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Product cost analysis during pre-development

Frank Bescherer

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Aalto University

School of Science and Technology

Department of Industrial Engineering and Management

Laboratory of Industrial Management

P.O.Box 15500

FIN-00076 AALTO

FINLAND

Tel. +358 9 4702 2846

Fax. +358 9 4702 3665

Internet http://tuta.tkk.fi/en/

Frank.Bescherer@gmail.com

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Supervisor	Prof. Eero Eloranta
Instructor	Dr. Jouko Karjalainen

Abstract

Competitive product prices and target cost together with excellent functionality and quality are essential for innovations. Non-competitive costs are a failure factor, making product cost an input to innovation, not an outcome of it. Correct decision making before technology selections and cost lock-ins help to lower future product cost.

The scope of this thesis is product cost analysis during pre-development – a gap in literature – as it is seen as critical activity, given the importance, the sums at stake and the high failure risk of innovations.

The objective of this study is to identify, classify and describe how new product development ideas can be analyzed with cost information gathered and to study why it is done the way it is.

The research uses a qualitative methodology and is done as an empirical seven-company multiple case study. Besides its descriptive part, this study uses a contingency approach to formulate theoretical outlines based on organizational contingencies of the case companies.

The results start with descriptions of managerial practices. Further results are the identification of organizational contingencies, such as e.g. the innovation funnel type, that impact the product cost analysis during pre-development. Further findings are interconnections and dependencies leading to specific tool families and evolution patterns of first time cost tool use in pre-development. Besides known tool uses, a novel tool – called directional costing – has been discovered.

Keywords R&D, new product development, front end of innovation, cost management, case study

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The biggest mistakes I have made have come from not trying.

Jamie Houghton, retired CEO

This work is dedicated to my parents and Dr. John Fogelholm

Acknowledgements

As I got to know several doctors and doctoral students in practice and academy when studying for my M. Sc. at TU Darmstadt, I got interested in doctoral studies. Thus I later took the chance when it appeared at Helsinki University of Technology, now Aalto University, to pursue my doctoral degree. Foolish I was, moving to Austria when I thought “it was nearly done”. That turned out to be far from the truth. Now, some years later, I am finally in the process of finishing this thesis for myself after having found the needed energy to finalize this work and to open a new chapter in life. However, this would have never been possible without the support of many:

I would like to express my deepest gratitude to Prof. Eero Eloranta and Dr. Jouko Karjalainen for their brilliant guidance and tutoring, on general and detailed level.

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Finally, if you are wondering about doing doctoral studies, I can encourage you to do them – it is worth it…

Vienna, September 2010 Frank Bescherer

Overview of the thesis

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1 Introduction

Companies operate in a global, intense, and dynamic competitive environment where efficient new product development is needed. A significant competitive leverage is generated if these new products match well the needs and expectations of target customers (Wheelwright and Clark, 1992).

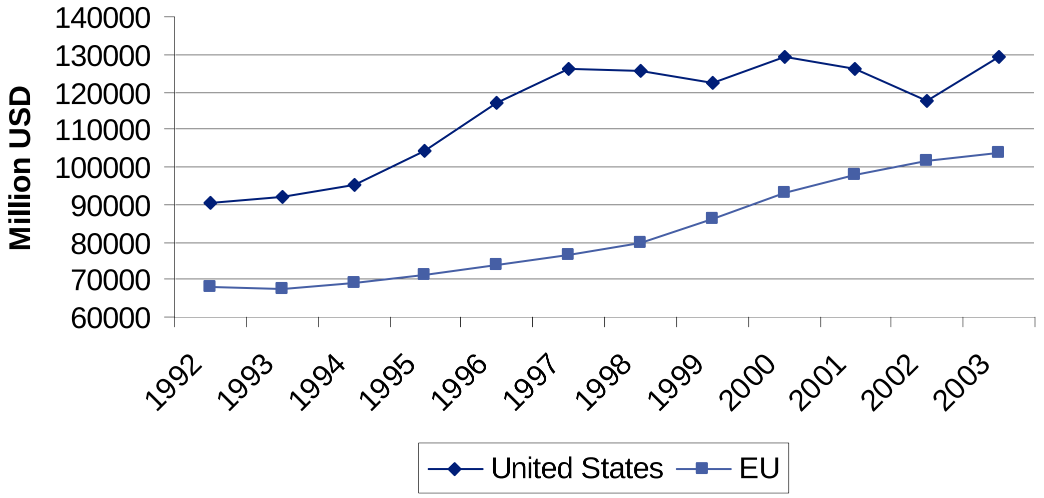

Figure 1: Development of the Business R&D spending of the manufacturing sector for the United States and the European Union (Source: Estimate of the OECD, 2006)

In 2003 the spending for corporate Research and Development (R&D) on the manufacturing sector is estimated[1] to be over 230 billion US Dollars for the US and the EU in total (OECD, 2006) (see Figure 1).

Mio. EUR	1987	1991	1996	2000	2004
Germany	20059	25204	25996	32490	35370
Finland	587	831	1431	2666	3061

Figure 2: Development of the Business R&D spending in the manufacturing sector for Germany and Finland (Source: Estimate of the OECD, 2006)

In 2004 the spending for corporate R&D of the manufacturing sector totaled 35 billion Euros in Germany and 3 billion Euros in Finland (OECD, 2006) (see Figure 2). Especially in Finland the R&D spending of companies in the manufacturing sector has risen significantly in the last two decades. This shows the monetary weight R&D plays in economies. When innovations are introduced to the market, this affects the cost or demand position of a company. This later yields a return for the innovator (Geroski, 1995). Yet, in a cycle of reinvesting profits, this R&D expenditure is made

[1] The OECD Secretariat estimates industry-level business enterprise R&D data based on official country submissions that are then adjusted for deficiencies and anomalies that exist in the official data. This estimated data series is stored in a database called Analytical Business Enterprise Research and Development database (ANBERD).

to create new products that will later 'pay-back' the investment made into R&D. This payback is reached if successful innovations can be developed. Much literature – partly contradictory – exists about the success factors of innovations and yet this mosaic of success factors has not been deciphered entirely.

Due to rapid changes in customer tastes, technology, and competition, companies should develop new products on a regular basis (Kotler and Armstrong, 2008). Yet, in the last decades costs have become an increasingly important aspect for innovations, especially as a trade-off between development time and costs can be found (Rothwell, 1994). The management of manufactured products cost is fundamental to long-term profitability for any firm operating in a competitive market (Hax and Majluf, 1982).

Since the 1970's research on innovation (constantly) finds that the efficiency of development is an important factor in the success of innovations (Zirger and Maidique, 1990). Yet, companies are faced with a tension between a need for innovation of products with competitive functionality and costs coupled with a fast time-to-market (Davila and Wouters, 2004). The best new product developments meet the market with specifications that are needed and desired by the customer. Furthermore, these developments should be completed faster than the one of the competition. Then the company has either more time to react on changing market needs and new technologies and/or they are ahead of the competition and reap the benefits of being able to sell first (Wheelwright and Clark, 1992).

The overall aim of innovation in the private sector is to develop products that are successful in the market. Companies follow aims of growth and profitability. Innovations are one way to increase profitability and the market position of a company. Yet, empirical studies found this effect small in total, but significant, and it might take several years to yield (Geroski, 1995). Companies are, however, also budget restricted in innovations (Schmitt-Grohe, 1972; Srinivasan et al., 1997; Werner, 1997; Bösch, 2008). That also applies to pre-development (Cooper, 1988; Wheelwright and Clark, 1992), as it is expensive to let new product development ideas through screens, just to kill them later (Wheelwright and Clark, 1992). Vice versa badly executed pre-development phases can lead to budget escalation problems in later development phases (Kim and Wilemon, 2002).

Developments also face other challenges: There could be a mismatch between the development of the company and the actual wish from the external environment. Or there is a mismatch in the organization, e.g. that engineering designs something production cannot manufacture on quality and costs (Werner, 1997). Furthermore the product should be unique and distinct to give a lasting competitive advantage. Additionally there can be technical problems and organizational difficulties in budgeting and organizational policies. Furthermore, companies want to utilize their resources most efficiently, improve the return on existing assets and capitalize on earlier R&D investments (Wheelwright and Clark, 1992).

For quite some time, one potential success factor for innovations has been identified: To correctly judge the viability of new product development ideas and to select the most promising ones (Zirger and Maidique, 1990).

Wheelwright and Clark (1992, p. 165) state:

> *"Great products and processes are much more than a clever design, novel technical solution, distinctive package, catchy promotion, or advanced equipment. Outstanding development requires effective action from all of the major functions in the business. From engineering one needs good designs, well-executed tests, and high-quality prototypes; from marketing, thoughtful product positioning, solid customer analysis, and well-thought-out product plans; from manufacturing, capable processes, precise cost estimates, and skillfull pilot production and ramp-up"*

The different company parts have to play well together to reinforce each other. A large assembly of different aspects – just like the different musical instruments in an orchestra – leads to the overall success of new product developments. This thesis focuses on one part (one instrument) of the big picture – cost information collection and analysis during pre-development.

1.1 Pre-development and product cost

If executives of companies could predict new product development success, these executives would direct their effort straight to successful endeavors. They would stop pursuing any other new product developments in order to not waste efforts on developments that are unsuccessful on the market. However, that would require that companies would know in advance which kind of development endeavors would be successful. Similarly, investors could direct their efforts towards developments that are 'certified' to be successful. Even though this state will probably never be reached; the basic and underlying assumption of this thesis is that a sophisticated management of innovation will increase the probability that an innovation will be successful or that it is stopped early enough if its chances of success do not satisfy the required level.

