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Real Options in Small Technology-Based Companies

Stefan Kortner

A thesis submitted to the Department of General and Industrial Management, Technical University of Munich in partial fulfillment of *Diplom-Wirtschaftsingenieur*.

June, 2002

Munich, Germany

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Abstract

This thesis reports on the results of a research study conducted by the Institute for Information Technology, National Research Council, over the summer of 2001. The study assessed the relevance of an emerging valuation approach known as real options to small technology-based firms. The approach addresses evaluation of investment decisions under uncertainty by viewing a firm‘s ability to respond to changing conditions as a bundle of options that can be exercised at the right time and under the right conditions.

Interviews were conducted with the representatives of the six participating firms, who found the concept of real options appealing.

Systematically scanning different functional areas for possible sources of uncertainty can help identify viable option scenarios in a firm. The functional areas include operations, procurement, R&D, IP management, distribution, sales, after-sales, finance, strategic planning, marketing, and IT infrastructure. Such a methodology can help to reveal opportunities that may otherwise be overlooked or remain implicit.

The scenarios discovered in the firms under study involved staged investments, partnerships with lead customers, patents, arrangements for securing manufacturing capacity, flexible pricing strategies, make or buy decisions, design of a product to allow outsourcing, right to buy out licensed IP, IT infrastructure initiatives, and flexible core technology. Rudimentary quantitative analyses of selected option scenarios confirmed their potential value. Some classical option scenarios reported in the literature were rejected. For example, exit strategies were not deemed viable real options by start-up firms.

The real options terminology can be used to communicate the firm‘s strategy to the stakeholders. This approach can provide firms with a competitive advantage, especially in highly volatile climates.

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Chapter 1: Introduction

This thesis explores the applicability of an innovative valuation approach known as real options for the specific needs of small technology-based companies. The real options approach for valuation has advantages over traditional valuation techniques when flexibility in the face of large uncertainty is present. Research in the practical application of real options has been mainly focused on large-scale applications in large companies. This thesis reports on a study that was conducted with six small companies in the high-tech sector to assess if and in what form the real options approach can also be applied in small-technology based companies.

The thesis is organized as follows.

Chapter 1 starts with the motivation for this thesis. The special characteristics of small technology-based companies and their possible requirements for real option analyses are presented next. The main results of this thesis are outlined, and an overview over related literature is given.

The real options approach is explained in Chapter 2 as an innovative valuation technique that can be used both in the strategic planning and in the capital budgeting process of a company. This emerging approach has advantages over traditional techniques like decision tree analysis and discounted cash flow analysis in the treatment of flexibility. These traditional valuation techniques are discussed after a brief overview over different risk categories. Then the binomial option pricing model is explained using the economic principles of replication and arbitrage-free pricing. The challenges arising from the migration of the option pricing model from financial assets to real assets are presented together with possible solutions. The chapter ends with an overview over the current applications of real options.

Chapter 3 describes the interview process with the six participating companies and the lessons learned from the study. The difficulties in finding hidden option scenarios in the interviews have lead to an alternative, functional classification of real options that allows a company to be systematically scanned for possible real option scenarios. The functional classification is outlined in Chapter 4. Numerous examples of real options in small technology-based companies are presented in Chapter 5. The examples are organized according to the presented functional classification, and include some previously unknown option settings as well as familiar examples from the literature. The valuation of such options is demonstrated in Chapter 6 through two examples that have been discovered.

After some remarks about remaining practical limitations in Chapter 7, the conclusion in Chapter 8 summarizes the results. Numerous hidden options exist in small technology-based companies and these options are a very important part of the business of those firms. The suggested functional option classification has proven to be helpful in the discovery of the option scenarios.

1.1 Motivation

An emerging approach for evaluating investment projects and valuing entire companies stresses the potential of flexibility to create additional value under uncertainty. This approach, known as *real options*, is considered to be superior to traditional valuation techniques in its ability to capture the value of flexibility. The real options approach argues that flexibility has value if it can be used strategically to react to change. For this reason, the real options approach is theoretically attractive for all companies that operate in highly uncertain environments. These companies are located on the right-hand side in the portfolio in Figure 1.1.

There are important reasons to further distinguish between small and large companies. As the portfolio shows, the real options approach is already employed successfully in some large companies, while evidence of its potential use in small companies is nearly non-existent. Furthermore, academic research in real options has mostly ignored small companies.

One reason for this might be the scale of investments undertaken by large companies. Large scale creates proportionately significant improvement potential, which in turn justifies the extra effort expended on real option analysis. Thus the scale offered by small firms possibly was not deemed as attractive to achieve the desired level of impact. Consequently, most examples of real options have mainly been confined to contexts relevant to large corporations.

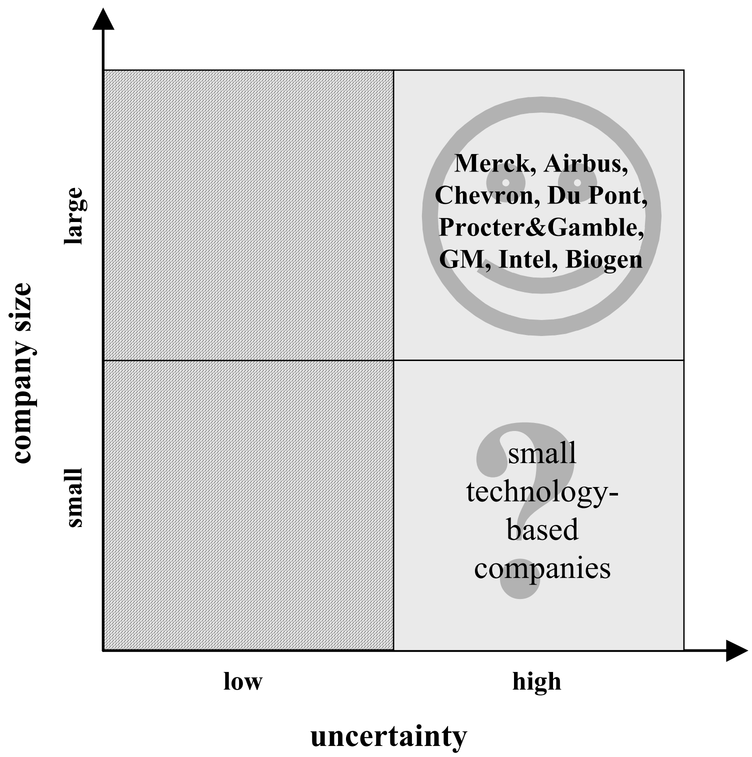

Figure 1.1: Applicability of the Real Options Approach to Different Types of Companies

There might also be a technical reason for the traditional focus on large corporations. The real options approach has its foundations in option pricing theory. Option pricing theory works best for financial assets whose risks are priced in the markets. The connection to the financial markets is usually stronger with large-scale problems because market proxies to the underlying real asset can more easily be found. With decreasing company size and scale, the connection to the financial markets deteriorates. This results in more serious violation of some fundamental assumptions in the valuation of real options.

In addition, small companies lack dedicated finance departments to perform complex valuation tasks. The scarcity and cost of experts prevents them from seeking outside help and exploring new techniques for their strategic planning. Many real option experts work as consultants who target large companies that can afford to pay for their expertise.

Advice is not only scarce, but also '*mostly aimed at specialists*' [1]. The real options literature criticizes that the *'theory has run ahead of practice'* [2], and that *'further empirical work has to be pursued to ensure the practical applicability'* [3].

With this background, it is desirable to analyze and possibly overcome these barriers that have prevented the real options approach to reach smaller companies. Small companies constitute an important and growing part of the economy, and many of them are driven by technological innovation. They operate in highly uncertain environments that suggest the use of the real options approach, and undiscovered options can be expected to exist in these companies.

It has been observed that especially *'new business ventures have the characteristics of growth options'* [4] and that the traditional approaches *'struggle to capture the outstanding growth prospects'* [5] and potential for shareholder value generation of technology-driven companies. Small technology-based companies have large growth potential, but don't have the resources for large commitments. They need leverage to grow, this leverage can possibly be provided by options.

Therefore small technology-based companies are promising candidates to participate in a scientific study that aims to broaden the range of applications for real options.

Two questions need to be answered in such a study:

1) Is the real options approach relevant for small technology-based companies?

2) If the answer is yes, then how can existing barriers be overcome?

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[1] Luehrman (1998), p. 51

[2] Dixit and Pindyck (1994)

[3] Perlitz, Peske and Schrank (1999), p. 267

[4] Willner (1995), p. 221

[5] Jaegle (1999), p. 272

1.2 Contributions and Main Results

The study has looked specifically for real options within small technology-based companies. The hypothesis that many applications for real options exist has been confirmed. The environment of those small companies is at least as uncertain as the environment of large companies, and small companies have comparable flexibility to react to change as large firms. They also appear to possess growth options, timing options, learning options, and other types of operating options present in large firms. Only the exit option type was generally rejected by small companies because its execution would mean the shut-down of the entire company.

It was observed that small companies are primarily interested in the real options approach as a way of thinking and not so much as an analytical tool for quantitative analysis. They appreciate that the real options approach provides a framework and a language that is able to model and to communicate important business issues. The interest in quantitative analysis concentrates mainly on occasions when a company licenses or sells a technology, because the options associated with that technology can be part of the deal.

Progress was also made in the methodology to identify option scenarios. The small companies that participated in the study had difficulties to relate to the popular option examples of large companies. They need to be offered examples of options that are closer to their own business. Scanning the company’s functional departments (e.g. production, R&D, distribution...) for choices to react upon uncertainty has been a successful way to suggest as well as to identify option settings. The discovered option examples are sorted and presented according to the new functional classification for two reasons. First, these examples show the relevance of the real options approach for small technology-based companies. Second, they can serve as templates that help other small companies to look for similar options in their own business. By employing this new, and ‘user-oriented’ methodology, a major barrier to the wider adoption of the real options approach – the identification of options – can be overcome.

1.3 Relevant Work

In a recent study, Triantis and Borison (2001) have identified and interviewed 34 companies that are using the real options approach. The study gives a good overview over the current practical use of the real options approach. The companies belong to differrent industries that have large uncertainties and high investments in common. Apparently all of the companies are quite large. There is no evidence for the use of real options in smaller companies.

The study of Triantis and Borison also reports that different companies are attracted by different features of the real options approach. Some companies are interested in real options as an analytical tool, others understand the approach as a way of thinking that allows to frame and communicate investment decisions, others have included the approach in the organizational planning process to identify flexibility. These features could be also presented to smaller companies as reasons to use the real options approach. The recommended procedure to introduce the real options approach to a company is via a pilot project.

Hommel (1999) presents a comparison of different valuation techniques and shows the benefits of using option pricing for investments under uncertainty. He draws on the analogies of real options to financial options (uncertainty, flexibility, irreversibility) to identify possible real option settings in business.

Luehrman (1998) recognizes the uniqueness of most business opportunities and thus the difficulty of finding option settings. He also notes that most of the input data for a real options calculation are available from traditional discounted cash flow analyses so that the additional effort for calculating an option is low.

There is a wide agreement in the literature about the classification of options. Hommel (1999), Amram and Kulatilaka (1999), Perlitz, Peske and Schrank (1999), among others promote a classification of options according to the type of flexibility they provide (e.g. exit options, timing options). Especially Perlitz, Peske and Schrank give a good overview over other distinctive criteria of options (e.g. discrete/continuous price movements, traded/not traded underlying). These categories are very helpful to choose the appropriate mathematical option model, once the option itself is identified. Amram and Kulatilaka state that uncovering real option scenarios has been difficult.

A comprehensive introduction into the real options approach can be found in the textbook of Trigeorgis (1996).

Chapter 2: Background

2.1 Basic Option Concepts

The real option approach builds on the formula discovered for the pricing of financial options. A financial option gives its holder the right but not the obligation to buy (or to sell) a certain amount of a financial asset in the future for a pre-determined price (called the strike price). The holder of the option will execute the option only if it is profitable, that is, when the market price is high. Otherwise, the option will be forgone. By this choice, the payoff function with respect to different market prices is no longer linear. The maximum loss is limited to the amount that was initially paid for the option (the option premium). The resulting payoff function typically has the form of a hockey stick and is shown in Figure 2.1.

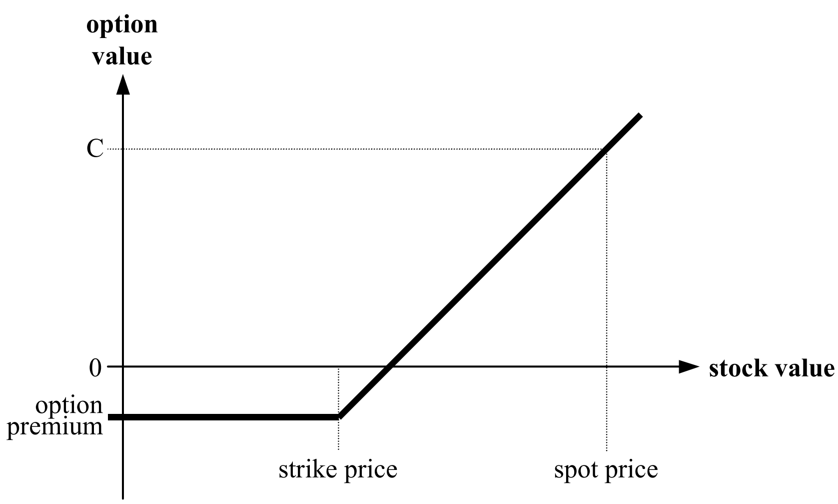

Figure 2.1: The non-linear payoff function ('hockey stick')[6]

The valuation of such an option to determine a fair option premium had been considered an unsolved problem for decades until the nobel-prize-winning work of Black, Merton and Scholes solved the problem in the early seventies. These three financial economists found an analytical solution to the value of a call option (the price to be paid to acquire an option to buy an asset) based on a standard model of asset price dynamics and on replication and no-arbitrage-arguments.

[6] Chatterjee and Ramesh (1999), p. 2

Later it was noticed that certain types of investments in real assets have similar non-linear payoff functions as financial options. These non-linearities result from managerial flexibility that can be taken advantage of to limit losses while retaining full upside potential of a business. The valuation of business opportunities with non-linear payoffs can be enhanced by the use of option pricing techniques. When option pricing techniques are employed correctly, the calculated option value represents the value of embedded flexibility. The more uncertain the economic and business environments are, the more valuable is flexibility.

