to defer, the option to abandon, the option to contract, the option to expand and the option to extend) as flexibility Real-Options. All these Real-Options are related to a company's operating activities. The classification of Real-Options by their type of combination is less informative. A switching option is neither a simple option, nor a compound option. As switching options are related to several modes of operation, these are flexibility options. Compound options usually are strategic Real-Options. A rainbow option however, can be either a simple option or a compound option. Hence, it can be either a flexibility or a strategic Real-Option. Therefore, the characteristics of a rainbow option do not give sufficient information about the strategic value of an option. Some sorts of Real-Options with strategic value are explicitly described in literature, by for example Trigeorgis (2005). Examples of such options are given in table 2.1. In most cases, Real-Options literature is concerned with flexibility Real-Options. Strategic Real-Options / Corporate growth options are often mentioned, but literature is fairly vague about how to cope with them. Probably because there is still no consensus about how to use Real-Options theory to this kind of options / opportunities (Borison, 2003).

Research performed by Smith and Triantis (1995) reveals some Real-Options specifically applicable when considering an acquisition. These are strategic Real-Options that are available to the acquirer in excess of the stand-alone value (with Real-Options) of the target company. In other words, these synergies are seen as Real-Options on top of the stand-alone value with Real-Options. The following three classes of Real-Options are important to acquisitions:

1. *Acquisition growth options*, e.g. an acquisition that would position the acquirer in a key emerging market.
2. *Acquisition flexibility options*, e.g. acquisition of a firm with flexible distribution channels will enhance the flexibility of its current distribution channels.
3. *Acquisition divesture options*, i.e. the same sort of option as the option to abandon or the option to exit. It is the right to sell parts (or all) of the acquisition's activities.

Smit and Moraitis (2010) identify the Real-Options mentioned above as asset acquisition options, which they distinguish from platform acquisition options. They define asset acquisition options as "single" strategic Real-Options that are available to the acquirer in excess of the stand-alone value. A platform acquisition option is a compound Real-Option with follow-on investment opportunities, which can be a critical component in a serial acquisition strategy.

2.1.5 Market and private risks

The value of Real-Options can be influenced solely by market risks, solely by private risks or by a combination of both. Market risks are risks captured in the price fluctuations of traded securities and private risks are risks not captured in the price fluctuations of traded securities (Amram & Kulatilaka, 2000). Assets influenced by a market-priced risk are associated with a wider set of opportunities because one can always acquire, reduce, or reshape the risk through a position in traded securities. The type of risk underlying a Real-Option has important implications for the applicability of Real-Options theory.

In Real-Options literature, there is consensus about the use of Real-Options theory to Real-Options that are solely influenced by market risks. Amram and Kulatilaka (1999) provides us with an example that shows us how market risks drives value, see example 2.

Example 2 *The following investment decision is under consideration: building a manufacturing plant whose raw materials (soybeans) and products (soybean oil) are both traded in the futures market.*

To decide whether to build such a plant, Chicago Soy needs to calculate the net present value, whereby they incorporate the Real-Option to shut down the plant temporarily.

Chicago Soy produces soybean oil from soybeans. Besides other costs, the plant's profit is mainly driven by the spread between the spot price of soy beans and the spot price of soybean oil, the crush spread. Furthermore, the value of the plant is also driven by the volatility on the crush spread. If the spread is highly volatile, the company may wants to hold off shutting down its plant, even when the spread narrows to the point where the plant is unprofitable.

Because the trigger points are derived from traded securities, they align the plant's operations with the markets, ensuring that it operates in a way that maximises long-term shareholder value.

Real-Options literature also agrees to some extent about the application of Real-Options theory to Real-Options that are influenced by a combination of market and private risks. Amram and Kulatilaka (1999) provides us with an example that shows how both risk factors drive value and how Real-Options theory could be applied, see example 3.

Example 3 *The following investment decision is under consideration: upgrade the information system, which would enable a mortgage selling company to significantly improve its customer service, leading to stronger growth. In order to implement such a system, the company faces large up-front expenditures.*

To decide whether to upgrade the information system, Eastern States Mortgage needs to calculate the net present value of the investment, whereby they incorporate the options created by the new platform for future upgrades and extensions. Furthermore, Eastern States Mortgage splits their investment decision into three stages, whereby they include an option to abandon after each stage. The investment decision is then described as follows:

- *Stage 1: A pilot project conducted in one region (will resolve private risks, after that point, risk in the project will be dominated by market-priced risks).*
- *Stage 2: Rolling out the technology on the retail side of the business.*
- *Stage 3: Rolling out the system to the rest of the company.*

By splitting the project into three stages, the company divides the amount of needed up-front investments over the three stages. After the first stage, the private risks are resolved. From then, the interest rate risk determines whether to continue to the next stage. Therefore, the interest rate risk is from there on the most important value driver of the project. If the interest rates rise to a level that damps overall mortgage demand, the project could probably better be abandoned.

After stage one, the value of the project is solely influenced by interest rate risks (market risks), therefore Real-Options theory should be used to calculate the value of the Real-Options at the end of stage one. To calculate the value of the Real-Options at the beginning of stage one, subjective estimates about the development of the project's value through stage one should be made.

When market risk can be separated from private risk, option-pricing methods could be applied to value the part of Real-Options that are influenced by market risk. Literature agrees with this method as this is basically the same as the method applied at example 2. However, it is not always possible to separate market risk from private risk.

Unfortunately, there is no consensus about the use of Real-Options theory to Real-Options that are solely influenced by private risks. According to our definition, Real-Options include all the future opportunities of a company that are created by todays investment. Regardless whether these future opportunities can be valued by option-pricing theory. Dixit and Pindyck (1994) indicate decision analysis should be used to calculate Real-Options influenced by private risks. This point of view is underwritten by many others (e.g. (Amram & Kulatilaka, 2000)). However, decision analysis can be very complex and time-consuming, as every decision can be influenced by different variables and could have possible multiple outcomes. Copeland and Antikarov (2001) came up with the Market Asset Disclaimer, the MAD assumption. The MAD assumption assumes that the present value of the underlying asset is equal to the value of the project without flexibility. This assumption is often followed by the assumption that the value of the underlying asset behaves as a Geometric Brownian motion[2] through time (other underlying distributions are also possible). From now on, we call the combination of these two assumptions *the MADD assumption (MAD inclusive Distribution)*.

The method that relies on this approach do we call *the MADD approach*, this approach makes it possible to calculate the value of Real-Options influenced by all risk types, in a way that is fairly easy to understand. Note that subjective estimates are necessary to derive the underlying distribution. Criticism on the first assumption is very mild, however the second assumption is subject to serious criticism. First of all, the assumed distribution should reflect reality, otherwise the option price could be subject to serious flaws. Second, applying option-pricing theory, which is based on no-arbitrage arguments, to illiquid assets that are not traded in the financial markets, violate the fundamental assumptions of option-pricing theory, which will be stated in section 2.1.6.

Just like the MADD approach, decision analysis also makes use of subjective estimates about the development of the value of the underlying asset through time. However, the behaviour of the asset's value is not "forced" to follow some distribution for convenience. Decision analysis is therefore theoretically a better method than the MADD approach to value Real-Options influenced solely by private risks. Note that scenario analysis is a form of decision analysis. However, if the decision tree becomes too large and complex, the MADD approach will probably be a better method to use, taking into account the ease of use.

The value of strategic Real-Options is (almost) always (partly) driven by private risks (Amram & Kulatilaka, 2000). Therefore, there is no consensus about whether strategic Real-Options actually could be valued with option-pricing methods. Sometimes market risks can be separated from private risks, Real-Options theory could then be used to evaluate market risks. Private risks could then be evaluated with decision analysis. The MADD approach can also be used to evaluate all risk types at once.

Regardless of which method will be used to value strategic Real-Options, if they can be valued at all, the use of Real-Options theory has significant other advantages. According to Triantis (2005), the use of Real-Options theory has at least four significant advantages over decision analysis:

[2]The Geometric Brownian motion is described in section 2.1.6

- There is a focused attention on the maximisation of shareholder value.
- Related to the previous point, to the extent that investors value expectations and to the extent their tradeoffs between risk and return are reflected in the equity and derivatives markets, information from these markets can be used to get more precise estimates of the value that would be created by projects under consideration from the perspective of the firms shareholders.
- The conceptual framework and shorthand vocabulary of options help to simplify the framing of investment decisions.
- Some decision analysts concede that Real-Options theory places more emphasis than earlier frameworks on downstream decisions, such as decisions to abandon uneconomic projects or to expand projects that will become more promising with time.

Borison and Triantis (2001) indicate as well that Real-Options as a way of thinking are important for companies. Furthermore, Amram and Kulatilaka (2000) indicate that securities markets are changing rapidly, what is private risk today may be securitised in the future. Therefore, the practicability of Real-Options theory will only increase in the future.

2.1.6 Quantification methods of Real-Options

According to Borison and Triantis (2001), the three dominant quantification methods are:

1. *Binomial (or trinomial) lattices*
2. *Risk-adjusted decision trees*
3. *Monte Carlo simulation*

Remarkably, the Black and Scholes option-pricing formula is not mentioned. This method was seen as too simplistic and not intuitive by Borison's (2001) sample. They state: "Where the Black and Scholes formula is used, it is usually seen as a quick and easy way to arrive at a rough value for simple investment opportunities". Also decision analysis is not mentioned, that is because decision analysis is not (yet) seen universally as a general accepted method to value Real-Options. Block (2007) surveyed Fortune 1,000 companies and got the same results. Out of their 279 respondents, 40 were using Real-Options. 16 of them primarily used binomial lattices, 12 of them primarily used risk-adjusted decision trees, 9 of them primarily used Monte Carlo simulation, 1 of them primarily used the Black and Scholes option-pricing formula and 2 were using primarily other methods. We will elaborate on the thee most applied quantification models by practitioners.

Binomial (or trinomial) lattices

The binomial tree is a diagram representing different possible paths that might be followed by the asset price over the life of the option (Hull, 2008). In each time step, it has a certain probability of moving up with probability p by a certain factor u and it has a certain probability of moving down with probability $(1-p)$ by a certain factor d. This is depicted in figure 2.2. The term "binomial" refers to the fact that during each short time interval in the model, the value of the underlying asset can take on two possible values. Consequently, in a trinomial lattice model, the underlying asset can take on three possible values.

The binomial lattice model allows for great flexibility, as allowing for optimal timing of the exercise decision as well as allowing for more general specifications of the distribution of the underlying asset's value at different points in time (Borison & Triantis, 2001). The greatest advantage of this model is that the actual probabilities of an up or a down movement of the underlying asset are not relevant, the model makes use of "risk-neutral probabilities". This method is first described by Cox, Ross, and Rubinstein (1979) and is also known as the "risk-neutral probability approach" or the "Cox, Ross and Rubenstein model".

To construct the binomial lattice model, S_0, u and d, p and r (the risk free rate of interest) are needed, where:

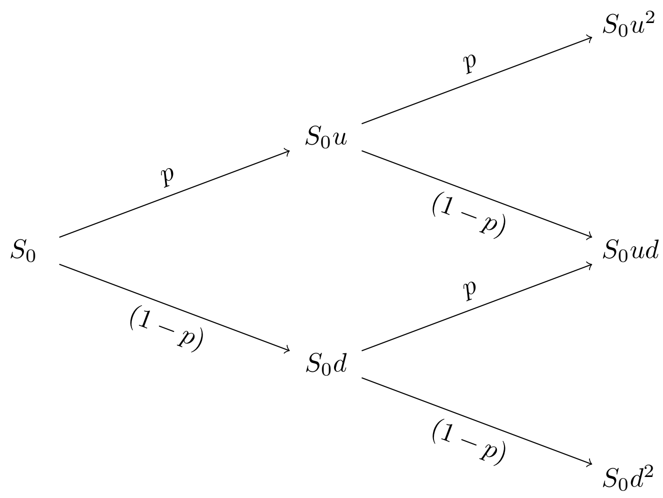


Figure 2.2: Example of a binomial tree

- S_0 is the current price of the underlying asset. This could be derived from market data or the MAD assumption.
- u and d are the factors for reaching the up or down state. In many cases practitioners will have a reasonable estimated guess for these values. When σ is known, u and d could also be derived. In that case, assuming an underlying normal distribution, $u = e^{\sigma\sqrt{\Delta t}}$ and $d = e^{-\sigma\sqrt{\Delta t}} = 1/u$.
- r is the corresponding risk free rate of interest
- p is the "risk-neutral probability", which could be derived from $p = \frac{e^{r\Delta t}-d}{u-d}$ (see Cox et al. (1979)).

To solve the binomial lattice model for the value of the Real-Option at different states, a risk-neutral portfolio must be set up. For a risk-neutral portfolio, one assumes a risk-neutral world, where all investors are indifferent to risk and where the expected return equals the risk free rate of interest. Together with the assumption that arbitrage opportunities do not exist, such a risk-neutral portfolio could be set up. The option values are calculated by starting at the end of the three and working back to the current time. Note that in case the Real-Option has multiple exercise moments, it must be checked whether early exercise is preferable to holding the Real-Option instead. When the value of the Real-Option is denoted as f and in state u and d its value is denoted as respectively f_u or f_d, the following equation must hold:

$$S_0u\Delta - f_u = S_0d\Delta - f_d \tag{2.3}$$

At time T, the value of the Real-Option in each state is known, so equation 2.3 can be solved for Δ, which is the hedge ratio. It means that a portfolio is riskless if you possess Δ shares in the asset and short one option. Because a riskless portfolio, in the absence of arbitrage opportunities, must earn the risk free rate of interest, both sides of the equation can be discounted at the continuously compounded risk free rate of interest to derive the option value at the previous state. So, $S_0\Delta - f = (S_0u\Delta - f_u)e^{-r\Delta t}$. Now we could solve for f, the initial price of the Real-Option. Besides, the assumptions already mentioned, assuming a risk-neutral world implies also that (Hull, 2008):

- Security trading is continuous, hence the market is fully liquid.
- It is possible to borrow and lend at the risk free rate of interest.
- The short selling of securities with the full use of proceeds is permitted.
- There are no transaction costs or taxes. All securities are perfectly divisible.

The binomial lattice model can handle market risks. In combination with the MADD assumption, it can also handle private risks. The model is not suited to handle private risks without further assumptions.

The binomial lattice model, as we used for an example, assumes that the asset price follows a random walk, however Dixit and Pindyck (1994) argue that it is more realistic to model an economic variable as a process that makes infrequent but discrete jumps, a jump process. The binomial lattice model is suited to cope with other underlying distributions as well.

Risk-adjusted decision trees

The risk-adjusted decision tree is a more general approach, which allows for multiple decisions and uncertainties over time. This method discounts expected cash flows at a risk-adjusted rate, where the risk-neutral probability approach (binomial lattice model) discounts certainty-equivalent cash flows at the risk free rate of interest. The basic principle is that objective probabilities are used instead of risk-neutral probabilities. Therefore, the model can also incorporate private risks that cannot be diversified.

To construct the risk-adjusted decision tree, S_0, u and d, p, r and k (the risk-adjusted discount rate) are needed. In this case S_0 can be derived in the same manner as for the binomial lattice model, u and d represent the actual up and down factor, p is the objective probability of moving towards the up state and k is the discount rate that equates the present value of $S_{0+\Delta t}$ with S_0. To determine the applicable risk-adjusted discount rate to equate $S_{0+\Delta t}$ to S_0, the following equation must be solved for k:

$$S_0 = \frac{S_{0+\Delta t}}{1+k} \tag{2.4}$$

Because in a risk-adjusted decision tree various uncertainties can be incorporated, reflected by their actual probabilities, the risk-adjusted discount rate is often not constant throughout the tree. To solve the risk-adjusted decision tree, we work back again to the current time. For example, the Real-Option value at node S_0u, in example 2.2 is:

$$f_u = \frac{f_{uu}p + f_{ud}(1-p)}{1+k}; \text{where } f_0 \text{ and } k \text{ are unknown}$$

These two unknown variables can be solved using the replicating portfolio approach, where B is either the number of dollars invested in a risk-free bond or the number of dollars borrowed against the risk free rate of interest:

$$\begin{aligned} \Delta S_0 u^2 + (1+r_f)B &= f_{uu} \\ \Delta S_0 ud + (1+r_f)B &= f_{ud} \end{aligned}$$

Solving for Δ and B yields the Real-Option value at node S_0u. The risk-adjusted discount rate k can now be calculated trough equation 2.4. By repeating this process, we can calculate the value of the Real-Option in all states. Again, it is important to check whether early exercise is preferable to holding the Real-Option instead.

Risk-adjusted decision trees can handle both market risks and private risks. It is also possible that one or more branches handle these risks together in combination with the MADD assumption. The entire method is stepwise explained by Borison (2003). Here, decision analysis tells us to assign subjective probabilities to the risks based on subjective judgment. Applied in a risk-adjusted decision tree, objective probabilities (i.e. probabilities withdrawn from the market) are assigned to market risks. This method is also described as the integrated (two risk types) approach. The steps to be taken are as follows:

1. Build a decision tree representing the investment alternatives.
2. Identify each risk as either market or private.
3. For public risks, identify the replicating portfolio and assign "risk-neutral" probabilities.
4. For private risks, assign subjective probabilities.
5. Apply a spreadsheet cash flow mode at each tree endpoint and calculate the NPV using the risk free rate of interest.
6. "Roll-back" the three to determine the optimal strategy and its associated value.

Monte Carlo simulation

Borison and Triantis (2001) explain the basic idea behind Monte Carlo simulation with respect to Real-Options well:

> *"Monte Carlo simulation is a powerful technique that allows for considerable flexibility in the number and specification of the uncertainties in the decision problem. Based on assumed probability distributions for each uncertainty, a large number of possible scenarios are generated for the underlying project cash flows or value. The Real-Option value is then calculated for each of these scenarios, and the average of these values is discounted back to the present. The Monte Carlo valuation approach is useful when the cash flows from a project are path-dependent, that is, when they depend on prior decisions taken by the firm. While it has traditionally been difficult to use this approach to value American options, new techniques are being developed to address this shortcoming".*

Considering path-dependent American options, the challenge is to determine if early exercise is preferable. Longstaff and Schwartz (2001) describe a least-squares approach to estimate the conditional expected payoff. Another method described by Andersen (2000), involves parameterising the early exercise boundary and determining it iteratively by working back from the end of the life of the option to the beginning. Both are good, but time-consuming methods to deal with path-dependent American options. Fortunately, there is software available today that performs most of the calculations for you (Copeland & Antikarov, 2001).

Monte Carlo simulation can thus be used to value many kinds of Real-Options. However, the specific way to apply Monte Carlo simulation is different for each type of Real-Option. Furthermore, additional software packages are needed for practitioners. In order to apply Monte Carlo simulation to a simple Real-Option on a traded asset, which payoffs are assumed to be normally distributed, the following steps must be taken:

1. Sample a random path for S (in a risk-neutral world).
2. Calculate the payoff of the Real-Options.
3. Repeat steps 1 and 2 until there are enough sample values to provide a reliable estimate of the payoff of the Real-Option (in a risk-neutral world).
4. Calculate the mean of the sample payoffs to get an estimate of the expected payoff.
5. Discount this expected payoff (at the risk-free rate of interest) to get an estimate of the value of the Real-Option.

Steps 2 to 5 are easy to fulfill, when step 1 is succeeded. For step 1, the process followed by the underlying asset must be defined. Note that we can model a sample path for any kind of uncertainty, not necessarily modelled in a risk-neutral world. Because of the assumptions made, equation 2.5 describes a random path for S, where dz is a Wiener process, $\hat{\mu}$ is the expected return in the risk-neutral world and σ is the volatility. A stochastic process S_t is said to follow a Geometric Brownian motion (GBM) if it satisfies equation 2.5. Equation 2.6 is a discrete approximation of equation 2.5, where the life of the Real-Option is divided into N short intervals of length Δt and ϵ is a random sample from a normal distribution with mean zero and standard deviation 1.0.

$$dS = \hat{\mu} S dt + \sigma S dz \tag{2.5}$$

$$S(t + \Delta t) - S(t) = \hat{\mu} S(t) \Delta t + \sigma S(t) \epsilon \sqrt{\Delta t} \tag{2.6}$$

Equation 2.6 enables us to calculate the value of S at time Δt from the initial value of S. From each sample of ϵ, we can calculate the value of S at the end of the next time interval. One sample path is completed after N random samples from a normal distribution are taken, this completes step 1.

2.2 Real-Options as add-on component

Putten and MacMillan (2004) state that there is an unspoken assumption that Real-Options and DCF valuation methods are mutually exclusive. However, they believe that the two approaches can be integrated, where the total value consists of a NPV component and Real-Option components. Putten and MacMillan (2004) define *project* value as:

$$\begin{aligned} Total\,Project\,Value &= Net\,Present\,Value + Adjusted\,Option\,Value + Abandonment\,Value \\ TPV &= NPV \qquad\qquad\quad + AOV \qquad\qquad\qquad + ABV \end{aligned}$$

Both the AOV and the ABV are Real-Option components, where the AOV gains value from the variability of the project's profit, adjusted for the variability of the project's cost and the ABV gains value from the manager's opportunity to abandon the project. Putten and MacMillan (2004) do not explicitly define a project, however they seem to assume any capital budgeting decision to be made by management. This makes the principle of their formula applicable to company value as well.

According to both Smit and Trigeorgis (2004) and Trigeorgis (2005), capturing the additional value of managerial operating flexibility and other strategic interactions calls for an expanded NPV, which they define as:

$$Expanded\,NPV = Passive\,NPV + Option\,premium + Strategic\,value \tag{2.7}$$

The expanded NPV (also named strategic NPV) consists of the passive NPV (also named static NPV), an option premium (also named flexibility value) and strategic value. Regarding a project, the passive NPV means that there is no value assigned to any flexibility. The option premium captures for example the value of deferring a decision. It basically includes all value inherent to managerial flexibility to revise future decisions. "When there are deviations from the expected plans, it introduces beneficial asymmetry in the distribution of project value returns by enabling upside (value-creation) opportunities to be exploited fully while limiting downside losses by choosing not to proceed or abandon" (Trigeorgis, 2005). The strategic value (game-theoretic value) in the definitions of Smit and Trigeorgis (2004) and Trigeorgis (2005) is derived from competitive counteractions. Early commitment can offset the option value to wait, because it can give a head start with respect to the competition. Smit and Trigeorgis (2004) state that taking into account competitive counteractions with the help of game-theory is the next step, after taking into account Real-Options value, in bridging the gap between financial and strategic analyses. Equation 2.7 is related to a project's investment decision and makes perfect sense in this retrospect. With respect to a company valuation, strategic value could be derived from strategic opportunities as well.

In another article by Smit, Smit and Moraitis (2010) state that a company's market value consists both of the net present value of its future cash flows, which is derived from the company's assets in place, and of the present value of a company's growth options. The present value of growth options include in their definition the potential options the company encompasses, as well as the evolving and future strategic position of the company. The market value of a company is then expressed as follows:

$$Market\,value\,(MV) = Assets\,in\,place\,(PV) + Present\,value\,of\,growth\,options\,(PVGO) \tag{2.8}$$

Smit and Moraitis (2010) add the Real-Option value and the strategic value together in the form of the PVGO, which is an established concept from corporate finance. Myers (1977) already noted that the value of the firm (V) can be broken down in the present value of assets already in place (V_A) and the present value of growth opportunities (V_G). Brealey et al. (2011) explain with respect to the price of a stock that one can think of a stock price as a capitalised value of average earnings under a no-growth policy, plus the PVGO, see equation 2.9. Kester (1984) takes a similar approach, stating that the difference between the total value of a firm's equity and the capitalised value of its current earnings stream estimates the value of its growth options.

$$S_0 = \frac{EPS_1}{r} + PVGO \tag{2.9}$$

Where EPS_1 stands for next year's expected earnings per share and r for the appropriate discount rate. In case of a pure *income stock*, PVGO would equal zero, which means that the stock price is only dependent on EPS and r. In case it is a *growth stock*, PVGO would have significant value. Investors have thus recognised Real-Options value and strategic value for companies a long time ago.