In order to achieve continual new product development success, researchers started treating new product development like a (production) process that should effectively be aided by tools and concepts similar to other processes that have been previously optimized (Cooper, 1990; Clark and Fujimoto, 1991; Wheelwright and Clark, 1992; Cusumano and Nobeoka, 1992). Much has been researched since these ground breaking publications, but it seems that one spot has been mostly skipped by research so far: **The product cost analysis during pre-development.**

So why is this work focusing on product cost? Competitive pricing is a success factor; non-competitive costs are a failure factor for innovations (Mishra et al. 1996). One success factor of innovations is to develop products with superior performance-to-cost ratio (Cooper, 1988). According to Hax and Majluf (1982) product cost should not be viewed as the simple accumulation of direct and allocated expenses for its manufacture and sale. Instead they should also be seen as an indicator of the ability of a company to manage its resources. Some – not well run – companies still cultivate the picture of the opposite of creativity and cost-effectiveness, leading to a camp mentality between employees from technology and business (Jens, 1999). Yet, the fruitful combination of both is crucial to success (Hauber and Schmid, 1999). Following the paradigm of 'one can only manage what can be measured' (Gassmann and Kobe, 1999), the cost analysis is seen as an important contribution for the management of innovation.

So why is this work focusing on pre-development? It is in the early phases of innovation, in which pivotal decisions under high levels of uncertainty are made for both the market and technology (Lindemann, 2008). Also, it is the phase with the highest leverage for successful strategy alignment in innovation (Jens, 1999). Studies found that pre-development activities play a significant role for the success of new product developments (Cooper and Kleinschmidt, 1986; Dwyer and Mellor, 1991). Yet, pre-development routines are sometimes not well implemented in business (Cooper, 1988). Also, Shields and Young (1994, p. 177) cite an R&D manager:

> *"The key to R&D workers' cost management is to realize that the R&D costs they cause are relatively small compared to the downstream costs they cause. The big dollars come later and they are determined by R&D decisions."*

Thus an extensive view of the flow of innovation costs downstream and eventually to the final customer is important. Shields and Young (1994) name this view the global cost consciousness. The Hilti group refers to it as controlling in terms of business development (Bösch, 2008). The focus of this research is part of this global cost consciousness. It looks at future product cost analysis during pre-development and how companies use it. Thus this thesis looks at one part needed for successful innovations.

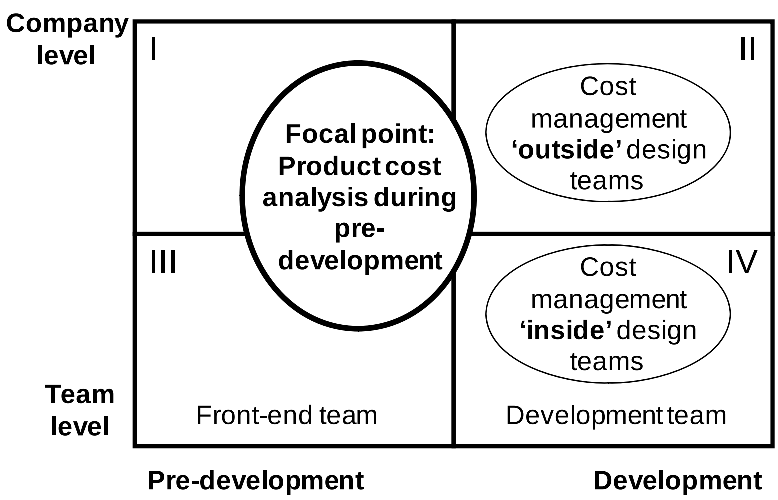

Figure 3: Focal point of this thesis

So far an articulated solution was to use target costing during the development stage. However, only lately the center of attention has been broadened to look around the main target costing practices. Davila and Wouters (2004) have widened the scope by investigating how cost information processing can contribute to efficient innovations. Most of the cost management literature has analyzed how the costs are managed 'inside' of development teams (Davila and Wouters, 2004). This is shown as the circle in quadrant IV in Figure 3. Contrary to that, Davila and Wouters (2004) have investigated how alternative practices 'around' the development teams can facilitate cost information processing and cost management (the circle in quadrant II in Figure 3). They have described several practices that bring cost criteria from outside of the development team into the development stage.

This thesis goes one step further and explores the possibilities of cost information collection and analysis during innovations, by looking at how cost information processing and cost management can be brought to innovation phases prior to the actual development phase (see the bold circle in Figure 3).

Koen et al. (2001) state their view that the new product development process starting from development kick-off is nowadays optimized in many companies. The interest for the research lies rather in the phases before this well-organized new product development process. However, good development processes should be beneficial right from the start. 'Better homework' is one of the identified improvement possibilities for more successful innovation revealed by Cooper (1990) and according to him need improvement (Cooper, 1990, p. 49):

> *"Of all the activities in the new product process, predevelopment activities were the ones most weakly executed in greatest need of improvement"*

This thesis takes the same point of view as Wheelwright and Clark (1992) and Franz (1992) that prevention and pre-diagnosis are better than 'after-the-fact' problem solving, i.e. treatment and healing once a problem has occurred. It can be disastrous for a new product development to find out that the production costs are much larger than planned and accepted by the market, ultimately leading to a development that is not profitable. Some academics even argue that 'cost' itself is a quality feature, and that an additional cost reduction project or redesign can actually be seen as a quality defect (Carr and Tyson, 1992; Anderson and Sedatole, 1998; Davila and Wouters, 2004).

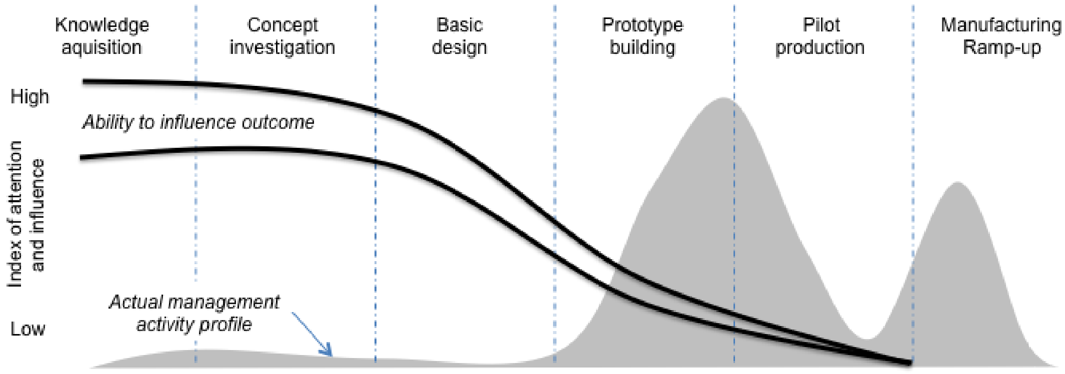

Figure 4: Timing and impact of management attention and influence according Wheelwright and Clark (1992, p. 33)

Main management attention might be dedicated to a development project too late, i.e. when the ability to influence the development has already gone dramatically down through lock-ins (Wheelwright and Clark, 1992), as can be seen in Figure 4. In this case, change is difficult and inefficient, as decisions have been made and implemented. Thus, the management is merely fixing the design, rather than directing the development. This typical activity scheme has also been found for the execution of innovation activities in general (Cooper and Kleinschmidt, 1986). However, through this lock-in effect, the pre-development phase provides the opportunity to improve the overall innovation effectiveness as ideas can be turned into high-quality proposals and designs. In his model Cooper (1990) labels the development start as the ‘decision on business case’ and gate 3. He describes it as the final gate before the development stage. Cooper claims that this is the position at which a new product development project can be killed before high expenditure incurs (Cooper and Kleinschmidt, 1993). Also Kotler and Armstrong (2008) state that product development costs rise greatly in later stages. Thus in their view a company should reduce new product development ideas early and proceed only with the most promising ones. The product development stage is the one that “calls for a large jump in investment” (Kotler and Armstrong, 2008, p. 259). Also, some projects tend to get a life of their own (Cooper, 1996). Companies might hesitate to stop well established new product development projects in fear of losing customers and demotivating employees (Varila and Sievanen, 2005). These are further reasons why the focus of this research lies before the development start.

The frontier of cost management research is moved further along the innovation time line in this thesis. It is moved to its early phases, starting with the front end of innovation. According to Koen et al. (2001) the later phases of the innovation are becoming understood and well documented in literature and thus the research focus has turned towards the first phase. Additionally, compared to research on costs in the new product development process and later stages, e.g. manufacturing costs, front end costing has received very little attention in the accounting literature. Similarly, in the NPD literature, analyses of costs are reduced to feasibility studies, which are usually far away from the preciseness that cost management tools could offer. The motivation for the research underlying this thesis is to understand how and when cost information is collected and processed in pre-development (Fields I & III in Figure 3).

As in any other field of business, managers working in the field of innovation management need accurate information for correct decision making. The area of cost management could aid this decision making process by providing information that enables companies to avoid unnecessary cost through the right selection and modification of new product development ideas during innovation phases (Voigt and Sturm, 2001). However, according to a study of the Institute of Management Accountants, 80 percent of the interviewed managers said that management accounting information is important “but only 23 percent [of these interviewed managers] are satisfied with their decision support information” (Clinton and Van der Merwe, 2006 ,p. 14). Fast and easy models could help practitioners, while other instruments might consume too many resources and time (Delgado-Arvelo et al., 2002; Davila and Wouters, 2004).

Summarizing, one can say that the theoretical background of this thesis is based on several concepts and notions:

1. New product developments experience lock-ins through decisions that are costly to be reversed
2. There is a trade-off between newness, performance increase, time-to-market, and cost
3. The right cost information has to be available and used for decision making as soon as possible

There are several calls for research that this thesis rejoins. In a call for research, Deszca et al. (1999) points out that it is difficult to develop breakthrough products, and a call for research on how companies can assess technologies and new product development ideas for breakthrough products. This work aims at exposing approaches that assist accomplishing these difficult tasks.