Consider an intuitive example of a plane ticket. Usually, a plane ticket can not be refunded if the passenger gets ill and misses the flight. If the passenger already suspects that he might get ill, he may want to buy a refundable ticket instead. Thereby he would limit his loss in the case of illness. The choice to give back the ticket enhances its value, therefore it will be more expensive. The price difference is the value of the option to get the ticket refunded.

Similar options occur in strategy planning and in the capital budgeting process of companies. Whenever managerial flexibility is identified to react to an uncertain future, application of option pricing techniques and the underlying thinking to valuation of real assets could be used to capture the additional value of the flexibility. "*Used properly, the real options approach can identify important sources of value that are often missed or de-emphasized by the traditional DCF approach*" [7]. Majd and Pindyck maintain that the application of modern financial theory leads to a better microeconomic foundation for investment behavior[8].

2.2 Risk Categories

A brief discussion of risk is helpful for understanding the limitations of the traditional valuation techniques. These will be explained in the later chapters.

Risk is the exposure to uncertainty. Most investors are risk-averse, in that they would take extra risks only if they are sufficiently rewarded. Investors require a higher return for a stock whose returns are more uncertain than a government bond that pays out income tied to a

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[7] Faulkner (1998), p. 50

[8] Majd and Pindyck (1987), p. 8

fixed interest rate. The rate of return of an asset with minimal or no risk is called the risk-free rate. It represents the minimum rate of return required of any investment. This rate can be observed in the markets. For example in the U.S., the risk-free rate is determined by the yield of short-term government bonds or treasury bills. This benchmark parameter will be denoted by r.

By definition, other forms of investments bear higher risks. The returns on stocks of certain public companies, for example, are very uncertain. Therefore investors require higher returns on risky stocks than on safer investments. This forces the companies to earn at least the required return, relative to other assets in the market.

Several models establish a relation between risk and return. One of the most well-known models is the Capital Asset Pricing Model (CAPM)[9]. The model decomposes risk into systematic and unsystematic components. The systematic component of risk affects all assets in the market, the unsystematic component affects only individual assets. According to CAPM, the expected return of an asset is proportional to the systematic risk of that asset, that is the component that affects all assets in the market. Since investors can diversify away unsystematic, or private risk, CAPM maintains that capital markets do not reward bearing private risk. This position in turn influences the choice of the proper rate of return, or discount rate, for valuing risky investments. CAPM is adopted throughout this thesis as the underlying model for selecting the proper discount rate in any quantitative analysis.

Even in the traditional valuation techniques like Discounted Cash Flow (DCF) and Decision Tree Analysis (DTA), the treatment of risk is a complicated problem that presents itself in the selection of a proper discount rate. The discount rate is used to transform future cash flows to present values and should reflect the cost of the employed capital. Because the capital markets do not reward private risk, companies should use a discount rate that reflects only the systematic component of risk present in a business.

It may however be inappropriate to use a single discount rate even within a single project. The actual level of risk may vary substantially in the different phases of a project (for example

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[9] Ross, Westerfield, Jordan and Roberts (1996)

in research, development, commercialization)[10]. Risk often declines in later phases, resulting in excessive risk-adjustments when the discount rate is kept constant throughout the entire business case.

2.3 Discounted Cash Flow (DCF)

The advances in understanding how capital markets work and how risky assets are valued have been transferred to capital budgeting techniques. In particular, Discounted Cash Flow analysis is a widely used technique that has been derived from finance theory[11].

‘DCF spreadsheets are at the heart of most corporate capital-budgeting systems’ [12]. A survey in the year 1994 showed that 95% of the participating companies indicated that DCF analysis was either very important or somewhat important in getting a project accepted[13].

‘The fundamental idea of the discounted cash flow approach is that the value of a project is defined as the future expected cash flows discounted at a rate that reflects the riskiness of the cash flow’ [14]. The discount rate should take into account the systematic risk of the cash flows, that is the extent to that cash flows are correlated with the market as a whole.

Discounted cash flow analysis involves two steps:

1. Coming up with the best estimate of the cash flows over a time horizon
2. Discounting these expected cash flows back to the present time at a risk-adjusted discount rate.

The result of a DCF analysis is also called the Net Present Value (NPV). The formula for calculating the NPV is:

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[10] Hodder and Riggs (1985)

[11] Myers (1984), p. 126

[12] Luehrman (1998), p. 51

[13] Flatto (1996), p. 2

[14] Copeland, Koller and Murrin (1990)

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+k)^t} - I$$

C_t = forecasted cash flow for period t

T = project lifetime

k = opportunity cost of capital

I = investment required at t = 0

The NPV rule says that a project should be executed if its net present value is greater than zero. If all alternative projects have positive NPVs then the alternative with the highest NPV should be chosen.

'The discounted cash flow method has become the standard for valuing bonds, stocks and other fixed-income securities. It is especially sensible for relatively safe stocks which pay regular dividends' [15].

DCF analysis applied to a company or project valuation makes an implicit assumption concerning the expected scenario of cash flows. DCF analysis can evaluate only the actual cash flows a project is expected to yield, not taking into account any flexibility that might influence the cash flows.

'DCF analysis does not explicitly recognize that managerial flexibility has a value' [16]. It usually *'underestimates investment opportunities because it ignores management's flexibility to alter decisions as new information becomes available'* [17].

Therefore DCF is not as helpful in valuing companies with significant growth opportunities like technology start-ups. *'The DCF approach is likely to be more useful for cash cows than for growth businesses with substantial risk and intangible assets'* [18].

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[15] Myers (1984), p. 134

[16] Benaroch and Kauffman (2000), p. 200

[17] Flatto (1996), p. 2

[18] Myers (1984), p. 134

The importance of choosing an appropriate valuation method is underlined by the statement that *'an uncritical acceptance of the sometimes subtle implications of DCF can lead the way into strategic error'* [19].

2.4 Decision Tree Analysis (DTA)

'The decision tree analysis helps management to structure a decision problem by mapping out all feasible alternative actions over time contingent on uncertain events in a tree-like manner' [20]. It provides a significant conceptual improvement over the way that DCF analysis handles uncertainty and flexibility[21]. A decision tree like the example in figure 2.2 shows the expected payoffs that are contingent on future states of the environment and on future decisions of the management.

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[19] Faulkner (1998), p. 50

[20] Trigeorgis and Mason (1988)

[21] Benaroch and Kauffman (2000), p. 200

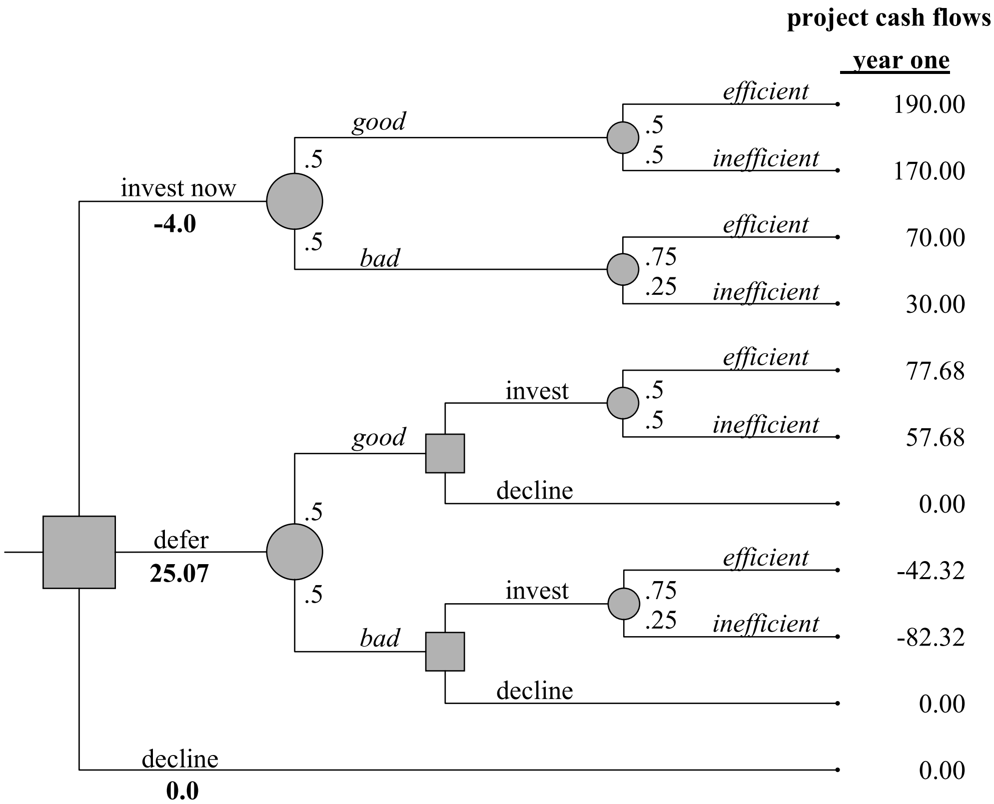

Figure 2.2: Example of a Decision Tree[22]

Branching can occur in the tree either in form of an event node to map out different outcomes of the environment or in form of a decision node that represents a specific decision. To each branch a probability is associated. Many large companies maintain a database of past projects that aid with probabilistic estimates[23]. To solve the decision tree, the calculation is started at the terminal date, recursively computing the expected payoffs while choosing the best decisions. The Net Present Value, incorporating the benefits of flexibility, is the value associated with the root of the tree.

The main shortcoming of DTA is the problem of determining the appropriate discount rate to be used in working back through the decision tree. The flexibility represented in each decision node is equivalent to an option. By this flexibility, the probability distribution of the projected payoffs is changed. *'A single discount rate cannot be used since asymmetric claims*

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[22] Smith and Nau (1995), p. 804

[23] Boer (2000), p. 3

on an asset with limited downside risk and unlimited upside risk do not have the same expected rate of return as the underlying asset itself' [24].

The adjustment of the discount rate according to the probability distribution is accomplished by option pricing techniques. Therefore option pricing is claimed to be superior to decision tree analysis if DTA is applied naively[25]. If both option pricing and decision analysis are applied correctly, they must give consistent results[26].

2.5 Financial Options

A discussion of financial options will help to understand how real options work. A financial option gives its holder the right, but not the obligation, to buy or sell a financial asset before or on a specific day for a predetermined price, called the strike price. An option to buy an asset is referred to as a *call option*. A *put option* gives its holder the right to sell an asset. The asset on which the option is written or based is called the *underlying*. If the exercise of the option is only possible at the *expiration date* in the future, the option is called a *European option*. If the exercise is possible at any time until the expiration date, the option is called an *American option*.

The holder of an option always has the choice to exercise the option or not. In advance, it is not possible to tell whether the option will be exercised or not, because this decision is contingent on the value of the stock in the future, which is uncertain. In some cases the exercise of the option will be profitable, in some other cases the exercise would lead to a loss. For example, the exercise of a call option will be profitable if the future market price of the asset is higher than the strike price. In this case the option would be exercised. If the future market price falls below the strike price, exercise would lead to a loss, so the option would expire worthless.

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[24] Chatterjee and Ramesh (1999), p. 2

[25] Copeland, Koller and Murrin (1990)

[26] Smith and Nau (1995), p. 795

For several reasons, options have been introduced to the financial markets. Speculation, which is often associated with options or derivatives, is only an inevitable side-effect. Options can be used as an insurance against price uncertainty of stocks. For example, the holder of a stock of a public firm can buy a put option on that stock, allowing him to sell this stock for a floor price if the stock value drops sharply. Options can also act as an insurance against drops or raises in foreign currencies. Their main feature is a non-linear payoff, limiting downside potential while maintaining full upside potential. The maximum loss is limited to the purchasing price of the option. Options can also be thought of as levered positions on the underlying asset. For example, one can synthesize a call option by partly financing the purchase of the underlying asset through a risk-free loan. In turn, options have greater financial risk than the underlying asset.

Options have value because they give the holder a chance on some future profits. The practical calculation of the option value remained impossible until the path-breaking work of Black, Merton and Scholes in the early seventies. Several economic insights and arguments were linked together which allowed for the valuation of standard financial options. *'The breakthrough in option pricing theory resulted in a valuation technique that circumvented the need to estimate risk-adjusted discount rates for financial options'* [27]. The technique was adopted soon as a possible tool for valuing contingent claims due to the deficiencies of existing techniques[28].

2.6 Binomial Model

Each option is written on an underlying asset. The future payoff of the option depends on the future price of the asset. Therefore, the current price of the asset and estimates about its future development are very important inputs for option pricing. Models of option pricing typically begin with the specification of how the prices of the underlying assets evolve over

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[27] Triantis and Borison (2001), p. 12

[28] Lindt and Pennings (1997), p. 84

time. The objective is then to identify the price of an option, taking the behavior of the underlying process as a given[29].

The formula of Black and Scholes is a closed-form solution that computes the value of a European call option. It assumes that the value of the underlying asset follows a *lognormal diffusion process*, or *Geometric Brownian Motion*. The binomial model can be viewed as a discrete-time approximation of the Black and Scholes model. The binomial model is easier to understand and more suitable for modeling complex options[30]. McGrath emphasizes that the underlying asset on that the option is written must be priced, and that this price must be known[31].

Suppose that the underlying asset is the stock of a public firm. The current stock price is denoted S. Its value is known because it can be observed in the financial markets. After one period, the stock can have only two possible prices. The higher price is denoted by S^+, the lower price by S^-. The ratio of S^+ to S is called the upward factor, denoted by u, and the ratio of S^- to S is called the downward factor, denoted by d.

In reality, the stock can assume an infinite number of possible prices after one period. By linking several binomial periods together, more realistic distributions of the stock price can be created.

The volatility σ is a measure of the total risk of the stock. It can be used to capture the uncertainty surrounding the price movement. The volatility is usually estimated using historical performance data of the stock. For the binomial model, a valid combination of u- and d-factors can be computed according to

$$u = e^{\sigma} \quad \text{and} \quad d = \frac{1}{u}.$$

Then, the development of the underlying stock from the beginning to the end of the period can be written as

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[29] Sundaram (1997), p. 85

[30] Cox and Ross and Rubinstein (1979), p. 229f

[31] McGrath (1997), p. 975

$$S \qquad \begin{array}{l} S^{+} = u \cdot S \\ S^{-} = d \cdot S \end{array}$$

At the end of the period, the net payoff of the option conditional on its exercise is the stock price minus the strike price. If the payoff is negative, the option will not be exercised and its future value becomes zero, thus creating a nonlinear payoff function.