However, we remark one very important difference in the definitions of PVGO in Smit and Moraitis (2010) and Kester (1984). Smit and Moraitis (2010) describe PVGO as the strategic value of a company, where according to Kester's (1984) definition, any value derived from growth is incorporated in a company's PVGO. As most of the corporate finance literature defines PVGO the same as Kester, we define PVGO also as all value derived from growth. We therefore adjust the term "PVGO" in equation 2.9 to "strategic Real-Options value". Smits' (2010) definition becomes then as follows:

$$Market\,value\,(MV) = Assets\,in\,place\,(PV) + strategic\,Real\,Options\,Value \tag{2.10}$$

Equation 2.10 does however not comply with the content of section 2.1.4, where we specifically stated that foreseen/planned future investments are no types of options. If a company's management knows certain that the company is going to commit itself to some future investments, they should not see the entire investment as an option. Real-Options theory is therefore not qualified. Uncertain future opportunities can however be valued with Real-Options theory. We adjust equation 2.10 therefore once again, where we replace the present value of the assets in place with the present value of the future assets in place. The renewed equation, based on the insights from Smit and Moraitis (2010), is depicted in equation 2.11.

$$Market\,value\,(MV) = Future\,assets\,in\,place\,(PV) + strategic\,Real\,Options\,Value \tag{2.11}$$

There are thus two possibilities to use Real-Options as an add-on component, either estimating all (possible) value derived from a company's future growth (PVGO) or estimate a company's strategic Real-Options. The advantage of estimating all value derived from growth is that the other component (i.e. the static PV) in the equation of total company value is very easy to determine. For a stock's value it is $\frac{EPS_1}{r}$ and for a company's value it is $\frac{FCF_1}{WACC}$, where $WACC$ is the weighted average cost of capital. The disadvantage of this method is that estimation of PVGO can be very difficult. The advantage of estimation of a company's strategic Real-Options is that it is easier and more understandable than estimation of a company's PVGO. The disadvantage is that it is more difficult and a bit unclear how to determine the present value of a company's future assets in place.

A typical enterprise DCF valuation of a company's future cash flows does incorporate some Real-Options value. According to Myers (1984), projects bringing intangible assets or growth opportunities to the firm have correspondingly higher NPVs. But DCF valuation does not capture a company's Real-Options value fully because it is not suited for that. It is very hard for (operating) managers to estimate future long-run cash flows. Long-run cash forecasts often end up as mechanical extrapolations of short-run trends. Another very important aspect is that second-stage investments, which are dependent on the first, are a type of option, where options are not properly valued by discounting cash flow methods (Myers, 1984). So, as a typical enterprise DCF valuation is more (assuming growth is positive) than the static PV, but less than total company value, it probably approaches the present value of a company's future assets. The present value of a company's future assets in place thus might be estimated by a "typical" enterprise DCF valuation.

Hence, we conclude that we can assume that the value of a company can be decomposed as in equation 2.12, where the static PV is the value of a company under a no-growth policy, the PVGO is all value derived from (possible) future growth, the present value derived from assets in place is the future value derived from a company's current assets and the strategic Real-Options value comprises strategic value, which include all value inherent to a company's strategic opportunities.

$$Company\,Value = \underbrace{static\,PV + PVGO}_{\text{static PV model}} = \underbrace{Future\,Assets\,in\,place\,(PV) + strategic\,Real\,Options\,Value}_{\text{Future assets in place (PV) model}} \tag{2.12}$$

2.3 Functions of Real-Options

2.3.1 Current functions

There are several types of Real-Options and they serve some common functions. We make a distinction between Real-Options functions on:

1 *Project-level*

2 *Management-level*

Real-Options on project-level are the Real-Options that influence the capital budgeting decision of a specific investment project of a company. Examples of such Real-Options are the option to defer a project or the option to abandon a project. The presence of these Real-Options within a project can be decisive for the start of a project, however these Real-Options are not concerned with triggering new projects in the future. In case the start of a project creates strategic growth options as well, strategic value should be incorporated in the capital budgeting decision. For example, developing and producing a certain innovative product can put the company in a favourable position to potentially exercise an option to create a successor. This option is relevant for this specific project, but is interesting for management as well. Therefore such an option is both an option on project-level and on management-level.

On project-level, Real-Options can serve as a better valuation tool for capital budgeting decisions. Their function is to correctly incorporate the value attached to the following factors in a project's capital budgeting decision (Dixit & Pindyck, 1994):

1 *Irreversibility*

2 *Uncertainty of future rewards*

3 *Timing or staging*

The three factors that affect Real-Options value on project-level are all influencing the amount of managerial flexibility. Where more managerial flexibility leads to more valuable Real-Options on project-level (Copeland & Antikarov, 2001). Important to realise is that when incorporating Real-Options value on project-level, one assumes that management will make fully rational decisions, i.e. they will follow an optimal decision-strategy with respect to their projects (Triantis, 2005).

Figure 2.3 depicts the reasoning behind the value inherent to managerial flexibility on project-level. If future rewards are highly uncertain, but management is likely to receive a lot of information regarding these rewards in the future and management is able to defer some important decisions, a project may encompass high option value.

We conclude that Real-Options on project-level are important to make correct capital budgeting decisions and to correctly sketch the optimal decision-making path for management. These Real-Options contribute the most if the project's value without flexibility is close to break-even and one or more of the factors irreversibility, uncertainty of future rewards or timing lead to managerial flexibility.

Real-Options on management-level encompass all strategic Real-Options of a company. It are the Real-Options that could initiate new projects in case they are executed. Note that the value of some of the Real-Options on management-level could already be included in the capital budgeting decision of a specific project. For example, the option to create a successor, can be both an option on project-level

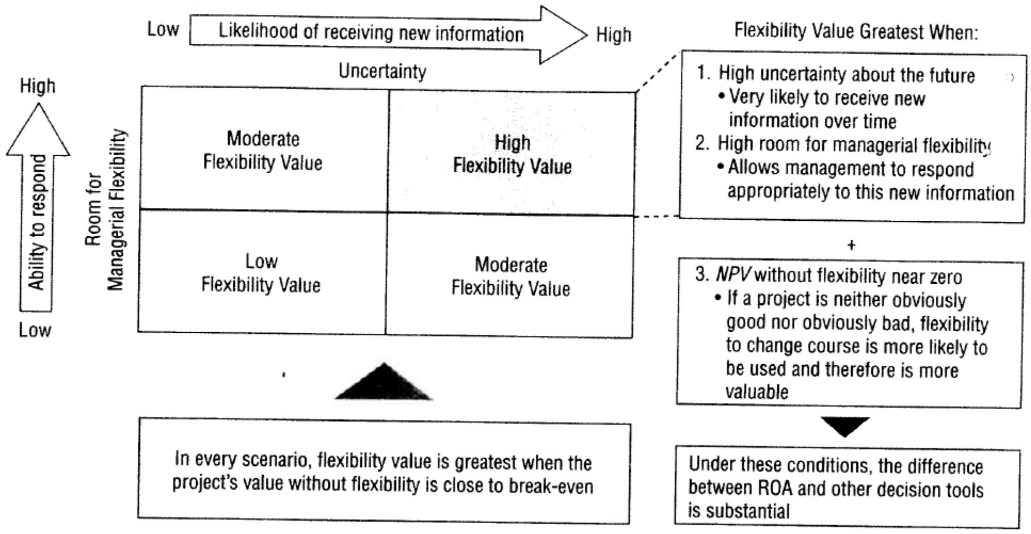


Figure 2.3: The value of managerial flexibility

and on management-level. It influences the capital budgeting decision of one specific project, but also encompasses strategic value. The relationship between on the one hand Real-Options value on project-level and management-level and on the other hand flexibility and strategic Real-Options is depicted in figure 2.4.

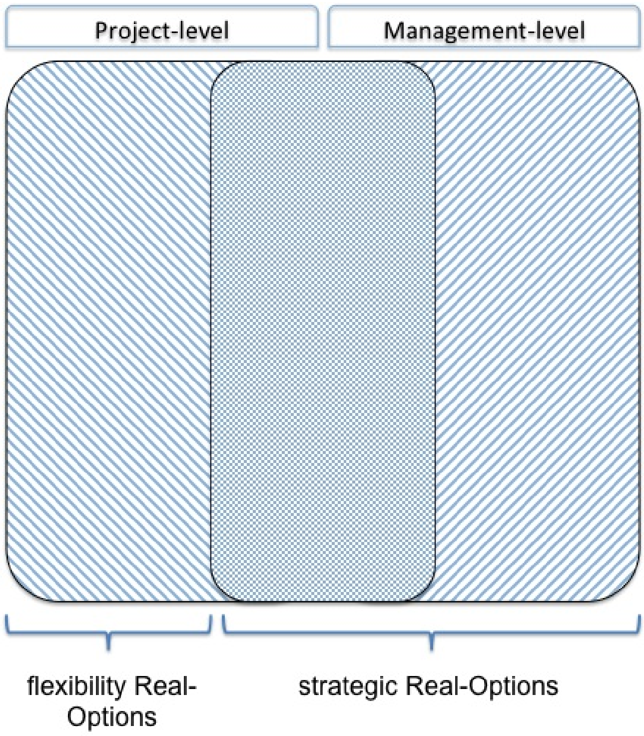


Figure 2.4: Sketch of the relationship between flexibility and strategic Real-Options on project-level and management-level

On management-level, we adapt to the classification of functions of Borison and Triantis (2001):

1 *Real-Options as a way of thinking*, i.e. framing strategic decisions qualitatively.

2 *Real-Options as an analytical tool*, i.e. valuing strategic investment decisions.

3 *Real-Options as an organisational change process*, which includes both the previous two functions. This function is used by management to identify and exploit strategic Real-Options. This function fits seamlessly with Myers' (1984) view, who stated that Real-Options can close the gap between strategic and financial analyses.

Borison and Triantis (2001) conclude that Real-Options are mainly used by companies engaged in either the energy sector or life sciences. These industries are being characterised by large investments and companies in these industries usually have experience with the use of sophisticated analytical tools. Block (2007) performed a research to Fortune 1,000 companies that are using Real-Options. Out of 279 respondents, 40 announced to use Real-Options theory. A chi-square independence of classification test rejected the null hypothesis that there was no relationship between the type of industry and the use of Real-Options. The distribution of their research is depicted in table 2.2. Block (2007) also identified for which kinds of investment decisions Real-Options were being used, his results are depicted in table 2.3. Remarkably, all types of applications of Real-Options out of Block's (2007) research can be classified as strategic Real-Options, thus Real-Options on management-level.

	Number of participants	Using Real-Options
Beverages	3	0
Energy	25	11
Finance	31	2
Food processing	9	0
Health care	26	4
Manufacturing	57	3
Publishing	5	0
Retail	44	0
Technology	36	13
Transportation	12	1
Wholesale	9	0
Utilities	22	6
Total	279	40

Table 2.2: Real-Options usage by industry

Types of applications	used by (%)
New product introduction	36.2 %
Research & Development	27.8 %
Mergers or acquisitions	22.1 %
Foreign investment	9.6 %
Other	4.3 %
Total	100 %

Table 2.3: Types of applications of Real-Options

Real-Options on management-level are thus related to strategic Real-Options and could be important in three different ways for a company's management. These strategic Real-Options seem to be more important for managers active in certain industries and for managers facing particular investment decisions, as table 2.2 and table 2.3 showed. Furthermore, the value inherent to strategic Real-Options, instead of the value inherent to flexibility Real-Options, seems (mostly) to be the reason to use Real-Options theory.

2.3.2 (Possible) functions to improve the enterprise DCF model

It is this research's goal to incorporate the value inherent to managerial flexibility correctly in the enterprise DCF model. We have seen thus far that a company's PVGO encompasses its strategic Real-Options and that a company's strategic Real-Options can be found on project-level and on management-level. Furthermore, incorporation of strategic value seems to be the main reason to use Real-Options theory. However, there is still no consensus about how such strategic value could be incorporated.

In section 2.1.6, we described the most important valuation methods for valuing Real-Options. The disadvantage of those methods is that they are in particular suited for valuing one specific kind of Real-Option and not for valuing all strategic value a company possesses. We will therefore discuss a broader overview of possibilities to improve the enterprise DCF model with the use of Real-Options theory.

According to Amram and Kulatilaka (1999), the biggest flaw in a DCF analysis is that it forecasts sales, profits and a company's terminal value as seemingly precise numbers, which impose a fixed path on a business' future development. However, this fixed path view is artificial. "The Real-Options approach recognises this uncertainty. It sees what managers see: that an investment today creates opportunities, or options, to change operating and investment decisions later depending on the actual outcome. Those future decisions will be contingent on the way events unfold". In another article of Amram, Amram and Kulatilaka (2000) emphasise that Real-Options can function as solution to value high-growth, negative cash flow generating companies. These companies possess opportunities that are the key to value creation, but are far from generating positive cash flow. "In the absence of positive cash flow, traditional tools don't work well".

In practice, scenario analysis (which is a form of decision analysis) is often executed by practitioners to cope with uncertainty. Scenario analysis used for company valuation can be distinguished as follows:

- Cash flow scenarios related to foreseen future investments.
- Cash flow scenarios related to investments currently undertaken, related to possible future investments, or related to both the previous two, where a company positions itself to possibly profit from the way future events unfold.

In case of foreseen investments, scenario analysis is a good valuation tool as the investment decision is already made. In the other case, scenario analysis is used to value strategic Real-Options, where basically management is sorting and nurturing its growth options to profit from future developments. For valuing Real-Options, Real-Options theory instead of scenario analysis should be applied. Decision analysis can be used to provide subjective estimates for the distribution of the underlying asset's value, which is still different from scenario analysis.

Together with the insights gained in the previous sections of this chapter, we decided to consider the following functions for Real-Options theory in a company valuation:

- *Capturing (strategic/corporate) growth value*, i.e. valuing the value inherent to all a company's strategic Real-Options. Useful in particular to value high-growth, negative cash flow generating companies.
    - *Forecast valuation parameters*, e.g. forecasts of outcomes for sales, profits, terminal value, etc. (Amram & Kulatilaka, 1999)

In capturing strategic value, we will assess whether the static PV model or the future assets in place (PV) model is better suited. Determining forecast valuation parameters is a special case of capturing corporate growth value. The valuation parameters used in the enterprise DCF model will be evaluated in the next chapter. Further operationalisation of these functions will be done in chapter 4.

Another possible function of Real-Options theory is supporting acquiring firms in determining the value they can create from synergies. This function is stated below for completeness. We will not further analyse this function in the remainder of this research, as synergy value differs per firm and is only applicable in case of M&A activities.

- *Capturing synergy value*, e.g. growth, flexibility and divesture options created by acquisitions (Smith & Triantis, 1995)

2.4 Conclusions

The objective of this chapter was to get an insight in which functions of Real-Options theory could be used to improve the valuation of companies, by giving a comprehensive insight in the Real-Options literature, with special attention to Real-Options' functions and their quantification methods.

Section 2.1 discussed the basics of Real-Options theory. Out of all of the contributors to Real-Options theory, we picked the most important one to narrow our literature research. Amram and Kulatilaka (2000) provided this research's definition of Real-Options, which reflects Real-Options' development:

> *"Viewed narrowly, the Real-Options approach is the extension of financial option-pricing models to the valuation of options on real (that is, non-financial) assets. More broadly, the Real-Options approach is a way of thinking that helps managers formulate their strategic options, the future opportunities that are created by todays investments".*

This definition differs from the first definition of Real-Options from Myers (1977) on two important points. First, it emphasises that Real-Options theory could be used to value strategic options and second, it lets go of the requisite to use financial option-pricing methods to value Real- Options.

To understand the possible functions of Real-Options, we explained the value drivers and gave a broad overview of the types of Real-Options. The value drivers of Real-Options could be captured with the same six key variables as for financial options. In contradiction to financial options, determination of these variables for Real-Options is not straightforward. With the exemption of the risk free rate of interest, determination of these variables could become very complex. Practitioners will need to develop a good sense of intuition to understand where modelling simplifications are allowed. Furthermore, we categorised all Real-Options as either flexibility (i.e. non-strategic) or strategic Real-Options. Real-Options literature generally means flexibility Real-Options when it mentions Real-Options, however, valuing strategic Real-Options seems to be the main reason for using Real-Options theory for companies.

In section 2.1.5, we discussed that Real-Options value is influenced by both market and private risks. Option-pricing methods can be used to value market risks, however decision analysis is probably better suited to value private risks. The MADD approach can be used to unify and value both risk types, but requires some strong assumptions.

In section 2.1.6, we gave an overview of the mostly used quantification methods, which are:

1. *Binomial (or trinomial) lattices*
2. *Risk-adjusted decision trees*
3. *Monte Carlo simulation*

Section 2.2 discussed how Real-Options theory as add-on component can be used in general to a company valuation. We argued in favour of this approach, as a stand-alone Real-Options approach does in fact not value options, but values regular flexibility value. We concluded that a company's value can be decomposed in either a static present value component and the PVGO or in the present value of a company's future assets in place and the strategic Real-Options value. Where the static PV is the value of a company under a no-growth policy, the PVGO is all value derived from (possible) future growth, the present value derived from the future assets in place is the future value derived from a company's current plus future assets and the strategic Real-Options value comprises strategic value, which include all value inherent to a company's strategic opportunities. See equation 2.12 below:

$$Company\,Value = static\,PV + PVGO = Future\,assets\,in\,place\,(PV) + strategic\,Real\,Options\,Value \tag{2.12}$$

Section 2.3 discussed the current functions of Real-Options, where we distinguished Real-Options' functions on two levels:

1 *Project-level*

2 *Management-level*

The functions of Real-Options we identified that are interesting for the general valuation process are:

- *Capturing (strategic/corporate) growth value*
    - *Forecast valuation parameters*

Another function that might be interesting for acquiring firms is:

- *Capturing synergy value*

The next chapter will elaborate on the enterprise DCF model. It is important to this research to understand a general enterprise DCF valuation, a static present value valuation, a valuation of a company's future assets in place (PV) and the exact difference between these. Furthermore, it is important to understand the composition and effectivity of the input parameters, regarding a company valuation. The conclusions that will be drawn in the next chapter, together with the conclusions drawn in this section, will serve as guidance for chapters 4 and 5.

Chapter 3

The enterprise DCF model

The objective of this chapter is to develop an in-depth understanding of DCF valuation processes for companies. The first section of this chapter will explain the general enterprise DCF model and its process. The second section will evaluate all relevant input parameters of the model. The third and the second-to-last section will analyse the "static PV" and the "future present value of the assets in place". These could be important inputs for our Real-Options model, therefore differences between a static PV, the present value of the future assets in place and the value derived from the enterprise DCF model needs to be clear.

3.1 General enterprise DCF model

Koller et al. (2010) state that the enterprise DCF model is the most accurate and flexible method for valuing projects, divisions and companies. However, they add that any analysis is only as accurate as the forecasts it relies on. The enterprise DCF model specifically discounts free cash flow (FCF), meaning the cash flow available to all investors – equity holders, debt holders, and any other non-equity investors – at the weighted average cost of capital (WACC), meaning the blended cost for all investor capital. For determining equity value, the claims on cash flow of debt holders and other non-equity investors must be subtracted from the enterprise value.

According to Koller et al. (2010), the valuation of a company's common equity by the enterprise DCF model can be divided in the following two steps. First, to determine company value, the following steps must be completed:

1.1. Value the company's operations by discounting free cash flow at the weighted average cost of capital.

1.2. Identify and value non-operating assets, such as excess marketable securities, non-consolidated subsidiaries, and other equity investments. Summing the value of operations and non-operating assets gives enterprise value.

Second, to derive at the company's common equity value, the following additional steps must be completed as well:

2.1. Identify and value all debt and other non-equity claims against the enterprise value. Debt and other non-equity claims include (among others) fixed-rate and floating-rate debt, unfunded pension liabilities, employee options, and preferred stock.

2.2. Subtract the value of non-equity financial claims from enterprise value to determine the value of common equity. To estimate price per share, divide equity value by the number of current shares outstanding.

Step 1.1. is most interesting for the purpose of this research as estimating/modelling future cash flows is of essential importance to this step. The information needed to complete step 1.2. can probably be withdrawn from a company's balance sheet or from the financial markets. When this is not sufficient, a same kind of analysis as step 1.1 is needed, for example to value subsidiaries or investments. Steps 2.1. and 2.2. can be completed without further modelling, a thorough study of the company's balance sheet items will be sufficient.

3.2 Input parameters

Using the definition of the enterprise DCF model, we recognise two important input parameters. The enterprise DCF model discounts *free cash flows*, by Koller et al. (2010) also called the enterprise DCF model's measure. This model discounts those free cash flows at the *weighted average cost of capital*. Equation 3.1 depicts this in a formula, where n is the company's lifetime, which could go to infinity.

$$PV = \sum_{i=1}^{n} \frac{FCF_n}{(1+WACC)^n} \tag{3.1}$$

$$PV = \underbrace{\frac{FCF_1}{1+WACC} + \frac{FCF_2}{(1+WACC)^2} + ... + \frac{FCF_T}{(1+WACC)^T}}_{PV(free\,cash\,flow)} + \underbrace{\frac{PV_T}{(1+WACC)^T}}_{PV(terminal\,value)} \tag{3.2}$$

Equation 3.1 can be decomposed in equation 3.2, which is the usual way to value a company according to the enterprise DCF model. Where the value of a business is computed as the discounted value of the free cash flows up to a valuation horizon (T), plus the forecasted value of the business at the horizon, also discounted back to the present value (Brealey et al., 2011), which we will call *the terminal value*. The advantage of using a terminal value is that you do not have to forecast free cash flows to infinity. After a certain valuation horizon, one assumes that the business will grow steadily with a growth factor g. The present value of free cash flows after the valuation horizon could then easily be captured, because as n goes to infinity, the terminal value function converges to a finite sum.

The disadvantage of using and including a terminal value calculated with the perpetuity growth formula is that the choice of a certain forecast horizon could affect enterprise value if it is associated with changes in the economic assumptions underlying the terminal value estimate (Koller et al., 2010). To prevent this from happening, an appropriate length of the explicit forecast period should be chosen. Because terminal value approaches cannot easily account for declining margins, the business must be operating at an equilibrium level at the end of the explicit forecast period. Despite this guideline, Brealey et al. (2011) state that in practice the forecast horizon is often chosen arbitrarily.

Therefore, the process related to step 1.1. is the most important to this research, which consists of determining thee important variables. Hence, we conclude to evaluate the following three variables in the next sections:

- *Discount rate*
- *Free cash flows*
- *Terminal value*

3.2.1 Discount rate

Future cash flows are discounted because of the rationale that a dollar possessed today is worth more than a dollar possessed tomorrow. There are two main reasons for this. First, a dollar today can be invested at the risk free rate of interest (e.g. Treasury bills), which will earn a return. Second, inflation diminishes the buying power of future money. The enterprise DCF model discounts future free cash flows at the weighted average cost of capital. The weighted average cost of capital is literally the weighted average cost of capital, see equation 3.3, where $V = E + D$, which is the firm's total market value, consisting of the firm's equity plus debt, r_e is the firm's cost of equity, r_d is the firm's cost of debt and T_c is the firm's average corporate tax rate. Because interest is a tax-deductible expense for most companies, we are interested in the after-tax cost of debt.

$$WACC = \frac{E}{V} r_e + \frac{D}{V} r_d (1 - T_c) \tag{3.3}$$

Note that the WACC is not the same as the company's opportunity cost of capital or hurdle rate. The opportunity cost of capital and hurdle rate have the same meaning and are a measure of the opportunity lost. When evaluating an investment, it is the return offered by equivalent investment alternatives (Brealey et al., 2011).