This goes hand in hand with the call for research of Shields and Young (1994). They would like to see further studies on what R&D professionals base decisions on that affect product life-cycle and target costs.

More generally, Foster and Young (1997) call for finding relatively unexplored areas in management accounting. This thesis analyzes the cost information gathering and analysis of different companies during pre-development. It presents timelines that demonstrates when which kind of cost information analysis and cost management tools are used during pre-development.

As Zimmerman (2001) states, the empirical managerial accounting literature has not so far created a substantive cumulative body of knowledge. Most of it focuses on describing the current accounting practice. According to Zimmermann, managerial accounting research still has to go the way other accounting research areas have already traveled – from mere description to the development of theories. He argues that one major reason for that is the lack of publicly available data, which is also a challenge to this thesis. Thus the cases and theorizing findings presented here aim also at filling a gap in the body of knowledge.

1.2 Research questions

The motivation for the research underlying this thesis is to understand how and when cost information is collected and processed in early innovation stages. This thesis and its findings aim to contribute to scientific and also practical use.

Descriptive part:

RQ I: How is product cost analysis done during pre-development?

Theorizing part:

RQ II: Why is the product cost analysis during pre-development done the way it is?

The purpose of this study is to identify, classify and describe how new product development ideas can be analyzed with cost information gathered in pre-development phases. The first research question calls for an analysis with a descriptive nature, while the second research question is the base for the theorizing part of this thesis.

1.3 Key definitions

This thesis is dealing with future product cost analysis during pre-development and before starting the discussion, some key concepts should be clear and defined.

Pre-development

Pre-development is the time phase that lies before the actual development start of physically developing a specific new product. This definition is in line with Cooper (1990) and Griffin (1997). A further discussion of the different contents of pre-development can be found in subsection 2.3.1.

Tool

This work follows the definition of Brady et al. (1997) that a tool is a document, a framework, procedure, system or method which enables companies to achieve or clarify particular objectives.

Lock-in effects

In literature it is claimed that usually a large share of all the costs a product will occur in its life are determined already in the development phase, even though the costs arise at a later stage (e.g. Boothroyd, 1988). This effect is called lock-in and it is experienced when a new product development proceeds. Academic authors also state that it is costly and time consuming to change earlier decisions (e.g. Blanchard, 1978; Cooper and Slagmulder, 1997). Thus making wrong decisions up-front in development can lead to sub-optimal situations. A detailed discussion about cost lock-ins can be found in subsection 2.4.3.3.

Cost management

Cost management focuses on cost reduction, continuous improvement and change. This work follows the definition of Horngren et al. (1994, p. 5) that cost management is "actions by managers to satisfy customers while continuously reducing and controlling costs". More about cost management and how product cost can be influenced through correct cost appreciation and managerial decisions can be found in subsection 2.4.2.

1.4 The cost view of this thesis

Cost can be seen from two different angles. It is important to point out that this thesis looks at one of these two angles:

The view on costs taken in this thesis is that of future product costs per product unit once new developments are launched in the market (view A).

The view is not on the actual (or budgeted) development costs that occurred between idea generation and market launch of a new product development (view B).

Even so, view B is an important and interesting issue; this budget cost view is not dealt with in this thesis. This is done as the research on future product cost management (view A) **before development start** is a nearly blank spot in literature so far. Contrary to that, a large number of publications in the field of cost management deal with the cost control of development projects – thus the actual (or budgeted) development costs (view B). E.g. Shields and Young (1994) call view A the global cost consciousness and view B the local cost consciousness. They focus mostly on development cost budgets (i.e. the local cost consciousness; view B) in their study of cost consciousness behavior of R&D professionals. Also Völker (1999) uses view B in his study on controlling of development cost budgets to steer R&D efforts to generate product portfolios with the highest net present value. Also, project management literature focusing on product development project costs usually takes the view B of costs as spending for the development project (e.g. Turner, 1998). Baldwin (1991) even arguments that control through the use of budgets (view B) are counterproductive to innovation and company performance.

In a product profitability view over its life cycle, the development spending naturally has to be also covered by the profit generated with the newly developed product and can e.g. be covered by depreciation or any other inclusion of R&D overhead costs. Nowadays product integrated software plays a significant role in new product developments. Programming can be a significant pre-launch cost for software-intensive products. These costs are also included in the view A, through e.g. depreciation or internal overheads. Additionally, there will be, of course, additional other costs like e.g. administrative and sales costs that also must be covered by the profit generated by the new product.

Figure 5: Main elements of cost according to Chadwick (2002)

For clarity the cost explanation of Chadwick (2002) is stated in Figure 5. The total costs are the sum of the direct cost and added overhead expenses. Direct cost consist of a) direct labor to transform raw materials into finished goods, b) direct material in form of product components including packaging, and c) direct expenses that can be charged to a specific job or product. Overhead expenses are indirect expenses (e.g. the cleaning of production facilities) that a new product development has to bear once launched on the market. A discussion of which overheads a new product development should bear would distract too much of the thesis topic. However, overheads should also be included for the product cost analysis during pre-development, as especially decisions made during the innovation process can influence the overhead costs. E.g. designing a development idea out of 23 instead of 45 parts could lower the raw material logistic costs for this new product development.

A further enlargement of the future product costs concept (view A) is the notion of life cycle cost. Life cycle costs are the sum of all costs that are incurred during the life span of a product; starting with its development, production, and operation until (and including) its disposal (Woodward, 1997). Thus the product costs are studied over the entire life span.

1.5 Location in the parent discipline and scope

The main parent discipline of this work is economics and business administration and more precisely the discipline of management accounting. Nevertheless, there are several research areas in management accounting, one of them being cost management. To further break it down, the focal point of this work is pre-development. Yet, this still leaves a fairly large area of possible research. Out of that area, the research problem is the cost information analysis done by companies with a view on future product costs.

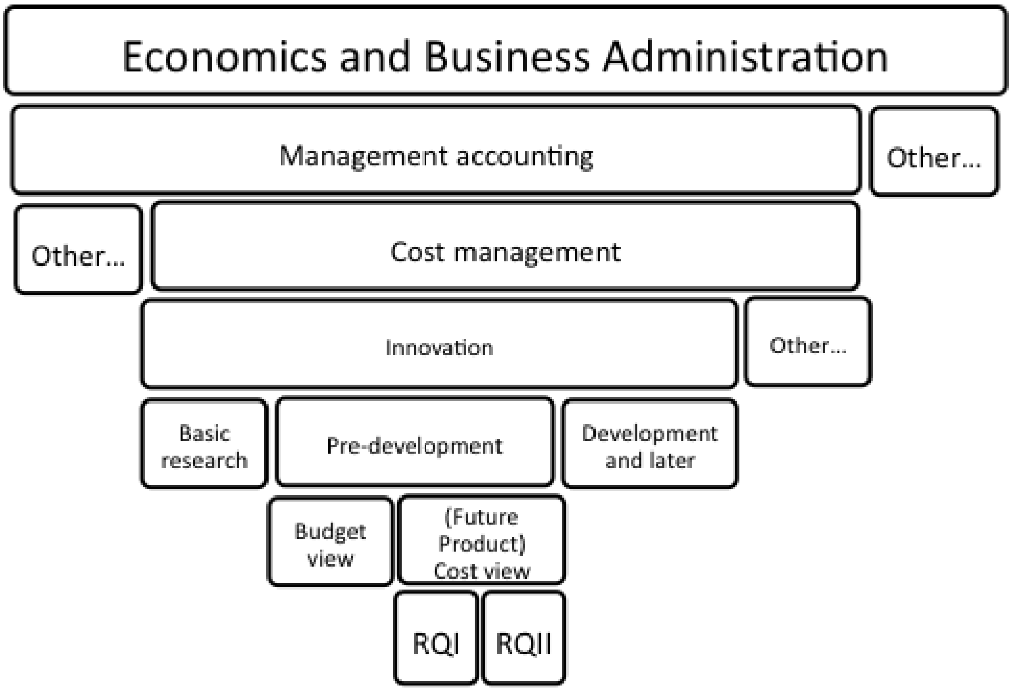

Figure 6: Research question position in the domain of the scientific body of knowledge

In order to clarify the focus and position of the research in the body of knowledge, Perry (2002) recommends making an overview of the location of the research in the parent theory. Figure 6 shows this overview.

The scope of this study is restricted to:

1. Cost analysis
2. Analysis itself, i.e. providing information for decision making not decision making itself
3. The cost view stated above
4. Product and industrial service related developments
5. Pre-development
6. Use of tools, rather than detailed technical implementations

To 1.) Many parameters are important if an innovation should be successful; this thesis focuses on the analysis of costs and cost information of new product developments. Other parameters, like quality and time spent on the development from idea creation to market launch, are secondary in this work. If a negative or positive side effect was mentioned during the interviews, these are included. However, these side effects are not in the prime research focus. Instead it is investigated how the future costs of a new product development idea are analyzed.

To 2.) This thesis looks at the process of analysis as a combination of gathering information and processing it in order to examine the situation a company is facing for its new product development idea. This analysis can be both, looking inside or looking outside of the company. When the analysis is looking inside, the new product development idea itself is analyzed. When the analysis is looking outside, the situation of the market and competition is examined. This thesis studies how information can be provided for correct decision making. It does not study the decision making process itself. Thus this thesis deliberately examines only on one part of cost management – the analysis.

To 3.) See subsection 1.4.