The future values of the option are denoted by C^+ and C^-, and its present value by C.

$$C \qquad \begin{array}{l} C^{+} = \max(S^{+} - X, 0) \\ C^{-} = \max(S^{-} - X, 0) \end{array}$$

When the two possible developments of the stock, S^+ and S^-, and the strike price X are known, then the future option values C^+ and C^- are also known. To calculate the present value of the option C, two economic arguments can be used: *replication* and the *law of one price* (no arbitrage).

In the binomial model, it is always possible to find a portfolio of primitive securities that exactly replicates the option's payoffs at any state. This portfolio consists of the underlying stock itself and of a risk-free asset, such as a bond or a risk-free loan. These two securities are sufficient to complete the market. There are two possible states of the world and two linearly independent securities. *'Every risky cash flow can be represented as a linear combination of the payoffs of these two securities'* [32]. The value of the bond develops with the risk-free interest rate r. Its present value is set equal to one, after one period it will have the value r. The development of the stock is also assumed to be known in the binomial model. If the future value of the portfolio is known, its present value is also known. Then, by the law of one price, the current option value C must be identical to the present value of the replicating portfolio. *'This procedure is economically correct in that it is guaranteed to deliver arbitrage-free prices'* [33].

The components of the replicating portfolio, the number of the shares of the stock and the amount borrowed in the risk-free bond, need to be further specified. Let N denote the number

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[32] Smith and Nau (1995), p. 799

[33] Black, Fischer and Scholes (1973)

of units of the underlying stock to buy and B the amount to be borrowed at the risk-free rate. The replication ties the value of the portfolio to the option value, the law of one price serves as a bridge from the future values to the present value. Figure 2.3 illustrates this solution.

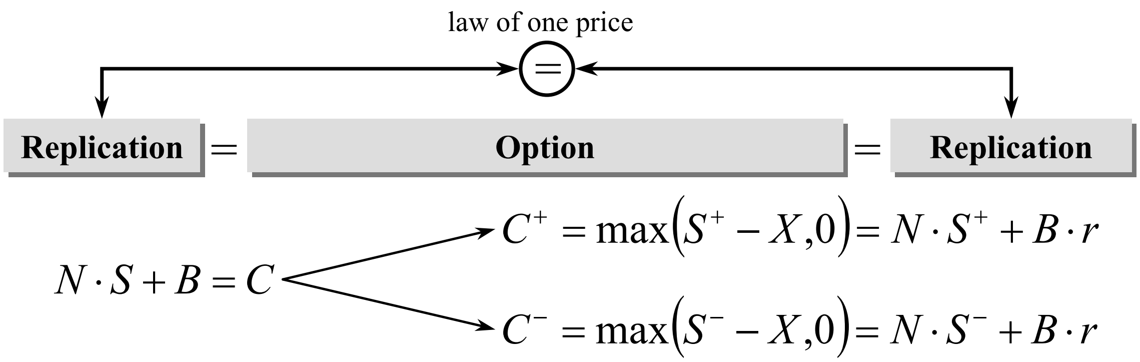

Figure 2.3: Option Pricing by Replication and the Law of One Price

In this formula, three variables are unknown: C, N and B. Therefore, three equations are needed to solve for the unknowns. These three equations are:

$$
\begin{aligned}
C &= N \cdot S + B \\
C^+ &= N \cdot S^+ + B \cdot r \\
C^- &= N \cdot S^- + B \cdot r
\end{aligned}
$$

Solving these equations yields for the unknown C:

$$C = \frac{\frac{r-d}{u-d} \cdot C^+ + \frac{-r+u}{u-d} \cdot C^-}{r}$$

This formula can be rewritten as:

$$C = \frac{p \cdot C^+ + (1-p) \cdot C^-}{r}$$

by introducing:

$p = \frac{r-d}{u-d}$ and $(1-p) = \frac{-r+u}{u-d}$.

If the upward and downward factors fulfill the condition d < r < u to prevent arbitrage, then p and (1-p) are greater than zero and less than one, so they have the properties of a probability. The measures p and 1-p are called the risk-neutral probabilities (or also martingale measures), because they would be equal to the actual probabilities if the investors were risk-neutral. Using the risk-neutral probabilities enables a test of consistency in model specification, because inconsistently specified models permit arbitrage opportunities. An arbitrage opportunity represents a free lunch, the creation of something out of nothing. *'It can be shown that a model of option pricing is complete if, and only if, the model admits exactly one risk-neutral probability'* [34].

Hence the option pricing using the binomial model relies on the input parameters shown in Table 2.4.

S	Present value of the stock
(S^+, S^-) or (u, d) or σ	Estimations about the stock's future development
X	Strike price
r	Risk-free interest rate

Table 2.4: Input Parameters of Option Pricing

For financial options, these input data can be either observed or estimated easily. The present value S of the stock can be observed in the financial markets because stocks are traded continuously. The strike price X can be chosen deliberately, so once it is chosen, it is also known. The risk-free interest rate r can be observed as the yield of short-term government bonds. For the future stock development, historical data of the stock prices can provide a sufficient estimate of the volatility.

2.7 Migration from Financial Options to Real Options

The technique to value financial options can also be used to value real options. While financial options are written on an underlying financial asset, a real option is based on an underlying real asset. Similar to a financial asset, the future value of the underlying real asset is uncertain. The first examples of real options were found in businesses where the underlying real assets are close to the market. Financial assets are traded, that means that a current

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[34] Sundaram (1997), p. 86

price can be observed in the markets, as well as a series of historical prices from which the volatility σ of the asset can be derived. The financial markets are also assumed to be efficient, which means that all available information about the future development of the asset is already reflected in the market price. Real assets that behave very much like financial assets are for example the right to drill for crude oil (that is correlated with the future oil price), and real estate. Oil is traded in a market, thus a spot price and information about its volatility exists. Real estate is also traded, meaning that the market attaches a price to it. Information about the future prices is also already included in the spot prices. For example, if it was believed that the future oil price will rise because of a shortage, the spot price will also rise accordingly. The closeness to the market of some real assets enable the application of option pricing techniques to option-like situations in these businesses. For example, once an oil field has been developed, the oil price can be relatively high so that exploration is profitable. The oil price could also be so low that exploration would lead to a loss. In this case, the oil company would choose not to exploit the oil and to wait until the oil price has climbed again. The liberty to choose between exploiting and not exploiting is valuable because it protects the company from losses due to the uncertain price of oil. The value of this option would be impossible to capture with traditional DCF analysis. It can be calculated using option pricing techniques and added on top of the DCF to compute a total value of the oil field development.

Since these early examples, the option pricing techniques have spread into other businesses, where the behavior of the underlying assets diverge from traded financial assets. New popular applications of real options are in research and development, with the idea that a newly developed technology leads to the option to develop a product. The developed product itself gives the option to market it in the case that markets are favorable. Here, the underlying assets have different properties than financial assets. *'A striking problem that arises from the observation that the underlying asset of a real option is non-traded concerns the estimation of the volatility of the underlying asset. In contrast with financial options, there are no historic time series that enable to estimate the uncertainty of the underlying asset'* [35]. For example, the underlying of an option to market a new product is the revenue based on the market volume. If the demand and thus the market volume is high, it will be profitable to launch the new product. If the demand is low, the product will not be launched. To model the

[35] Lindt and Pennings (1997), p.84

underlying, the present value of the future market volume with its volatility must be estimated. These values are sometimes very hard to estimate, because the underlying is not traded. Two techniques are used to find estimates for the volatility, known as spanning and hotelling[36].

'The so-called spanning duplicates a non-traded asset by a twin security' [37]. The twin security is also often called a proxy. It is a traded asset or a portfolio that is highly correlated with the actual underlying. Such a portfolio is called a tracking portfolio because it tracks the volatility of the target market. The pharmaceutical company Merck uses its own stock volatility as a proxy for the volatility of the NPV of future cash flows resulting from new products[38]. For the option to wait before developing land, real estate companies use data on land transactions to get an estimate of the volatility[39]. Other businesses opportunities, especially technology-based projects, are unique, so the likelihood of finding a similar asset is low[40]. In these cases, hotelling can be used.

'Hotelling Valuation is to estimate the market potential for the product and then try to evaluate this potential and use it as the underlying' [41]. The expected value of the underlying can be found in the traditional DCF spreadsheets that are commonly prepared to evaluate investment proposals[42]. The minimum and maximum boundaries of the future values of the underlying are explicitly estimated, using judgements of the senior management to attain reasonable values for the uncertainty[43]. In complicated cases, the estimation can be aided by

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[36] Perlitz and Peske and Schrank (1999), p. 259

[37] Pindyck (1993)

[38] Nichols (1994)

[39] Quigg (1993)

[40] Luehrman (1998), p. 52

[41] Sick (1989)

[42] Luehrman (1998), p. 51

[43] Lindt and Pennings (1997), p. 85

a Monte Carlo simulation that synthesizes a probability distribution function for project returns[44].

Then, still an estimate for the discount rate is needed to bring the uncertain future values back to the present. The discount rate has to reflect the riskiness of the underlying, more precisely the systematic component of its risk. It is argued that any spreadsheet that computes NPV already contains the information necessary to compute S (and X)[45]. This is correct if a proper discount rate has been used.

In different real-world settings, different data can be collected. Sometimes this data is not exactly what option pricing techniques require as an input. The data needs to be transformed into the input parameters of the option calculation. For example, Figure 2.5 gives an overview over different sets of input parameters that are sufficient for the binomial model.

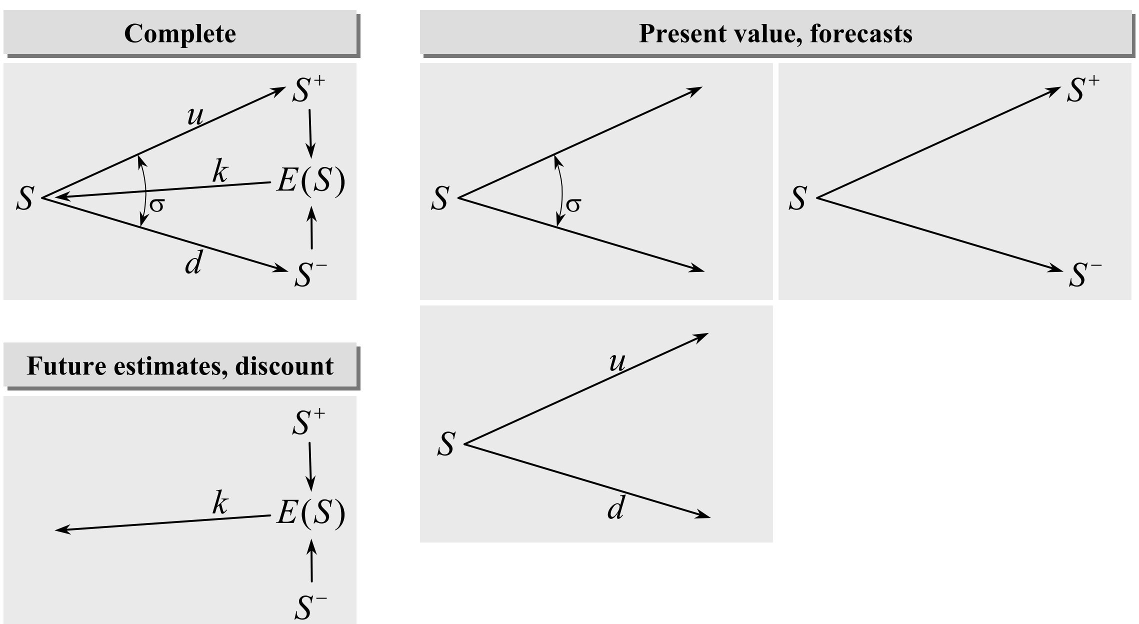

Figure 2.5: Relations between Alternative Input Parameters of the Binomial Model

In the upper left corner, the relationships among alternative input parameters are shown. If only some of them are known, the rest can sometimes be calculated. In some cases the present value of the underlying S and forecasts about the future are available. This is the

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[44] Luehrman (1998), p. 58

[45] Luehrman (1998), p. 53

case for example with stock options. The present value S can be observed in the stock market, and the historic volatility gives an estimate about the future volatility σ. Under the assumption of lognormal diffusion[46], knowing σ is equivalent to knowing the upward factor u and the downward factor d of the binomial model. With these factors, the future values of the underlying S+ and S- can be calculated. These three cases of knowing the present value and having estimates about the future are equivalent and can be interchanged.

The situation is more complicated if no present value can be directly observed. In all real option applications that are not based on traded underlying assets, a discount rate k is needed to calculate the present value. This is especially true for real options in small technology-based companies. It is the same problem as in the calculation of the DCF. A practicable way is to start with the expected future value of the underlying E(S). This estimate will be readily available from sales forecasts for example. *'It is assumed that unbiased estimates of cash flows are provided. Clearly, this assumption is also used in all discounted cash flow studies'* [47]. The next step is to estimate the best case S^+ and the worst case S^- of the future value of the underlying. Hotelling and spanning does not work in this case because they start from the present value, which is not known in this case. Therefore explicit assumptions about S^+ and S^- need to be made. Then, a discount rate k is needed to calculate the present value. The discount rate should reflect the market risk of the underlying asset.

2.8 Recent Applications of Real Options

The field of applications for the real options approach has been continuously expanded in the last years. One of the earliest and most popular examples was found in the oil industry, only a few years after the publication of the option pricing formula by Black, Merton and Scholes in 1973. A lease on land provides the option to drill for oil. *'If an exploration project is successful, a company has the option to drill wells and pump oil. If the project doesn't pan out, the company has the option to cease development and cut its losses. The option increases the value of the exploration project because it protects the full potential gain of the*

[46] Cox, Ross and Rubinstein (1979)

[47] Lindt and Pennings (1997), p. 85

investment while reducing the possible losses' [48]. Another early example was the valuation of gold mine reserves that provide the option to extract gold if the gold prices are favorable[49]. These first examples of real options were appealing because of their close proximity to the financial markets. In these examples, *'the value of the underlying asset depends on price movements of natural resources'* [50]. This means practically that the prices are observable in markets. The present value can be used directly as an input for the option pricing formula, the historical development of the price can be used to compute the volatility. After more than two decades of application, the real options approach is not limited anymore on projects based on natural resources. Although the first examples remain very popular, applications in other industries have been found. The viewpoint that *'current applications of real options mainly concern investment projects dependent on natural resources'* [51] is being outdated by many examples from the high-tech sector.