The rationale to discount a firm's free cash flows at the WACC is that the company's cost of capital is seen as the best estimator for the company's overall risk. Investors require a return to the extent of the risk they take, so for more risky investments they will require more return. Therefore, investors will only invest in companies or lend to companies if these companies compensate them the "right amount" for the risk they take. Whereby the "right amount" is directly related to the risk perceived by investors/the financial markets. So, discounting at a company's WACC does not only just adjust future free cash flows for the time value of money, but also for the risk associated to those cash flows. The WACC is thus basically a company's risk measure.

To determine a company's WACC, one needs to establish the company's cost of equity, r_e. Also the cost of debt, r_d and the corporate tax rate, T_c must be acquired. Furthermore, one needs to know the long-term capital structure the company targets. Thus, the firm's targeted debt to equity ratio (D/E).

Cost of equity

The enterprise DCF model does not specifically describe how the cost of equity should be determined. In practice, this is done with the capital asset pricing model (CAPM), which is by far the most popular method of estimating the cost of equity (Graham & Harvey, 2001). Another popular method is the Fama-French three-factor model, which is based on arbitrage pricing theory (APT).

CAPM assumes that in a competitive market, the expected risk premium varies in direct proportion to a company's beta. Beta provides a measure of how a company's stock responds to changes in the market. The market represent the undiversifiable risk, this is common to all stocks and therefore the stock's beta reflects the riskiness of the stock relative to the market. For example, a beta of 1 means that the returns on the stock vary identically with the market returns and a beta of 2 means that the return on a stock is expected to be twice the expected risk premium on the market. The CAPM relationship can be written as equation 3.4, from which we can derive the cost of equity. The difference between r_m (i.e. the expected market return) and r_f is called the market risk premium, both factors are common to all companies on a specific moment. Beta is mathematically defined as equation 3.5, which is the covariance between the return of a stock i and the market return (σ_{im}), divided by the variance of the market return (σ_m^2).

$$r_e - r_f = \beta(r_m - r_f) \tag{3.4}$$

$$\beta = \frac{\sigma_{im}}{\sigma_m^2} \tag{3.5}$$

A company's beta is usually based on a stock's historical return over the past 60 months. There are however two issues with establishing the beta. First, there is always a large margin for error when estimating the beta for individual stocks (Brealey et al., 2011). Second, the beta used to determine the company's cost of equity to calculate a company's WACC, should be adjusted for the company's target debt ratio. By using a industry beta, which is an average of betas of stocks in the same industry, the error related to beta declines with the square root of the number of betas. Adjusting the beta to a company's targeted debt to equity ratio is an important additional step, which is not complex. This works as follows:

1. *Unlever beta*
   The beta of a company's stock, as derived from the financial markets, is also named the equity beta or the levered beta of a company. The beta related to all the assets of the firm is called the firm's asset beta or unlevered beta. The asset beta is equal to the weighted average of the debt and equity beta and measures the stock's volatility, as if it had no debt. Unlevering the beta is the process of deriving the company's asset beta (unlevered beta) from the company's equity beta (levered beta). The formal equation to unlever the equity beta is depicted below in equation 3.6.

$$\beta_A = \beta_D \frac{D}{V} + \beta_E \frac{E}{V} \tag{3.6}$$

2. *Relever beta*
   Relevering the beta is adjusting the firm's equity beta for its targeted capital structure. The asset beta derived at step 1, together with the targeted debt to equity ratio now serve as inputs. The formal equation to relever the equity beta is depicted below in equation 3.7.

$$\beta_E = \beta_A + (\beta_A - \beta_D) \frac{D}{E} \tag{3.7}$$

In practice, β_D is mostly ignored. As debt claims have first priority, β_D is close to zero and because it is so small compared to β_E, β_D is often assumed to be 0 (Koller et al., 2010).

Therefore, equation 3.6 and 3.7 could be written respectively as equation 3.8 and 3.9.

$$\beta_A = \beta_E \frac{E}{V} \tag{3.8}$$

$$\beta_E = \beta_A \frac{V}{E} \tag{3.9}$$

To finalise the calculation of the cost of equity with the CAPM, we need an estimate for the market premium. Subsequently, we can determine a company's WACC with equation 3.3[1]. Koller et al. (2010) explain three general models with respect to valuing the market premium, of which none has gained universal acceptance. They conclude that generally the market risk premium varies continually between 4.5 and 5.5 percent.

CAPM assumes that one single factor, the market beta, completely captures the cross-sectional variation of expected excess returns. However, it oversimplifies the complexity of market behaviour. Fama and French (1995) found two classes of stocks outperforming the market portfolio, namely the small caps (i.e. stocks with small market capitalisation) and the value stocks (i.e. stocks with high book-to-market ratio). Therefore, they added the size factor (SMB) and the value factor (HML) to the CAPM regression. Their equation for a stock's return on equity is stated below:

$$r_e = r_f + \beta_{market}(r_m - r_f) + \beta_{size} SMB + \beta_{value} HML$$

The Fama-French three-factor model assumes that the betas (market, size and value) completely capture the cross-section variation of expected excess returns. The Fama-French three-factor model is a specific example of applied Arbitrage Pricing Theory (APT). APT assumes that each stock's return depends partly on pervasive macroeconomic factors and partly on noise. Thereby, the return is assumed to obey the following relationship:

$$r_e = \alpha + \beta_1(r_{factor1}) + \beta_2(r_{factor2}) + \beta_3(r_{factor3}) + ... + \epsilon$$

APT does however not specify the factors. Despite the CAPM may not the best model for estimating the cost of equity (Fama & French, 1992), it is still the most applied model, as stated before. To understand its simplifications, we have shown the most applied other possibilities to determine the cost of equity (Koller et al., 2010). We will end this section with an enumeration of the CAPM assumptions:

[1]In practice, additional risk premiums on top of the return on equity are often seen, e.g. a small firm premium for small firms. This is however out of the scope of this research.

- The expected return on a stock is a positive linear function of a stock's beta.
- The existence of a "real" risk free rate of interest. In theory, U.S. Treasury bills will approach such a rate, but they do not guarantee a return.
- Investors can borrow money at the same rate as they lend.

Cost of debt and tax

The cost of debt is the long-term debt rate of company. It is the rate related to the target debt to equity ratio of the company. When a company's debt ratio increases, the risk to creditors increases. Therefore, they will demand a higher return on debt (which increases the cost of debt for the company). The cost of debt can mostly be reasonably estimated, Koller et al. (2010) give the following possibilities to estimate the cost of debt:

- The yield to maturity of the company's long-term, option-free bonds (in case the company has a credit rating of at least BBB).
- In case the company has only issued short-term bonds or bonds that rarely trade, determine the company's credit rating on unsecured long-term debt. Then estimate the cost of debt by averaging the yield to maturity on a portfolio of long-term bonds with the same credit rating.
- If the company has a credit rating below BBB, the difference between the promised return of a bond and the expected return of a bond is becoming important. The cost of (high-yield) debt could in this case be estimated with CAPM. CAPM is actually a general pricing model, applicable to any security.

The tax rate is the applicable corporate tax rate to the company, which can mostly be assumed to be equal to the current corporate tax rate. The amount of corporate tax payable influences the cost of debt of a company, because the interest that a company pays is a tax-deductible expense. By financing itself partly with debt, a company creates a so-called tax shield. Tax shields are valuable assets, which are probably less risky than a company's operating assets. Tax shields depend only on the corporate tax rate and on the ability of the company to earn enough to cover its interest payments. Therefore, it is commonly assumed that risk of the shields is equal to interest payments generating them. According to Brealey et al. (2011), the theoretical value of tax shields is equal to:

$$PV(tax\,shields) = \frac{T_c(r_D D)}{r_D} = T_c D$$

In practice, the value of tax shields can be less if the firm does not have enough taxable income to use the interest tax shields.

Debt to equity ratio

As we saw in the previous paragraph, a company has an incentive to fund itself with debt. Because tax shields decrease the amount of corporate tax payable, the debt to equity ratio is important for a company's value. According to Modigliani and Miller (1958), a company should take on as much debt as possible, to fully utilise the value inherent to tax shields. However this may not be rational, the value of the firm certainly depends on its capital structure. In order to determine a firm's value, one should know the firm's targeted future debt to equity ratio. The trade-off theory and the pecking-order theory are the most influential theories about a company's debt to equity ratio.

The trade-off theory of capital structure assumes that a firm's optimal capital structure is determined by a trade-off between the costs and benefits of debt. The benefits are valued by the present value of the company's tax shields and the costs of debt are valued by the present value of the company's costs of financial distress. The optimal debt to equity ratio is reached when the present value of tax savings due to to further borrowing is just offset by increases in the present value of costs of distress.

Under the trade-off theory, the optimal debt to equity ratio can be different for each firm. Companies with safe, tangible assets and plenty of taxable income to shield ought to have high target ratios. Unprofitable companies with risky, intangible assets ought to rely primarily on equity financing. Despite its logic, the trade-off theory is not always successful in predicting and explaining a company's capital structure (Brealey et al., 2011).

The pecking-order theory assumes that the first choice of financing for a firm is internal funds, the second choice is issuing new debt and the last choice is issuing new equity. This theory is based on the influence of asymmetric information. Managers know more about their companies' prospects, risks and values than outside investors. Furthermore, asymmetric information favours the issue of debt over equity as the issue of debt signals the boards' confidence in the firm and that the current stock price is undervalued. Therefore, the cost of financing increases with asymmetric information. The attraction of interest tax shields is assumed to be second-order (Brealey et al., 2011). The pecking-order theory has no well-defined target debt to equity ratio.

The targeted debt to equity ratio as established by management will be the input for the calculation of a firm's WACC. Management can base their targeted debt to equity ratio on several theories, however in practice actual debt to equity ratios could often not be explained with those theories.

3.2.2 Free cash flows

Free cash flow is the amount of cash that the firm can pay out to investors after making all investments necessary for growth (Brealey et al., 2011) and is calculated as equation 3.10, where $Profit\,after\,tax$ is calculated before interest expenses.

$$FCF = Profit\,after\,tax + depreciation - investment\,in\,fixed\,assets - \Delta working\,capital \tag{3.10}$$

Equation 3.10 is a simplified formula, based on a correct rationale. A more detailed formula, based on the same rationale, is given by Koller et al. (2010). They define free cash flow specifically as the cash flow generated by the core operations of the business after deducting investments in new capital and is calculated by equation 3.11. In equation 3.11, net operating profit less adjusted taxes (NOPLAT) represents the total after-tax operating income generated by the company's invested capital, available to all financial investors.

$$FCF = NOPLAT + Noncash\,operating\,expenses - Investments\,in\,Invested\,Capital \tag{3.11}$$

In more detail, NOPLAT can be calculated by equation 3.12, non-cash operating expenses include amongst others depreciation and non-cash employee compensation. Investments in invested capital can be calculated by adding the following items:

1. Change in working capital
2. Net capital expenditures
3. Change in operating leases
4. Investments in goodwill and acquired intangibles
5. Change in other long-term operating assets

$$NOPLAT = EBITA - adjustments\,to\,EBITA - Operating\,cash\,taxes \tag{3.12}$$

Earnings before interest, taxes and amortisation of acquired intangibles (EBITA) equals turnover less operating expenses (operating expenses include for example cost of goods sold, selling costs, general and administrative costs and depreciation). Adjustments should be made for any non-operating gains and expenses that are sometimes embedded within EBITA (e.g. non-operating gains or losses related to pensions, embedded interest expenses from operating leases, restructuring charges). After subtracting operating cash taxes (i.e. tax expenses adjusted to an all-equity, operating level), NOPLAT is calculated. For the calculation of FCF, non-cash operating expenses are added. To maintain and grow their operations, companies must reinvest a portion of their gross cash flow back into the business. These investments are segmented into the five primary areas listed above.

The definition of Koller et al. (2010) of FCF is more detailed and is better suited for valuation purposes as it focuses on the company's core operations and removes non-operating items. However, for the understanding of free cash flow, the definition of Brealey et al. (2011) is better suited as it can be aligned easier with a company's financial statements. Most of the components in equation 3.10 can be directly withdrawn from a company's accounts. As we are not going to calculate FCF in this chapter, the remainder of this chapter will use the definition of Brealey et al. (2011).

In practice, the free cash flow of the latest year can be derived from the company's financial statements. In order to forecast future free cash flow, assumptions must be made about the sales growth of the company and about some of the components in equation 3.10. The necessary assumptions are described below:

- *Sales growth.* In a forecast it is common practice to start the with the projection of sales. Forecasts of growth percentages over the coming years become more difficult for each next year. Normally, growth percentages for the first T years are estimated per year and can thus deviate from each other. After T years, a certain long-term growth percentage is mostly assumed.
- *Cost of sales.* This includes all operational expenses. The (direct) cost of sales are mostly assumed to behave as a linear function of a company's sales.
- *Investment in fixed assets.* Unless the company has a surplus capacity, fixed assets are mostly assumed to grow along with sales.
- *Investment in working capital.* Working capital is mostly assumed to behave as a linear function of a company's sales as well. By making yearly estimates, seasonal influences are excluded.

The following components can be derived from the earlier made assumptions:

- *Depreciation.* Depreciation is assumed to be a fixed percentage of the net fixed assets. Therefore, the amount of depreciation is a direct consequence of the assumption made about the development of the investment in fixed assets.
- *Profit after tax.* In a simplified financial statement, the only items influencing a company's profit after tax are sales, cost of sales, depreciation and tax. Profit after tax is then easy to determine.

If all the components of equation 3.10 are known, the amount of free cash flow of a company is easy to determine. It appears that just three of these components are crucial in order to determine the amount of free cash flow in a simplified situation. These thee components are all dependent on future sales, where it is mostly assumed that they behave as linear function of sales. When the value of a component i is denoted as y_i, and sales are denoted as x, these relationships can be described as follows:

$$y_i = a_i x + b_i; \; for \, i = 1, ..., 3$$

Hence, to estimate free cash flows, one needs to estimate a company's sales growth, and the factors a_i and b_i for each of the three components i. This is of course under the assumption that we now possess all information to calculate profit after tax and that cost of sales, investment in fixed assets and investment in working capital behave as a linear function of a company's cost of sales. It is however not unthinkable that for example the investment in fixed assets is better described with a jump process.

3.2.3 Terminal value

The terminal value is described in equation 3.2 as the present value at time T of a company's future free cash flows, PV_T, discounted back to the present at the company's WACC. Where PV_T is described by equation 3.13.

$$PV_T = \frac{FCF_{T+1}}{1+WACC} + \frac{FCF_{T+1}(1+g)}{(1+WACC)^2} + \frac{FCF_{T+1}(1+g)^2}{(1+WACC)^3} + ... + \frac{FCF_{T+1}(1+g)^{\infty-1}}{(1+WACC)^{\infty}} \tag{3.13}$$

When we assume one long-term growth rate g, PV_T is an infinite geometric series, which equals $\frac{FCF_1}{WACC-g}$[2]. Discounting this back to the present will deliver the terminal value. This method is based on the perpetuity growth formula. By determining the terminal value with this method, it appears that the terminal value can change drastically in response to minor changes in assumptions (Brealey et al., 2011). Furthermore, assuming a long-term growth factor means that the amount of free cash flow is assumed to grow forever. This assumption is very hard to make, as economic theory suggest that every market will eventually settle in a long-term equilibrium, where a growth factor g is equal to zero. Koller et al. (2010) underwrite this line of thinking, "the best estimate for the growth rate is probably the expected long-term rate of consumption growth for the industry's products, plus inflation".

Another method to determine the terminal value – which is often used as a reality check – is based on a multiple approach. Two frequently used multiple approaches are (Brealey et al., 2011):

- *Terminal value based on P/E ratio.* Pick the P/E ratio of a business whose scale, risk and growth prospects today roughly match those projected for your company in year T. Then the forecasted earnings of your company in that year, times this P/E ratio, discounted back to the present, is a reasonable guess for your company's terminal value.
- *Terminal value based on market-book ratio.* Pick the market-book ratio of a sample of businesses whose scale, risk and growth prospects today roughly match those projected for your company in year T. Then the forecasted book ratio of your company in that year, times this market-book ratio, discounted back to the present, is a reasonable guess for your company's terminal value.

In practice, the DCF growth formula is used to determine a company's terminal value in the enterprise DCF model. Approaches based on multiples could provide a further reality check. However, it appears that the terminal value can represent a large amount of total company value and that a small change in the assumptions can have a huge influence on the terminal value.

3.3 Static PV

3.3.1 Definition

We earlier defined the static PV as the value of a company under a no-growth policy. This means that the growth factor g, which reflects the growth of the future free cash flows is equal to zero. A zero growth rate implies furthermore that there is zero inflation. The value of such a static PV can be expressed as equation 3.14, where FCF is the normalised free cash flow:

$$Static\,PV = \frac{FCF}{WACC} \tag{3.14}$$

To establish a company's static PV, we therefore have to establish two input parameters:

- The discount rate, for which we should use the WACC
- The amount of free cash flows

[2] Koller et al. (2010) argue in favour for their value driver formula instead of the growing FCF perpetuity formula. "Although the value driver formula and the growing FCF perpetuity formula are technically equivalent, applying the FCF perpetuity is tricky, and it is easy to make a common conceptual error". If growth in the terminal value period is forecasted to be less than the growth in the explicit period, then the proportion of NOPLAT that must be invested to generate growth also is likely to be less. The value driver formula, $\frac{NOPLAT_{t+1}(1-\frac{g}{RONIC})}{WACC-g}$, takes this explicitly into account. In this formula g represents the growth in $NOPLAT$ and $RONIC$ represents the return on new invested capital.

The discount rate, the WACC can be established in the same way as for the enterprise DCF model. Therefore, we are only concerned with how to determine the amount of free cash flows in a static present value analysis.

3.3.2 Free Cash Flow

As we already know how to determine a company's WACC, we should only normalise a company's FCF. A normalisation of a company's FCF means that we adjust the FCF for unusual influences. Normalisation of a company's sales and costs is quite common under practitioners. The static PV should also be adjusted for investments in (and the depreciation related to) all flexibility and strategic Real-Options. Investments related to all usual operations of a company should be included in this normalised FCF (e.g. investments in replacements of key assets).

3.3.3 Static PV model

The static PV model is described in section 2.2 and assumes that a company's value can be found by adding a company's PVGO to its static PV, see equation 2.12. The PVGO includes all value derived from possible future growth. After normalising a company's FCF for the static PV model and determining a company's WACC, the static PV can be calculated easily. In section 4, we will evaluate if a company's PVGO could be calculated properly.

$$Company\,Value = static\,PV + PVGO \tag{2.12}$$

Unfortunately, this model cannot cope with negative growth. The model assumes that a company will at least be able to secure its current amount of FCF forever. There are of course plenty of companies active in a decreasing market. Furthermore, we know from basic economic theory that many markets will eventually saturate or even decline. The static PV component in the model is therefore perhaps too "static" and should allow for some flexibility.

3.4 Future assets in place (PV)

3.4.1 Definition

We earlier defined the present value of a company's future assets in place as the value derived from a company's current plus future assets. All variances with respect to the current operations should be taken into account. This includes also all flexibility Real-Options on a company's current assets. Furthermore, the assets in place (PV) excludes all value inherent to strategic opportunities. All variances with respect to the current operations should be taken into account. This includes also all flexibility Real-Options on a company's current assets. Furthermore, the future assets in place (PV) excludes all value inherent to strategic opportunities. Note that all flexibility Real-Options a company possesses are always related to a company's current or future assets in place. When the company executes strategic Real-Options, it acquires also new flexibility Real-Options that are specifically related to the new project.

The present value of a company's future assets in place can be valued by the same formulas as the formulas used for the enterprise DCF model, see equations 3.1 and 3.2. Furthermore, the WACC can be determined in the same way as for the enterprise DCF model, but the amount of FCF should be established different. The amount of free cash flow taken into account in the present value of a company's future assets in place should be adjusted for flexibility related to non-operational activities. This will also have an effect on the terminal value. To understand which type of flexibility the future assets in place (PV) should allow for, the following section provides an analysis to the causes of the types of flexibilities that should be included.

Flexibility in the future assets in place (PV) component

The variance and deviations in a company's FCF in the future assets in place (PV) component could be caused by:

- *Efficiency.* It is mostly assumed that a company's growth is related to the investments they make. Changes in a company's amount of FCF could however also be caused by operating in a more efficient way, which will be a continuous goal for operating managers.
- *Growth from flexibility Real-Options.* The expansion of activities within a project, which do not initiate new projects. The value from these options is directly related to a company's future assets in place.
- *Growth from planned future investments.* To the contrary of replacement investments, investments in new assets are related to growth. Planned investments are no type of option, but can drastically change a company's FCF. Sometimes the future FCF that is created by these planned investments is so uncertain that cash flow scenarios are used to come to a reasonable estimation. Creating, nurturing or executing strategic Real-Options for possible future investments is not incorporated.
- *Market.* Changes in market size can also affect the amount of FCF of a company. Consumption growth for the industry's products should be incorporated. Strategic opportunities in upcoming markets are however excluded.
- *Random operational variability.* This is the basis for the value of managerial flexibility. Many factors important to a company can change (e.g. prices of inputs or the selling prices). The direction of change can sometimes be predicted, however the exact outcome not. By managing these deviations, the effect of change on a company's free cash flow could be limited.

Changes with respect to the efficiency of utilising current assets, which are expected to occur, should be incorporated in the future assets in place (PV), just like changes resulting from the execution of flexibility Real-Options. Therefore, the future assets in place (PV) incorporates the effect of managerial flexibility. Flexibility Real-Options that are related to an investment outlay (e.g. the option to expand), but do not trigger new projects, should also be incorporated. Just as the influences of market trends on the FCF should be incorporated in the future assets in place (PV). Last, random operational variability leads to possible value creation by managerial flexibility. Although this is mostly an important argument to use Real-Options valuation, we argue that random operational variability should have no effect on the future assets in place (PV), as random variability is of all times and is therefore, by use of extrapolation, already incorporated in the forecast. The forecast is namely based on historically realised figures, which already includes random operational variability.

According to Myers (1984), "a typical enterprise DCF analysis often entails good forecasts for the near future, as operating managers can often make reasonable subjective forecasts of the operating variables they are responsible for (e.g. operating costs, market growth, market share, and so forth), at least for the future that they are actually worrying about". As in fact any forecast is subject to interpretation, all forecasts are subjective. This statement of Myers (1984) therefore suggest to use a DCF analysis for forecasting the results from a company's operational activities for at least the near future. It embraces therefore the future assets in place (PV) model.

3.4.2 Free cash flow

The free cash flow of a company should be normalised for investments in strategic opportunities for the current year and for the future. The impact of flexibility Real-Options, investments that are necessary to maintain a company's current operations for the future, planned investments and growth related to future changes in market size are thus incorporated in the FCF for the future assets in place (PV).

Growth

Note that also within this model, the amount of FCF is not expected to grow very fast year by year. The drivers of growth will be related to the included flexibility in the future assets in place (PV) component, where the main driver of growth will probably be a company's planned investments. For example, a supermarket plans to grow the next five years 5% per year for which it needs to make additional investments of 4% per year in both working capital and real estate. Growth could also be realised within the present value of future assets by execution of some efficiency options that improve the operational result of a company in the long term, or by the execution of other flexibility Real-Options. Or it can vary between certain boundaries (restricted by for example production limits) due to market trends. Opportunities to expand vertically, horizontally or by gaining market share through unplanned investments are not incorporated in the FCF forecast of the future assets in place (PV).