To 4.) The focus is on product innovations and its forerunner – the new product development project. If not stated otherwise, this thesis deliberately focuses mainly on product and industrial service related developments, rather than e.g. process improvements. Products can be seen as a compound of different components that deliver a certain customer benefit for a certain price (Baum et al. 2004). However, many things stated here will be analogous, and applicable to other developments than products.

To 5.) The scope of this thesis is restricted to pre-development. The development activities that start with development kick-off are not studied. It is acknowledged that many presented tools could also be used in later phases of the product life cycle. However analyzing how tools and/or information gathered during pre-development could be used later would go beyond the focus of this thesis.

To 6.) Detailed handling and technical implementation of the analysis is not exhaustively reported here. Even though the actual technical implementation was discussed with the case companies, a comprehensive description of the actual realization in these companies lies out of the scope of this thesis. E.g. if information is stored in the intranet, it is not reported whether this is done via a specific program or rather an MS-Excel form. This would lead to an overload of presented data that would distract the reader from the essential research questions.

1.6 Thesis structure

This thesis consists of seven chapters that are arranged as follows. Chapter 1 is an introduction to the thesis. Its aim is to raise the interest of the reader and to present the research questions and scope of this thesis. Chapter 2 reviews the innovation and cost management literature relevant to this thesis. Chapter 3 presents a methodological discussion about several ways of conducting research. It concludes with a choice that structures the rest of this thesis by following the chosen methodology. Through that, the basis is built for the seven company case study. Chapter 4 concentrates on the within-case analysis, while the chapters 5, and 6 focus on the cross-case analysis. Consequently in chapter 7, the different findings of the case studies are reflected against literature and the research questions are answered. Furthermore, the chapter concludes this thesis with a discussion of validity and limitations. An overview of the structure of this work is shown in Figure 7.

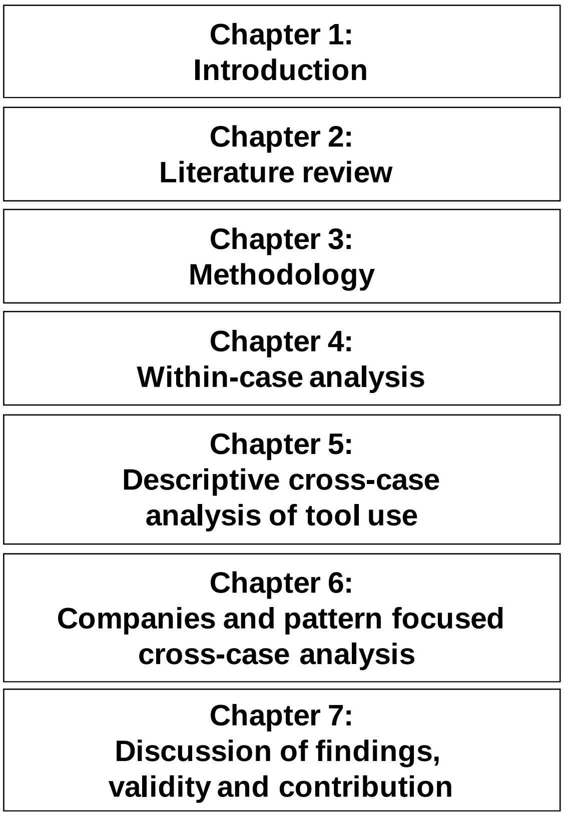

Figure 7: Overview of the structure of this work

2 Literature review

Section 1.5 above illustrates the location of the research of this work in the academics parent discipline. The research lies at the intersection of cost management and pre-development. This chapter reviews main concepts on this intersection of innovation as well as cost management as the relevant part of management accounting.

It starts with selected innovation concepts that can be used for classification purposes. These concepts are reviewed and presented in the following. Consequently, this chapter presents other important aspects concerning cost analysis during pre-development, before some literature case studies are presented.

2.1 Innovations

One major key concept of this thesis is the expression of innovation. Innovation is discussed for quite some time in academic literature and over the years many definitions of innovation have been made by different authors. In 1939, the economist Schumpeter (1939, p. 87) describes and defines innovation as follows:

> *"We will now define innovation more rigorously by means of the production function previously introduced. As we know, this function describes the way in which quantity of product varies if quantities of factors vary. If, instead of quantities of factors, we vary the form of the function, we have an innovation. But this not only limits us, at first blush at least, to the case in which the innovation consists in producing the same kind of product that had been used before, but also raises more delicate questions. Therefore, we will simply define innovation as the setting up of a new production function. This covers the case of a new commodity, as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on."*

In the 1960s Becker and Whisler (1967) already find many definitions. Innovation is often distinguished in facets between new-to-the-world and new-to-a-business-unit. This work deliberately follows the definition of Tushman and Nadler (1986, p. 75) that "**innovation is the creation of any product, service, or process which is new to a business unit.**" Thus, innovation can apply to various fields. This thesis intentionally narrows its focus further down to the development of products. It takes a product development perspective, i.e. focusing on product innovations rather than on innovations of services or organizational structures as a whole. Tushman and Nadler (1986) also distinguish product and process innovation. The first deals with changes in the product offering of a company. The second deals with changes in the way a product is made. This work focuses on the first type, product innovation.

The term invention has to be distinguished from innovation. An invention or idea becomes an innovation "only when it can be replicated reliably on a meaningful scale at practical costs" (Senge, 1990, p. 6). For example in 1903 the first flight aircraft of the Wright brothers proved that powered flight was possible. Yet it took over 30 years that the innovation of a commercial aircraft reached the market. Introduced in 1935, the McDonnel Douglas DC-3 “was the first plane that supported itself economically as well as aerodynamically” (Senge, 1990, p. 6). The planes built before “were not reliable and cost effective on an appropriate scale” (Senge, 1990, p. 6).

Innovations differ from each other and one can distinguish different types of innovation. In the academic literature differences between types of innovations have been strongly emphasized in the past (Damanpour, 1991). E.g. one difference is their origin, whether they come from a market need or rather from a new technology development. Another difference is the newness that the innovation presents to a company or a market. This section also looks at the classification of innovation types according to newness, so that it is better understandable what kind of innovations are looked at in the different cases.

2.1.1 Innovation character

Innovations can be very dissimilar and several character traits of innovations can be distinguished in literature. These are usually attached to the idea source, the idea focus or the extent of change connected to an idea.

Type	Classes	Relevant to innovation according
Processing focus	• Product innovation • Process innovation	Tushman & Nadler, 1986; Wheelwright & Clark, 1992
Final offering	• Product • Service	Ulrich & Eppinger, 2000
Origin	• Market driven • Technology driven	Ulrich & Eppinger, 2000 Hauschildt and Salomo, 2007
Origin	• Company internal • Company external	Gemünden & Littkemann, 2007 Kotler & Armstrong, 2008 Zaltman et al., 1973
Initiative	• Innovation by chance • Institutionalized innovation • Customer led innovation • Idea suggestion • Improvement & recycling search	Hauschildt and Salomo, 2007
Modularity	• Platform driven • Without platform	Ulrich & Eppinger, 2000
Manufacturing type	• Assembled • Non-assembled	Parish & Moore, 1996; Ulrich & Eppinger, 2000
System complexity	• Innovative system components • Innovative systems • Innovative integrated systems	Hauschildt and Salomo, 2007

Figure 8: Different innovation character types

Figure 8 shows different classes of innovation character types together with a selection of literature references that found this distinction important and relevant for innovation. One can distinguish **product** and **process innovation**. The first deals with changes in the product offering of a company. The second deals with changes in the way a product is made (Tushman and Nadler, 1986; Wheelwright and Clark, 1992).

Additionally **product** and **service** innovations can be distinguished (Ulrich and Eppinger, 2000).

Further innovation types can be distinguished according to origin. The first distinction is whether an innovation is **market** or **technology driven** (Ulrich and Eppinger, 2000; Hauschildt and Salomo, 2007). Technology driven innovations focus on new product developments in the area of technology. Technological and production aspects are in the center of attention. On the contrary, market driven innovations focus on new product developments in the area of marketing.

Also, **company internal** and **external** sources for innovations can be distinguished (Zaltman et al., 1973; Kotler and Armstrong, 2008). External sources can be customers, competitors, distributors, suppliers, and others. For company internal and external innovation sources Gemünden and Littkemann (2007) point out several paradigms that explain initiatives for innovations in companies. One paradigm is the planning paradigm. It is a top-down approach to innovation. It investigates changes in society and uses roadmapping of technology and market developments to derive attractive and lucrative opportunities. A second is the entrepreneurial paradigm. It focuses on pro-active and self-responsible efforts with a fast execution. A third is the barrier paradigm focusing on managers and employees in lower or middle management. These managers should spot needs for innovations and their possibilities. The innovation activities should increase if these managers get more freedom and support. However, with increasing freedom the absolute value of these measures decreases, while the screening costs and frustration are increased linearly. A fourth paradigm is the network paradigm. Its primary mission is to acquire innovation initiatives from outside of the company.

Innovations can also be distinguished according to the **initiative** from which they come to a company (Hauschildt and Salomo, 2007). There can be innovation by chance. This is completely the opposite of institutionalized innovation, which follows an intentional, rational and structured search for new product development ideas. Customer led innovation can also be distinguished were impulses come from wishes and needs of either the direct customer or the final customer. Another very important source of innovation is idea suggestions. They usually come from employees and can be collected continuously or based on idea competitions. Idea suggestions systems were already used in 1909 at Bayer (Hauschildt and Salomo, 2007). Thus idea suggestions systems are already used in companies for over 100 years. Finally, product improvement and the search to use by products can also lead to innovations.

Similar innovations of **assembled** vs. **non-assembled** products can be distinguished. The latter is severely restricted by the production process, as this process cannot be changed easily (Ulrich and Eppinger, 2000).