Examples of real options have been found in many industries and in many different settings. Figure 2.6 gives an overview over industries in which the real options approach is already used, with examples of companies that participated in a recent real options survey[52].

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[48] Amram and Kulatilaka (1999)

[49] Brennan and Schwartz (1986)

[50] Brennan and Schwartz (1985)

[51] Lindt and Pennings (1998), p. 3

[52] Triantis and Borison (2001)

Financial Services	Credit Suisse First Boston, Morgan Stanley
Real Estate	Beazer Homes
Energy	Anadarko, Chevron, Cinergy, ConEdison, Conoco, Constellation Power, Dynergy, El Paso, Enron, Lakeland Electric, Ontario Power Generation, Texaco, Wisconsin Public Service Corporation
Consumer & Industrial Products	DuPont, LLBean, Procter & Gamble
Transportation	Airbus, Boeing, British Airways, Canadian Pacific, General Motors
High Tech & Infocom	Hewlett Packard, Intel, Rockwell, Sprint, Ultratech
Life Sciences	Amgen, Genentech, Genzyme

Figure 2.6: Companies using Real Options

The energy sector is very comparable to the oil industry because natural resources are used as a source of power, and on the other side the energy is traded in a market where energy prices can be observed. The observation of prices is also possible for real estate. The pharmaceutical industry is already using real option models frequently in capital budgeting[53]. The return of a new drug is highly uncertain and calls for innovative valuation techniques. One of the pioneering companies in that industry is Merck[54]. The pharmaceutical industry can be seen as a sector of the more general life sciences industry. There are also examples from the transportation industry, consumer and industrial products, and high-tech industries.

All of these industries have in common that large investments need to be made, and that the returns are very uncertain. The expansion of the real options approach into engineering-driven industries was favored by the experience and history of these companies in the internal use of analytic tools[55].

The following list gives an impression of the abundance of possible option settings. If not noted otherwise, the examples are taken from Trigeorgis (1996).

- Property rights are an option to extract mineral reserves.

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[53] Axel and Howell (1996)

[54] Nichols (1994)

[55] Triantis and Borison (2001), p. 5

- A patent gives the option to develop a new product.
- In a production facility, the option to expand can be contained. By making an additional investment outlay higher revenues can be obtained.
- Building a plant with lower initial construction costs and higher operating costs creates the flexibility to contract operations by cutting down on operating costs if the product turns out to do worse than initially expected.
- Some productions offer the possibility to shut down the production or not to operate temporarily if the cash revenues are not adequate to cover the variable costs of operating. This represents a call option on that year's cash revenue, the exercise price is the variable cost of operating.
- Option value can exist in the ability to terminate a project, selling the assets on the secondhand market for their salvage value.
- Flexibility in inputs (electricity, gas) and outputs (chemicals) of a facility can contribute to its value.
- An acquisition of an unrelated company can be undertaken for the sake of optional access to an new market.
- A research project, if successful, provides at completion the opportunity to acquire the revenues of the developed, commercialized product upon incurring a production outlay.
- If a lead customer gives a guarantee to purchase or a guarantee on minimum prices, the probability distribution of the payoffs becomes nonlinear, reducing risk.
- Corporate liabilities can be viewed as call or put options on the value of the firm.
- Outsourcing a project transfers the risk of a project failure to other parties, reducing downside risk and creating a nonlinear payoff.[56]
- Option valuation can be used to calculate how much to spend on lobbying, thereby actively changing the boundary conditions of an option.[57]

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[56] Benaroch and Kauffman (1999)

It has been observed that although real options appear in a large number of settings, *'they tend to take a limited number of forms'* [58]. The literature has established a classification of real options that distinguishes among timing options, growth options, staging options, exit options, flexibility options, operating options, and learning options[59].

- Timing options give the flexibility to choose a favorable time for a decision.
- Growth options provide a company with the strategic chance to expand into new markets or businesses.
- Staging options are created by dividing long-term projects into phases. After each phase, the option to continue will be exercised if the previous phase was successful.
- Exit options act like an insurance. They provide the chance to sell off an unprofitable business for its salvage value.
- Flexibility options give the choice between different inputs and outputs of a production process.
- Operating options in a production process give the ability to shut down a production temporarily or to change the production volume in favorable and unfavorable times.
- Learning options can be used to defer a project or an investment to wait for the arrival of new information for a better decision.

This classification has been made according to the type of the management's reaction upon the uncertainty. It helps to communicate the idea of real options to the management because frequent decisions of the management are addressed.

Although the real options approach originated from the pricing of financial options, the calculation of an option value is not the only way real options are used in companies. A recent

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[57] McGrath (1997), p. 974f

[58] Amram and Kulatilaka (1999), p. 96

[59] Amram and Kulatilaka (1999), p. 96

survey[60] has identified three purposes for which the real options approach is used in different companies.

1. Real options can be understood as a way of thinking. In these cases, real options are primarily used as a language that frames and communicates decision problems qualitatively.
2. Real options are used as an analytical tool. The option pricing models are mainly used to value projects with known and well-specified optionality.
3. Real options are included as a part of the organizational process. Real options are used as a management tool to identify and exploit strategic options.

The survey also reports on the relevance of the real options approach:

‘For the great majority of firms, real options is not viewed as a revolutionary solution to new business conditions. Instead, it is seen as part of an evolutionary process to improve the valuation of investments and the allocation of capital, thereby increasing shareholder value. The adoption of these techniques is viewed as providing a competitive advantage through better decision-making. For other firms, real options is perceived as a dramatic departure from the past that has the potential to alleviate important concerns, manage critical business risks, or reveal exciting growth opportunities’ [61].

[60] Triantis and Borison (2001), p. 6

[61] Triantis and Borison (2001), p. 4f

Chapter 3: The Interview Process

Several small technology-based companies were asked to participate in the study underlying this thesis. At the time of the interviews, all of the companies were in the beginning of their lifecycle and had not yet reached their maturity or market saturation. They pioneered technologies that had just left research stage or entered the commercialization stage.

Therefore, in each company a significant amount of uncertainty about the future could be expected. A series of interviews was held with six such companies. The purpose of these interviews was to introduce the real options approach to the companies, and to assess the relevance of the approach for each company.

The initial interview strategy consisted of five steps:

1. Present a simple and intuitive option example to communicate the concept.
2. Explain uncertainty and flexibility as preconditions for options.
3. Ask for option scenarios within the company.
4. Solve the option scenarios.
5. Present the results to the company and obtain feedback.

A variety of key people from each company were addressed. Their acceptance and knowledge of the real options approach and their understanding of it varied widely. The idea and purpose of real options and of option pricing was found to be very difficult to communicate to technically oriented people. The middle management was more ready to accept the concept of real options. People from the top management (CEO, CFO) had mostly already heard about option pricing. Especially CFOs were mostly already familiar with the well-known Black-Scholes formula in the context of financial options.

As a first step, the interviewed people were presented a basic and intuitive example of real option valuation, followed by the explanation of uncertainty and flexibility.

Purely technically oriented employees tended to challenge the real options approach. This was also helpful for the study, because it showed main points of criticism that can be held against the real options approach, which needed to be clearly addressed if the real option approach was to become more popular. In particular, the interviewees asked what advantages the real options approach has over established techniques. The interviewer explained that DCF doesn’t capture the value of future decisions based on uncertainty at all. DTA is able to include future decisions, but it needs to be pointed out that the naïve DTA always uses the same discount rate for the payoffs, which might be wrong. In this sense, option pricing should be explained as an ‘economically corrected decision tree analysis’, that takes into account that risk changes over time, and that the discount rate also varies.

Another critical question was the purpose and relevance of employing real options. The ultimate answer to this question must lie in the making of improved decisions. The decisions will be tied closer to the financial markets, allowing *‘a more accurate valuation of alternatives and thus more educated decisions in the face of uncertainties’* [62]. But besides quantitative valuation, the real options approach was also explained as a way of thinking, providing appropriate vocabulary to frame and communicate important parts of a decision under uncertainty. Also, the real options approach can be embedded in the managerial process to look specifically for chances within uncertainties.

The top and middle management did not challenge the real options approach at all. The benefits of real options were clearly understood and readily accepted, but here the obstacle was a different one. After hearing the initial basic example of a real option, the most common response was that the example was appealing, but that similar situations did not exist within their own companies.

The first interviews revealed that the companies need to be offered a finer grid of option examples. In the follow-up interviews they were shown a known classification of possible real options examples, categorized according to their impact on business (growth options, time-to-build options, options to defer, options to change scale, options to switch input or output, and exit options). This classification was an attempt to suggest templates to relate to. It was not helpful in discovering option scenarios, because the option examples in this classification were relevant mostly for large corporations in specific industries, such as real estate, natural resources and pharmaceutical, and did not capture typical problems of small, technology-based companies. For example, the exit option was consistently received as a kind of “suicide” strategy, and therefore rejected. Large companies are able to dispose of a single

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[62] Amram and Kulatilaka (1999)

project and re-allocate the resources easily, but for small start-up companies that often focus on a specific product or product line, failure is not an option.

Thus it became evident that existing templates or examples of real options did not appeal to small technology-based companies. Moreover, the companies were obviously not yet ready to identify option scenarios by themselves. Therefore a different methodology of screening for option scenarios that suited better to the context of the companies under study, was needed.

To get an insight into the biggest uncertainties and the most difficult decisions of the companies, the interviewees were asked about their historic development path. Then, this information was used to form hypothetical option scenarios, which were presented to the companies. Even if these suggested options did not actually exist, they were closer to the companies' businesses than the previously mentioned examples from oil and pharmaceutical companies. They helped to direct the companies' attention to specific topics and to discover true real option scenarios. For example, a chip-design company without manufacturing facility was presented the hypothetical option to build such a facility. It was assumed that the company could build a facility at any future time whenever it would be profitable. The option would be executed if demand was high, and the option would simply expire if there was enough free capacity in other facilities. Again, this suggestion reflected the situation of a large semiconductor company, overlooking the fact that the price of a new factory could easily exceed billions of dollars, thus making this option unfeasible for small startup-companies with limited access to financial resources. But this example turned the discussion to the capacity problem, which was indeed an important question for the young company. Further questions in this topic lead to the discovery of the capacity option.

This discovery also showed that the right examples and templates that appeal to the companies can be very helpful in the future screening for option scenarios. This observation lead to an alternative classification of real options.

Chapter 4: A Functional Classification of Real Option Scenarios

There is still much discussion on whether the real options approach will gain wide popularity or not. It is argued that even the NPV rule took many years to become established in the corporate practice. To become widely used, mainstream real options have to be useful not only for a handfull of companies, but for a larger and more diverse corporate population. Almost all of the real option examples today are found in large companies with large-scale problems. These examples do not reflect the typical situations of smaller firms.

The first step is to identify real options. *'Up to date, uncovering real option scenarios is difficult'* [63]. The basic approach is usually starting with an existing example and trying to find similar situations. Consequently, finding a new option involves an element of luck. Thus, existing examples need to be structured and illustrated in a way that is relevant to the context of the target organization.

The necessary preconditions for an option scenario are the existence of uncertainty and of a choice, a contingent decision. To structure real option scenarios, one possible way is to look for common sources of uncertainty that apply to most of the companies. Many examples in the literature locate the uncertainty in the target markets of a company. Market uncertainty applies to almost all companies. The companies' reaction to it will be individual and can be structured according to defer, switch, growth and exit opportunities. More recent examples have located uncertainty within research, also with a large portion of final market risk. Following the question of different sources of risk, other answers are also possible. On the input side of a company, opposite to its sales markets, are the procurement markets. The insight that more sources of uncertainty exist opens the door to a completely new classification of options, according to the functional origin of uncertainty. Examples of options in procurement already exist. The optional plane orders from Boeing are an example of contractual options in procurement. These procurement options are promising applications of real options when prices of procured assets can be observed in the markets.

As more examples will be discovered, this functional map can be expanded. It can serve as a reference to companies that attempt to manage and make most out of their optionality.

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[63] Amram and Kulatilaka (1999), p. 96

This classification is compatible with increasingly used risk management systems. The purpose of risk management is to protect companies form downside risk in all possible areas. Risk management systems can help to identify other sources of uncertainty.

Although the companies under study initially claimed that they did not have any option-like scenarios, a number of new options could be exposed by using the functional framework. It has been experienced that unfamiliar examples or classifications of options are very difficult to relate to.

A practical way is to list all corporate functions and to look for options within them using a questionnaire. This systematic approach avoids overlooking options in seemingly irrelevant areas. It is important that all aspects of the company are covered in the map, from strategic to operational. For example, even for companies that are not in the IT business, their IT infrastructure development can still involve opportunities that can be addressed with the real options approach. Such a checklist could take the form of a matrix and contain the functional areas shown in Figure 4.1.