3.4.3 Terminal value

The terminal value is the present value at time T of future free cash flows related to the future assets in place, discounted back to the present at the company's WACC. Time T is the last point in time for which we can make a reasonably good forecast of a company's FCF. As we explained in section 3.2, time T should be at that point in time for which the business is going to operate at an equilibrium level. After time T, a reasonable forecast of the development of the future assets in place (PV) and the development of the variability within the future assets in place (PV) is probably not possible. Furthermore, at some future point in time, growth in the value of the future assets in place will temper or may even turn negative, therefore the amount of FCF is not expected to show heavy growth after some time. Basically, the best estimate for the growth rate g within the future assets in place (PV) is also the expected long-term rate of consumption growth for the industry's products, plus inflation. The formula to calculate the future assets in place (PV) component is depicted in equation 3.15.

$$PV = \frac{FCF_1}{1+WACC} + \frac{FCF_2}{(1+WACC)^2} + ... + \frac{FCF_{T-1}}{(1+WACC)^{T-1}} + \frac{\frac{FCF_T}{WACC-g}}{(1+WACC)^T} \tag{3.15}$$

Equation 3.15 is a simplified model to calculate the future assets in place (PV) component and could be adjusted in case additional knowledge is present. The long-term growth rate applicable to a company's FCF, derived from market changes, is the most important assumption in this model. In case we know how a company's FCF from its (future) assets in place is related to certain market trends, we can model a company's FCF in combination with the expected long-term market changes. If this knowledge is present, the terminal value should take into account the long-term consumption growth for the industry's products, plus inflation, g, and the correlation coefficient c_i between g and the effect on a company's FCF in period i. Furthermore, it may also be the case that planned future investments or investments to cope with market growth are less profitable than current investments. Koller et al. (2010) has introduced the return on new invest capital (RONIC), this factor should then be incorporated.

3.4.4 The future assets in place (PV) model

The future assets in place (PV) model is described in section 2.2 and assumes that the value of a company could be established by adding a company's strategic Real-Options value to its future assets in place (PV), see equation 2.12. Strategic Real-Options value is therefore excluded out of the forecast of FCF up to time $T-1$ and is excluded out of the terminal value. In chapter 4, we will see however that the terminal value is interwoven with strategic Real-Options value.

$$Company\,Value = Future\,Assets\,in\,place\,(PV) + strategic\,Real\,Options\,Value \tag{2.12}$$

3.5 Conclusions

The objective of this chapter was to get an in-depth understanding of DCF valuation processes for companies. In the first section, we have analysed the enterprise DCF model, whereby we have analysed the input parameters, in which manners these could be derived and the underlying assumptions in each case. Furthermore, we have analysed and determined how a static PV and the present value of the future assets in place can be derived with a DCF analysis.

Section 3.1 discussed the four steps in the general application of the enterprise DCF model. We concluded that step 1, discounting a company's free cash flows at the weighted average cost of capital, is the most interesting to this research, as steps 2 to 4 are more a formality than subject to any discussion. A very important remark with respect to the correctness of the outcome of an enterprise DCF valuation was given by Koller et al. (2010), that any analysis is only as accurate as the forecasts it relies on.

Section 3.2 established the three main input parameters of a enterprise DCF model and discussed these subsequently. The three main input parameters are:

- *Discount rate*
- *Free cash flows*
- *Terminal value*

The appropriate discount rate of a company's FCF is its WACC. To establish the WACC, we should establish the cost of equity, the cost of debt and the target debt to equity ratio. There is however not one unambiguous way to derive these variables. Practitioners have their preferences and shortcuts to derive these variables, but these can always be subject to discussion.

Free cash flow is the amount of cash that the firm can pay out to investors after making all investments necessary for growth (Brealey et al., 2011). Free cash flow can be derived by equations 3.10 and 3.11 of respectively Brealey et al. (2011) and Koller et al. (2010). The equation of Koller et al. (2010) focuses on a company's operational activities, is more detailed and is therefore better suited for valuation purposes. However, the equation of Brealey et al. (2011) provides a better insight. Therefore the equation of Brealey et al. (2011) is used for analyses in this chapter. In this equation, there are four crucial parameters that must be forecasted up to the terminal year. The most important one is the company's sales growth. The cost of sales, investment in fixed assets and investment in working capital are often assumed to behave as a linear function of the company's sales.

To derive the terminal value, a long-term growth factor g must be estimated. The terminal value can then easily be derived. However, a small change in g can have a huge impact on such a value. As g is mostly a very rough estimate, this assumption can be subject to heavy discussion. It is therefore recommended to establish the terminal value with other methods as well. Furthermore, the assumption that the FCF will grow forever at a specific growth factor g is a very weak assumption. When a certain market matures, the industry will settle in a competitive equilibrium, where g is expected to be zero. The best estimate for the growth rate is probably the expected long-term rate of consumption growth for the industry's products, plus inflation (Koller et al., 2010).

Section 3.3 discussed how a static PV can be estimated with a DCF analysis. Only the company's WACC and last year's normalised FCF seems to be important. The static PV model assumes that all value derived from future growth is included in a company's PVGO. A disadvantage of the static PV model is that it could not cope with negative growth, the static PV component is therefore perhaps too "static". The static PV could be determined by equation 3.14.

$$Static\,PV = \frac{FCF}{WACC} \tag{3.14}$$

Section 3.4 discussed how the present value of the future assets in place could be determined. In contradiction with the static PV, the present value of the future assets in place includes planned investments and the value inherent to the variability of the company's assets. FCF needs to be forecasted to a certain point T in time and needs to be normalised for optional strategic investments. After time T, a long-term growth rate of consumption is assumed to determine the terminal value. The WACC is used to discount the free cash flows. In the future assets in place (PV) model, value derived from strategic opportunities is incorporated in strategic Real-Options value. The basic method to calculate the present value of the assets in place is depicted in equation 3.15. Adjustments to cope with a company specific relation to consumption growth and another (lower) return on new invested capital are also possible.

$$PV = \frac{FCF_1}{1 + WACC} + \frac{FCF_2}{(1 + WACC)^2} + ... + \frac{FCF_{T-1}}{(1 + WACC)^{T-1}} + \frac{\frac{FCF_T}{WACC-g}}{(1 + WACC)^T} \tag{3.15}$$

The next chapter will evaluate the possible functions of Real-Options for company valuation, whereby it uses the insights obtained in this chapter.

Chapter 4

Real-Options – Company valuation

The objective of this chapter is to determine which of the possible function(s) of Real-Options that we have established in chapter 2, should be operationalised in order to improve the valuation of companies, with respect to the assumptions and shortcomings of the enterprise DCF model we identified in chapter 3. We will start with exploring the possibilities and the need to operationalise these functions. In the second-to-last section of this chapter we will evaluate when Real-Options theory should be used from a theoretical perspective for the functions that we are going to operationalise.

In chapter 2 we identified the following possible functions of Real-Options theory that might improve the enterprise DCF model, where forecast valuation parameters is a special case of all the possibilities to capture strategic growth value:

- *Capturing (strategic/corporate) growth value*
    - *Forecast valuation parameters*

In chapter 3, we explored how to calculate a static PV and the present value of a company's future assets in place. Both models could be theoretically be used in combination with Real-Options theory to capture strategic growth value and will therefore be analysed in this chapter.

4.1 Capturing (strategic/corporate) growth value

Strategic growth value is the value derived from a company's strategic Real-Options and could be estimated either bottom-up or top-down, where:

- *Bottom-up*, i.e. from the company's assets. A company possesses various assets, which can own various types of single and compound Real-Options. Furthermore, the company itself can own corporate growth options / strategic options. Trigeorgis (1993) demonstrates that Real-Options on the same underlying asset interact with each other and are not additive. Interactions generally depend on the type, separation, degree of being "in the money" and the order of the Real-Options involved (Trigeorgis, 1993). Unfortunately, how Real-Options on different underlying assets of the same company interact and how to value all the Real-Options of one company is not described in Real-Option literature.
- *Top-down*, i.e. from the financial markets. This is of course the easiest way, however not every company is traded or has a traded "twin-security". Furthermore, this method does not create any insight in the types of Real-Options applicable and their interactions.

4.1.1 Bottom-up valuation strategic Real-Options

It is important to explore the possibility to value strategic Real-Options value bottom-up, as it indicates if the future assets in place (PV) model could be operationalised in order to improve the enterprise DCF model.

A bottom-up valuation of a company's strategic Real-Options should be possible if one can both:

- Identify all strategic Real-Options a company possesses.
- Determine their joint probability density function.

It is important to realise that this is not the same as a complete bottom-up valuation of all Real-Options a company possesses. In this section, we restrict us to to the bottom-up valuation of strategic Real-Options.

Trigeorgis (1993) shows that the interaction between Real-Options on project-level for a specific project are very important and that the value of these Real-Options is non-additive. The degree of interaction between multiple Real-options on the same underlying asset depends on:

- *The types of Real-Options*, i.e. whether the options are of the same type (e.g. two puts or two calls) or are opposites (i.e. a put and a call).
- *The times to expiration*, i.e. the separation of their exercise times (influenced by whether they are European or American options).
- *The value*, i.e. their relative degree of being "in or out of the money".
- *The order or sequence.*

In the special case that two Real-Options on the same asset are of opposite type (both European), both out of the money and have the same time to maturity, their value would be purely additive (Trigeorgis, 1993).

Strategic Real-Options are however different. First of all, strategic Real-Options of a company are not restricted to have the same underlying asset. Second, a company can only handle a limited number of new strategic activities at the same time, so it will choose its most valuable strategic Real-Options. Furthermore, capital constraints will play an important role in limiting the number of possible strategic investments of a company. Thus the execution of one strategic Real-Option, or perhaps one or a few more, "kills" the other strategic Real-Options around that moment in time.

Identification of such strategic Real-Options will be a challenge, we make a distinction between short-term strategic Real-Options and distant strategic opportunities.

Short-term strategic Real-Options

In the short term, strategic opportunities that are either recognised by management or by the market should be taken into account. We assume that all opportunities recognised by the market are known to management as well. The opportunities that the market recognises will be shared strategic Real-Options, as the market does not know in which competitive advantages specific companies are investing. When these shared Real-Options are also seen as possibly favourable opportunities by management, these Real-Options should be nurtured. Otherwise, they should not be taken into account. Strategic Real-Options solely recognised by management should be taken into account as well. These are a company's proprietary strategic Real-Options.

We assume that short-term strategic Real-Options are the opportunities that are identified by management before a certain time T, which corresponds with the time T in a DCF analysis. These Real-Options could however be executed later. Short-term strategic Real-Options will be present both on project-level and on management-level. Management should nurture these Real-Options and when they become (largely) in the money, management could decide to execute them. Assuming that valuation of these kind of compound and rainbow options can be done, these strategic Real-Options could be valued separately. Joint valuation of these Real-Options will be a challenge over and over again for each company. However, as a company has probably significant less strategic Real-Options than flexibility Real-Options, joint valuation will be easier for this purpose than for flexibility Real-Options.

Distant strategic opportunities

In the long term, that is after time T in a DCF analysis, new opportunities for a company will definitely arise. However, as these are currently unknown, we could not threat them as Real-Options. Furthermore, if we try to account for opportunities that will occur in the future, when is our list complete? If a company is active in a market that is developing fast, there will be lots of possibilities to grow faster than the long-term rate of consumption growth for the industry's products. However, there will also be plenty of risks in such markets, which can result in a lower growth than the long-term rate of consumption growth for the industry's products or even in bankruptcy.

In the long term, we assume that every company in a certain industry will probably have the same opportunities (with respect to its size), hence the same distant strategic opportunities (with respect to its size). These opportunities could not be valued with Real-Options theory, as therefore we need to know amongst others the value drivers and the investment costs related to the specific opportunity. It is therefore best to assume that the future free cash flows of a company after time T will grow with a growth rate equal to the long-term rate of consumption growth for the industry's products, plus inflation. Such a rate could be assumed to include shared distant strategic opportunities, as these affect industry size. Hence, distant strategic opportunities are already included when the long-term rate of consumption growth for the industry's products, plus inflation is used to determine a company's terminal value.

It is important to notice that our distinction between short-term strategic Real-Options and distant strategic opportunities does not give any information about the expiration date of the short-term strategic Real-Options and the time of the (incoming) cash flow streams after execution of these options. Short-term strategic Real-Options could therefore impact the FCF before and after time T.

Altogether, determining the interaction between strategic Real-Options must be possible and will not be as complex as it is for Real-Options with the same underlying asset, which can be found on project-level. The Real-Options that should be taken into account are the options that are currently considered as possible future opportunities, the short-term strategic Real-Options.

Identification of distant strategic opportunities might be possible, however these cannot be translated to Real-Options. The value of distant strategic opportunities should therefore be taken into account by using the long-term rate of consumption growth for the industry's products, plus inflation for including FCF growth after time T. We conclude that it should be possible to operationalise the valuation of strategic Real Options (i.e. short-term strategic Real-Options) by a bottom-up valuation. The expectation of the long-term rate of consumption growth for the industry's products, plus inflation should be used to take into account the value of distant strategic opportunities.

4.1.2 Bottom-up valuation PVGO

The possibility to value a company's PVGO indicates whether the static PV model can be operationalised to improve the enterprise DCF model.

A bottom-up valuation of a company's PVGO should be possible if one can both:

- Identify all flexibility and strategic Real-Options a company possesses.
- Determine their joint probability density function.

Furthermore, all other factors which can cause deviations in a company's FCF (i.e. market factors) should be incorporated in a company's PVGO.

Based on the evaluation in section 4.1.1, we conclude that bottom-up valuation of a company's PVGO is much more difficult in every aspect than a bottom-up valuation of a company's strategic Real-Options. Identification of all flexibility and strategic Real-Options and finally determining their interactions will be a very complex and time-consuming task. Furthermore, the effect of both market trends and flexibility Real-Options on a specific company's FCF could be forecasted very well within a DCF analysis by operating managers. We therefore conclude that bottom-up valuation of a company's PVGO will not be operationalised in this research.

4.1.3 Top-down valuation PVGO

This approach uses generally accessible information from the financial markets to map PVGO for publicly traded companies. The most important assumption is that the residual value of a company's stock price minus EPS/r captures all the present value of a company's growth options.

The PVGO could be normalised and expressed as a percentage of the firm's stock price, S_0 (Smit & Trigeorgis, 2006). This proportion of growth option value is an important metric to compare the amount of PVGO across industries. Smit and Trigeorgis (2006) have performed research to the relationship between the volatility of industries and the PVGO of specific companies in such industries. They made two important observations:

- Industries with higher volatility tend to have a higher proportion of PVGO.
- Within industries there is high positive correlation between a stock's volatility and the company's proportion of PVGO.

Thus, according to these observations we could assume a relationship between volatility and the proportion of PVGO on industry-level and also on company-level. This assumption is strengthened from our knowledge from option theory, which underwrites that the volatility is the most important value driver of options.

It seems that the result above is very straightforward. Companies active in the same industry will share most of their growth options, regardless whether some companies have a slight advantage to utilise these shared options. Therefore, the proportion of growth options will be related in some extent to a company's main industry. Possible reasons for deviations in the proportion of PVGO across companies in the same industry can be that some companies may be active in other industries as well, or they may be very active in a specific niche. That the proportion of PVGO is related to a stock's volatility is also easy to understand, as volatility is the most important driver of option value. The PVGO of a non-traded company can therefore be estimated by the amount of PVGO of comparable publicly traded companies.

The top-down approach could be used in static PV model, where the static PV in combination with a company's PVGO after T years might be a best estimate to incorporate future strategic value. However, this approach does not provide any insight in how such value is established and is therefore not preferred. The top-down approach could also be used as indicator to determine if a company possesses growth option value. However, as we already know that the proportion of PVGO is industry-related, PVGO is already usable as indicator. Therefore, it does not need to be operationalised. Furthermore, the amount PVGO derived from the financial markets does not give any insight in the options that a company possesses on project-level or management-level. These options are all embedded into one value, which gives no further information about how a company's option value is composed.

We conclude that a top-down approach is not preferred, as it provides no insight in Real-Options value. However, a top-down approach might be useful in combination with the static PV model. This will further be evaluated in section 4.3. Furthermore, the top-down approach is already usable as indicator for growth option value.

4.2 Forecast valuation parameters

In the enterprise DCF model, a typical long-term forecast is made up of extrapolations of short-run trends (Amram & Kulatilaka, 1999). Thereby, it assumes mostly fixed values or a fixed development of key parameters. We will evaluate a possible role of Real-Options theory to improve these parameters.

4.2.1 Discount rate

The weighted average cost of capital is a theoretically correct discount rate for a company. Furthermore, Real-Options theory does not give us a tool to improve the establishment of the weighted average cost of capital. The models and the assumptions to establish the cost of equity, the cost of debt and tax and the debt to equity ratio of a company are therefore adopted by this research.

The cost of equity is sometimes adjusted for some specific risks. For example, risks related to liquidity uncertainty or risks related to small firm uncertainty. We have not covered theory about determining such risks premiums, however we want to make clear that Real-Options theory is not suited to improve the establishment of those premiums. Real-Options theory is specifically suited to translate uncertainty to upside potential.

4.2.2 Free Cash Flow and terminal value

The amount of the (future) free cash flows to a company plays a vital role in the valuation of a company and is at least influenced by the factors stated in section 3.2.2, i.e. sales growth, the cost of sales, investments in fixed assets and the investments in working capital.

In the enterprise DCF model, free cash flow needs to be estimated for T years, whereafter it is mostly assumed to grow with a fixed growth rate g. Growing with a constant growth rate g, means that the company is able to constantly invest against a premium over its WACC. What is perhaps even more important, is that its previous investments will remain competitive and will also earn a premium forever. All these assumptions are necessary to determine a company's terminal value with the perpetuity growth formula. Some assumptions could be relaxed when we do not assume a fixed-growth rate, but even when we assume a non-fixed growth rate, we implicitly make some unrealistic assumptions. However, Real-Options theory does not hand us a better tool to determine a company's terminal value, we will therefore hold on to use a growth-rate to establish a terminal value.

Up to the moment T, forecasts of the development of FCF can be very good (Myers, 1984). Real-Options theory could assist with incorporating value inherent to managerial flexibility regarding a company's operational activities (by means of flexibility Real-Options) and regarding a company's strategic activities (by means of strategic Real-Options). We will look at how that value is incorporated in the general enterprise DCF model before and after time T.

Flexibility Real-Options value, i.e. flexibility value related to a company's assets in place, is in the short term often well understood and is therefore well incorporated in the forecast of FCF up to a moment T (Myers, 1984). As time T, see section 3.2, should be that point in time for which the business will operate at an equilibrium level, value inherent to a company's flexibility Real-Options after time T is already included in the best possible way.

Strategic Real-Options value up to a moment T is usually partly incorporated in an enterprise DCF model. It could be included by adjusting all the factors influencing free cash flow upwards as managers understand that they will profit from some currently unknown strategic opportunities in the future. It could also be included by modelling different scenarios related to future uncertainty. For example, the company is according to the base case at least worth €X. But, in case some future uncertainty resolves in the right direction, another scenario, scenario 2, seems to become reality and the company will be worth €X+Y. In this case management actually executes a Real-Option. A Real-Option they had identified and consciously kept open and which eventually became into the money. After T years, the enterprise DCF model assumes that FCF will constantly grow with a constant growth rate g, which is the he long-term rate of consumption growth for the industry's products, plus inflation. We already argued that this is the best way to take the value inherent to distant strategic opportunities into account.

We conclude that the enterprise DCF model forecasts the amount of FCF mostly as good as possible up to moment T, but that after moment T, the amount of FCF is predicted by parameters that can be subject to heavy criticism. Real-Options theory can not improve the determination of the variables used in the enterprise DCF model. But, it can assist with including value inherent to managerial flexibility. The enterprise DCF model takes value inherent to flexibility Real-Options into account well, but can be improved for taking into account value inherent to strategic Real-Options. Up to moment T, strategic Real-Options value is usually partly incorporated. This can be done by adjusting critical parameters in the FCF forecast or by modelling different scenarios related to future uncertainty. Real-Options theory could assist with a complete and correct valuation of a company's short-term strategic Real-Options. Strategic Real-Options value after time T is incorporated well. How to apply Real-Options theory to unforeseen investments, probably driven by market and private risks, will be operationalised in the next chapter.

4.3 Preliminary conclusion

This preliminary conclusion is drawn such that we can analyse in the next section for which function we need to determine when its value should be incorporated into a company valuation model.

In combination with the future assets in place (PV) model, Real-Options theory can be used to value short-term strategic Real-Options bottom-up. With bottom-up valuation, there are two main issues, first the identification of Real-Options and second, the determination of their joint probability function. Regarding short-term strategic Real-Options, we concluded that all short-term strategic Real-Options that are taken into account should be acknowledged by the company's management. Regarding their interaction, we concluded that companies will only nurture their most valuable strategic Real-Options. Furthermore, the execution of one strategic Real-Option will probably "kill" other strategic Real-Options around that moment in time. The value of distant strategic opportunities in the future assets in place (PV) model is included in the long-term growth rate of consumption growth for the industry's products, plus inflation. Thereby, we assume implicitly that the value inherent to distant strategic opportunities is equally available to all company's active in a certain industry.

In a general enterprise DCF model, short-term strategic Real-Options value is either partly included in a FCF forecast and/or sometimes partly included through a scenario analysis related to future uncertainty. In the first case, strategic Real-Option value is not backed by good arguments and some strategic Real-Options value is not acknowledged, which can never be correct. In the latter case, Real-Options theory is better suited. These short-term strategic Real-Options influence however both the FCF forecast and the terminal value. Short-term strategic Real-Option value is therefore present before and after time T (Real-Options acquired before time T could be executed after time T and the executed Real-Options will probably be responsible for cash flows after time T).

Incorporating short-term strategic Real-Options while holding on to the base case of the enterprise DCF model is obviously the easiest for practitioners. However, by holding on to the base case of the enterprise DCF model, there is a significant risk that strategic Real-Options value is valued twice. By setting limits to the typical FCF forecast for the enterprise DCF model, as is the case with the future assets in place (PV) model, we are better able to capture all strategic Real-Options value correctly. Furthermore, the forecast needed to set up the future asset in place (PV) model is just slightly different. In both models, we argue to cope with strategic Real-Options value after a time T in the same manner.

In our Real-Options model we will operationalise the valuation (and interaction) of short-term strategic Real-Options. This can be a solution for the incorrect use of scenarios or other methods to incorporate (some) strategic value. We will also take into account that for the long term, every company active in the same industry will have the same opportunities to grow, hence has relatively the same distant strategic opportunities.

4.4 Financial parameters

In the next chapter, we want to operationalise the use of Real-Options theory to value a company's short-term strategic Real-Options. Basically, that are all the strategic Real-Options applicable to a company, which are in in the end identified by a company's management.

The market values all value related to the expected growth of company, a company's PVGO. The PVGO is not the same as strategic Real-Options value, but is a sort of superset of strategic Real-Options value. Therefore, it is likely to assume that a high proportion of PVGO relates to a high proportion of strategic Real-Options value, as valued by the market.

The proportion of PVGO is expressed as $\frac{PVGO}{S_0}$ (Smit & Trigeorgis, 2006). Brealey et al. (2011) distinguish income stocks from growth stocks, where income stocks have a generally lower proportion of PVGO than growth stocks. Growth stocks tend to have also a higher volatility than income stocks and from Smit and Trigeorgis (2006), we know that industries and companies with a higher volatility tend to have a higher proportion of PVGO. There are thus enough indicators to estimate the extent of the proportion of growth option value and therefore strategic Real-Options value, as valued by the market.