Furthermore, one can distinguish **platform driven innovations** from normal ones. If a company assumes that new products can be derived from established technological subsystems (platforms), it might choose this type of innovation or customize existing products (Ulrich and Eppinger, 2000).

Moreover, the degree of system complexity can be distinguished. **Innovative system components** are parts that improve an existing product (e.g. airbag for a car). **Innovative systems** are new products or processes that are newly developed and constructed from scratch (e.g. the Smart car). **Innovative integrated systems** are networks of several separate and innovative systems to a new entity (e.g. new motorway toll system in Germany) (Hauschildt and Salomo, 2007).

2.1.2 Newness

Innovation newness is measured in several degrees from incremental innovations to highly radical innovations. Innovations can then be classified according to those degrees. Thus when researching innovations, it is helpful to be able to classify different types of innovations. However, many different notions for those degrees are used today in business and academic worlds and thus several classification schemes are proposed in literature.

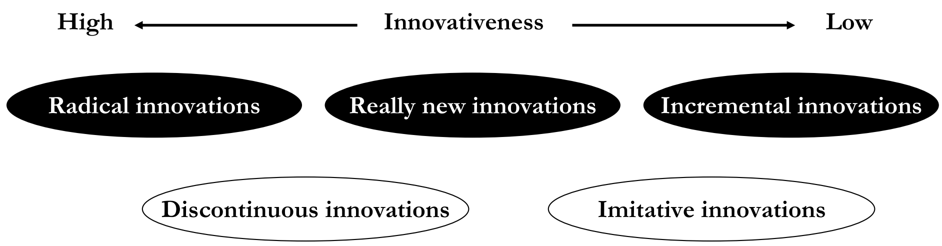

Figure 9: Innovation types according to Garcia and Calantone (2002)

The classical distinction is between **incremental** and **radical** innovations (Shenhar and Dvir, 1996; Tatikonda and Stock, 2003). Yet, in their literature review, Garcia and Calantone (2002) found out that many terms that should indicate the degree of newness in innovations are used. Some of the terms used are '**radical**', '**really-new**', '**discontinuous**', '**incremental**' and '**imitative**' (see also Figure 9). Incremental innovations are defined as "products that provide new features, benefits, or improvements to the existing technology in the existing market" (Garcia and Calantone, 2002, p. 123). Furthermore they define 'really new innovations' as a moderately innovative result positioned between radical and incremental innovation. However, there are also two types of innovation categories that lie between the three mentioned above – discontinuous and imitative innovations. Discontinuous innovations may either be a radical or a really new innovation, depending on which level (micro / macro) they affect and if market and technology are both changed or if one is kept (Garcia and Calantone, 2002). Similar imitative innovations can either be really new or incremental innovations, depending on their technological and market innovativeness degree (Garcia and Calantone, 2002).

Another newness classification is based on the type of innovation and its newness in different areas – four in total (Gemünden and Littkemann, 2007). The first area is the market. The **market** related newness increases with the amount of customers affected if a new product development has a significant value increase. The second area is the **technology**. The technology related newness augments with the increase in functionality and performance. The third area is the **organization**. The organization related newness increases with the degree of changes in the organization. These can be changes in the strategy, formal structures, processes, competences, culture, and reward systems. The fourth area targets the changes in the **environment** of the innovating company. The environmental related newness depends on the amount of different organizations and parties that are involved in complex competition and cooperation relationships, as well as the degree of market regulation.

2.1.2.1 Market based distinctions

A further distinction in literature is made between **pioneering** and **incremental** innovations (Crawford, 1992; Ali et al., 1993; Barczak, 1995). The benefit of pioneering innovations is seen through proprietary learning, the small possibilities of imitation and a long head start. In this case pioneering innovations can work out a cost advantage that leads to higher profits compared to following innovations (Lieberman, 1987). On the contrary, postponing a pioneering innovation by waiting and being an early follower has the benefit that a dominant design could have emerged that facilitates product, process and infrastructure development with the benefit of a higher efficiency (Deszca et al., 1999). However, companies that have always covered pioneering innovations can experience difficulties handling incremental innovations and vice versa (Dougherty and Corse, 1995).

Another innovation classification is the binary distinction of Christensen (1997). Focusing on a longer time scale, Christensen (1997) defines two categories of technology innovations pending on the performance of the new product development. The first category is called **sustaining** innovations. These are innovations, which improve the performance of a product. They can be discontinuous and radical or incremental. The second category is called **disruptive** innovations. These are innovations which reduce the performance of a product category, at least in the near outlook. They have a different value proposition than the existing technologies, which might not look appealing to the users of the established technology. However, the technology might be cheaper, simpler or create smaller products, which will in the long turn replace the established technology (Christensen, 1997). That is why they might also be called **competence destroying** technologies (Geroski, 2003).

Similar to Christensen (1997), Tidd (2001) also uses the concept of a more than radical innovation that completely changes business rules and names this innovation type '**disruptive**' (see Figure 10).

Type of innovation	Competitive advantage
Disruptive	Re-writing rules of the competitive game, creating a new 'value proposition'
Radical	Offering a highly novel or unique product or service, premium pricing
Complex	Difficulty of learning about the technology keeps entry barriers high
Continuous incremental	Continuous movement of the cost/performance frontier

Figure 10: Newness type of innovation and its associated competitive advantage according Tidd (2001)

The next type of innovation in the scheme of Tidd (2001) is called '**radical**'. According to Tidd (2001) a radical innovation offers a very new or unique product that allows a premium pricing on the market. The third type is the **complex** innovation that is characterized by market entry barriers due to complex technology knowledge. The forth and last type is the **continuous incremental** innovation that is a response to the permanent cost / performance pressures of the markets. However, a radical change in a component or subsystem may result in only an incremental performance change of an end product (Tidd, 1995).

2.1.2.2 Technology based distinctions

Wheelwright and Clark (1992) also developed an innovation classification focused on where in an organization and to which extend an innovation is carried out. These four different types of development projects are shown in Figure 11.

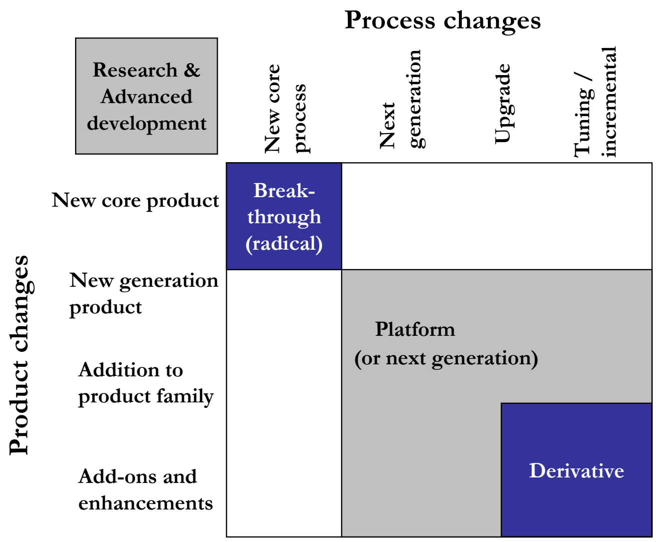

Figure 11: Four types of product / process developments according Wheelwright and Clark (1992)

Wheelwright and Clark (1992) distinguish four different types of development projects. The first type is **research** or **advanced** development projects. The scope of these projects is to invent and capture new science and know-how, so that this gained information can then be used in specific new product development projects. The second type is **breakthrough** development projects. These projects develop entirely new products and processes using core concepts and technologies that are completely new to the developing organization. The third type is **platform or generational** development projects. These concepts are aimed at creating platforms and basic architectures on which several follow-up generations can be built on. Last but not least, the fourth type is **derivative** development projects. They refine and improve selected performance dimensions to better meet the needs of specific market segments (Wheelwright and Clark, 1992).

Roy et al. (2005) take up this point that many new product developments are actually a mix of conventional and new technologies. Thus they distinguish four types:

1. **New to the company** content type
2. **New with similar attributes** to a specified design
3. **Modified redesigned** from an existing stated design
4. **Exactly the same** as an existing stated design **(carry over)**

	A, low-tech	B, medium-tech	C, high-tech	D, super high-tech
Technology	No new technology	Some new technology	Integrating new, but existing, technologies	Key technologies do not exist at project's initiation
Typical industries	Construction, production, utilities, public works	Mechanical, electrical, chemical, aerospace, some electronics	High-tech and technology-based industries; e.g. computers, aerospace, electronics	Advanced, high-tech and leading industries, electronics, aerospace, computer
Type of products	Buildings, bridges, telephone installation, build to print	Additional, non-revolutionary models, derivatives or improvements of a product	New military system; new, first of its kind family of products, within state-of-the-art	New, non-proven concept, beyond existing state-of-the-art
Development and testing	No development, no testing	Limited development, some testing	Considerable development and testing. Prototypes usually used during development process	Must develop key technologies together with product. Usually develop an intermediate prototype to test concept and new technologies
Design cycles and design freeze	Only one cycle. Design freeze prior to project's execution phase	One to two cycles. Early design freeze, no later than first quarter of execution phase	At least two cycles. Design freeze usually during first or second quarter	Two to four cycles. Late design freeze, usually during second or third quarter
Communication and interaction	Mostly formal communication at predetermined low rate meetings	Increased frequency of communication, some information interaction	High levels of communication through multiple channels; informal interaction is common	Extensive number of channels; management facilitates informal interaction
Project manager and type of workers	Manager has good administrative skills. Mostly semi-skilled workers; a few academicians	Manager must possess some technical skills. About half of the workers are academicians	Good technical skills of manager. Many professionals and academicians on the project	Project manager is an exceptional technical leader. Highly skilled professionals and high rate of academicians
Management style and attitude	Firm style. Management sticks to the initial plan	Moderately firm style. Ready to accept some changes	Moderately flexible style. Expecting many changes	Highly flexible style. Living with continuous change and 'looking for trouble'

Figure 12: Project characteristics and level of technological uncertainty according to Shenhar and Dvir (1996)

Development teams have to manage the uncertainty connected to the demand, technology and competition in order to develop new products successfully (Zhang and Doll, 2001). Shenhar and Dvir (1996) are using a technological uncertainty and newness classification with four categories from '**A, low-tech**' to '**D, super high-tech**' for innovation (see Figure 12). One should point out that the provided definition sets itself clearly apart from other literature due to its compromising and well reflected description.