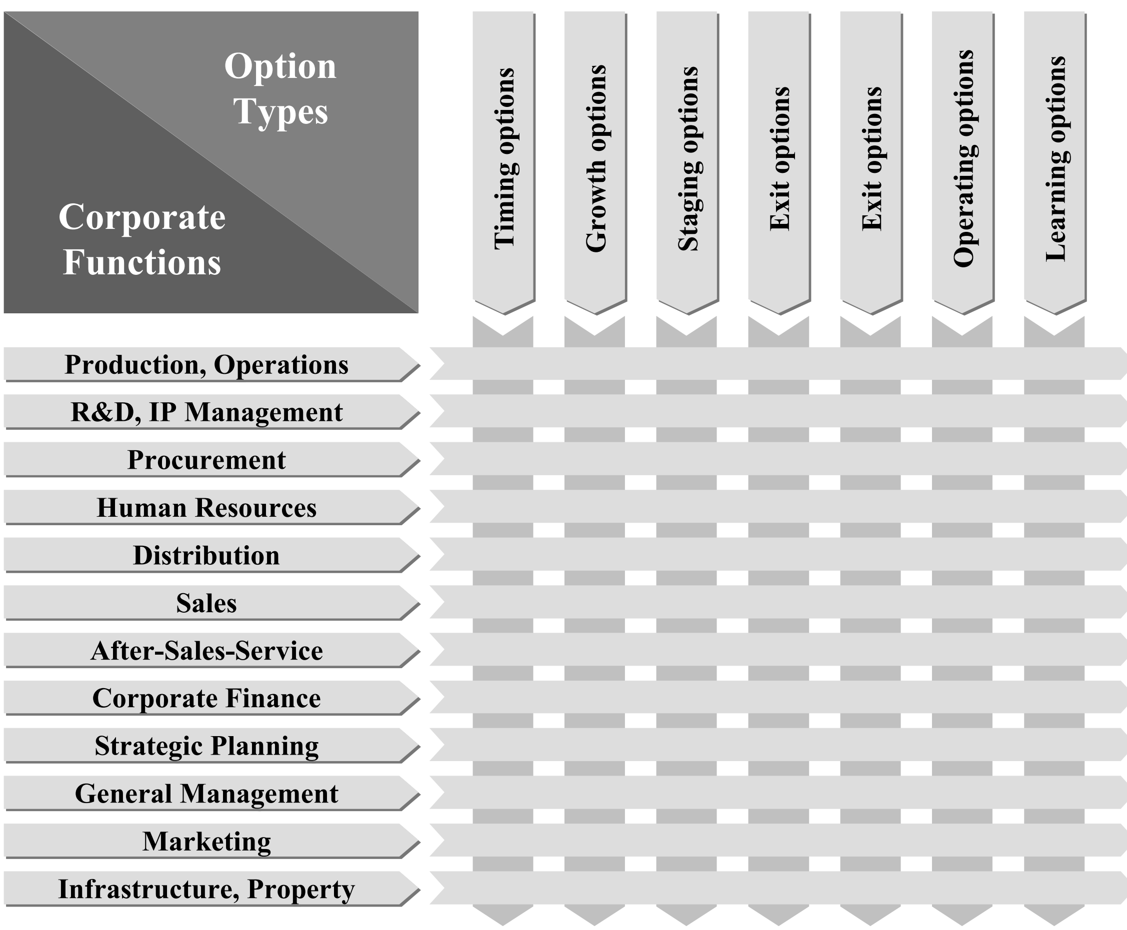

Figure 4.1: Checklist of Functional Areas

Once this list has been set up for the company, using the list of example cases as a reference, a set of questions can be used to detect option scenarios within each of the areas.

- What are the most important decisions?
- What do these decisions depend upon?
- What are the most important sources of uncertainty?
- What alternatives do you have?
- Does some alternative provide flexibility?
- Do you need flexibility?

The purpose of these questions is to find the source of uncertainty in each area and a decision that is contingent upon the resolution of the uncertainty. Then, quantitative analysis based on option pricing techniques can be used to reveal the advantage of a flexible alternative over an inflexible alternative.

Chapter 5: Examples of Real Options

During the interview process, a number of real option scenarios were identified. The option scenarios are presented as a collection of cases according to the new functional classification. Some of the following option scenarios are already familiar and covered in the literature. They concentrate on popular functional areas like R&D and information technology. Other option scenarios are entirely new. Novel options scenarios that were discovered were:

- Capacity option
- License buyout option
- Special design for outsourcing
- Customer acquisition

Although the list is extended with some known examples from the literature, the list is not assumed to be exhaustive. The cases show that the real options approach is relevant to small companies as well as large companies. They also serve as templates for uncovering similar options in other organizations.

5.1 Production

The production department of a company can be the source of numerous options. Production facilities can be very expensive, and before an investment for a production system is made, financial analyses should be performed to find the most economic alternative. If there is significant uncertainty in the future product markets, or in manufacturing costs, real options analysis should be considered to justify the best decision under uncertainty. There might be flexibility in the creation of new manufacturing capacity that contributes to a higher value than suggested by a standard NPV analysis. An example is the 'factory shell' of Intel[64]. In 1996, Intel had to decide whether to build a new manufacturing plant for computer chips or not. The plant required huge investments above two billion dollars, and the future demand for the chips was very uncertain. An NPV analysis did not support the project to build the plant. A

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[64] Triantis and Borison (2001), p. 38f

real option analysis showed the benefits of breaking up the investment into two phases, instead of building the plant all at once. The first phase was the development of a “factory shell” as an empty facility that could be quickly fitted with the expensive equipment in the second phase and started up if demand surged for the new product. The execution of the second phase was contingent on the demand for the chips, and the decision to build the empty shell created the option to install the complete manufacturing equipment quickly. Up to this option value could then rationally be spent for the building of the empty facility.

5.1.1 Securing External Capacity

When a small semiconductor company was presented the “factory shell option” of Intel as an introductory example, its first remark was that own manufacturing plants are out of reach for most small companies. Nevertheless, manufacturing capacity is needed, and sometimes it is better to obtain an option on manufacturing capacity than to pay for a reserved capacity.

This option was discovered in a start-up semiconductor company that owns a new technology that increases the performance of silicon chips. The company had discovered a recipe that adapts a manufacturer’s process to use the new technology to manufacture performance chips.

The company also started to design and manufacture circuits with its new technology. The circuits promised a high profit margin, but there was uncertainty surrounding the market size. Main application areas were broadband and wireless communications. The company soon realized that their current manufacturing capacity might be not sufficient to satisfy market demand.

The company could react to this market potential in many ways. One choice would have been to continue with limited capacity as before. This would mean forgoing a valuable opportunity. The choice of building or buying a facility was out of reach because of limited capital resources. The most practicable way of taking a chance on the large market potential turned out to be a growth option.

The company now helps other large chip manufacturers to establish the new technology within their proprietary facilities. The equipment has to be configured and the employees need to be trained. In return, the chip manufacturers guarantee the company a certain capacity to manufacture performance chips in their proprietary facility. The company will use this opportunity if the demand for performance chips is high. If the demand is low, the company will not need the extra capacity.

This deal is a good choice for the company in either situation. On the one hand, it can benefit from a favorable market, and on the other hand, its losses are limited to the cost to upgrade the facility of the manufacturer. The options analogy and a quantitative example involving the capacity option will be presented in Chapter 6. This setting shows that options can be essential to small technology-based companies, and that they are often pursued intuitively.

5.1.2 Flexibility for Inputs and Outputs

In the option settings described in this chapter, the main operational process is at the center of attention, for example a manufacturing plant or a production machine. Generally, this process requires inputs and produces outputs. In some cases, a firm has the choice between alternative manufacturing technologies, which can be either rigid or flexible. Flexible technologies allow for switching the inputs or outputs easily.

An example for output flexibility is given in flexible manufacturing systems (FMS). *'The trade-off here lies in selecting between a more expensive but flexible manufacturing system that allows changing operating modes rapidly at very low switching costs in response to uncertain market developments, versus a high-volume, specialized and inflexible alternative. In a low-uncertainty environment, the specialized alternative may be more cost-effective, but the value of flexibility may justify the additional cost of the flexible system under higher uncertainty'* [65]. Flexibility in production can be used to manufacture entirely different products. It can also be used to make parts in different quantities and qualities.

On the input side of a process, flexibility can also be valuable. For example, flexibility can exist in the choice of the energy source[66]. Consider a plant that can use either oil or gas for its operation. If the energy prices are stable, committing to the cheaper source of energy is the best choice. If energy prices are highly volatile, it could be valuable to switch to the temporarily cheaper source of energy. Building a flexible plant provides this choice.

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[65] Kulatilaka and Trigeorgis (1994), p. 795

By fitting these examples into a systematic view of the production process (Figure 5.1), more parameters can be identified, each giving rise to flexibility. For example, information is also required as an input for complicated manufacturing processes like three-dimensional milling (manufacturing data and machine parameters). A flexible alternative can be a Computerized Numerical Controlled machine (CNC). It has advantages over a rigid manufacturing line if frequent changes in the production program are expected.

The overview of the process characteristics can be used to look systematically for option scenarios in the production.

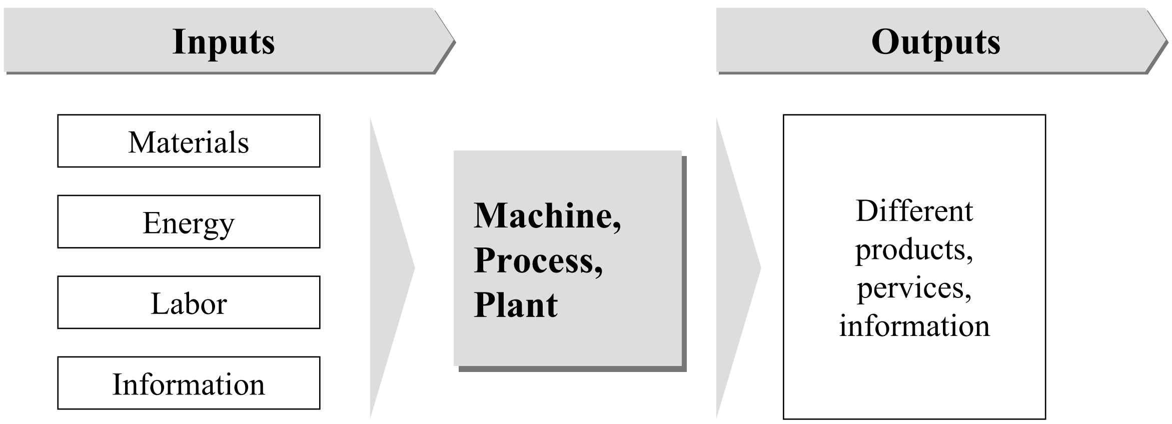

Figure 5.1: Example for Inputs and Outputs of a Production Process

Traditional financial investment evaluation methods are often unsuitable, because they do not capture the value of the flexibility. *'Investment justification is a serious problem that often impedes the introduction and use of flexible manufacturing systems'* [67]. Real options analysis can help to justify a flexible manufacturing system.

5.1.3 Scaleability

'If future conditions are favorable, a project may be expanded to take advantage of these conditions. On the other hand, if the future is unfavorable, a project may be curtailed or even

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[66] Kulatilaka and Trigeorgis (1994), p. 796

[67] Kumar (1995), p. 281

canceled as the conditions warrant. A traditional net present value analysis does not take these factors into account' [68].

This general issue of scaleability can be important in the design of a manufacturing plant. For example, an efficient plant that is able to run on very low operating costs might be expensive to build. Another plant, which consumes more operating costs, could be cheaper to build, using older technology. The difference in the investment costs to build the plants could be justified by options analysis.

5.2 Infrastructure and IT

Information technology is an important part of nearly every company's infrastructure. Some companies' business models even rely critically on infrastructure, which can consist of both hardware and software.

Infrastructure investments can be viewed as platforms whose value comes largely from the options they provide for future growth[69]. In this context, investments are made sequentially in two stages. Usually the first stage consists of an investment to build up a physical infrastructure (e.g. a telecommunications network), the second stage installs an application that uses the infrastructure. The value of the second-stage investment is often unknown at the beginning of the whole project. The first-stage investment represents a learning option that allows the company to gather more information about the application's future profitability. If the outlook is favorable, the company may proceed with the second-stage investment. Thus the company holds a right but not an obligation to make the second-stage investment. This freedom of choice inherent in sequential investments is not captured by traditional valuation techniques[70].

Information technology has become the largest single item in the capital spending budget in the United States and accounts momentarily for almost a third of all corporate

[68] Flatto (1996), p. 3

[69] Kumar (1996), p. 187f

[70] Dos Santos (1991)

expenditures[71]. The value of an investment in infrastructure is not justified by the infrastructure itself but by the applications that are enabled by the infrastructure. *'The transition to the new economy has created many difficult decisions for corporations, and many have responded by adopting a real options mindset to provide some structure in making these decisions'* [72].

Other real options arise from the flexibility within an infrastructure. Sometimes the ability to grow a company depends on the ability to grow the physical infrastructure[73]. Breaking up the infrastructure into modular pieces creates the opportunity to replace individual modules easily if the necessity arises[74]. For a company facing a series of technological innovations, different migration strategies may be chosen. A real option analysis can be used to determine the best decision under uncertainty (compulsive, leapfrog, buy-and-hold, and laggard strategy)[75].

Infrastructure can also consist of a software platform that enables certain applications. Software platforms do not directly generate value but they enable different value-generating applications. The value of a software platform thus depends on the applications that can be optionally implemented[76]. Another example is the investment in data warehouses that creates option value through the ability to quickly develop new applications[77].

The use of the real options approach has only recently been introduced to applications in information technology, but since then it has gained much popularity. The "new economy" together with the fact that not only big corporations rely on technical infrastructure provides many interesting option scenarios.

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[71] Flatto (1996), p. 1

[72] Kingley (1999), p. 1

[73] Flatto (1996), p. 1

[74] Baldwin and Clark (1999)

[75] Grenadier and Weiss (1997), p. 399

[76] Taudes, Feuerstein and Mild (2000), p. 228

[77] Kingley (1999), p. 2

5.3 Procurement

The survey of Triantis and Borison has located optionality also in the supply chain management. *'Among other recent changes in the business environment is the proliferation of contractual arrangements between firms, from an increased prevalence of purchase and supply contracts along the value chain, to new governance structures involving joint ventures or alliances. In companies that have adopted the real options mindset, these contracts are viewed as bundles of options, and the transactions are discussed and even negotiated using options language'* [78].

Among the companies that use the real options approach are airlines and the aircraft manufacturers Boeing and Airbus. Airlines are subject to high uncertainty in the future number of passengers. Nevertheless, airlines have to order new airplanes a long time in advance. Since an aircraft is an extremely expensive investment, a correct calculation of the value of a new aircraft is important for the airline as well as for the manufacturer. Besides aircrafts, airlines purchase options on aircrafts. These real options are a way of sharing risks among several parties (airlines and manufacturers).

Procurement options do not only exist for large businesses. Almost every manufacturing company depends on suppliers, and the management of the supply chain becomes more important with the trend towards outsourcing. Sometimes it is desirable to have more than one potential supplier for a technical part, to be able to switch whenever it is profitable (supplier reduces prices, develops new technology etc.). Screening another potential supplier costs some additional effort, and it might also be necessary to make some technical adjustments to the products to be able to utilize parts from multiple suppliers. By making this extra effort, an option to switch suppliers is created. For example, one of the interviewed companies depended critically on one manufacturer of optical components. The value of having a second supplier was described to be very high by the company. In less obvious cases, a real option analysis can be used to determine if being able to use additional suppliers justifies the extra effort.

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[78] Triantis and Borison (2001), p. 9

5.4 R&D and Intellectual Property Management

The pace of innovation has been accelerating. During the last decade or more, technological advances have changed the rules of business for many corporations. Especially young, technology-based companies that aim at new markets depend on research and development to create and maintain the basis for their future success. Hamilton and Mitchell[79] summarize that scarce resources need to be allocated, and that managerial judgments about research focus, applications, and pace of commercialization are required.

Real options can be applied to R&D for two major purposes. First, real options can help to justify investments in R&D. Second, real options analysis can be used to improve decisions within projects.