Strategic Real-Options value, valued or identified by the market, is not the same as the strategic Real-Options value, valued or identified by management. First of all, management is not able to identify all strategic opportunities the market does, or will resolutely reject some of these opportunities. The unidentified or rejected opportunities will never be exploited and will therefore have no value to the company. Second, management could identify strategic opportunities for their company the market does not. Figure 2.1 depicted two types of Real-Options, proprietary Real-Options and shared Real-Options. Shared Real-Options are mostly the opportunities that are common knowledge in the market, but proprietary Real-Options are much more difficult to identify for the market. The parameters and methods treated thus far do not make clear how to determine a company's proprietary Real-Options.

In case a company owns strategic proprietary Real-Options, we want to distinguish the most valuable strategic proprietary Real-Options. Luehrman (1998b) provides us with a framework to "quickly"[1] distinguish valuable Real-Options from less valuable Real-Options. Therefore, he introduced the value-to-cost metric in (Luehrman, 1998a).

The value-to-cost metric contains all the usual information captured in net present value (NPV), but adds the time value of being able to defer the investment. This value-to-cost metric is expressed as NPV_q and is defined by Luehrman (1998a) as the value of the underlying assets the company intends to build or acquire, divided by the present value of the expenditure required to build or buy them. Equation 4.1 depicts how NPV_q is exactly defined, where S_0 is the present value of project's operating assets to be acquired, K is the exercise price and r_f is the risk free rate of interest.

$$NPV_q = \frac{S_0}{PV(x)} = \frac{S_0(1+r_f)^t}{K} \tag{4.1}$$

Luehrman's (1998b) framework is called the option space, and distinguishes options by their cumulative volatility, defined as $\sigma\sqrt{t}$, and their value on Luehrman's value-to-cost metric into six regions, as partly depicted in figure 4.1. The six regions he defines are the regions:

1. Invest now
2. Maybe now
3. Probably later
4. Maybe later
5. Probably never
6. Invest never

[1] We will see in our analysis in section 5.5.2 that using Luehrman's (1998b) framework requires in case of a company valuation significant effort.

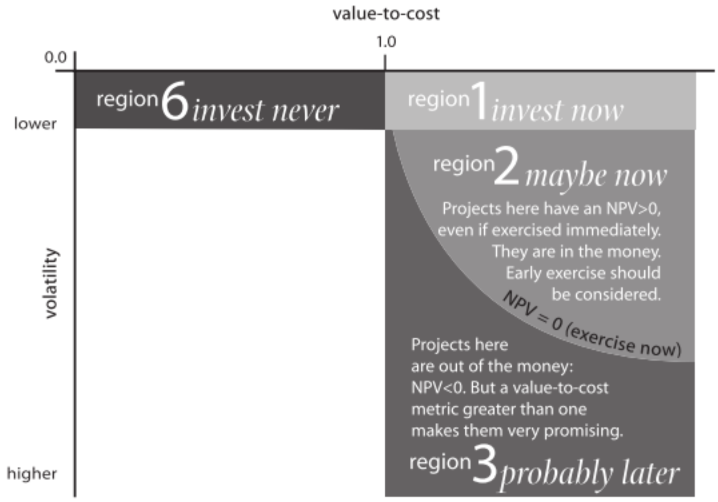


Figure 4.1: Dividing option space into regions

To evaluate if a company possesses short-term strategic Real-Options, market-based indicators as the average volatility in the industry, the volatility of competitors, the average proportion of PVGO in the industry, the proportion of PVGO of competitors and classifications made by third parties about growth and income stocks for again competitors and other companies active in the same industry, could be used to get an impression of a company's strategic shared Real-Options. In case these indicators point out that the company possesses strategic (shared) Real-Options value, Real-Options theory should be used. In case these indicators do not point out that the company possesses strategic Real-Option value, the option space framework of Luehrman (1998b) could be used to evaluate the identified proprietary Real-Options of a company. If the proprietary Real-Options under consideration fall into the first four regions, Real-Options theory should definitely be used. If they fall into the fifth region, Real-Options theory could be considered. In case the company does only owns strategic Real-Options that fall into the sixth region, the use of Real-Options theory is not necessary.

4.5 Conclusion

The objective of this chapter was to determine which functions of Real-Options theory should be operationalised in order to improve the valuation of companies in combination with a DCF analysis. In our preliminary conclusion, section 4.3, we concluded that we will operationalise the bottom-up valuation of short-term strategic Real-Options.

In addition to this conclusion, we concluded in section 4.4 that market-based indicators can be used to estimate whether a company possesses strategic (shared) Real-Options value. Furthermore, the option space framework of Luehrman (1998b) could be used to evaluate the identified proprietary Real-Options of a company.

In the next chapter, we will frame our theory on how and when short-term Real-Options should be valued and incorporated into a company valuation model. This model will combine Real-Options theory with a DCF analysis and is based on our interpretations of the insights gained in this research. Furthermore, we will try to operationalise a company's short-term Real-Options valuation as detailed as possible.

Chapter 5

Real-Options – Operationalisation

The objective of this chapter is to operationalise the valuation of a company's short-term strategic Real-Options as detailed as possible. This will be our answer to this research second deliverable. In order to be able to accomplish this, we should first frame our theory about how and when short-term Real-Options should be valued and incorporated into a company valuation model, which will be our answer to this research first deliverable. A real case of PhiDelphi serves as support.

5.1 The general model

In the previous chapter, we concluded first that Real-Options theory is suited to value a company's (short-term) strategic Real-Options regarding a company valuation and we concluded that Real-Options theory could contribute the most to a DCF analysis by valuing a company's short-term strategic Real-Options. The valuation of strategic Real-Options could align strategic and financial analyses. To integrate a bottom-up valuation of a company's strategic Real-Options with a DCF analysis, we should use the future assets in place (PV) model.

The general model consist of three important parts, namely:

- A DCF analysis up to time T, i.e. determine a company's present value of its future assets in place
- An analysis to capture strategic Real-Options value
- A terminal value

Company value is under this model described by equation 5.1. Where FCF in (1) is the normalised free cash flow, strategic Real-Options value has to be determined differently per company and g represents the forecasted long-term rate of consumption growth for the industry's products, plus inflation.

$$\begin{aligned}
(1)\, Short\, term\, DCF &= \frac{FCF_1}{1+WACC} + \frac{FCF_2}{(1+WACC)^2} + ... + \frac{FCF_{T-1}}{(1+WACC)^{T-1}} \\
(2)\, Strategic\, Real\, Options\, Value &= Strategic\, Real\, Options\, Value \\
(3)\, Terminal\, value &= \frac{\frac{FCF_T}{WACC-g}}{(1+WACC)^T} \\
Company\, value &= (1) + (2) + (3)
\end{aligned} \tag{5.1}$$

5.1.1 The DCF analysis up to time T

In chapter 2, we derived the formula that should be used to capture strategic Real-Options value separately from a company's value related to its (certain) current and future operational activities, derived by a DCF analysis. Such a DCF analysis leads to a valuation of a company's present value of its future assets in place. The model (i.e. the formula) that combines this present value of a company's future assets in place with a company's short-term strategic Real-Options value is called the future assets in place (PV) model. This part of the model is based on Smit and Moraitis' (2010) formula, see equation 2.11.

In chapter 3, we analysed and sort of operationalised the DCF analysis of this model. More specific, we explained how to derive the value inherent to the future assets in place (PV) up to time T. Summarised:

- Normalise free cash flows, i.e. exclude strategic scenarios related to unforeseen possible investments from the forecast and clear a company's forecast from any strategic Real-Options value.
- Include the estimated effects of variability derived from the market and from the execution of flexibility Real-Options in the free cash flow forecast. (Note this is not different for the enterprise DCF model. Because operating managers could forecast short-term trends on a company's current activities very well (Myers, 1984) and bottom-up valuation of flexibility Real-Options is almost impossible, see section 4.1.2. Therefore, a good forecast including short-term trends for the company's current activities is probably the best way to incorporate flexibility Real-Options value.)

In chapter 4, we concluded that we are going to operationalise the valuation of a company's short-term strategic Real-Options. Thereby, we implicitly chose to use and recommend the future assets in place (PV) model for incorporating strategic Real-Options value into a company valuation.

5.1.2 The analysis to capture strategic Real-Options value

In case a company's management identifies valuable proprietary short-term strategic Real-Options for a company, they should take these into account. In order to determine whether these identified Real-Options are valuable, Luehrman's (1998b) option space framework could be applied. In case management could not identify any shared Real-Options, market-based indicators could indicate if a company possesses shared strategic Real-Options value.

A company's short-term strategic Real-Options value is taken into account in our general company valuation model, see formula 5.1. Still, the fundamental question remains how to value value these short-term strategic Real-Options and how such a valuation could be generalised.

In chapter 2, we concluded that the definition of Real-Options is subject to development. A Real-Option should currently be seen as a future opportunity that is created by todays investments and Real-Options theory should be seen as a way of thinking that helps managers formulate their strategic options. This definition implies that future strategic opportunities could be Real-Options as well and that that the use of financial option-pricing theory to value Real-Options is not mandatory. In section 2.1.5, we listed four possible methods to determine the value of a strategic Real-Option:

- Option-pricing methods in combination with decision analysis (e.g. a risk-adjusted decision tree)
- Decision analysis
- Option-pricing methods in combination with the MADD approach (e.g. a risk-adjusted decision tree or a binomial tree)
- Option-pricing methods in combination with both decision analysis and the MADD approach (e.g. a risk-adjusted decision tree)

Furthermore, we concluded in chapter 2 that, irrespective of the valuation method, both the structure of a Real-Option and the other option-characteristics are very important. The structure of the Real-Option (e.g. a compound put, a rainbow call) influences how a certain valuation method needs to be applied. In contradiction to a call, a put gains value if the underlying asset's value is moving upwards. In case of a rainbow option, the underlying asset's value is influenced by more than one variable. Determining the interaction of these variables is then first priority. The option-characteristics influence the way of application of a valuation method as well. For example, a Real-Option with a deterministic volatility could be valued by using multiple trees and a Real-Option on an in value decreasing opportunity could be modelled by incorporating dividends. There are plenty of studies to the valuation of specific Real-Options, distinguished by their option-structure and other option-characteristics. These need however to be summarised in order to map best practices, further research could then complement this for all kinds of Real-Options. This step is needed as well to stimulate the use of Real-Options theory for practitioners, but is out of the scope of this research. We will continue with operationalising the valuation method as detailed as possible, without taking into account the option-structure and the other option-characteristics. Because if we do take this into account, we could never reach our goal to operationalise a generalised model.

In chapter 2, we also concluded how to determine which approach should be used to model the underlying asset's value and to calculate the Real-Option value. Therefore, practitioners should walkthrough and understand the following steps:

1. Market risks should be modelled with option-pricing techniques, hence market risks and private risks should be separated when possible.
2. Private risks should be valued by preference with the MADD approach, as that will simplify the valuation process. However, if the underlying distribution does certainly not behave as a Geometric Brownian motion and could also not be described by a jump process (or any other underlying distribution), decision analysis should be used.
3. If market risks and private risks could not be separated, these risks should by preference be valued with the MADD approach. Again, if the underlying distribution does certainly not behave as a Geometric Brownian motion and could also not be described by a jump process (or any other underlying distribution), decision analysis should be used.

The valuation method for Real-Options driven solely by market risk is basically the same as the valuation method for Real-Options driven by market and private risks, which are solely valued with the MADD approach. The only difference is that the underlying asset's value and its volatility is not derived from the financial markets, but from management's (subjective) estimates. Decision analysis is totally different from these approaches and is not suited to operationalise. Therefore, we will capture strategic Real-Options value by operationalising the MADD approach, as the valuation of Real-Options driven solely by market risks is straightforward. On the one hand, the MADD approach is the best method to simplify the valuation of strategic Real-Options, but on the other hand, the MADD approach requires some strong assumptions that could easily be violated. The use of MADD approach is defended by Copeland and Antikarov (2001), its assumptions are according to them no stronger than those used in NPV approaches. Despite the reality of the valuation outcome, it stimulates Real-Options thinking, see section 2.1.5.

In chapter 4, we concluded that in order to value a company's short-term strategic Real-Options bottom-up, we should identify them and determine their joint probability density function (i.e. the way they interact). In order to be able to identify short-term strategic Real-Options, it is first important that management adopts to Real-Options thinking. From there, an easy way to start is to examine the enterprise DCF valuation (in case this is available). The strategic investments incorporated in the FCF forecast and the different strategic scenarios related to possible future investments for the company can point us to the already identified short-term strategic Real-Options. Finally, all short-term strategic Real-Options that are taken into account should be already identified/acknowledged by a company's management (we assume that all strategic Real-Options acknowledged by the market are also known to and properly evaluated by a company's management), because if management does not identify some strategic opportunities as valuable, they will never be executed and will therefore have no value.

The determination of the interaction between strategic Real-Options is important to establish the (non-additive) sum of strategic Real-Option value. The number of strategic Real-Options that can be executed within a certain time frame is limited by capital restrictions. Therefore, determining the interaction should be manageable.

In sum, we are going to operationalise a method to capture strategic Real-Options value by using option-pricing methods in combination with the MADD approach. For valuing the Real-Option, we will use a risk-adjusted decision tree, this will have two major advantages. First, we could easily extend the tree to cope with risks we want to model with decision analysis and second, we could allow the volatility to change during the lifetime of the Real-Option. In order to complete our generalised model to enable practitioners to easily value Real-Options, the influence of the option-structure and other option-characteristics should be taken into account. Where two of the six other option-characteristics, i.e. the value of the underlying asset and the asset's volatility, are necessary input variables for the MADD approach. With a summary of current literature and with some oriented further research, it should be possible to identify a limited number of categories (based on structure and other option-characteristics) for which the method to establish the value of the key variables could be the same. For example, the acquisition of a new business could probably always be structured as an American call, with a defined time to expiration and a variable exercise price.

5.1.3 The terminal value

This part of the model allocates one value to both the stream of cash flows related to a company's current activities after time T and to the distant strategic opportunities of a company. We assume that all of this value could be captured by letting the amount of free cash flows grow with the long-term growth rate of consumption growth for the industry's products, plus inflation. Thereby, we assume that the long-term growth rate for an industry's consumption also captures the influence of distant strategic shared Real-Options on the industry. Under this approach, each company active in a specific industry will thus have the same chances in the future to utilise upcoming opportunities.

In chapter 3, we concluded that the terminal value formula, as depicted in equation 5.1 is simplified for convenience. In case essential information about the reaction of a company's FCF to certain market trends or about the return on new invested capital (RONIC) is present, the terminal value formula could be adjusted.

5.2 Reflection on objectives

First of all, we stated as goal to capture the value inherent to managerial flexibility for a company's valuation correctly (with Real-Options theory). Therefore, we established two deliverables:

- Deliver a theory about incorporating Real-Options value into a company valuation model. This theory should answer the question when Real-Options theory should be applied and subsequently how it could be applied.
- Operationalise (a part of this theory) and deliver a company valuation model, that captures the value inherent to managerial flexibility correctly, when such value is not negligible and well understandable by practitioners. This model will integrate Real-Options theory with DCF analysis.

The first deliverable is "delivered". Equation 5.1 depicts how the important value inherent to managerial flexibility could be captured correctly in combination with a DCF analysis. The corresponding theory is described in section 5.1 and in more detail in chapters 2, 3 and 4. In section 5.1.2, we also described in the form of a guidance how Real-Options theory subsequently should be applied.

The second deliverable should basically operationalise the first deliverable and deliver a tool and/or an understanding about when we could use this operationalisation. The possibility for generalisation is however limited, as the operationalisation of the valuation method depends on the option-structure and on other option-characteristics. We therefore choose to operationalise a part of the theory derived as first deliverable, as explained in section 5.1.2. Because, we want to hold on to the precondition to deliver a generalised model, we are not able to deliver one generalised model to capture the value inherent to managerial flexibility for a company's valuation. However, this study tries to make it as easy as possible for practitioners to incorporate strategic Real-Options value. This in contradiction to most recent studies, which are showing an increased complexity in the valuation of Real-Options in order to deal with critique.

The second part of this second deliverable, delivering a tool and/or understanding about when we should make use of our company valuation model, is "delivered" in section 4.4. If management has identified strategic Real-Options for their company, management should attempt to estimate their significance. By understanding the creation of Real-Options value, they probably could make such an assessment without further analysis. Otherwise, the option space framework of Luehrman (1998b) is a good and, according to Luehrman (1998b), a relatively easy tool to use. The strategic Real-Options identified by management can be shared and/or proprietary Real-Options, where a true classification can sometimes be very hard. If management does not identify any Real-Options at all, market-based indicators could be used to indicate whether a company should probably possess strategic Real-Options. With respect to volatility averages and average PVGO proportions in the market, a company could identify if their industry, their niche segment or comparable companies are expected to possess strategic Real-Options. Final identification and acknowledgement of these strategic Real-Options must be done by management.

What this research and model makes unique is that we acknowledge the shortcomings of the valuation methods and that we stay close to the financial option theory with respect to the structuring of Real-Options. In section 2.1.3, we discussed the influence of the option-structure and the option-characteristics. Thereby, we identified six key variables that influence the value of the option. These all contribute to a specific description of a certain Real-Option and thereby influence the calculation as well. We argue that strategic opportunities for companies can be categorised into a limited number of categories for which the structure of the Real-Option can be modelled identically and the method to cope with the remaining four option-characteristics can be the same.

5.3 Strategic Real-Options valuation

The general company valuation model, depicted in equation 5.1, consists of three components. From now on, we will deepen into the operationalisation of the second component, strategic Real-Options value. The general model serves as guidance to properly include a company's strategic Real-Options value in a company valuation, as defined by this research.

A theoretical guidance, based on this research, to use option-pricing methods to value strategic Real-Options is stated in section 5.1.2. We will try to apply option-pricing methods in combination with the MADD approach on strategic Real-Options retrieved from a PhiDelphi case, in order to demonstrate our concept and to find out and show to what level of detail we are able to operationalise our (generalised) model.

Section 5.4 will introduce the case, which is concerned with the valuation of a strategic opportunities to expand manufacturing and sales to other countries. But first, we will operationalise the MADD approach in order to apply this on our case.

5.3.1 Operationalising the MADD approach

Copeland and Antikarov (2001) have established the MAD assumption, which is according to them and to many others (e.g. (Trigeorgis, 1999), (Brealey et al., 2011)) the best estimate for the underlying asset's value. In creating the binomial lattice, subsequently, Copeland and Tufano (2004) do not propose a general method to determine the project's volatility. Instead, they recommend practitioners to look at the value drivers. In an example, they use the volatility of the spread between the price of the factory's output and input, which are both traded in the financial markets. Brandão et al. (2005) rightly remark that this method is too complex and not intuitive for practitioners.

Copeland and Antikarov (2001) suggest however another method to estimate the volatility of a project that has multiple uncertainties. Besides Monte Carlo methods, they suggest to use subjective estimates provided by management. According to Copeland and Antikarov (2001), most managers and industry experts have subjective, non-formal, non-statistical estimates of volatility in their heads. If you let management answer what are the highest and lowest values that a variable (e.g. FCF) could take in some year, with α% confidence, and you assume the uncertainty follows a Geometric Brownian motion, you can establish an estimate of the variable's volatility. Copeland and Antikarov (2001) show that when α is 95%, the volatility of the variable could be determined according equation 5.2. Where, V_T^{Upper} and V_T^{Lower} are the highest and the lowest estimate respectively for the variable's value after T periods, r_i is the growth of the variable in each ith period and V_0 is the value of the variable after 0 periods, which is the start value of the variable.

$$\sigma = \frac{\ln(\frac{V_T^{Upper}}{V_0}) - \sum_{i=1}^{n} r_i}{2\sqrt{T}}, \sigma = \frac{\sum_{i=1}^{n} r_i - \ln(\frac{V_T^{Lower}}{V_0})}{2\sqrt{T}} \tag{5.2}$$

In a good free cash flow forecast, all risks attributable to that project are incorporated. The forecasted free cash flows are expected values. If management can provide us with good estimates of the highest free cash flow in some future period T, with α% confidence, we can determine the project's volatility. Fortunately, management often makes multiple cash flow forecast for projects they plan to undertake, so practitioners will be familiar with such a method. In our model, we choose α to be as well 95%, as we want to be as close to 100% as possible, but don't think management's estimates can be any better. Besides, we will always want to know the value of V_T^{Upper}, as we are interested in the potential growth. Based on symmetry of the standard normal distribution, we can then accordingly model the cash flows for V_T^{Lower}.

Unfortunately, the free cash flow series of a project are probably not homoscedastic, but heteroskedastic, which means that the variance of the free cash flows differ through time. Especially for projects in the earlier phases, free cash flows will probably have a high variance (hence high volatility). In later phases, the amount of free cash flows will probably stabilise and the variance (hence volatility) will drop. We will therefore ask management as well to identify periods with about the same level of volatility, for each period they need to estimate again with 95% confidence to what level (or with which ratio) free cash flow will grow. The disadvantage of this method is that by allowing the volatility to change, the binomial lattice becomes non-recombining. A risk-adjusted decision tree can however include multiple binomial lattices.

The main advantage of using binomial trees is that Real-Options could easily be incorporated and valued. Incorporation of flexibility alters the fair discount rates, but by using risk neutral valuation, the discount rate is for each branch in every phase equal to the risk free rate of interest.

The main advantage of the MADD approach is that it integrates the value drivers of an underlying asset, just like Monte Carlo simulation does. In contradiction with many other methods, this method does not force you to make a value driver – which is traded in the financial markets (e.g. an asset, spread, commodity, etc.) – responsible for all the project's uncertainties. In many cases, it will not be true that the volatility of the underlying asset is exactly replicated by some asset traded in the financial markets. However, when an asset's uncertainty is replicated by some traded asset, as for example with Real-Options in the oil industry, volatility derived from the financial markets should always be used instead of management's estimates. Furthermore, the MADD approach can also be used to estimate the volatility of variables that influence the project's free cash flow.

A Matlab function, with the input parameters FCF, $WACC$ and VT, can be found in appendix B. FCF is a $(1\,x\,m)$ matrix with the forecasted amounts of free cash flows of the project till time m, $WACC$ is the company's weighted average cost of capital and VT is the highest possible amount of FCF for the project after m periods with 95% confidence. This function could be called as follows: [sigma, S] = waarde(FCF, VT, WACC). Matlab will then return the asset's value S (based on the provided free cash flows), the asset's volatility $sigma$ and a multiplot that includes the range of free cash flows and the expected free cash flows based on the asset's volatility and based on the actual growth and average growth of free cash flows.

5.4 Introduction to the case

Due to non-disclosure agreements between PhiDelphi and their clients regarding their clients' financial performance and their names, we were obliged to anonymise any data we received. We will therefore use artificial names and company data might be adjusted to prevent the possibility to retrieve the company's identity. The adjustments made to the original data will have no effect on the conclusions of this research.

5.4.1 The company – Bucket

Bucket's original company profile could be found in appendix C.

Business overview

Bucket is an international niche packaging supplier, offering high added value through quality, functionality, user friendliness and design. Bucket employs 110 FTEs, including management, and is headquartered in Delden, the Netherlands, where also their production plant is located. The total surface of of the facilities amounts to circa 50,000 m^2, of which 25,000 m^2 is occupied with buildings. They have sales offices in the Netherlands, Germany, Denmark, Norway, the UK, the USA. Furthermore, they have agreements with selected resellers in Italy, Ireland, Switzerland and several other countries. Bucket is owned by their company's management and by a private equity firm.

Products and strategy

Bucket products can be divided into three main product groups. For each product group, Bucket has determined a particular strategy. Their product groups are:

- Packaging
- Specialties (project business)
- Material handling (project business)

Packaging

Within the packaging product group, the focus is on standardised packaging solutions. Bucket is operating in the high-end segment of packaging products, they are a niche player in the global packaging market. Because of that, they can maintain high margins (with respect to industry standards). They focus on the pharmaceutical and the chemical markets, for which they obtained the highest necessary certifications to secure the quality. Their products are being used for intercompany transport and export. An important key advantage of Bucket is that they have long-term (locked-in) client relationships. From 2008 to 2010, packaging has become more important. From 60% of total sales in 2008 to 68% of total sales in 2010, with a turnover of respectively 25.0 million in 2008 and 26.8 million in 2010.