2.1.2.3 Organization and knowledge based distinctions

Another area is pointed out by Tushman and Nadler (1986). They distinguish three degrees of innovation with increasing **learning requirements** – incremental, synthetic and discontinuous. Incremental innovations are mostly based on learning by doing. Synthetic innovations are based on major process improvements and finally discontinuous innovations are a complete change of underlying technology, e.g. the change from steam to diesel locomotives (Tushman and Nadler, 1986).

A further classification scheme is presented by Murmann and Frencken (2006). It also has a four type distinction and looks at the degree in which new knowledge is needed and simultaneously at the extent of performance improvement that an innovation brings.

	Low performance improvement	High performance improvement
Small scope of new knowledge	Incremental innovation	Radical innovation, sense 1
Large scope of new knowledge	Radical innovation, sense 2	Radical-square (r^2) innovation

Figure 13: Types of radical innovations according to Murmann and Frencken (2006)

Figure 13 demonstrates how a change of two parameters – the needed knowledge and the performance improvement – change the nature of innovations. If both parameters stay similar one can speak of an incremental innovation. However, if one parameter is significantly changed, the radicalness of innovation rises. Furthermore, the radicalness is the highest if both parameters are changed. In this case, the authors are speaking of a **radical-square (r^2) innovation**. They distinguish between an innovation that is radical because its high performance improvement (sense 1) and because of its large scope of required new knowledge (sense 2) (Murmann and Frencken, 2006).

2.1.2.4 Effects, implications and changing newness over time

According to Garcia and Calantone (2002) radical innovations are innovations that result in discontinuities on macro and micro level of economic systems. A radical innovation will cause a discontinuity on a world, industry or market level and through that, automatically cause a discontinuity on a company and customer level.

Radical technology and product innovations need a different management as incremental developments occur (Gassmann and Kobe, 1999). Yet both types of new developments have high importance. On one hand, new incremental developments need to be managed well within the existing core competences in the short run. On the other hand, new technologies are needed to jump from one technology S-curve to the next in the long run (Gassmann and Kobe, 1999).

Yet, whole industries might be more prone for radical developments than others (Pavitt et al., 1989). Also, companies of industries with large technological opportunities face higher potential threats of technological entry from outside than other industries. According to Pavitt et al. (1989) this may explain the notion that radical innovations are often made by newcomers to a market.

Established companies spend 80-90 percent of their technology budgets on incremental innovation. Only a minor fraction is spend on more radical innovations, as managerial understanding for them is weaker and success is rare (Roberts, 2007).

However, radical innovations are more willingly adopted and implemented in times of crisis and external threat. This is as uncertainty and worries created by the crisis make managers open to adopt new structures that show promise of relieving the situation (Shepard, 1967).

One characteristic of new product developments is environmental uncertainty (Ax et al. 2008), which is reduced from stage to stage the further a new product development goes towards market launch (Cooper, 1996). Thus uncertainty can be seen as a contingency factor for innovation (Damanpour, 1991). Less radical innovations with lower uncertainty will also lead to lower cost in regard to the search for solutions in the new product development process (Zaltman et al., 1973).

Uncertainty can also be regarded as a subjective phenomena, rather than physical realities (Ax et al. 2008). Thus the perceived uncertainty can also play a role for the cost analysis during pre-development.

Last but not least it has to be kept in mind that the innovation type and its radicalness can change over time for the (re-)developments connected to a new product development idea. According to Kash and Auger (2005) this happened with the diesel fuel injection systems of Bosch. They went through several development phases, starting from the fundamental breakthrough innovation before World War II. However, what followed were first some more incremental innovations, before there was another wave of major re-developments in the 60s. This wave was followed by another major re-developments phase in the 80s, before the innovations again became more incremental. Thus it is not said that there is a mere movement from radical to incremental innovations, but it can also move back to more radical innovations.

2.1.2.5 Summary on newness classifications

Summarizing, one can say that there are many different innovation newness classifications in literature. In general, newness of innovations is assessed in a spectrum from incremental innovations, with little change to product and needed knowledge, to radical innovations, with more change to product and needed knowledge. Figure 14 shows an overview of the introduced concepts of different authors.

Type	Focus	Classes	Authors
Normative newness definitions	General	• Radical • Discontinuous • Really-new • Imitative • Incremental	Garcia & Calantone (2002)
Newness for different areas	General	• Market • Technology • Organization • Environment	Gemünden & Littkemann, 2007
Market entry	Market	• Pioneering • Incremental	Crawford, 1992; Ali et al., 1993; Barczak, 1995
Newness and performance changes	Market	• Disruptive • Sustaining	Christensen, 1997
Newness and performance changes	Market	• Disruptive • Radical • Complex • Continuous incremental	Tidd, 2001
Newness and process changes	Technology	• Research /advanced development • Breakthrough • Platform or generational • Derivative	Wheelwright and Clark, 1992
Newness and performance changes	Technology	• New to the company • New with similar attributes • Modified redesigned • Carry over	Roy et al., 2005
Newness and uncertainty	Technology	• D, super high-tech • C, high-tech • B, medium-tech • A, low-tech	Shenhar & Dvir (1996)
Newness and performance changes	Organization	• Radical-square • Radical • Incremental	Murmann & Frencken, 2006

Figure 14: Overview of newness classifications

Also, several definitions of 'radical innovations' exist. Garcia and Calantone (2002) and Christensen (1997) look at the discontinuity of existing offerings; Wheelwright and Clark (1992) look at the novelty of product and process; and finally Murmann and Frencken (2006) look at the additionally needed knowledge and the extent of performance improvement.

Furthermore, it should be noticed that there might be a **bias in academic research** due to study perspective and newness. Verworn et al. (2008) point out that literature has taken two different perspectives when analyzing incremental and radical innovations. The studies focusing on incremental innovations usually take a micro perspective of adoption of a company. On the contrary, studies focusing on radical innovations usually take a macro perspective based on factors outside of companies, such as newness to the world (Verworn et al., 2008). This work focuses on the company focused, micro perspective, independently of the newness of the studied new product development ideas.

2.1.3 Successful vs. unsuccessful

Innovations have to create additional value. Resources are needed and are primarily sponsored by investors and banks. If a company cannot deliver successful innovations it risks it's refinancing and endangers the workplace of its employees (Schindler, 1999). While companies like Apple placed successful innovations like the iPod and the iPhone on the market, other companies are less successful. E.g. Texas Instrument lost 660 million USD before leaving the home computer segment (Kotler and Armstrong, 2008). Thus, one can also differentiate successful and unsuccessful innovation endeavors. Naturally, companies are trying to have all of their developments successful, but for research purposes, failed new product developments are also interesting. Reality also shows that not all innovations are successful (Cooper, 1979; Stevens and Burley, 1997; Ulrich and Eppinger, 2000; Kotler and Armstrong, 2008).

Furthermore, it is actually complex to differentiate the successfulness of an innovation, as there is a multitude of possible innovation success measures (Dwyer and Mellor, 1991). These measures can either be a pre-indicator of the financial success or be a result of the financial success. Often the success of an innovation is measured in commercial success and expressed in financial figures, e.g. turnover, profit and market share gained through an innovation (see e.g. the rational plan perspective in Brown and Eisenhardt, 1995; Cooper, 1996; Poolton and Barclay, 1998; Ernst, 2002). That is also why finance is often setting the ground rules for evaluating and monitoring innovation programs and projects (Pavitt, 1990). A study of Griffin and Page (1996) indicates that companies do measure the success of an innovation with parameters that are in line with the strategic priorities of a company. E.g. if the time to market is valued very highly in a company, managers of that company will use measures that express the timeliness of an innovation. Thus it has to be kept in mind that not all innovations try to be profitable and sometimes the development aims are those other than financial success.

New product development can be seen as the challenge that companies must develop new products, but the odds stand profoundly in opposition to success (Kotler and Armstrong, 2008). It is not in the prime focus of this work to give an overall recipe for successful innovations, as the success of an idea depends on much more than what is examined in that work. However, the future product cost analysis during pre-development phases described in this work, can be a step that helps to develop ideas further into successful innovations as, in general, excellence matters in the innovation process.

Wheelwright and Clark (1992) have found that companies with superior development capabilities have a more comprehensive development strategy framework that provides a more secure foundation for individual development projects – in the front end as also in the back-end. Product cost analysis during pre-development can help to increase the odds for success.

2.2 Pre-development in the innovation process

According Van de Ven (1992), researchers should distinguish three main types of processes. The first process type is an input-process-output model that uses process logic to explain causal relationships between observed input variables and dependent variables for variance theoretical explanations. This input-process-output model is often a black box. The second process type uses process as one category of several concepts that are not directly examined. The third process type is a developmental sequence of events or activities that describe the process over time. This thesis looks at the third type of processes.

In general, the innovation process is characterized by connected tasks, uncertain results and feedback loops (Vinkemeier and von Franz, 2007). Several models are constructed to show how innovation should ideally be developed. In the following three classes of models are distinguished. The first model class uses **several phases and selection gates** in between and is named here the stage-gate view. The second model class looks at the amount of ideas and describes a narrowing **funnel effect**. It is named the funnel view in this work. A third, more abstract class compels models that take the view that **more and more information has to be collected during the innovation** process. It is named the information acquisition view in the following.