Berk, Green and Naik[80] observe that managers in both large and small corporations are under increasing pressure to quantitatively justify expenditures on R&D. Being asked the question: 'What does your research contribute to our success?', they are sometimes *'unable to communicate the range of benefits that are opened up to the corporation'* [81].

A part of what R&D does is to create long-term strategic options for the sponsoring corporation*. 'The value of R&D is almost all option value'* [82]. The investments in R&D do not pay off immediately, but successful R&D creates the option to commercialize a new technology. The investments in R&D can be seen as the cost of the growth option that the company is buying by undertaking the R&D initiative. The strike price represents the total costs of the commercialized product, the underlying represents the revenues that will be generated by the sales.

The traditional valuation techniques like net present value or return on investment do not capture the option value of R&D properly, and have the tendency to undervalue projects. For this reason, some research people refer to ROI (return on investment) as actually standing for

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[79] Hamilton and Mitchell (1990), p. 150

[80] Berk, Green and Naik (1999), p. 1

[81] Hamilton and Mitchell (1990), p. 159

[82] Myers (1984), p. 136

"*restraint on innovation*"[83]. The high uncertainty and the enormous pressure to innovate in R&D-intensive industries favor the use of sophisticated instruments that help to evaluate opportunities and risks of R&D-projects as well as to choose the right ones[84].

Because option models include the option characteristics of research, they assign a higher value to long-term strategic R&D projects than traditional discounted cash flow models[85]. This way, real options help to justify investments in strategic R&D projects with uncertain markets.

Large corporations are already beginning to use the real options approach for the valuation of their research options. For example, options are used to evaluate corporate acquisitions in pharmaceutical R&D[86]. In general, *'there does not exist any discussion between finance and R&D departments'* [87]. Consequently, only few companies are capable of an economically sound valuation of their R&D.

To value R&D projects in accordance with the financial markets, systematic risk and private risk should be separated[88]. The risks associated with the ultimate cash flows the firm expects to realize on completion of the project are mainly systematic, while the purely technical risks are private to the company. The systematic risk and the required risk premium of the venture are highest early in its life, and both decrease as the venture approaches completion. A traditional DCF analysis would assume a fixed risk premium for the project throughout its entire life, possibly leading to an undervaluation of the venture.

Technical uncertainty is associated with the success of the research itself (e.g. clinical trials of a new drug, exploratory drilling for oil). The exogenous risk associated with the actions of a competitor also have to be treated as private. For example, a new drug may be rendered unnecessary by a superior treatment option, or a software product may become

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[83] Mechlin and Berg (1980)

[84] Perlitz, Peske and Schrank (1999), p. 255

[85] Lindt and Pennings (1997), p. 92

[86] Benaroch and Kauffman (2000), p. 4

[87] Szakonyi (1994)

[88] Boer (2000), p. 1

obsolete because of technological advances in hardware[89]. According to CAPM, the markets do not reward private risk. Therefore, in general, private components of R&D risks should not be reflected in the discount rate.

Figure 5.2 gives an overview over typical issues along a development path of a new technology, which can be seen from a real options viewpoint.

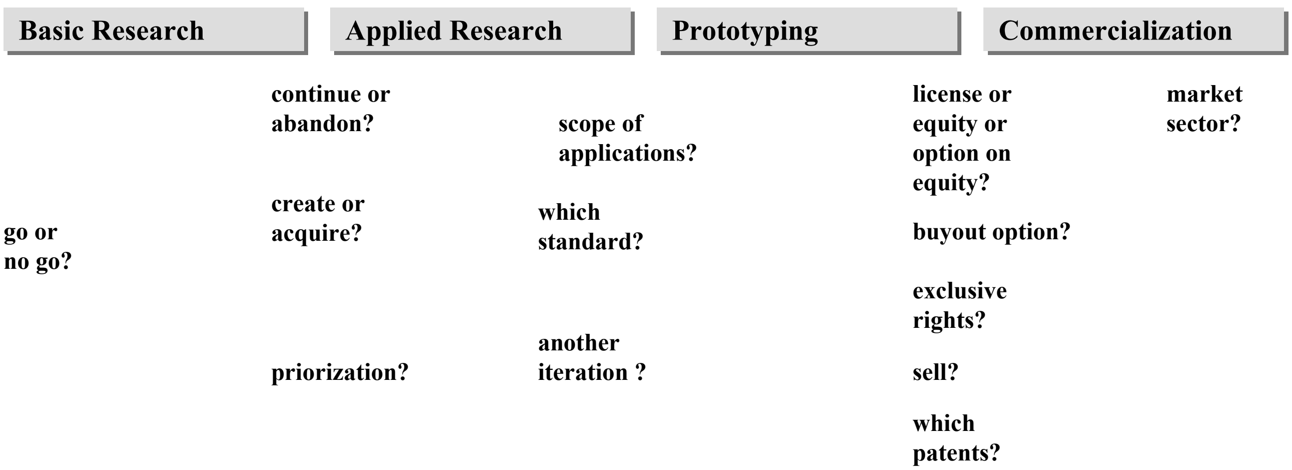

Figure 5.2: Typical Issues along a Development Path of a New Technology

At the beginning of the basic research, real options analysis can be performed to justify the decision to start a new and uncertain research endeavor. Before the transition to applied research and prototyping, there is always the option to cancel the project if the results are not satisfying, but naturally these exit options are not popular with small companies that are not diversified. Along the path, flexibility can be created, kept or abandoned by choices of potential applications, by choices of potential technical standards, or by choices of alternative development processes. Each additional field of application represents an option on additional revenues, but this expanded scope of applications may require further development costs. The flexibility to choose among different market sectors in the commercialization phase has an option value, but the option itself must be created earlier in the development phase when the scope of applications is set.

The most interesting option scenarios were found at the transition from the prototyping phase to the commercialization phase, because this is frequently the time when a technology

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[89] Berk, Green and Naik (1999), p. 1

changes its ownership, for example from a research organization to a spin-off. All stakeholders need to be aware of the fair value of the technology, and usually the value includes a number of options that can be shared among the stakeholders. A fundamental question is the form of engagement between the selling company and the spin-off. A license deal can be made to agree on the payment of license fees, for example a fixed amount of money per year or per units sold. By an equity deal, the parent organization can take a stake in the ownership of the spin-off. This represents the option to benefit from any gains in the value of the spin-off. If the start-up is unsuccessful, the loss of the sponsoring corporation is limited to the invested money, which is the option value. Such options can be an important additional source of funding for research institutes, which would not be possible only with license deals.

The parent organization also has to decide about the scope of the rights that are given to the spin-off. If the new company is granted the exclusive rights for a new technology, all possible growth options belong to the spin-off. If a new field of application emerges, the spin-off can design a new product and take advantage of its exclusive rights. Otherwise, the growth options remain with the parent organization, which has the choice of granting rights for any new applications to others. An example is a new software technology that can extract the most important phrases out of a written text. Possible applications could be a summarizer, that can be used to get a quick overview over a long article, and a filtering software that extracts only the most important phrases from e-mails to send them to mobile devices with limited screen sizes. The developer of this technology can choose to grant licenses for the new technology only for individual applications, reserving the option to give away new licenses in the case that a new application emerges.

5.4.1 Staged Investments with Exit Options

Rather than treating a research project as a whole, its execution can be divided into several stages. Large companies already use staged models of the R&D process to improve decisions about the continuation of a project (for example the stage-gate model: ideas gate, charter gate, contract gate, launch gate)[90].

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[90] Jaegle (1999), p. 276

Figure 5.3 shows a staged model that is used by pharmaceutical companies.

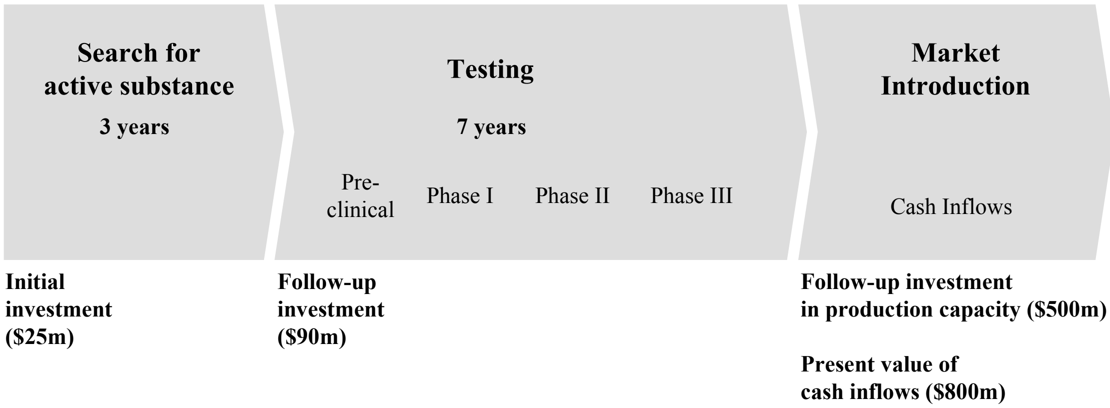

Figure 5.3: Sample R&D Process for Drug Discovery[91]

Each completed stage provides the option to continue the process, but also keeps the choice open to abandon the project if market worsens or if the competition achieves an advantage (exit option). Finally, the completed stages create an asset that is *'the underlying right of the firm to extract returns from the exploitation of the now-commercialized technology'* [92].

These exit options are valuable for large corporations that support a number of research projects, abandoning one of them does not threaten the future of the company. Exit options are also interesting for venture capital firms that invest in small technology-based companies. Funding usually takes place in several rounds, depending on the success of earlier rounds. After each round, the venture capital firm can choose to stop the investment to limit its sunk costs.

The value of a research project that is divided into stages is enhanced not only by exit options. For small technology-based companies, other options arising from distinct phases create value. *'Managerial flexibility has value in the context of uncertain R&D projects, as management can repeatedly gather information about uncertain project and market*

[91] Perlitz, Peske and Schrank (1999), p. 266

[92] Kester (1981)

characteristics and, based on this information, change its course of action' [93]. Dividing a project into stages creates a number of control points, where information about the project's future can be updated and the course of the project can be corrected. As seen before, the scope of applications can be changed, as well as the development pace.

5.4.2 Patents

Once a new technology or product is developed, a firm may want to obtain a patent on it to protect its intellectual property. A patent itself does not grant the success of a product, but in the case of success, the patent secures a long-term competitive advantage and pays off an '*excess profit that does not immediately induce a competitive response*'[94].

In this sense, a patent can be seen as an option on the excess profit of a new technology. It will be exercised if the conditions for the new technology turn out to be favorable. Option pricing techniques can be used to calculate the option's value. Up to this amount can be spent for obtaining the patent.

For a project that is deep in the money (a clear winner) or deep out of the money (a clear loser), options analysis would be an overkill[95]. But if the decision to spend money for a patent is difficult, real options analysis can be useful.

For example, one interviewed company had to make a decision about which countries to cover with the patent rights for a new technology, because patents are granted for individual countries. The company chose to cover entire North America and some of the European countries, because the acceptance of the new technology was predicted to be very different in the individual European countries. A patent in each additional country would secure the option to serve that market if conditions turn out to be good.

In the literature, patents are mainly discussed as factors that influence the competitive options of large corporations (fear of preemption undermines value of waiting, investment is delayed in fear of starting a patent race)[96] .

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[93] Huchzermeier and Loch (2001), p. 85

[94] Alchian (1991)

[95] Erdogmus (2000)

5.4.3 Standardization

In the early stages of a new technology development, the issue of standardization can be very important. When the product market is characterized by high uncertainty surrounding future standards, betting on the wrong technology standard can have a detrimental effect on future market shares (e.g. internet standards, digital video). A historic example of competing standards is the development of videotape standards twenty years ago.

In these situations, the management can be confronted with the dilemma of developing a single standard at the risk of later having to switch to a winning competing standard, or developing two or more standards simultaneously at the expense of incurring additional R&D costs.

Developing a second standard creates the option to choose between the two technologies. Substantial value exists in the firm's ability to postpone the final decision between both technologies until the product-launching stage. The option value of simultaneously developing two correlated product standard has been shown to lead to *'significantly different conclusions from calculations with the standard NPV analysis'* [97]. Thus the use of option pricing techniques can help to allocate scarce R&D resources.

5.4.4 License Buyout Option

The real option approach can become highly relevant when patents or intellectual property rights change ownership. In these cases, the value of the options associated with the intellectual property should be known to agree on a fair price for both stakeholders. For instance, a project that is being licensed out or spun off can contain options that are part of the deal[98].

An interesting example is the license buyout option, found in a software company that was spun off from a research organization to commercialize a new technology.

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[96] Weeds (1999)

[97] Lindt and Pennings (1998), p. 1

[98] McGrath (1997), p. 975

The spin-off company has to pay license fees to the research organization for the use of its technology. The license fee depends on the number of units sold. The company also holds a license buyout option, which was agreed upon at the time the company was spun off. This means that the company can buy the technology from the research organization for a fixed price, instead of continuing to pay the remaining license costs.

If the demand turns out to be favorable, a large number of licenses would be needed. In this case it would be profitable for the spin-off to exercise the license buyout option, that means to pay a lump-sum instead of the remaining series of license fees.

This option was created by a contract, so it is an example of a 'contractual option'. The license buyout option will be covered with a numerical example in Section 6.2 in more detail.

5.5 Design Flexibility

Successful R&D opens up the opportunity to design new products. The design phase is very important, because many of the product's final properties (price, manufacturing costs, functionality) are fixed in the design phase, and commitments to the manufacturing technology are made. '*The ability to postpone a design freeze and to delay commitments can add value to a project*'[99]. Options in design flexibility are examples of *the learning options* described in the literature[100].

By waiting, further information about future market segments, manufacturing technologies, or customer requirements can be collected. Especially in software design, waiting to see if a customer really wants a feature before implementing it represents a learning option.

5.5.1 Delaying Design Decisions: Different Market Segments

Different market segments may require different technical solutions. Once a basic technology is developed, a company might face the choice between focusing on one market segment or keeping the choice open. An example is a spin-off company that has developed a new technology for optical devices. These devices will be used in future optical data

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[99] Huchzermeier and Loch (2001), p. 85

[100] Amram and Kulatilaka (1999), p. 96

networks. The market will be divided into two segments having different requirements for the optical devices: long distance and local metropolitan. The distribution among these two market segments is uncertain. Focusing on one market segment in the development has the advantage of concentrating development effort, leading to a shorter time-to-market. There is also the risk of betting on the wrong market segment. Because of the high uncertainty, the company has chosen to keep its design flexible to be able to wait for further information about the market segments. The option to choose the right market segment has a value that can be captured with option pricing techniques. If keeping the design flexible costs less than the option value, the design should be kept flexible.