In the coming years (2011 - 2015), Bucket wants to realise annual growth figures of around 10 - 15% within packaging, what they have called their core business. To secure these growth figures, they think about geographical expansion to for instance Asia and the USA, they want to focus on new product development and they want to further penetrate their current customer base.

Specialties

Within the specialties product group, the focus is on highly customised packaging solutions. Bucket's specialties business has a blue chip reputation and a concentrated customer base. Specialties comprises 22% of total sales in 2008 and declined to 16% of total sales in 2010, with a turnover of respectively 9.0

million in 2008 and 6.2 million in 2010. In the coming years (2011 - 2015), Bucket wants to adopt to a consolidation strategy within specialties. They will shift their focus on their capacity filler and on just one key client.

Material handling

Within the material handling product group, there is no clear focus. Bucket simply produces solutions (e.g. crates) for material handling. Bucket's business in material handling is primarily concentrated in the Benelux and is focused on the agricultural, non-food and the automotive market. Material handling comprises 18% of total sales in 2008 and declined to 16% of total sales in 2010, with a turnover of respectively 7.4 million in 2008 and 6.2 million in 2010. In the coming years (2011 - 2015), Bucket wants to adopt to a consolidation strategy within material handling. Material handling will be used as a cash cow. Bucket continues to serve their loyal customer base and focuses on niche segments.

5.4.2 The packaging market

According to sector reports from Rabobank (2012) and Rabobank International (2012), the global plastic packaging market is matured. High growth figures and high margins belong to the past. The European plastic packaging market, from a producer's perspective, can be characterised as follows:

Fragmented The top 50 European plastic packaging producers have a combined market share of 42% of the total European market.

Weak positioned In the value chain, the producers of plastic packaging solutions have a weak position. They are positioned between raw material suppliers and consumers, which could be large international companies.

Economies of scale The plastic packaging production is a capital intensive industry. Therefore, there are economies of scale with regard to development, purchasing, production and sales.

Internationalisation The largest customers of the plastic packaging suppliers operate on European or global level. These customers expect the same of their suppliers.

Commodity packaging Specialties, i.e. customised packaging solutions, become commodities, i.e. standardised packaging solutions.

Consolidation The listed points above lead to market consolidation among suppliers. The largest suppliers are responsible for multiple acquisitions over the last years. This process is not expected to be over.

Niche markets Regardless of the consolidation trend, there are multiple niche markets. These niche markets demand small suppliers, which can be more flexible and service oriented.

Within the packaging market, short-term market demand is strongly correlated with economic development (GDP), where increasing production and consumption figures result in a larger demand to packaging products. On average, 1.0% economic growth results in 1.5% growth in demand to packaging products (Rabobank, 2012). Furthermore, the costs of raw materials are very important to packaging suppliers. On average, raw materials are responsible for 45% of the total production costs. However, for some products, the costs of raw materials can comprise more than 70% of production costs. The costs of raw materials (e.g. PET, HDPE, LDPE, PP) depends largely on the oil price. Therefore, the costs of raw materials are currently relatively high and are expected to increase. According to Rabobank (2012), short-term demand for plastics packaging products is expected to decline marginally due to weak economic forecasts, while margins can be pressured due to still high raw material costs and rising labour costs.

"The long-term demand for plastics packaging products is relative stable: large scale substitution between packaging materials is not expected. Long-term opportunities for plastic packaging suppliers are present, as consumers, brand owners and retailers are constantly changing. Plastics packaging could increasingly become a silent sales man: (i) need for more individualisation of packaging and (ii) brand design to stand out and improve customer loyalty" (Rabobank International, 2012). According to Rabobank (2012), the production of annual plastic packaging products is expected to grow by 4% on average per year between 2010 - 2030.

Bucket's niche

Bucket operates in a niche of the packaging market, in which there are a few competitors with a comparable high-quality product / service offering. Entry barriers are amongst others the need to have the right certifications, Bucket is highly certified in both the EU and the USA. Other important competitive advantages are Bucket's well organised sales channels, Bucket's product quality, their delivery speed and their delivery accuracy. The distribution of Bucket's sales across countries is depicted in figure 5.1.

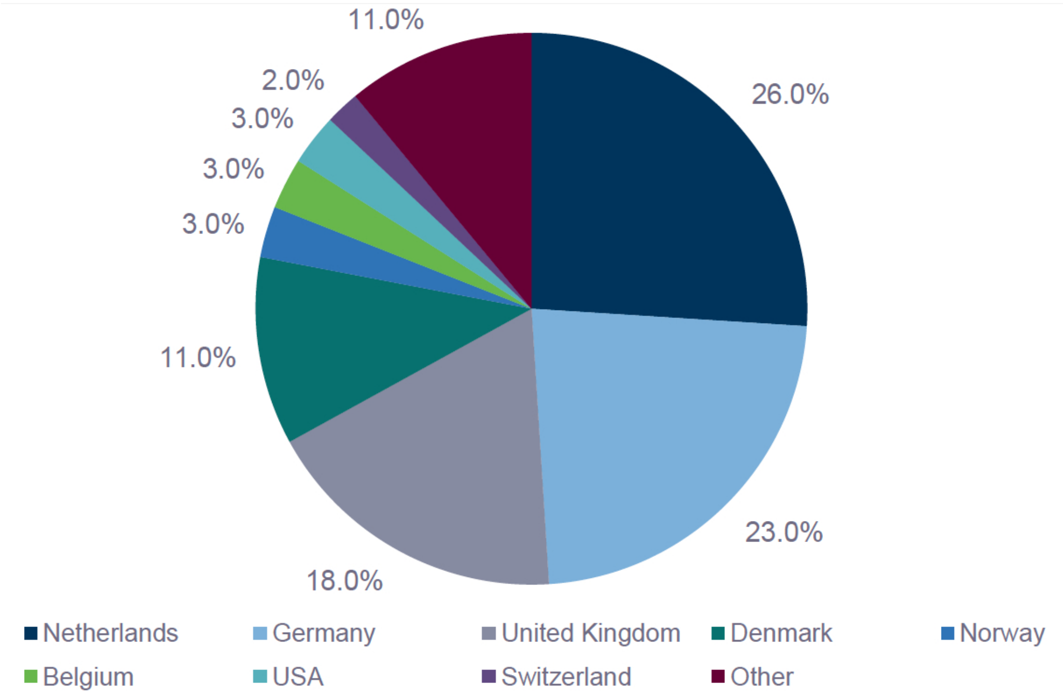


Figure 5.1: Distribution of sales across countries

Bucket's management has identified the following opportunities:

- The company currently has excess production capacity (30%). This could be used to increase sales, but would require additional investments in the sales network.
- The company has a greenfield position and basic client base in the USA. The USA is becoming a more important market due to the amount of large potential clients (pharmaceutical and chemical companies). The company could set up a production facility to save transportation costs when servicing USA clients and to make a true shift towards the USA market.

- Another opportunity is to focus on / set up a greenfield in Asia. This area is currently receiving little attention from management. The company does sell some products in Asia through resellers, but does not yet have a sales office nor a production facility.

Market opportunities

The specialty packaging business distinguishes itself from the commodities packaging business in some important aspects: this business maintains high margins on low volumes, demand is less cyclical, there should be a focus on product leadership (best product) or customer intimacy (best solution), production is mainly make-to-order and production capacities are usually fast and flexible, there are less competitors and high entry barriers, clients have high switching costs and need a customised package (Rabobank International, 2012).

Based on Bucket's strategy, they have the following growth options according to Rabobank International (2012):

- *Broaden product offering,* playing on the trend of one-stop-shopping. Offering a broad range of packaging products and/or materials. Mostly used when going for customer intimacy.
- *Develop new products,* essential growth direction when opting for product leadership. Product developing is often in cooperation with raw material supplier, customer, packaging designer, or machine supplier. Ongoing development is necessary to avoid the commodity trap.
- *International expansion,* enter new markets. Strategy can be useful in order to serve internationally operating customers in multiple countries and/or take advantage of fast growing markets. Most likely for large producers.

5.5 Real-Options analysis

To value the Real-Options in this case, we first have to identify Bucket's strategic Real-Options. In case we could not identify any strategic Real-Options, we should look at market-based indicators to make an estimation whether Bucket possesses strategic Real-Options value. Subsequently, we should assess whether the identified strategic Real-Options have significant value to take into account. If this is not obvious, we should use Luehrman's (1998b) option framework. Assuming that the strategic Real-Options possess value, we are going to determine which risks drive the value of these Real-Options, whether private risks can be isolated and how these Real-Options should be structured. After the valuation of single Real-Options, we are going to evaluate the effect of interaction between the short-term strategic Real-Options.

5.5.1 Identification of Real-Options

If Bucket's management has adopted Real-Options thinking, they will see the general market opportunities, an industry's shared Real-Options, as well. Based on Bucket's strategy, Bucket's management will not see opportunities for their company to broaden its product offering or to develop new products. As the identification of strategic Real-Options by a company's management is necessary for taking them into account, these opportunities drop out.

From the three future opportunities Bucket's management perceive, the opportunity to increase sales by using their excess capacity and invest additionally in their sales network is a flexibility Real-Option. The utilisation of current assets in place will normally be a continuous debate between the operational manager and the sales manager of Bucket. These managers should therefore be able to incorporate any future value derived from utilising Bucket's assets more effectively. The effects of this possibility needs therefore to be taken into account in their free cash flow forecast for the value of the company's future assets in place. The following strategic Real-Options remain for Bucket:

- The Real-Option to set up a production facility in the USA (an expansion option)
- The Real-Option to set up a greenfield in Asia (an expansion option)

5.5.2 Evaluating strategic Real-Options value

As Bucket's management has identified applicable strategic Real-Options, it is not necessary to look at market-based indicators. We should however evaluate if the identified strategic Real-Options are valuable enough to take into account. We can do this in two ways:

- Logical sense
- The option space framework

According to Luehrman (1998b), their option space framework is effective and simple, as managers should determine the present value of a project's operating assets and the costs to acquire these assets also for a DCF analysis. However, Luehrman (1998b) assumed here that the practitioner's objective is the valuation of the opportunity, where our objective is to value a company. The required information, the Real-Options asset's value, its exercise price, its volatility and the applicable risk free rate comprise almost all information that is necessary to actually value the strategic Real-Options. As this information is not yet available, we are going to use some logical sense. Because Bucket realises relatively high margins on their products, we assume that their main risk for turning their opportunities into a success is reaching a certain sales volume. This can only be assessed by management. In this case, if management assesses that reaching a certain sales volume in the future is realistic, where nurturing the strategic opportunities (by for example maintaining contacts with clients abroad) is be very important, we should include these strategic Real-Options. Because management will probably assess that a certain sales volume is realistic in the future if they continue to nurture these strategic Real-Options, we will include these Real-Options and continue with our Real-Options analysis.

5.5.3 Underlying risk and structure

Both the strategic Real-Options are American call options, both certainly driven by private risks and perhaps by some market risks as well. The strategic Real-Option to set up a greenfield position in Asia will however be somewhat more riskier as there is almost none experience in this market. The risks applicable to these options will therefore be almost identical. For the valuation of the strategic Real-Options, we should first check whether we could structure these options as compound options. In example 3 in section 2.1.5, we showed how to do this for investments related to an upgrade to a company's information system. It appears that the necessary investments could be divided over three stages, each with another risk type. This had two advantages, first after each stage we could choose to delay or to stop with further investments and second, we could separate risks.

Both strategic Real-Options are related to an expansion of production facilities. Additional production facilities will however always require more clients, hence investments in Bucket's sales force. If Bucket is able to successfully target these new markets, sales will increase steadily and will not adjust immediately to their full capacity. Bucket will therefore benefit from a production location that could increase in capacity in line with the expected sales growth. If this is possible, the investments of Bucket could be split up and comprises:

- An investment in a production location that is suited to produce a certain amount X, which is expected to be offset in Y years, plus an investment in the necessary assets to produce the required amount for the first Y year(s).
- One, two or more expansion investments in assets to increase the production capacity of the plant to ultimately the location's maximum capacity.

The initial investment is the riskiest, the risks that are related to it are related to either the demand to Bucket's products and their market price or to the cost of the plant and the costs related to production. In more detail[1]:

- Demand
  - *Sales force.* The success/capacities of the sales force influences how many new clients could be attracted per month and whether long-term client relationships could be established. Furthermore, the average volume of the attracted clients is important. Before Bucket starts to invest, early agreements with clients can be essential. The signing of pre-contracts will solve lots of uncertainty.
  - *Competition.* Bucket will mix itself in an existing market. If competition is intense and they offer comparable products, it will be difficult for Bucket to create demand for their products.
- Market price
  - *Competition.* The price Bucket could ask for their products is also influenced by competition. As the price determines the margin Bucket could realise on their sales, it will be of great influence to the final decision of executing the Real-Option. Furthermore, the intensity of competition will also influence whether Bucket could increase its price when its cost price increases.
- Production plant
  - *Initial investment costs.* The costs of investment are very important to the decision of executing the Real-Option. However, these do not have to be risky as it should be possible to estimate these well up-front and even to come to some early agreements about the possible costs.
- Production
  - *Cost price.* The cost price will comprise the costs of raw materials, production costs per product and overhead costs per product. The costs of raw materials may vary and could therefore lead to (high) volatility in the cost price. Because the cost price is very important to the margin on Bucket's products, volatility in the cost price may be very risky.
  - *Errors.* Failures in production may lead to significant additional costs. When putting into use a new production plant, there is an increased risk of failure in production, which may lead to a lower production efficiency and therefore to higher production cost per product.

The presence of competition appears to be very important to the evaluation of Bucket's strategic Real-Options. Just like with the initial investment costs, Bucket could map the competitive environment up-front and should therefore be able to make reasonable estimates for the sales volume that should be reached with their sales force and the price they could ask. Risks related to demand are therefore mainly subject to the success of Bucket's sales force. Risks related to the market price are related to the possibility of Bucket to increase the price when the costs of raw materials increase. The initial investment costs don't have to be risky, but production costs are. The production cost per product may vary due to relatively many errors in the beginning. Most important to the risks related to the production is however the volatility in the price of raw materials. According to Rabobank (2012), the cost of raw materials could be influenced mainly by market risks.

The expansion investments are less risky, as many private risks will be either resolved or less volatile. After a solid client base is established, bringing in new clients is less important and risks related to demand are increasingly more driven by the performance of established clients (hence, could become market risk). The risks related to the market price will almost be fully resolved, as experience and agreements will make clear to Bucket if it is possible for them to increase their price to maintain gross margins. The investment costs for the expansion are also not risky, as these could be determined up-front

[1]General risk types are not included in the analysis, as for example organisational risks (e.g. culture, the presence of qualified personnel), political risks, etc..

(even better than for the initial investment due to experience with local contractors). Meanwhile, the effective production rate of the factory is known, expansion investments are not expected to really change this, hence this risk is also resolved. The volatility in the cost of raw materials will stay an important risk factor.

It is unclear whether it would be a possibility for Bucket to invest in stages in one of the strategic opportunities. Our analysis shows however that it would be very useful for Bucket to leave room for at least one expansion investment. First, this decreases the initial investment amount and therefore probably increases the profitability in the first stage and second, the risks applicable to the first investment either resolve or turn (partly) into market risk. We therefore conclude that both strategic Real-Options should be seen as compound American call options, where the first option is driven mainly by private risks, but the next option will be dominated by market risks.

5.5.4 Option-characteristics

Stated in section 5.1.2, the option-characteristics are important for the valuation of strategic Real-Options, but impede a general valuation guide for strategic Real-Options valuation. The valuation of the strategic Real-Options for Bucket makes this insightful. We will discuss the important option-characteristics and their influence on the valuation. The influence of the option-characteristics can be evaluated for both strategic Real-Options in the same way, because they have the same structure and the same underlying risks. The value of the underlying asset and the volatility of the underlying asset are needed to use our MADD approach, for modelling the project value through time. The other variables are necessary for the final valuation of the Real-Options.

Value of the underlying asset

Because the strategic Real-Options are structured as compound options, there are more underlying assets. If we assume that there will be just on expansion stage, each compound option consist of two options. As the underlying assets are not traded in the financial markets and we are using the MADD approach, we will use the MAD assumption to determine these assets' values.

To establish the value of the underlying assets, without flexibility, we need to be able to make estimates about amongst others the sales of Bucket's new location over the years, about the costs of goods sold over the years, about the selling price and about the other costs.

In appendix D, we included Bucket's financial accounts over 2008, 2009 and the latest estimate over 2010. Unfortunately, Bucket's turnover and its cost of goods sold (COGS) are not separated any further than per product group. In order to estimate the value of the project(s) under consideration, we need to know which product types contribute most to the turnover per product group and especially what are the costs to produce these. Thereby, we should know exactly which raw materials are needed, in order to forecast the development of the costs of goods sold. It is therefore not possible to set up reasonable free cash flow forecasts, without flexibility, for the opportunities under consideration, with the information currently available. Hence, it is currently not possible to determine the value of the underlying assets of the Real-Options. Additional information from Bucket and estimates from Bucket's management are needed, as well as analyses to the future development of the costs of goods sold, for a solid free cash flow forecast.

Exercise price

The exercise price of the Real-Options is equal to the required investments. It is however reasonable to assume that the required investment amount will grow with the years. The growth rate could be set equal to the inflation rate, but could also be estimated more precisely, by deepen into the cost drivers of the investment.

In order to determine the exercise prices, we should deepen ourselves in the investments costs. For the first of the two sequential options, we should at least know:

- The cost for the location we wish to acquire
- The cost to build the factory building
- The costs related to the required assets (e.g. machinery, facilities, trucks, etc.)

For the second option, we should know what additional investments in assets and perhaps to the building are necessary.

Appendix D includes also Bucket's balance sheet. Unfortunately, Bucket's assets are all taken together, this does not provide any insight. In order to estimate the investment costs, insight in the original costs of the required assets in the past, just as their current market values and their book values will be very helpful. Furthermore, a lot of additional information is needed from Bucket's management and from analyses that needs to be executed to the new environment and new developments in machinery. Hence, it is not possible to determine reasonable exercise prices with the current information available.

Time to expiration

Bucket management does not see the strategic Real-Options as a now or never position, but probably wants to know if they should invest in one or both of these opportunities in the next five years. Therefore, we assume that the time to expiration of the first opportunity is five years, the time to expiration of the expansion opportunity is infinite.

Volatility of the underlying asset

To determine the volatility of the underling assets, we must establish the volatility of the asset's value / the free cash flows. As the uncertainties regarding the investment costs and the effect of the competition should be resolved up-front, uncertainties related to Bucket's sales (force), production errors, costs of raw materials and the possibility to increase the market price remain. We assume that management should be able to estimate the effect of production errors to the free cash flow forecast. If we assume that Bucket can include the effects of changing raw material prices in their selling price, then the risks related to the costs of raw materials and the market price resolve. If this is not the case, the gross margin depends on the volatility of the costs of raw materials. The demand to Bucket's products will be influenced mainly by private risks for the first Real-Option, for the second, the demand will be influenced by private and market risks.

The amount of free cash flow Bucket could realise depends mainly on their number of sales and on the gross margin they could realise on their sales. As the gross margin is either fixed or determined by market risk (and this risk type is isolated), this should not be forecasted with the MADD approach and the free cash flows should not be forecasted with the MADD approach either. The MADD approach should therefore, in this situation, be used to forecast the (distribution of) sales of the new plant. From there, we can calculate the effects of the sales distribution, together with the volatility of the gross margin, on the project's free cash flow and its value. This will enable us to determine the overall volatility of the first stage of the project.

The sales that could be realised during the second stage of the project depend partly on market risk (performance of existing clients) and partly on private risks (attracting new clients and holding on existing clients). Therefore, the volatility of the sales will be estimated again with the MADD approach, management estimates should now however lead to a lower volatility.

Risk free rate of interest

The applicable risk free rate of interest to the first option is the rate on a 5-year Asian or US government bond. The applicable risk free rate of interest to the second option is the rate on a 30-year Asian or US government bond. Because there do not exist Asian government bonds and the risk free rate within Asia could differ heavily across countries, we use the rates applicable to US government bonds. The annual yield on a 5-year US government bond is 1.097% and on a 30-year US government bond is 3.343%[2].

Dividend

If Bucket judges that the opportunity in either the USA or Asia becomes less valuable when competition enters that market as well, then we should estimate by what amount the opportunity becomes less valuable each year. Such leakage value could then be included in the valuation of the opportunity.

5.5.5 Valuation

In section 5.3, we indicated that the case serves as support to our theory and model, that it will enable us to demonstrate our concept and to determine to what level we could operationalise our model. The discussion about the obstacles practitioners may encounter when they value a company's strategic Real-Options by applying our company valuation model is more important to this research than the actual valuation of the strategic Real-Options in our case. We therefore choose not to persist in valuing Bucket's strategic Real-Options, as right now this requires such strong assumptions (due to a lack of information) that will make the outcome unreliable. This will have two important disadvantages, first an unreliable outcome will not enable us to draw any useful conclusions. Therefore, it does not strengthen, but will weaken our research. Second, opponents of Real-Options theory might seize it to criticise this research.

For the valuation of strategic Real-Options, a lot of additional information is necessary. Information that is not necessary to value a company with the enterprise DCF model. Some of this information may be available in a company's information system, however a lot of additional information must be required by additional analyses. As the discussion in section 5.5.4 showed, dealing with that information is not that difficult. Contrary to the claims in literature, the reason that Real-Options theory don't breakthrough in the capital budgeting decision might not be due to the complicated use of analytical methods, but might be due to the additional effort it takes.

The conclusion in the previous sentence may apply especially to our model, as we simplified the application of Real-Options theory. The determination of the underlying assets' values is not difficult with the MAD assumption, it will be even very straightforward for practitioners as the DCF valuation method is well known. However, in order to make the required free cash flow forecast, we need a lot of additional information that is not easily available.

To derive the volatility of the underlying assets, we showed that Bucket should use the MADD approach to take into account the volatility caused by the uncertainty regarding their sales. Despite we don't have sufficient information to give a reliable estimate of the volatility in Bucket's sales, we will demonstrate the method to do this in example 4.

Example 4 *In section 5.3.1, we operationalised the MADD approach and wrote a Matlab function to plot the range (the 95% confidence bounds) of future free cash flows through time. This function could also be used to calculate the volatility of other variables, in this case Bucket's sales, and to plot the range of future sales through time. The function should then called as follows: [sigma] = waarde(FCF, VT, WACC). Where FCF is a (1xm) matrix of the expected sales results for the coming m periods, VT is the the highest value sales is expected to be at the mth period, estimated with 95% confidence and WACC could actually be any value as it only influences the value of S, which is not a return variable. We will attribute the value 1.0 to WACC.*

Suppose, table 5.1 depicts management's forecast of the expected sales for the first ten years. They only enter the market if they have signed pre-contracts that amount to 1.0 million and they expect 50% growth in the first two years. Subsequently, they expect growth to decline to 20% per year, which will hold on to year five. After five years, they expect less heavy growth, which is 10% for the next three years and

[2]Acquired on 06/09/2013 from http://www.investing.com/rates-bonds/usa-government-bonds?maturity_from=130&maturity_to=290.

5% growth for the latest two years. Management should also estimate the maximum amount of sales at the end of a period with about the same level of volatility. They separate the first five years, from the latest five years. This first period is expected to be more volatile, as Bucket should position itself in the new market, in the last five years they expect to grow steadily to their new location's maximum capacity. Therefore, they estimated with 95% confidence the maximum amount of sales after five years and after ten years.