2.2.1 The stage-gate view

Some process models view new product development as a sequence of steps with intermediate checks and reviews. This subsection focuses on these kinds of models. Several of these models are proposed in literature; each focusing on different main aspects.

Implementing a stage-gate process is a significant investment. Yet, the benefits are multiple. Firstly, it shortens the time to market for new product developments. Secondly, it improves the development quality, as fewer mistakes and less rework are required. Furthermore, it also leads to a higher success rate (Cooper, 1990). However, in real business settings there is much iteration in and over the different stages that can limit the usability of stage-gate models (Varila and Sievanen, 2005). Yet, the idealized stage-gate models are well suited as a base construct for research.

2.2.1.1 A general stage-gate model

In his 1990 article about stage-gate systems, Cooper (1990) states that many innovation processes implemented at companies are surprisingly similar and incorporate a stage-gate approach. An analogy of these processes is the manufacturing of a physical product (Cooper, 2009). In both cases the whole process is divided up into different stages or work phases and between these there is usually a quality control checkpoint, before moving it into the next phase. Thus, similar like in manufacturing, the quality of the innovation process should be improvable by adapting best practices and removing variances (Cooper, 1990). The basic idea is that the innovation process is cut into different slices where specific tasks are performed. Furthermore, there is usually a go/no-go decision to be made so that the innovation can proceed into the next step. A typical process like this is shown in Figure 15.

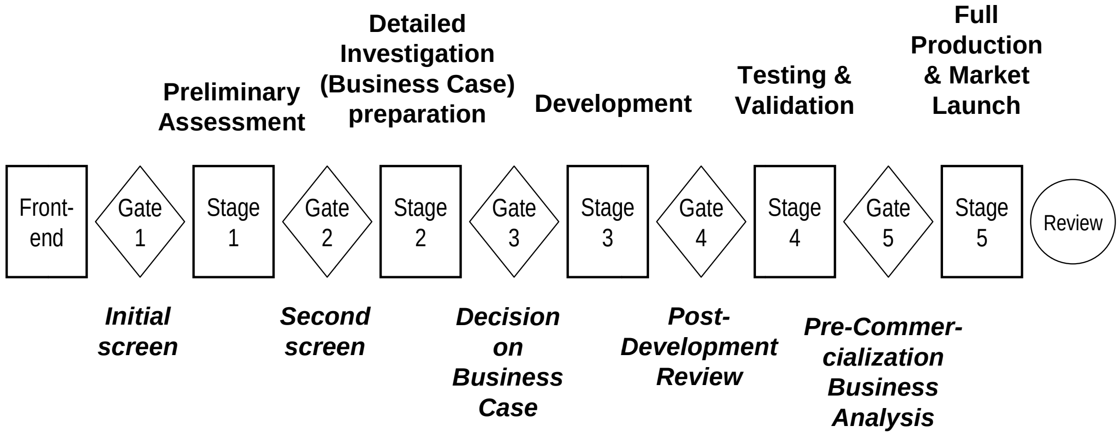

Figure 15: Stage-gate model according to Cooper (1990)

Cooper (1990) defines stage-gate systems as conceptual and operational models for developing a new product idea from idea generation to market launch. In the model of Cooper (1990) the different innovation phases are clear-cut. It is an innovation time line concept known and used by many academics as well as practitioners.

Yet, the stage-gate systems found today in companies can also be shorter (Cooper, 2009). Some have the front end and two stages before the development stage (as shown in Figure 15), while others have one or even two stages less before the development stage (Cooper, 2009).

2.2.1.2 A strategy focused stage-gate model

One institutional origin of innovations can be strategic work and consideration. If a general or specific innovation strategy is available, new product development ideas can be derived from that strategy.

Figure 16: Innovation process according to Vinkemeier and von Franz (2007)

Figure 16 presents a five-stage model often used in practice according to Vinkemeier and von Franz (2007). This process starts with the definition of the innovation strategy. This strategy is the basis and guideline for the other phases, starting with the idea generation. After the idea generation comes the research and development, before ideas are handed over to production and finally released to the market (Vinkemeier and von Franz, 2007).

2.2.1.3 An organization focused stage-gate model

Summarizing some models in literature, Zaltman, Duncan and Holbek (1973) present their (organizational) model. It consists of two main stages (‘Initiation stage’ and ‘implementation stage’) that are further divided into sub-stages (see Figure 17).

I. Initiation stage
1. **Knowledge-awareness substage**
2. **Formation of attitudes toward the innovation substage**
3. **Decision substage**

II. Implementation stage
1. **Initial implementation substage**
2. **Continued-sustained implementation substage**

Figure 17: The organizational oriented model of the innovation process according to Zaltman, Duncan and Holbek (1973)

Zaltman et al. (1973) take the view of an individual adoption unit (i.e. in a business unit) and subdivide the innovation process into two stages that are named ‘initiation’ and ‘implementation’. The initiation is the point where either a new idea has become approved by the stake-holders in a company and/or the decision has been made to implement a new idea. Following that, the implementation stage compromises the actual mechanics of managing the changes that innovation may imply (Zaltman et al., 1973).

The first sub-stage in the model is the ‘Knowledge-awareness sub-stage’. The authors see the knowledge of the innovation as a crucial first sub-stage in the initiation stage. The unit of adoption (i.e. the employees of a business as potential adopters) must be aware that the innovation exists and that there is an opportunity to exploit the new idea in the organization. This can be triggered by the company searching for ways to improve its business and then discovering a new idea (pull) or by getting to know a new idea and identifying it as a potential new business (push). The second sub-stage in the model is the ‘formation of attitudes toward the innovation’. It comprises the openness to the innovation and the potential of the innovation. The third sub-stage is the ‘decision sub-stage’ where the information concerning the potential innovation is evaluated. At this point the organization needs to process a good amount of information and have effective channels of communication (Zaltman et al., 1973). If the relevant decision makers are then favorable to the new idea and motivated to innovate, the idea will proceed into the implementation stage.

This implementation stage is divided by Zaltman et al. (1973) into two sub-stages. The first of these is the ‘initial implementation sub-stage’, where the first trial of the particular innovation is made. The second sub-stage is the ‘continued-sustained implementation sub-stage’, where the innovation is rolled-out if the trials were perceived as successful. However, the authors acknowledge that a multitude of possible strategies and sequences exist in the implementation stage (Zaltman et al., 1973).

Overall one can say that the model of Zaltman et al. (1973) takes the view of how innovations are processed in organizations and focuses less on special new product developments.

2.2.1.4 An innovation activity focused stage-gate model

Another time sequenced classification of the innovation process is presented by Ulrich and Eppinger (2000), who have segmented the product innovation process into six different phases. It can be seen as an ‘innovation activity focused’ classification concept of innovation and is shown in Figure 18.

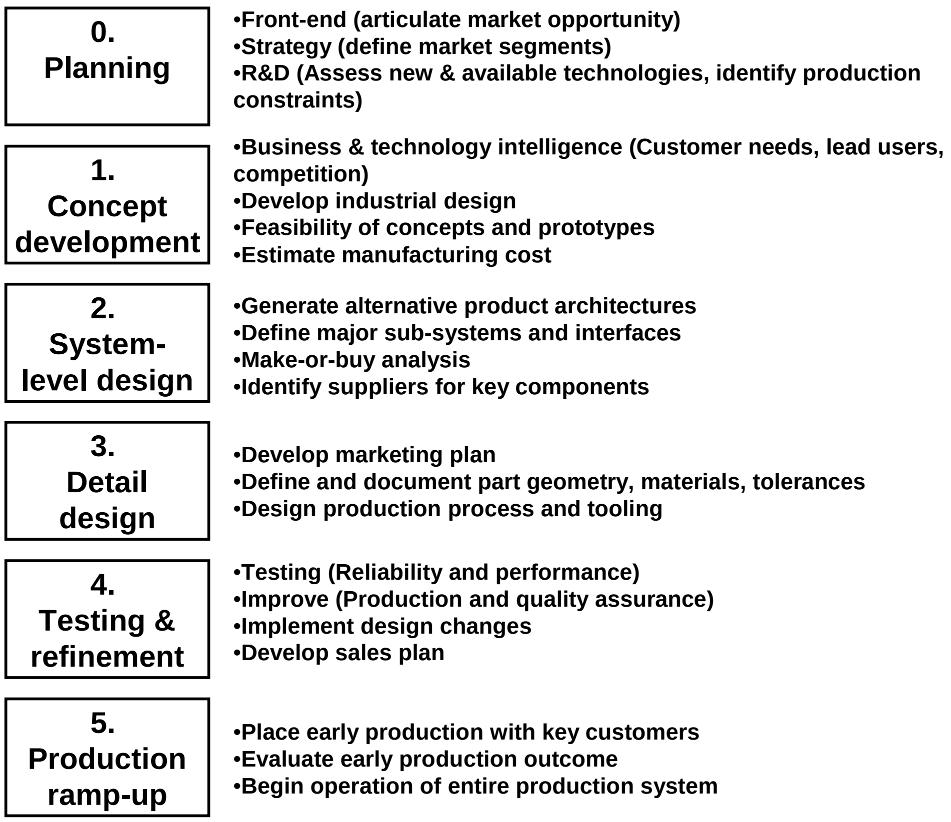

Figure 18: Ulrich and Eppinger’s (2000) different phases and main activities of a product development process

The research for this thesis is focusing on the stages 0 to parts of 1. The initial phase (planning) starts with strategy formulation and assessments of technology developments and market aims. The following phase (concept development) deals with the identification of needs of the target market. In this phase different product concepts are generated and evaluated. The different tasks of the concept development are discussed and shown in Figure 26 further down in more detail. It is the first phase in which Ulrich and Eppinger (2000) also describe the use of cost management methods. These methods are used to estimate the manufacturing costs.