5.5.2 Make or Buy: Special Design for Outsourcing

A large portion of the manufacturing costs of a new product is determined early in the design phase. Decisions in the design usually influence the future manufacturing costs strongly. If the future manufacturing costs or other characteristics of the production process are uncertain, flexibility built in the design can provide options to change the manufacturing process and create value.

One interviewed company is preparing its production of its new optical devices. They are composed of electronic, optical and mechanical parts, which are difficult to assemble. The manufacture of some critical parts and the assembly are currently too complicated to be outsourced. The company wants to have this flexibility to outsource as many manufacturing steps as possible if it becomes necessary or profitable. Therefore it creates the option to outsource manufacturing steps by extra design to make the assembly easier.

5.5.3 Flexible Core Technology and Modularity

Many small technology-based companies engage in the development of software. The biggest expenses such a company faces are the costs for the development of the software. Especially after the first boom in the ‘new economy’ is over, cost-conscious software design becomes more important. The discipline of *software economics* tries to enhance the software design process by applying traditional financial metrics. Because exposure to uncertainty is an inherent part of software development, new approaches include the real options thinking to improve the design process[101].

Flexibility built in the design offers numerous options. Uncertainty exists as well in the sales and supply markets of a software company, as also in the development process itself. The sales markets can generally be volatile, also the requirements of the customers can change very quickly. Re-usable software components may require more programming effort (the option price), but they create options for the rapid deployment of future software products[102]. The development of a software component library will not be profitable by itself, but it will open up the option on a future product line.

The common practice to develop a software prototype before the full product is an intuitive way of following the real options idea. By the prototype, the technical uncertainty can be resolved with a limited budget. The successfully completed prototype creates the option to develop the final version of the software.

Well-known examples of flexibility are also open architectures and the component-based development. It is increasingly common to use Commercial Off-The-Shelf products (COTS) in new software systems. By preserving an open architecture, it is possible to accomodate multiple vendors of COTS products. The value of such options is derived from the ability to refresh technology rapidly with limited costs[103].

One of the interviewed companies has developed a simulation software for the design of non-silicon lasers. Special additional effort was made to keep the core simulation engine as general as possible, to be able to adapt the software to the changing demands of future customers. It would have been cheaper to design the software specifically for the first customers, but then the acquisition of more customers would have been far more expensive. The flexible core engine gives the option to win future customers easily if the demands change.

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[101] Erdogmus (2000)

[102] Baldwin and Clark (1999)

[103] Kingley (1999), p. 2

5.6 Human Resources

In human resources, the real options approach could be used mainly as a language to frame some decisions.

5.6.1 Qualifications of Employees

The qualifications of a new employee could be seen as an option, for example a second language that enables the employee to work in a foreign country. If these options are valuable for a company, it will be willing to offer a higher salary to the new employee, the extra compensation representing the option premium.

5.6.2 Temporary Employment

In situations of uncertain future demand for employees, the flexibility of having temporary workers rather than permanent employees has an option value. The workforce can be easily adjusted to the desired levels. The price for the flexibility is higher transaction costs.

5.7 Distribution

5.7.1 A New Distribution Channel

A new distribution channel requires investments to set it up. Once it exists, it gives the option but not the obligation to use it. An example of a new distribution channel is the Point-Of-Sales network built by the Yankee24 bank[104]. The future value of the network was uncertain, but the investment consisted of two phases. The first phase was the physical infrastructure, and the application in the second phase was contingent on the acceptance of the customers.

5.7.2 Inventory

If the sales markets are highly volatile, it can be valuable to have inventory. Inventory means being ready to deliver, but keeping inventory also causes costs. A real options analysis can be used to answer the question of how much inventory is desirable in uncertain markets. By calculating the option value, an upper limit for the inventory costs can be found.

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[104] Benaroch and Kauffman (1997)

5.8 Sales

5.8.1 Customer Acquisition

Consider a company that plans to acquire new customers. If the potential sales to a new customer were known and certain, it can be calculated how much should be spent on the acquisition of this customer. More often, the future sales are subject to uncertainty. Sometimes, the relationship turns out to be profitable, sometimes not. There is usually no obligation to continue selling to an unprofitable new customer. Thus, acquiring a new customer creates the option to serve that customer if and only if it is profitable.

5.8.2 Pricing Options

Pricing options may give flexibility to the buyer of a product or a service. For example, by buying a software program the customer could get an option to upgrade the software for a reduced price for the next two years. Another example could be a single software license that can optionally be expanded to a site license. Many different kinds of optional benefits that enhance the value of a deal are possible.

5.8.3 Marketing

One of the objectives of marketing is the active shaping of the environment in which the company operates, for example by advertising or by lobbying[105]. These activities can enlarge a company's market and contribute to higher sales. The value of growth options is also influenced by advertising and lobbying in a positive way. For example, a small company has developed a new technology for pollution control. The adoption of this technology will occur only if the government passes a new environmental control regulation that contains certain provisions. By lobbying, the company can shift the chances towards the passing of the new regulation, thereby changing the sales forecasts of its uncertain project. This way, a firm can *'act as an agent of endogenous change and it can seek to shape contingencies in its favor'* [106].

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[105] MacMillan (1978)

[106] McGrath (1997), 977

5.9 Valuation of Companies for IPO and M&A

Many small technology-based companies have the goal to become public. They need to communicate their value to the future shareholders for the Initial Public Offering (IPO). The investment in a start-up venture can be seen to be similar to an investment in a compound real option[107]. An investment in a start-up company is usually not undertaken so as to initiate the immediate selling of a product or service, but *'to start a multistage process that may eventually reach that point'* [108]. Even if a product has been developed, the market might have not emerged yet. The real option valuation can help to include important growth options in the company valuation.

At some large companies, M&A activity is already being discussed from an options perspective[109]. Especially in the life-science industry, the real options approach has been established as an alternative besides traditional methods for the valuation of small biotech-companies[110]. By an acquisition of a business, not only tangible assets of the business are bought. A business does not only consist of assets-in-place, but also of growth opportunities. Usually businesses are not acquired for the immediate profit that they can contribute, but for the growth opportunities they provide. If the business is traded, these intangibles are already clearly valued by the market and reflected in its stock price[111]. By an acquisition, the growth options inherent in the business are included in the transaction. If the business is small and not already public, the determination of the intangible value of the growth opportunities can be difficult.

'The option value of growth and intangibles is not ignored by good managers. These values may be brought in as strategic factors, dressed in non-financial clothes' [112]. Real options analysis can be used to find the value of a growth option, more precisely the value the

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[107] Willner (1995), p. 224

[108] Willner (1995), p. 223

[109] Smith and Triantis (1994)

[110] Hommel (2001), p. 5

[111] Myers (1984), p. 127

[112] Myers (1984)p, p. 136

growth option would have if it were traded in a market. This value can be used in the determination of a fair acquisition price.

Chapter 6: Numerical Examples of Selected Option Scenarios

In this chapter, the real options approach is demonstrated as an analytical tool to compute the value of managerial flexibility. Two examples are given from the interviewed companies: the option on manufacturing capacity and the license buyout option.

6.1 The Option on Manufacturing Capacity

This option gives the startup company (hereafter called Company A) the right to manufacture chips in the proprietary facility of a different company (hereafter called Company B). To obtain this option, Company A upgrades the facility of Company B to handle a new manufacturing technology. (Alternatively, Company A could also require a direct payment for its efforts). The question is how much Company A should rationally spend for the option to manufacture in the proprietary facility. An answer can be provided by option pricing.

To discover the option on manufacturing capacity, Company A was asked a set of questions to identify the primary source of uncertainty and the flexibility in the company's reaction. This information constitutes the option setting as it is depicted in Figure 6.1.

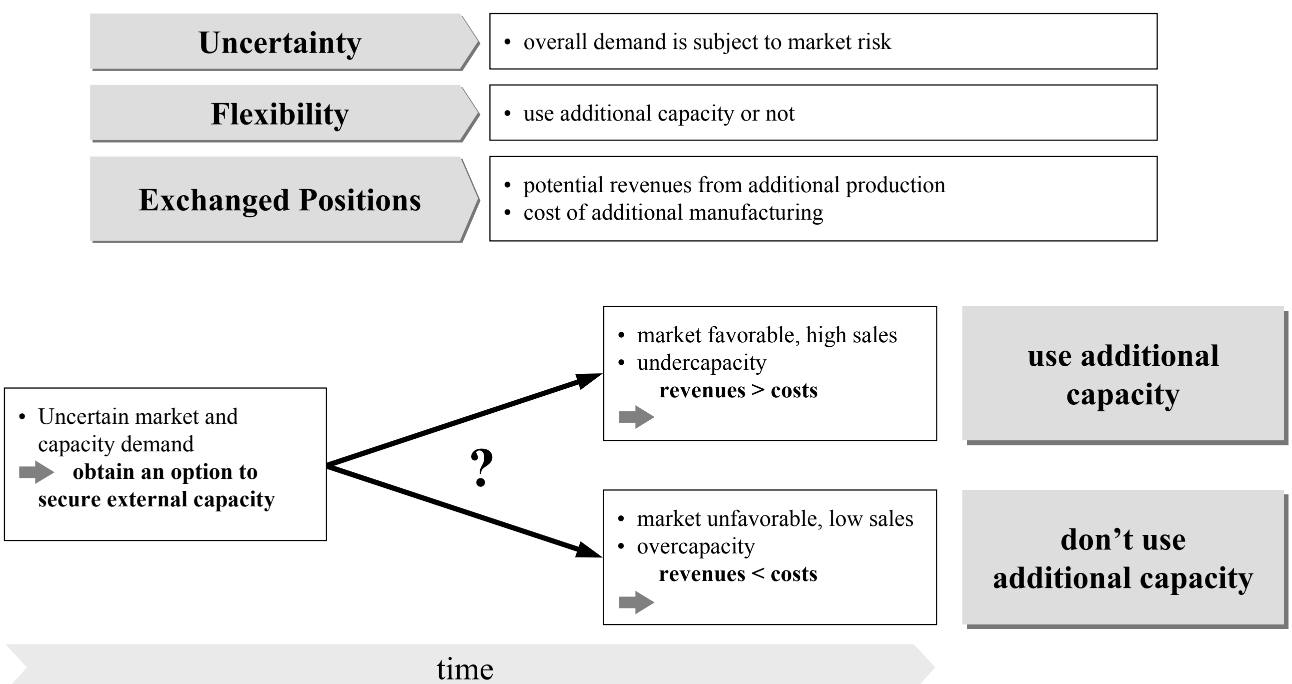

Figure 6.1: Structure of the Capacity Option

The main uncertainty is the total future demand for the new chips, driven by the demand in the broadband and wireless markets. Company A plans to offer chips for three market segments and has developed three different scenarios about the future demand. In the best case, all three market segments will take off. In the worst case, only one market segment will be successful for sure. The most realistic scenario is the expectation that two of the three market segments will be successful. The way of estimating the future sales by a best case, worst case, and average scenario is quite common in industry and provides a basis for the calculation of the option value.

Company A has the option to use the additional capacity if its own production capacity is not sufficient to satisfy the market demand. If the company chooses to exercise the option, it will receive the revenues from the additional production, but it has to pay for the cost of the additional manufacturing. The difference is the net payoff of the option. If the difference is negative, which will be the case if the demand is low, the company will choose not to exercise the option. In this case, the net payoff will be zero. The three scenarios (best case, average case, worst case) provide sufficient information to find the most important input parameters for a rudimentary real options analysis. The analysis needs the present value of the underlying asset and an estimate of its volatility. The underlying asset is determined by the future payoffs. To find its present value, a discount rate is needed that reflects the systematic risk of the underlying asset. It is assumed that the future payoffs are subject only to market risk, thus the risk in this setting is entirely systematic. According to CAPM, the risk premium should be proportional to the level of systematic risk. In this example, the difference between the upward and downward factors of the binomial model (u-d) are used as an approximative substitute for the level of systematic risk. The discount rate consists of the risk-free interest rate (in this example, assumed to be 5%) plus the risk premium. Figure 6.2 illustrates a hypothetical function of the discount rate with respect to the assumed uncertainty. CAPM stipulates a positive relationship between market risk and the discount rate. When the assumptions about the magnitude of the market risk are varied, it is necessary to adjust the discount rate as well.

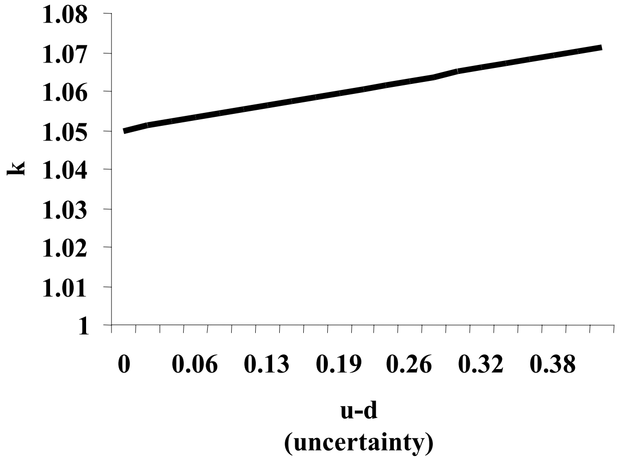

Figure 6.2: Hypothetical Discount Rate k, Dependent on Uncertainty

Sensitivity analysis can be performed to demonstrate the behavior of the option value with respect to different parameters. The option value relies on the assumption of the uncertainty, expressed here by the differences in the best case and worst case scenarios. In this example, the uncertainty was varied but in a way that the expected scenario stayed always the same. The expected number of sales was set to 1000 units (all figures in this example were created for illustration purposes only). A second parameter that was varied was Company A's own manufacturing capacity. It was varied from 1000 units downwards. Figure 6.3 shows the option values as a function of existing capacity and the uncertainty measure used.