Period	0	1	2	3	4	5	6	7	8	9	10
Expected sales (EUR $\times$ million)	1.00	1.50	2.25	2.70	3.24	3.89	4.28	4.70	5.17	5.43	5.71
Maximum sales estimate	n.a.	n.a.	n.a.	n.a.	n.a.	5.00	n.a.	n.a.	n.a.	n.a.	6.50

Table 5.1: Example of a sales forecast

The related Matlab input and (text) output are stated below for the two periods with the same volatility (in chronological order). Thereby, we choose not to round off any numbers, as this will have had a great impact on the return variable and the plots. The plots of the range of future sales, with 95% confidence and assuming an underlying normal distribution, are depicted in figure 5.2 and 5.3.

```
[sigma] = waarde([1,1.5,2.25,2.7,3.24,3.888],5,1)

sigma =

      0.0562
```

```
>> [sigma] = waarde([3.888,4.2768,4.70448,5.174928,5.4336744,5.70535812],6.5,1)

sigma =

      0.0292
```

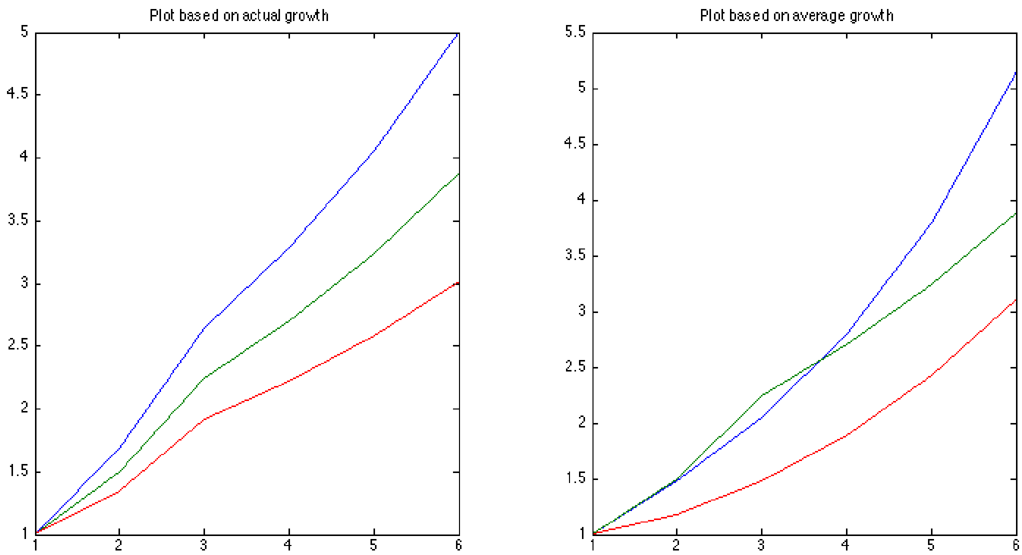


Figure 5.2: Expected sales range for period 1-5

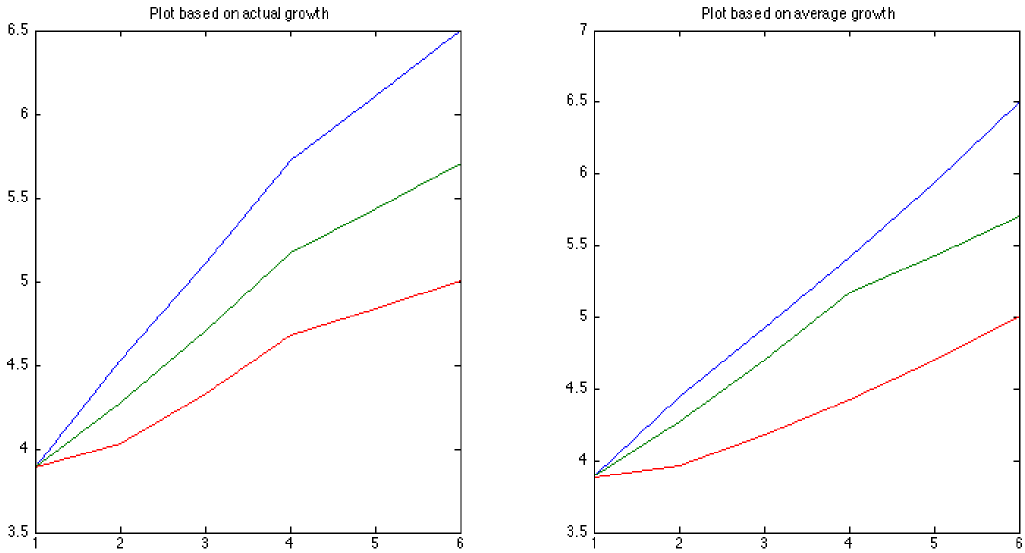


Figure 5.3: Expected sales range for period 6-10

In the situation described in example 4, management should conclude that based on their expectations, the volatility of sales in period 1-5 is 5.62% and is 2.92% in period 6-10 under a normal distribution. With the plots of the range of their expected sales, they should check whether this is really according to their expectations, whether their indirect volatility estimate makes sense. If this is not the case, management should reject the outcome of the MADD approach and model its expected future sales with another underlying distribution or apply decision analysis instead.

For valuing the strategic Real-Options, issues regarding the variables related to the other four option-characteristics needs to be discussed. The same reasoning as for the determination of the value of the underlying assets applies to the determination of the exercise prices. Determining the present value of the initial and the expansion investment will not be difficult, but requires information that is currently not available and usually not available to practitioners when they value a company. Specially applicable to Bucket's strategic Real-Options is that the exercise prices are not fixed. When K is the exercise price, m is the execution period and g is the applicable growth rate of the exercise price, the exercise price could be determined as follows: $K_m = K_1(1+g)^m$.

The applicable time to expiration and the applicable risk free rate of interest for the strategic Real-Options under consideration are already determined in section 5.5.4. If there are costs involved to the delay in the execution of the strategic Real-Options and these costs could be reasonably estimated, these costs could be included as dividend. Including these costs as dividend does not increase the complexity of the option valuation. It requires that one should work from the end of the three backwards to calculate the Real-Option value at each branch, which was already required to cope with American options and non-fixed exercise prices. A reasonable estimate of the costs related to a delay of investment will be the most complex, as this demands game-theory.

Finally, in case we had finished the valuation of the individual strategic Real-Options, their interactions should be taken into account. Because the Real-Options have another underlying asset, their value could theoretically be additive. However, it does not seem reasonable that Bucket will execute both strategic Real-Options in the (near) future due to capital constraints and the related risks. We therefore assume that Bucket will maximally execute one of their strategic Real-Options in the future. When the value drivers of the Real-options are also the same, the option values will always move in the same direction, which will mean in this case that Bucket's total option value is equal to the value of the strategic Real-Option on the opportunity of which the underlying asset has the largest present value (as the proportion option value over asset value is for both options the same). The value driver related to the expected sales is for both Real-Options however different, both have a unique market, probably unique clients and probably unique competitors. Therefore, it could be the case that the sales expectation in for example Asia is developing in a favourable direction, in contrary to the sales expectation in the United States. On the other hand, the expected sales will also depend on some common factors, such as the global market development.

Hence, the two strategic Real-Options (i.e. the correlation between the expected sales in Asia and the USA) will have a positive correlation. The (Pearson) correlation is defined between [-1,1], where a correlation of -1 describes a perfect negative (decreasing) linear relationship, a correlation of 0 describes that the two variables are uncorrelated and a correlation of 1 describes a perfect positive (increasing) linear relationship. Because, we concluded that the two value drivers have a small tendency to move in the same direction, their interaction will be larger than 0 and smaller than 0.5. A reasonable guess could be made on the basis of Bucket's experience and its data about the set up of sales offices abroad. With such an estimate, it should be easy for practitioners to model both assets' values through time and determine Bucket total option value. In sum, Bucket's total option value will be more than the option value of one of its individual options, but less than the two individual options taken together. The exact value will depend on the correlation between Bucket's sales expectations, which should lie between 0 and 0.5.

5.6 Conclusions

The objective of this chapter was to operationalise the valuation of a company's short-term strategic Real-Options as detailed as possible. Therefore, we had the availability to a PhiDelphi case, which allowed us to demonstrate our concept and to find out and show to what level of detail we were able to operationalise our (generalised) model.

In section 5.1, we concluded that a company that possesses short-term strategic Real-Options value, should be valued by equation 5.1. Where the valuation of the first and third component is already described in chapter 3.

$$
\begin{aligned}
(1)\, Short\, term\, DCF &= \frac{FCF_1}{1+WACC} + \frac{FCF_2}{(1+WACC)^2} + ... + \frac{FCF_{T-1}}{(1+WACC)^{T-1}} \\
(2)\, Strategic\, Real\, Options\, Value &= Strategic\, Real\, Options\, Value \\
(3)\, Terminal\, value &= \frac{\frac{FCF_T}{WACC-g}}{(1+WACC)^T} \\
Company\, value &= (1)+(2)+(3)
\end{aligned}
\tag{5.1}
$$

Regarding the bottom-up valuation of strategic Real-Options, we concluded that there are four possible general methods to determine the value of a strategic Real-Option and that the way in which these methods needs to be applied differ for an option's structure and for an option's characteristics. A summary of existing literature and some oriented future research should map best practices for specific Real-Options valuation in the future. In order to determine which approach should be used, we concluded that practitioners should walkthrough and understand the following steps:

1. Market risks should be modelled with option-pricing techniques, hence market risks and private risks should be separated when possible.
2. Private risks should be valued by preference with the MADD approach, as that will simplify the valuation process. However, if the underlying distribution does certainly not behave as a Geometric Brownian motion and could also not be described by a jump process (or any other underlying distribution), decision analysis should be used.
3. If market risks and private risks could not be separated, these risks should by preference be valued with the MADD approach. Again, if the underlying distribution does certainly not behave as a

Geometric Brownian motion and could also not be described by a jump process (or any other underlying distribution), decision analysis should be used.

Furthermore, we concluded in section 5.1.2 that the best method to operationalise is the MADD approach. The MADD approach simplifies the valuation of strategic Real-Options, it could be included in a risk-adjusted decision tree and it could cope with other methods. Theoretically, the MADD approach could be used as stand-alone method, in which case it truly generalises the Real-Option valuation. However, it could also be used to value/model private risks. Despite the MADD approach will require some very strong assumptions, which are likely to be violated, it stimulates Real-Options thinking. Practitioners should be aware of the assumptions made and in situations where the assumptions are violated, interpret the outcome with care.

In section 5.2, we reflected upon our objectives and concluded that we already "delivered" our first deliverable and a part of our second deliverable. With respect to the objective to deliver an improved company valuation model, we concluded that it is only possible to operationalise a part of our deducted theory, which will be the operationalisation of the MADD approach

In section 5.3.1 and 5.4, we operationalised the MADD approach and introduced the case. In section 5.5, we identified the applicable strategic Real-Options in the case and demonstrated amongst others the MADD approach. Thereby, we gained some important new insights. First, Luehrman's (1998b) option space framework is not suited to quickly identify whether the strategic Real-Options under consideration possess significant value, hence should be taken into account. For a quick estimate, application of logical sense seems the best method. Second, the reason that Real-Options theory don't breakthrough in the capital budgeting decision might not be due to the complicated use of analytical methods, but might be due to the additional effort it takes. Most of the required information to value a company's strategic Real-Options is not necessary for a company valuation with the enterprise DCF model, hence not (directly) available. To obtain the required information, additional effort and analyses are needed.

With respect to Bucket, we concluded that based on the opportunities identified and acknowledged by its management, Bucket should evaluate two short-term strategic Real-Options. By applying some logical sense, we concluded that both short-term strategic Real-Options are valuable enough to take into account. After an analysis of the value drivers and the structure of the two strategic Real-Options, we concluded that both strategic Real-Options should be seen as American compound call options, where in both cases the first option is driven mainly by private risks, but the next option will be dominated by market risks, as many private risks (partly) resolve. Thereby, we assumed that Bucket can include the effects of changing raw material prices in its selling price. In that case, the most important risk for Bucket is related to its demand, its expected future sales. Because Bucket's FCF is influenced by its gross margin, which is either fixed or influenced by market risk, and by its amount of sales, the MADD approach cannot be used to model its FCF, but could be used to model its expected future sales. Furthermore, we concluded that the execution of the two strategic Real-Options will be limited to one, due to capital constraints. The interaction between the two strategic Real-Options will be positive, because there value drivers have a small tendency to move in the same direction.

Chapter 6

Discussion

In this chapter we will evaluate and discuss our findings to answer our general research question and its subquestions. Subsequently, we will state the limitations of this research and recommend areas for further research. Finally, we will discuss the theoretical and the practical implications of this research for science and for PhiDelphi.

6.1 Conclusions

In chapter 1, we introduced Real-Options theory and asked ourself the following question: When and how could Real-Options theory be applied to improve the valuation of companies make and how could this information be used to modify the enterprise DCF model?

Real-Options theory is praised and criticised at the same time as capital budgeting technique and could according to some respectable authors be used to improve the valuation of companies. Well-structured research in this field was however missing. Therefore, it was unclear how and when Real-Options theory could be used. This research has tried to fill that gap by going back to the basic functions of Real-Options theory. From that starting point, we came to several possible functions of Real-Options theory to improve the valuation of companies. This approach differs from most of the recent studies to Real-Options theory, those are mainly focused on the application of Real-Options theory in a specific area, without taking other possible better suited methods into account.

The set up of this research supports our unique research design, where each chapter has a short conclusion that answers a part of the general research question. These conclusions in between were helpful to build further upon acquired insights. This final conclusion will answer all our questions in a structured way.

In chapter 2, we started with defining Real-Options. One important contribution of this research is the distinction between the term Real-Options and option-pricing methods. The field of Real-Options theory has developed rapidly throughout the years, therefore a broad definition (see below) is used by this research, one that could best describe what Real-Options are today. By taking into account over 35 years of Real-Options theory, we concluded that literature demands a clear definition of Real-Options. Currently, a lot of studies refer to Myer's (1977) first definition of Real-Options, but build upon insights acquired in other studies that use a broader definition of Real-Options. Logically, these authors often question the use of Real-Options theory.

Real-Options Real-Options are based on an important analogy with financial options, Real-Options are rights and not obligations related to companys assets. Furthermore, Real-Options are also a way of thinking that helps managers formulate their strategic options, the future opportunities that are created by todays investments.

This definition of Real-Options classifies much more opportunities as Real-Options as the early describers of Real-Options do. Thereby, it lets go of the requirement to value Real-Options with option-pricing methods. This insight should solve much of the confusion about Real-Options theory.

Real-Options value related to market risks should be valued with option-pricing methods, Real-Options value related to market and private risks could be valued by either option-pricing methods or decision analysis, in which option-pricing methods are preferred, just like Real-Options value related to solely private risks. However, if the underlying distribution certainly does not behave as a Geometric Brownian motion and can also not be described by a jump process (or any other underlying distribution), decision analysis should be used.

The use of option-pricing methods differ for Real-Options theory. For plain vanilla European call or put options (i.e. options that have standard, well-defined properties and trade actively (Hull, 2008)), the Black and Scholes formula is a good option-pricing method. However, strategic Real-Options not rarely have a variable exercise price and an unknown time to expiration. Furthermore, the value of the underlying asset and the volatility should be derived in another way and dividend means leakage value. The value of the underlying asset could be derived by finding a “twin security”, which is practically impossible or with the MAD assumption, which assumes that the present value of the cash flows of the project without flexibility is the best unbiased estimate of the market value of the asset. The volatility could be derived from the financial markets or via management estimates. The best method to allow for modelling flexibility and the incorporation of private risks is the risk-adjusted decision tree. Hence, in absence of reliable data from the financial markets, the MAD assumption in combination with management estimates, finally modelled with a risk-adjusted decision tree, provides a good basis for strategic Real-Options valuations.

The MADD approach is a good solution to model the underlying asset’s value through time, if both the asset’s value is (partly) related to private risks and the asset’s value could assumed to behave as a Geometric Brownian motion. Till date, literature points only to the dangers using this method. This research concludes that the MADD approach is a proper solution in many cases, but should be used with a clear awareness of its limitations. An understanding of the assumptions the MADD approach may violate, makes a practitioner able to draw its own conclusions about the outcome and even adjust this outcome. Furthermore, many assumptions underlying the MADD approach seem to be no stronger than those underlying NPV approaches. Moreover, applying the MADD approach instead of not using Real-Options theory stimulates Real-Options thinking.

It is interesting to notice that a method, first described by Copeland and Antikarov (2001), is not picked up by others over the years. One reason may be this research’s clear focus to deliver an operationalised, easy to use method to value strategic Real-Options. Where others reject this method instantly because they were looking for a method to improve the current valuation of Real-Options, we were looking for a method to simplify the valuation of Real-Options. This brings us to another reason, there is still a debate going on between proponents and opponents of Real-Options theory, where the main argument of the opponents is that Real-Options driven (partly) by private risks, are not valued properly. Therefore, proponents of Real-Options theory are mainly focused on the improvement of current valuation methods, which makes these valuation methods even more complex and not suited for generalisation.

Another important finding of this research is which Real-Options should be taken into account in a company valuation. Our extensive elaboration distinguishes flexibility and strategic Real-Options, Real-Options on project-level and management-level and short-term and distant strategic Real-Options. The distinction between flexibility Real-Options and strategic Real-Options is very important for the valuation of companies. Basically, flexibility Real-Options are related to a company’s current or future operational activities and strategic Real-Options are related to opportunities that can create new operational activities. Flexibility Real-Options could be valued well by operational managers within a DCF analysis, but strategic Real-Options often not. Therefore, it is important to identify a company’s strategic Real-Options, determine how these should be valued and add them subsequently to a DCF valuation without any incorporated strategic Real-Options value. Furthermore, strategic Real-Options could be found on both project-level and management-level, where flexibility Real-Options could only be found on project-level. It seemed also important to distinguish strategic Real-Options identified before and after moment T in a company’s free cash flow analysis, respectively a company’s short-term and distant strategic Real-Options. We concluded however that all Real-Options that are identified and applicable to a company, are a company's short-term strategic Real-Options, which could mature and derive a part of their value after time T as well. Distant strategic Real-Options are unknown, hence we call them distant strategic opportunities. The value of unknown future opportunities is therefore assumed to be incorporated in the long-term consumption growth rate for the industry's product, plus inflation.

This research also provides an answer to how a DCF analysis without any included strategic Real-Options value should be operationalised. The model that combines the value of strategic Real-Options with the aforementioned DCF analysis is called the future assets in place (PV) model. The DCF analysis of a company valuation without any strategic Real-Options value is called: the futures assets in place (PV). The future assets in place (PV) is the value derived from a company's current plus future assets. This is equal to a static PV, plus the value related to efficiency (i.e. a company could operate more efficient due to a learning curve), flexibility Real-Options, planned future investments, market growth and random operational variability.

We went also in detail about when strategic Real-Options value should be taken into account. Market-based indicators could be used to get an impression of a company's shared strategic Real-Options value and a company's management should identify whether a company possesses proprietary strategic Real-Options. In theory, the option space framework of Luehrman (1998b) could be used to evaluate the value of a company's strategic proprietary Real-Options. This framework uses the opportunity's NPV, corrected for the time value of money (i.e. the value-to-cost metric) and the opportunity's volatility to indicate whether the strategic Real-Option is valuable. However, in practice, using the option space framework to evaluate strategic Real-Options in a company valuation requires much effort, as not all of the required information is easy available. When practitioners understand the value drivers of Real-Options, an estimate based on logical sense must be sufficient to decide whether specific strategic Real-Options should be included.

Finally, in our case example, we concluded that the acquired information for a company valuation with the enterprise DCF model is not sufficient for a company valuation with our future assets in place (PV) model. A lot of additional information about the possible opportunities is required, which was not needed for the enterprise DCF valuation. Therefore, the reason that Real-Options theory does not breakthrough in the capital budgeting decision might not be due to the complicated use of analytical methods, but might be due to the additional effort it takes.

6.2 Limitations and further research

As stated in chapter 1, most literature in the field of Real-Options theory is either focused on the added value (and the need) of Real-Options theory, thereby reflecting to the shortcomings of other approaches in valuing flexibility, or it is focused on the application of specific types of Real-Options, to mostly projects. On the other hand, there is a lot of critique on the (current) application of Real-Options theory. Therefore, some crucial points were at the beginning of this research unclear:

1. *How Real-Options theory could contribute to the valuation of companies (which functions it could fulfil).*
2. *How Real-Options should be valued.*
3. *When Real-Options theory should be used.*

Because the use of Real-Options theory to the valuation of companies was an almost undiscovered field, we chose to start answering these crucial questions and repeat the fundamentals of Real-Options theory first. Therefore, this research should be seen as a first step to apply Real-Options theory to the valuation of companies and could unfortunately not go into detail about the application of Real-Options theory to special or extraordinary situations.

While we found the answers on the questions listed above, we had to make some decisions on how to continue this research. Thereby, the deliverables of this research were leading. Most of the limitations of this research could directly be related to those decisions. We concluded that both option-pricing methods and decision analysis are important to correctly value Real-Options. However, we have not covered decision analysis in this research. A better integrated approach to include Real-Options into a company valuation might therefore be possible by doing further research in this area.

Furthermore, we only operationalised the component strategic Real-Options value from equation 5.1, our improved company valuation model. The method to determine the future assets in place (PV) component is described, but not operationalised. Further operationalisation of this method may lead to important new insights for practitioners. The method to determine the terminal value component is not different to current methods. Due to the operationalisation of incorporating short-term strategic Real-Options into a company valuation, we came to the insight that strategic Real-Options value includes both shared and proprietary strategic Real-Options. The value of shared strategic Real-Options is however influenced by multiple option holders, therefore a game-theoretic approach could help in determining the true value for a company holding such strategic Real-Options. This research did however not covered game-theory, as this was out of the scope of this research. Further research in this field should be done to come to a better integrated approach to include strategic Real-Options into a company valuation.

An important result of this study that simplifies the valuation of Real-Options is the MADD approach, in combination with the derivation of the underlying volatility by management's estimates. Three important assumptions underlie this approach, first, the assumption that the present value of the cash flows of the project without flexibility is the best unbiased estimate of the market value of the asset. Second, that the asset's value could be assumed to behave as a Geometric Brownian motion through time (or according to another underlying distribution) and third, that the parameter σ of the underlying distribution could be retrieved from management's subjective estimates. The first and the third assumption could be justified as basically the same assumptions are needed for respectively NPV approaches and decision analysis. The second assumption is an important step to our simplification of Real-Options valuation, however we have not tested its impact. We therefore suggest practitioners only to use the exact valuation outcome if the second assumption could be justified. Further analysis to the both impact of the package of assumptions and to the use and derivation of other underlying distributions are needed to improve this method.

Last, this study has delivered a theory, of which parts are operationalised, to include Real-Options into a company valuation model. We concluded that Real-Options could be categorised based on their structure and on the methods used to derive the other important option-characteristics. It was outside the scope of this research to determine the best valuation method for all categories. Therefore, a summary of current research to map best practices of the application of Real-Options theory to specific Real-Options and some future oriented research to the valuation of the different kind of strategic Real-Options needs to be done to further operationalise our model.

6.3 Theoretical implications

This is the first research that attempts to derive a model that uses Real-Options theory for a company valuation. Therefore, this study was strongly focused on the theoretical perspective. This served also the interest of PhiDelphi, as that is concentrated on two points. First, they want an answer to the fundamental questions of the applicability of Real-Options theory as well. In more detail, they want an answer to / insight in the continuous debate if and subsequently how Real-Options theory should be used. Furthermore, they are interested in a model that can be used to value Real-Options by practitioners. The study is therefore mainly explorative, the theoretical implications derived are discussed below.

Our definition of Real-Options and the forthcoming insight that an opportunity that is classified as a Real-Option does not have to be valued with option-pricing methods is an important contribution to the academic field. It solves a lot of confusion and could steer the continuous debate in a new direction of collaboration, instead of the ongoing increase in complexity. The use of decision analysis in the field op Real-Option pricing is not new, but the recognition that option-pricing methods should be seen as one of the methods (hence, not the prescribed method) to value Real-Options is an important step for other academic fields to interfere in the valuation of Real-Options.

Also the distinction and the definition of flexibility Real-Options and strategic Real-Options, linked to their use in a company valuation model, is an important contribution to the academic world. From there on, we build the future assets in place (PV) valuation model. This is the first model that describes a detailed method to include strategic Real-Options value into a company valuation model, where till date literature has not come any further than introducing and pointing to terms like a "Static PV" and an "Expanded NPV". Where it emphasises that these terms could theoretically be combined, in a way that has to be determined, with the valuation of Real-Options. Our model and our analysis opens the way for other company valuation models that could be build upon this theory. Furthermore, the discussion about the appearance of flexibility and strategic Real-Options on project-level and management-level contributes to the understanding of the academic world where these Real-Options originate, just like the discussion about short-term and distant strategic Real-Options. Regarding these short-term and distant strategic Real-Options, we concluded that basically all strategic Real-Options are short-term strategic Real-Options and that the latter should be seen as distant strategic opportunities. This discussion contributes to the insight and understanding of strategic Real-Options as well.

Bottom-up valuation of Real-Options is often assumed to be practically impossible. However, our future assets in place (PV) valuation model makes use of bottom-up valuation of strategic Real-Options. This study has argued that due to capital constraints and a crucial difference between flexibility Real-Options and strategic Real-Options, this is possible. Flexibility Real-Options are often options on the same underlying asset, where strategic Real-Options have different underlying assets. Therefore, with respect to strategic Real-Options, this study shows that bottom-up valuation is a good method to incorporate strategic Real-Options value.

Where earlier studies to the valuation of Real-Options choose not to use methods similar to the MADD approach, we showed a way to use this approach in combination with management estimates for the asset's volatility. As stated in section 6.2, this approach could be improved further to improve and simplify Real-Options valuation. The renewed introduction of the MADD approach could be an important tool to the academic world for simplifying Real-Options valuation, instead of increasing complexity.

Last, the derivation and the analysis of the functions of Real-Options theory for a company valuation is also an important contribution. Thereby, we showed amongst other that the static PV (hence, the top-down approach) is not suited to include strategic Real-Options value. Also the result that Real-Options theory is not suited to improve valuation parameters in the enterprise DCF model could steer future research in the "right" direction.

6.4 Practical implications

This study has led to the insight that it is impossible to set up a stand-alone Real-Options model for a company valuation (the model presented by Schwartz and Moon (2000) does not comply with our definition of a model based on Real-Options theory). The model that we presented combines the valuation of Real-Options with a DCF valuation. This is an important step for practitioners. First of all, our approach stays close to the current approach of company valuation. Second, our approach stays close to the fundamentals of Real-Options. We do not attribute additional value to stochastic profit functions, but we try to identify explicit future opportunities.

We described what value could theoretically be captured and how this could be done in practice. However, during this research and the actual attempt to value strategic Real-Options, we came to the conclusion that the valuation of strategic Real-Options, despite a realised simplification, demands large effort by practitioners. Additional effort from the academic world is needed to come to a true practitioner's guide. However, practitioners, just like PhiDelphi, had raised questions about both the theoretical and the current practical possibilities, which this research answered.

The future assets in place (PV) model makes clear what should be valued by a DCF analysis (i.e. the future operational activities) and what should be valued by Real-Options theory. Practitioners could easily convert their enterprise DCF analysis in a DCF analysis for the future assets in place (PV) component. Thereby, it is important that they review any scenario analysis critically. Next to this research's contribution to the operationalisation of the DCF analysis for a company's operations, this research has operationalised the valuation of strategic Real-Options. The MADD approach, earlier introduced by Copeland (2002), but operationalised and made insightful by this study, could be extremely helpful in the valuation of these strategic Real-Options. When the conditions for using this approach are met, strategic Real-Options related to both market risks and private risks could be valued easily. Furthermore, by describing the assumptions of the MADD approach precisely, and by explaining the other methods for valuing strategic Real-Options as well, practitioners could fall back on this study and use is as a guide.

Another important practical implication, is the stimulation of Real-Options thinking. Being able to make a distinction between planned investments and possible future opportunities, thereby aligning strategic analyses with financial analyses, could give companies a competitive advantage. This counts also for PhiDelphi, as it is in their interest to optimise company valuation. We will recommend PhiDelphi to adopt Real-Options thinking and try to identify Real-Options in every company valuation. To review enterprise DCF valuations critically on Real-Options value and set up DCF valuations according the DCF valuation for the future assets in place (PV) in case they choose to value strategic Real-Options. Thereby, they should make use of the MADD approach to value Real-Options when this method is feasible.

References

Alexander, C., & Chen, X. (2012). A General Approach to Real Option Valuation with Applications to Real Estate Investments. *ICMA Centre Discussion Papers in Finance DP2012-04*(0).

Amram, M., & Kulatilaka, N. (1999). Disciplined decisions: aligning strategy with the financial markets. *Harvard business review*(February), 95–104.

Amram, M., & Kulatilaka, N. (2000). Strategy and shareholder value creation: the real options frontier. *Journal of Applied Corporate Finance*, *13.2*(Summer), 15–27.

Amram, M., Li, F., & Perkins, C. (2006). How Kimberly-Clark Uses Real Options. *Journal of Applied Corporate Finance*, *18*(2), 40–47.

Andersen, L. (2000). A simple approach to the pricing of Bermudan swaptions in the multifactor LIBOR market model. *Journal of Computational Finance*, *3*(2), 1–32.

Baker, H. K., Dutta, S., & Saadi, S. (2009). *Management Views on Real Options in Capital Budgeting.*

Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *The Journal of Polical Economy*, *81*(3), 637 – 654.

Block, S. (2007). Are"real options" actually used in the real world? *The Engineering Economist*, *52*(June 2012), 255–267.

Borison, A. (2003). Real Options Analysis: Where are the Emperors Clothes? In *Real options conference* (pp. 1–30). Washington: N.a.

Borison, A., & Triantis, A. J. (2001). Real Options: State of the practice. *Journal of Applied Corporate Finance*, *14*(2), 8–24.

Brandão, L. E., Dyer, J. S., & Hahn, W. J. (2005). Using Binomial Decision Trees to Solve Real-Option Valuation Problems. *Decision Analysis*, *2*(2), 69–88.

Brealey, R. A., Myers, S. C., & Allen, F. (2011). *Principles of corporate finance* (10th ed.). New York: McGraw-Hill/Irwin.

Copeland, T. E. (2002). What Do Practitioners Want ? *Journal of Applied FInance*, 7–14.

Copeland, T. E., & Antikarov, V. (2001). *Real Options: A Practitioner's Guide.* New York: Texere Publishing.

Copeland, T. E., & Tufano, P. (2004, March). A real-world way to manage real options. *Harvard business review*, *82*(3), 90–9, 128.

Cox, J. C., Ross, S. A., & Rubinstein, M. (1979). Option pricing: a simplified approach. *Journal of Financial Economics*, *7*, 229–263.

Davis, G. A. (1998, January). Estimating volatility and dividend yield when valuing Real Options to invest or abandon. *The Quarterly Review of Economics and Finance*, *38*(3), 725–754.

Dixit, A. K., & Pindyck, R. S. (1994). *Investment under Uncertainty.* New Jersey: Princeton University Press.

Dixit, A. K., & Pindyck, R. S. (1995). The Options Approach to Capital Investment. *Harvard Business Review*, *May-June*, 105–115.

Fama, E. F., & French, K. R. (1992). The Cross-Section of Expected Stock Returns. *Journal of Finance*, *47*(2), 427–465.

Fama, E. F., & French, K. R. (1995). Size and Book-to-Market Factors in Earnings and Returns. *The Journal of Finance*, *50*(1), 131–155.

Graham, J. R., & Harvey, C. R. (2001). The theory and practice of corporate finance: evidence from the field. *Journal of Financial Economics*, *60*, 187–243.

Hevert, K. T. (2001). Real Options Primer: A Practical Synthesis of Concepts and Valuation Approaches. *Journal of Applied Corporate Finance*, *14.2*(Summer), 25–39.

Hull, J. C. (2008). *Options, Futures, and Other Derivatives* (7th editio ed.). Prentice Hall.

Kester, W. C. (1984). Today's Options for Tomorrow's Growth. *Harvard Business Review*, *62*(2), 153–160.

Koller, T., Goedhart, M., & Wessels, D. (2010). *Valuation: Measuring and Managing the Value of Companies* (5th ed.). Hoboken, NJ, USA: John Wiley & Sons, Inc.

Longstaff, F. A., & Schwartz, E. S. (2001). Valuing American Options by Simulation : A Simple Least-Squares Approach. *The Review of Financial Studies*, *14*(1), 113–147.

Luehrman, T. A. (1998a). Investment Opportunities as Real Options : Getting Started on the Numbers. *Harvard Business Review*, *July-Augus*, 3–15.

Luehrman, T. A. (1998b). Strategy as a portfolio of real options. *Harvard Business Review*, *76*(5), 89–99, 187.

Modigliani, F., & Miller, M. H. (1958). The cost of capital, corporation finance and the theory of investment. *The American Economic Review*, *48*(3), 261–297.

Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics*, *5*, 147–175.

Myers, S. C. (1984). Finance Theory and Financial Strategy. *Interfaces*, *1984*(February), 126–137.

Panayi, S., & Trigeorgis, L. (1998). Multi-stage real options: The cases of information technology infrastructure and international bank expansion. *The Quarterly Review of Economics and Finance*, *38*, 675–692.

Pindyck, R. S., & Majd, S. (1987). Time to Build, Option Value, and Investment Decisions. *Journal of Financial Economics*, *18*, 7–27.

Putten, A. B. van, & MacMillan, I. C. (2004, December). Making real options really work. *Harvard business review*, *82*(12), 134–150.

Rabobank. (2012). *Rabobank Cijfers & Trends* (Tech. Rep. No. april). Author.

Rabobank International. (2012). *Unpacking the Dutch plastics packaging industry* (Tech. Rep.). Rabobank International.

Schwartz, E. S., & Moon, M. (2000). *Rational pricing of internet companies (Revised)* (No. January).

Smit, H. T. J., & Moraitis, T. (2010, February). Serial Acquisition Options. *Long Range Planning*, *43*(1), 85–103.

Smit, H. T. J., & Trigeorgis, L. (2004). Corporate Finance and Strategic Planning: A Linkage. *Princeton University Press*.

Smit, H. T. J., & Trigeorgis, L. (2006, September). Strategic planning: valuing and managing portfolios of real options. *R&D Management*, *36*(4), 403–419.

Smith, K. W., & Triantis, A. J. (1995). The Value of Options in Strategic Acquisitions. *Real Options in Capital Investment*, 135–149.

Triantis, A. J. (1999). A View Through a Real Options Lens. *Real Options and Business Strategy: Applications to Decision-Making*, 39–58.

Triantis, A. J. (2000). Real Options and Corporate Risk Management. *Journal of Applied Corporate Finance*, *64-73*(13.2).

Triantis, A. J. (2005). Realizing the Potential of Real Options: Does Theory Meet Practice. *Journal of Applied Corporate Finance*, *17*(2), 8–16.

Trigeorgis, L. (1988). A conceptual options framework for capital budgeting. *Advances in Futures and Options Research*, *3*, 145–167.

Trigeorgis, L. (1993). The Nature of Option Interactions and the Valuation of Investments with Multiple Real Options. *The Journal of Financial and Quantitative Analysis*, *28*(1), 1–20.

Trigeorgis, L. (1999). Real options: A primer. In J. Alleman & E. Noam (Eds.), *The new investment theory of real options and its implication for telecommunications economics se - 1* (Vol. 34, pp. 3–33). Springer US.

Trigeorgis, L. (2005). Making use of real options simple: An overview and and applications in flexible/ modular decision making. *The Engineering Economist*, *50*(June 2012), 25–53.

Appendix A

Glossary

The definitions below are derived from Investopedia[1] and modified if necessary.

Discounted Cash Flow (DCF) is a valuation method used to estimate the attractiveness of an investment opportunity. Discounted cash flow (DCF) analysis uses future free cash flow projections and discounts them (most often using the weighted average cost of capital) to arrive at a present value, which is used to evaluate the potential for investment. If the value arrived at through DCF analysis is higher than the current cost of the investment, the opportunity may be a good one.

Calculated as:

$$\sum_{i=1}^{n} \frac{CF_n}{(1+r)^n}; \text{ Where CF is cash flow and r is the discount rate}$$

The Discounted Cash Flow is often used in the Net Present Value calculation

Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyse the profitability of an investment or project. NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield.

Calculates as:

$$\sum_{i=1}^{n} \frac{CF_n}{(1+r)^n} - CF_0; \text{ Where CF is cash flow and r is the discount rate}$$

Note that above calculation is the same as:

$$DCF - CF_0; \text{ Where CF is cash flow and r is the discount rate}$$

Financial option is a financial derivative that represents a contract sold by one party (option writer) to another party (option holder). The contract offers the buyer the right, but not the obligation, to buy (call) or sell (put) a security or other financial asset at an agreed-upon price (the strike price) during a certain period of time or on a specific date (exercise date).

When an option writer writes respectively a call option, put option; he is in the possession of respectively a short call option, short put option. When an option holder buys respectively a call option, put option; he is in the possession of respectively a long call option, long put option.

Financial options can be either American or European. American options can be exercised at any time up to expiration date, whereas European options can be exercised only on the expiration date itself.

[1] Acquired on November 18, 2012

Hurdle rate is the minimum rate of return on a project or investment required by a manager or investor. In order to compensate for risk, the riskier the project, the higher the hurdle rate.

Least squares approach is a statistical technique to determine the line of best fit for a model. The least squares method is specified by an equation with certain parameters to observed data. This method is extensively used in regression analysis and estimation.

In the most common application – linear or ordinary least squares – a straight line is sought to be fitted through a number of points to minimise the sum of the squares of the distances (hence the name "least squares") from the points to this line of best fit.

Opportunity cost is the cost of an alternative that must be forgone in order to pursue a certain action. Put another way, the benefits you could have received by taking an alternative action. Explained otherwise, it is the difference in return between a chosen investment and one that is necessarily passed up. Say you invest in a stock and it returns a paltry 2% over the year. In placing your money in the stock, you gave up the opportunity of another investment - say, a risk-free government bond yielding 6%. In this situation, your opportunity costs are 4% (6% - 2%).

Sunk cost is a cost that has already been incurred and thus cannot be recovered. A sunk cost differs from other, future costs that a business may face, such as inventory costs or R&D expenses, because it has already happened. Sunk costs are independent of any event that may occur in the future.

P/E ratio is a valuation ratio of a company's current share price compared to its per-share earnings. In general, a high P/E ratio suggests that investors are expecting higher earnings growth in the future compared to companies with a lower P/E ratio.

Calculated as:

$$\frac{\text{Market Value per Share}}{\text{Earnings per Share (EPS)}}$$

Appendix B

Matlab code for 95% confidence plot

```

function [sigma,S] = waarde(FCF,VT,WACC)
T=length(FCF);
K=zeros(1,T);
for i = 1:T
    K(1,i) = FCF(1,i)/WACC^i; % Fill a matrix K with discounted values
end
S = sum(K);

%Continuous annual growth rates
annualgr = zeros(1,T-1);
for i = 1:T-1
    annualgr(1,i) = FCF(1,i+1)/FCF(1,i);
end
avannualgr = log(sum(annualgr)/length(annualgr)); %Calculate average growth rate
annualgr = log(annualgr);

%Calculate sigma from VT, assuming normal distribution
sigma = (log(VT/FCF(1,1))-sum(annualgr))/(2*sqrt(T-1));

%Calculate upper and down values
Upper_values = zeros(1,T);
Down_values = zeros(1,T);
Upper_values(1,1) = FCF(1,1);
Down_values(1,1) = FCF(1,1);
for i=2:T
    Upper_values(1,i) = FCF(1,i-1)*exp((annualgr(1,i-1))+2*sigma*sqrt(i-1));
    Down_values(1,i) = FCF(1,i-1)*exp((annualgr(1,i-1))-2*sigma*sqrt(i-1));
end

%Calculate smooth upper and down values
SUpper_values = zeros(1,T);
SDown_values = zeros(1,T);
SUpper_values(1,1) = FCF(1,1);
SDown_values(1,1) = FCF(1,1);
for i=2:T
    SUpper_values(1,i) = FCF(1,1)*exp((i-1)*(avannualgr)+2*sigma*sqrt(i-1));
    SDown_values(1,i) = FCF(1,1)*exp((i-1)*(avannualgr)-2*sigma*sqrt(i-1));
end


%Plot upper, down and normal values and smooth upper, down and normal
%values
figure;
x = 1:1:T;
subplot(1,2,1);
plot(x,Upper_values);
hold all;
```

```
plot(x,FCF);
hold all;
plot(x,Down_values);
title('Plot based on actual growth');
subplot(1,2,2);
plot(x,SUpper_values);
hold all;
plot(x,FCF);
hold all;
plot(x,SDown_values);
title('Plot based on average growth');
end
```

Appendix C

Company profile Bucket

Bucket's company profile is depicted on the next pages.

Bucket

Commercial

Business overview

- Bucket, founded in 1965, is an international niche packaging supplier, offering high added value through quality, functionality, user friendliness and design.
- Bucket is located in Delden, the Netherlands.
- The original company buildings date from 1971 to 1979; there have been significant renovations & expansions since 2002.
- Total surface of the facilities amounts to c. 50,000m2, of which 25,000m2 with buildings.
- The company currently employs 110 FTEs including management.
- Bucket is owned by management and a private equity firm.

Products & strategy

Product group

- Packaging
  - High-end / margin, niche position
  - Pharmaceutical & chemical key markets
  - Use: Intercompany transport and export
  - Long-term (locked-in) client relationships
- Material handling (project business)
  - Primarily Benelux
  - Agriculture and non-food / automotive
- Specialties (project business)
  - Concentrated customer base
  - Blue chip reputation

Goals

- Core business (yearly growth of 10-15%)
  - Geographical expansion (e.g. US & Asia)
  - Product development
  - Further penetration of customer base
- Consolidation, cash cow (project business)
  - Continue to serve loyal customer base
  - Focus on niche segments
- Consolidation
  - Capacity filler
  - Focus on one key client

Market position & clients

Niche player with few competitors	Bucket operates in a niche of the packaging market, in which there are a few competitors with a comparable high-quality product / service offering
High value industries	Bucket is focused on high value pharmaceutical and chemical industries for which Bucket obtained the highest necessary certifications securing the quality
Highly certified EU & US	UN certified; ISO 9001-2000, ISO 14001:2004; OHSAS 18001:1999; HACCP – Hygiene Management System; FDA – Drug Master File; Project GMP
Well diversified customer base	Bucket has a well diversified customer base of approximately 520 clients in 31 countries
Well organised sales channels	Clients are being delivered and serviced by sales offices in the Netherlands, Germany, Denmark, Norway, the UK, the US and selected resellers

USPs Bucket:

- Delivery speed
- Product quality
- Delivery accuracy

Bucket
Financial

Key financials
(EUR x million)

	2008A	2009A	2010LE
Revenues	41.4	37.2	39.2
Gross margin	25.0	24.0	24.8
As % of revenues	*60.4%*	*64.5%*	*63.3%*
EBITDA	6.0	7.4	7.3
As % of revenues	*14.5%*	*19.8%*	*18.7%*
EBITA	4.7	2.2	3.5
As % of revenues	*11.4%*	*5.9%*	*9.0%*
Capex	-2.6	0.0	-2.3

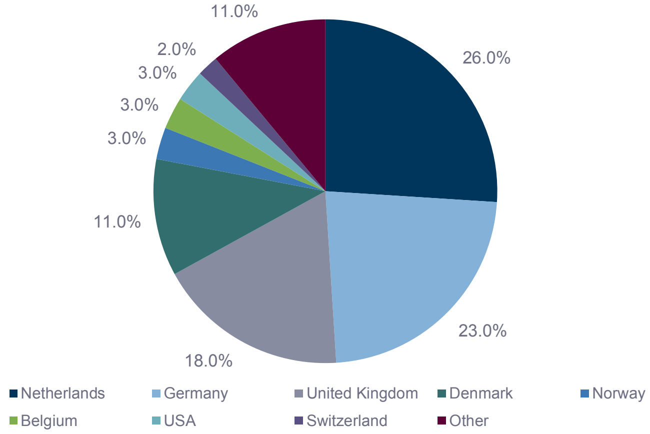
Remarks

- Generally capex include investments in own moulds and machinery.
- After 2005, the EBITDA margin significantly improved from 12% to 20% in 2009.
- Key drivers behind margin improvements are the higher margins generated in packaging and well-managed cost control.
- As a results of a cost reduction program, the EBITDA margin in 2008 remained 15% despite a sales decline of 8%.
- 2008 & 2009: Sales decline due to economic environment.
- 2009: No capex due to economic environment.
- 2010: Recovery of business and growth (Packaging + 13%).

Revenue split
(EUR x million)

	2008A	2009A	2010LE
Packaging	25.0	23.8	26.8
Material handling	7.4	5.6	6.2
Specialities	9.0	7.8	6.2
Total	41.4	37.2	39.2
Packaging	60%	64%	68%
Material handling	18%	15%	16%
Specialities	22%	21%	16%

Sales – Geographical



- USA sales have grown from 2.8% in 2009 to 4% of total sales to date 2010-October.
- Client A, Bucket's largest customer accounts for 6% of total sales corresponding to more than € 2m in 2009.
- Overall, Bucket has a well diversified customer base of approximately 520 clients.

Appendix D

Financial accounts Bucket

Bucket's financial accounts are depicted on the next pages. All the figures are in millions of Euros.

P&L

	Historical		
	2008A	2009A	2010LE
Packaging	25,000	23,800	26,800
Material handling	7,400	5,600	6,200
Specialties	9,000	7,800	6,200
Revenues	41,400	37,200	39,200
Packaging	(9,800)	(8,400)	(8,800)
Material handling	(3,000)	(2,000)	(2,800)
Specialties	(3,600)	(2,800)	(2,800)
COGS	(16,400)	(13,200)	(14,400)
Gross profit	25,000	24,000	24,800
Gross profit %	*60%*	*65%*	*63%*
Personnel expenses	(14,000)	(12,300)	(12,900)
Sales & marketing	(800)	(620)	(660)
General & administrative	(4,200)	(3,700)	(3,900)
EBITDA	6,000	7,380	7,340
EBITDA%	*14%*	*20%*	*19%*
Depreciation	(2,400)	(2,200)	(2,100)
Amortisation	(1,300)	(5,200)	(3,800)
EBIT	2,300	(20)	1,440
EBIT%	*6%*	*0%*	*4%*
Interest			(939)
Taxes			(125)
Net profit			376

Balance sheet	2009A	2010LE
Intangible fixed assets	14,272	10,472
Tangible fixed assets	9,336	9,556
TFA as % of revenues	*25%*	*24%*
Current assets	9,386	9,628
Current liabilities	(6,140)	(5,742)
Working capital	3,246	3,886
Working capital as % of revenues	*9%*	*10%*
Capital employed	26,853	23,914
Equity	7,561	7,937
Provisions	513	-
IB debt	21,603	19,021
Cash	(2,824)	(3,044)
Net debt	18,779	15,977
Financing	26,853	23,914