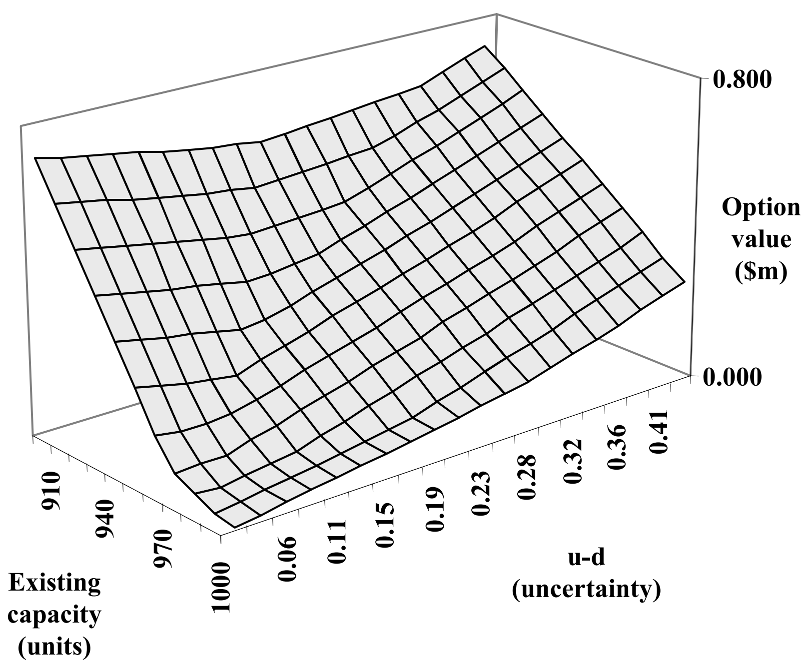

Figure 6.3: Sensitivity Analysis of Option Value

A sensitivity analysis in this extent is not needed if option pricing is applied by a company to answer a specific question. Nevertheless, sensitivity analysis can be used to validate the coherence of the analysis. For example, if the discount rate were kept the same while varying the estimate of the level of systematic risk, the calculation would fail for small values of uncertainty. Thus sensitivity analysis may uncover hidden inconsistencies in the quantitative results.

In this example, the sensitivity analysis also shows that the value of an option does not always increase with the amount of uncertainty. If the option has a positive value even in the absence of uncertainty (volatility measure equals zero), as is the case when extra capacity is always needed, it is possible that the option value decreases as uncertainty increases. This is the influence of the variable discount rate, which is adjusted according to the level of systematic risk.

A calculation with realistic numbers is presented in Figure 6.4.

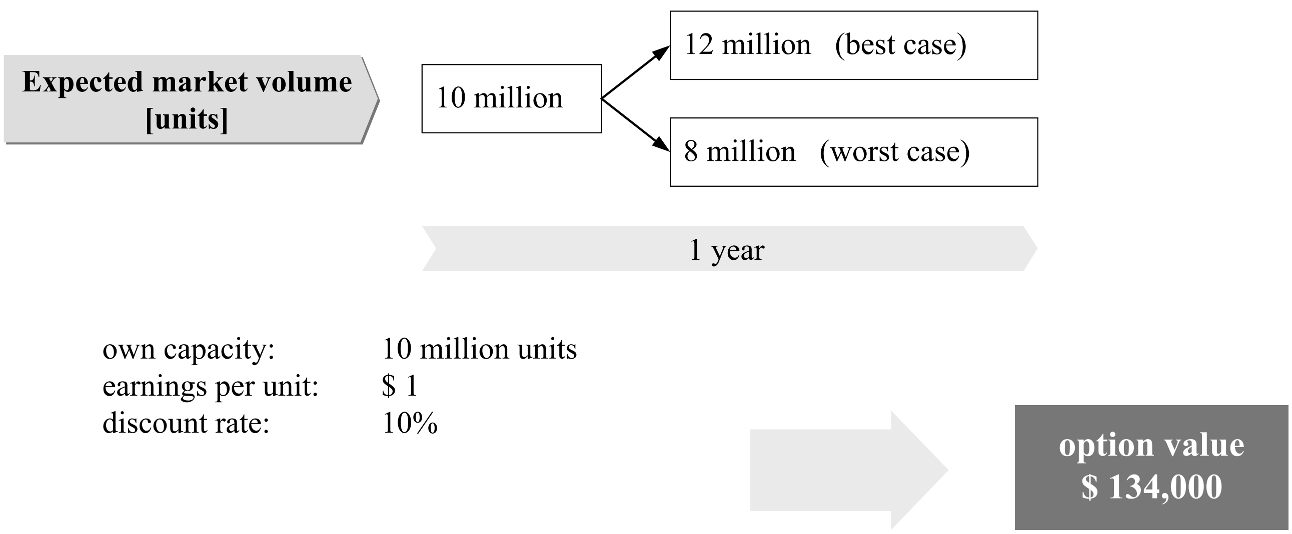

Figure 6.4: Numerical Example of the Capacity Option

Suppose that the expected market volume is estimated to be uncertain in the range of 8 to 12 million units with the most probable average of 10 million units. In addition, assume that the existing capacity equals 10 million units, and net profits are estimated at $1 per unit sold. The discount rate that reflects the riskiness of the business is assumed to be 10%. In this case, the value of the capacity option would be $134,000. Up to this amount could be spent by Company A to acquire the right to use the facility of Company B.

In reality, more complex settings are possible. For example, Company B could impose an upper cap on the capacity it reserves for Company A. In this case, Company A could try to create similar options with multiple manufacturers.

6.2 License Buyout Option

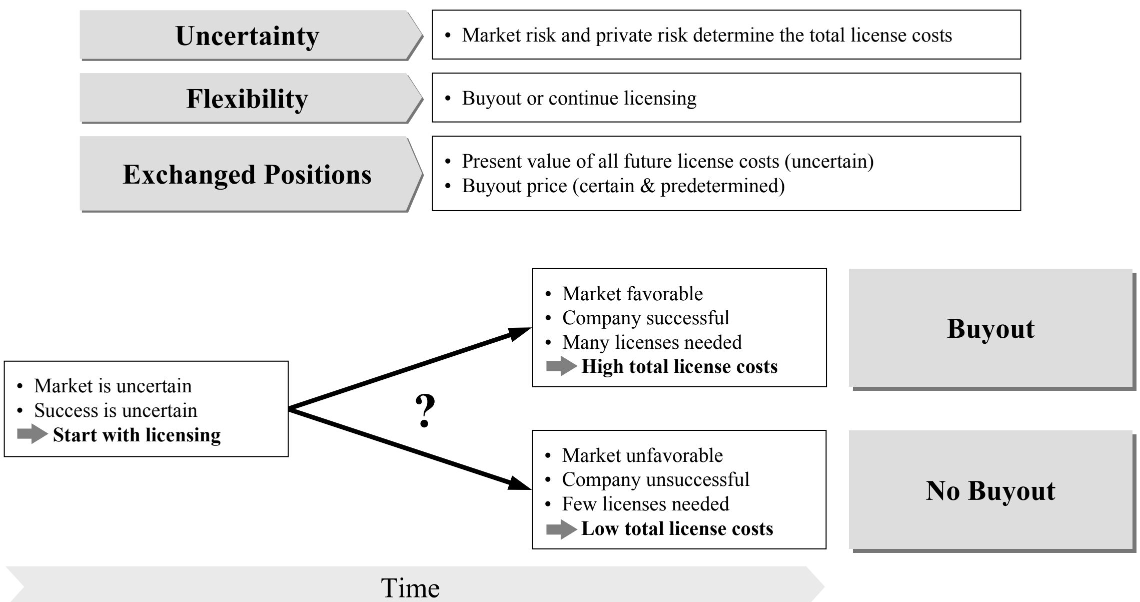

Figure 6.5: Structure of the Buyout Option

The structure of the buyout option is illustrated in Figure 6.5. A recent spin-off company from a research organization sells simulation software for lasers. For each copy, the spin-off has to pay a fixed license fee to the research organization. The future demand for the software is uncertain. If the demand is high, revenues will be high, but license costs will also be proportionately high, thereby pulling profits down. If the demand is low, license costs will be also lower. The spin-off has the option to buy the intellectual property rights to the software from the research organization for a fixed price. It will exercise the option if the demand is very high and the present value of all expected license costs exceeds the buyout price.

To model this option, a sales forecast similar to those used in business cases, can be the basis. An example is given in Table 6.6.

	2001		2002		2003	
WORST CASE						
Revenues	10	9	8	7	7	6
License cost	2	2	2	1	1	1
PV of license cost	8	6	**5**	4	2	1
AVERAGE CASE						
Revenues	10	11	13	16	20	25
License cost	2	2	3	3	4	5
PV of license cost	15	14	**13**	11	8	5
BEST CASE						
Revenues	10	13	18	24	33	44
License cost	2	3	4	5	7	9
PV of license cost	22	21	**20**	18	15	9

Table 6.6: A Sample Business Case (numbers in $m)

The company's predicted revenues will most probably evolve according to the 'average case' scenario, following an exponential trend line. The best-case and worst-case scenarios are derived from the average case scenario with yearly upward and downward factors. Using a binomial model, these factors are calculated from a volatility estimate as explained in Section 2.6. The license fees (costs) are proportional to the revenues, it is estimated that they account for 20% of the revenues. At the end of the first year or later, the company can exercise the buyout option. At this time, the present value of all future license costs could be either 5, 13, or 20 million dollars. These figures constitute the estimates of the underlying asset. The buyout price was agreed as $13m based on the average case scenario. In the options language, this is the strike price. The payoff is the difference between the expected present value of the underlying and the strike price. It can be either positive or equal to zero if the option is not exercised.

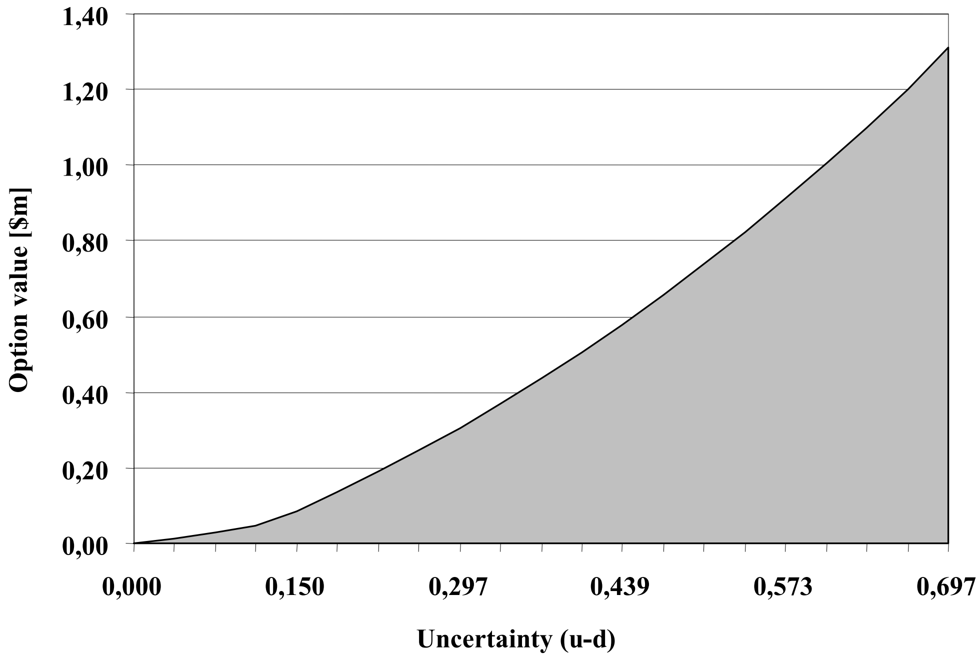

Figure 6.7: Option Values of the Buyout Option

Figure 6.7 shows a sensitivity analysis of the value of the buyout option with increasing uncertainty. Here, (u-d) is used as a measure for uncertainty as with the capacity option. The level of uncertainty associated with the sample business case of Table 6.6 corresponds to (u-d) = 0.697. The option value for this scenario is calculated to be $1.3m. This value can serve as a reference when the two parties negotiate the buyout option.

Chapter 7: Practical Limitations

The application of real options remains difficult and requires substantial know-how. During the quantitative analysis, many mistakes can be made. Among them is the improper choice of the discount rate. An appropriate discount rate is still needed for real options analysis, causing the same difficulties found in discounted cash flow analysis. The use of improper discount rates that do not reflect the systematic risk may cause results that violate CAPM and give rise to inconsistencies in sensitivity analyses. Difficulties in quantitative analysis still presents a barrier to the widespread adoption of the real options approach.

Inexperience in discovering hidden option scenarios needs to be addressed. Using the functional classification of option scenarios presented in Chapter 4 may be helpful in this regard.

Another difficulty for researchers is access to proprietary and confidential data for validation of new and existing quantitative techniques as well as for construction of realistic case studies. This seems to be a more severe problem for small companies than it is for large corporations. The survival of small companies often depends on being able to protect their IP, business strategy, and financials from competitors.

Chapter 8: Conclusions

The purpose of this thesis was to assess the applicability of the emerging real options approach to small technology-based companies.

Interviews with six such companies were conducted to find real options scenarios within their businesses. The conventional classifications of options scenarios according to the type of reaction to uncertainty, large-scale examples, and anecdotes from unrelated businesses, did not appeal to small companies. At the beginning, the interviewees did not see any link between their business opportunities and the real options approach. Further probing showed that there was indeed a number of option scenarios hidden in these companies' businesses. The most successful approach was to present option examples relevant to their specific business. This strategy helped focus the companies' attention. A questionnaire was used to identify sources of uncertainty and flexibility along with the examples.

The process of identifying real options has been improved through a functional classification of option scenarios. The study has discovered a number of options in different functional divisions of the companies. This lead to an alternative classification of real options, according to the functional department in which the option occurs. Options were found in many departments, such as production, R&D, design, and procurement. Collecting these option scenarios has created a systematic map with 'sample options' that can be used for future reference when searching for hidden options.

Although the interest of the participating companies for quantitative analyses was low, the real options approach was found to be helpful in identifying and communicating the creation of value by option-like opportunities.

The option scenarios collected suggest that the real options approach is relevant for small technology-based companies. As expected, several kinds of real options exist also in small technology-based companies. Sometimes small companies even rely on growth options as the primary means for corporate growth, due to their limited financial resources. The most interesting option scenarios have been found in settings involving transfer of intellectual property. Sometimes options are a significant part of such contracts.

The real options approach is still not widely accepted. This study has shown that the real options approach can be usefully employed not only by large companies but also by smaller firms, especially those that focus on development of new technologies. Many option scenarios exist even if they are not explicitly recognized. With the broadening of potential applications, it is likely that the real options approach will continue to receive attention and start to penetrate to small and medium enterprises.

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