2.2.1.5 A marketing focused stage-gate model

Similar to the strategy focused stage-gate model, a marketing focused stage-gate model can also be derived. Thus another institutional origin of new product development ideas can be marketing focused considerations or a specific marketing strategy.

Figure 19: Major product development stages according to Kotler and Armstrong (2008, p. 254)

Kotler and Armstrong (2008) have a marketing centered stage model. It focuses on eight major stages in new product development and is shown in Figure 19. The first stage is the idea generation. Kotler and Armstrong (2008) define this idea generation stage as a systematic search for new product ideas. This stage is open to all sources and should raise a large number of new product development ideas.

The second stage is the idea screening stage. The purpose of this stage is screening new product ideas in order to spot good ideas and drop poor ones as soon as possible (Kotler and Armstrong, 2008). They see the purpose as to reduce the number of ideas significantly. According to Kotler and Armstrong (2008) executives might be required to document new product development ideas in that stage. This is done on a standard form that is later reviewed by a committee. This overview talks about the product itself, the target market and the competition. The checked parameters include rough estimates about market size, product price, development time and costs, manufacturing costs and rate of return (Kotler and Armstrong, 2008). Thus manufacturing costs are already checked in the first screen.

The third stage is concept development and testing. Attractive ideas are then developed into product concepts. A product concept is a detailed version of the new product development idea stated in meaningful consumer terms (Kotler and Armstrong, 2008). Concept development is followed by concept testing. Concept testing is the evaluation of new product concepts with a group of target consumers to find out if the concepts have strong consumer appeal (Kotler and Armstrong, 2008).

The fourth stage in the process model is marketing strategy development. The purpose of this stage is to design an initial marketing strategy for a new product based on the product concept (Kotler and Armstrong, 2008). Part of marketing strategy development is a marketing strategy statement. In their view the marketing strategy statement consists of three parts. The first part describes the target market, the planned production positioning, and the sales, market share and profit goals for the first few years. The second part outlines the product's planned price, distribution and marking budget for the first year. The third part describes the planned long-run sales, profit goals and marketing mix strategy (Kotler and Armstrong, 2008).

The fifth stage is business analysis. It is a review of the sales, costs and profit projections for a new product development idea to find out whether these factors satisfy the company's objectives (Kotler and Armstrong, 2008). Only if these criteria are satisfactory, can the new product development idea move to the next stage.

The sixth stage is the product development stage. The aim of this stage is to develop the product concept into a physical product in order to ensure that the product idea can be turned into a workable product (Kotler and Armstrong, 2008). In their view, R&D or engineering develops the product concept into a physical product.

After the product development stage are the test marketing and commercialization stages. Test marketing is the stage in which the product and marketing program are tested in more realistic market settings. Finally, the commercialization is the stage in which a new product is introduced into the market (Kotler and Armstrong, 2008).

2.2.1.6 Summing up on different stage-gate views

Many companies use stage-gate process models that are a sequence of steps with in-between assessments (Cooper, 2009). However, there is a multitude of models proposed in literature.

Authors	Focus	Characteristic
Cooper (1990)	General	• Universal approach • Focus on gates as a regular review mechanism • Different innovation phases are clear cut
Vinkemeier & von Franz (2007)	Strategy	• Starts with the definition of the strategy • Strategy is the basis and guideline of innovation
Zaltman, Duncan & Holbek (1973)	Organization	• Focus on organizational adoption • Two main stages: Initiation and implementation • View of how innovations are processed in organizations
Ulrich & Eppinger (2000)	Innovation activity	• Product development as a systematic project execution • Focus on tasks in different stages
Kotler & Armstrong (2008)	Marketing	• Focus on consumer • Creativity as a base and marketing as main selecting criteria

Figure 20: Overview of stage-gate models

Figure 20 shows an overview of the different stage-gate models described above. The model proposed by Zaltman et al. (1973) is distinct to the others, as it focuses on organizational adoption of innovation, while the other models focus on the movement of new product development ideas through a series of stages.

In the respect of clarifying the different decision making gates of the innovation process, the overview articulated by Cooper (1990) is well suited to structure this research. It provides the flexibility and utility of a flexible shell that fits best to the analysis.

2.2.2 The funnel view

The innovation process can also be seen as a sequential reduction of options. Over time, more and more new product development ideas get screened out and stopped. In the funnel view the new product development process starts with a multitude of possible concepts and step-by-step condenses this multitude down to one or few specific new product developments (Srinivasan et al. 1997; Slack and Lewis, 2008). This subsection reviews literature that focuses on this notion.

2.2.2.1 The generic funnel view

Many ideas are sorted out during the innovation process. It has been claimed that it takes about 3000 raw ideas in the initial stage to come up with one commercially successful product (Stevens and Burley, 1997).

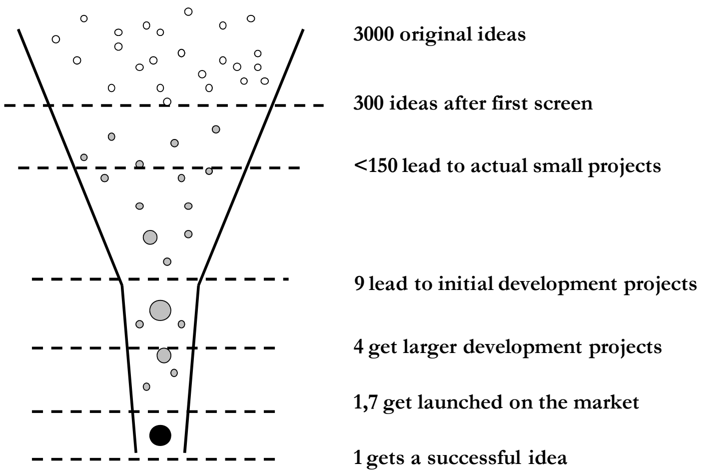

Figure 21: Many ideas are needed for one successful development according to Stevens and Burley (1997)

Figure 21 shows a general pattern for the several screening stages an idea goes through, independent on the analyzed product type. In a self-screening process R&D employees pick ideas, interesting and potentially feasible in their eyes, to do some simple experiments or discuss them with management. Through that the amount is reduced to 300 followed-up ideas according to Stevens and Burley (1997). Less than half of these are then leading to small projects which might result in a patent filing. Subsequently only nine of these lead to larger projects and only the half of that are enlarged to major development efforts. After that only 1,7 of the original ideas are commercially launched and on average only 59% of these ideas turn out to be successful (Stevens and Burley, 1997). So even if the number of raw ideas needed to get one product successfully launched might be lower in some industries, the demonstration still shows that many suggestions are needed for a successful innovation (see Figure 21).

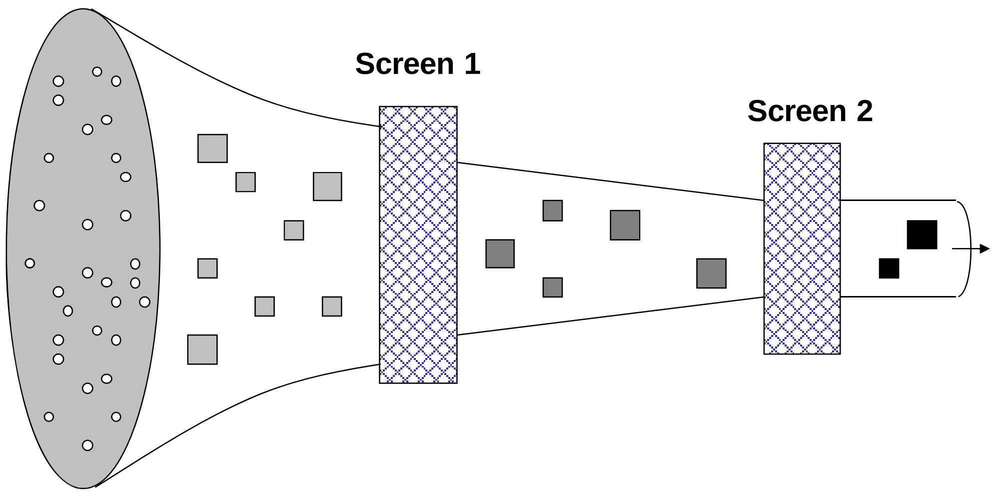

Figure 22: The development funnel preferred by Wheelwright and Clark (1992)

Another generic funnel with several phases is described by Wheelwright and Clark (1992). In the front-end, the new product idea generation and the concept development is taking place. In the following phase, the proposed project is detailed and the required knowledge is identified and acquired. The screen positioned between them has two major functions; to check for completeness and to identify similar ideas that can be grouped together, but not to make go/no-go decisions. The reviews of screen one are done at consistant time intervals and preferably by a mid-level group of managers. The point where go/no-go decisions are made is screen two. At this point, senior management steps in, evaluates the possible product development options and selects the ideas that should be pursued further in new product development projects. Wheelwright and Clark (1992, p. 111) define the operation logic of the development funnel as follows:

> *"A variety of different product and process ideas enter the funnel for investigation, but only a fraction become part of a full-fledged development project. Those that do, are examined carefully before entering the narrow neck of the funnel, where significant resources are expended in transforming them into a commercial product and/or process."*

Figure 22 shows a development funnel that is seen as optimal by Wheelwright and Clark (1992).

2.2.2.2 Specific funnels found in practice

The model shown in Figure 22 has developed out of the two funnel approaches found in reality by Wheelwright and Clark (1992) (shown in Figure 23).

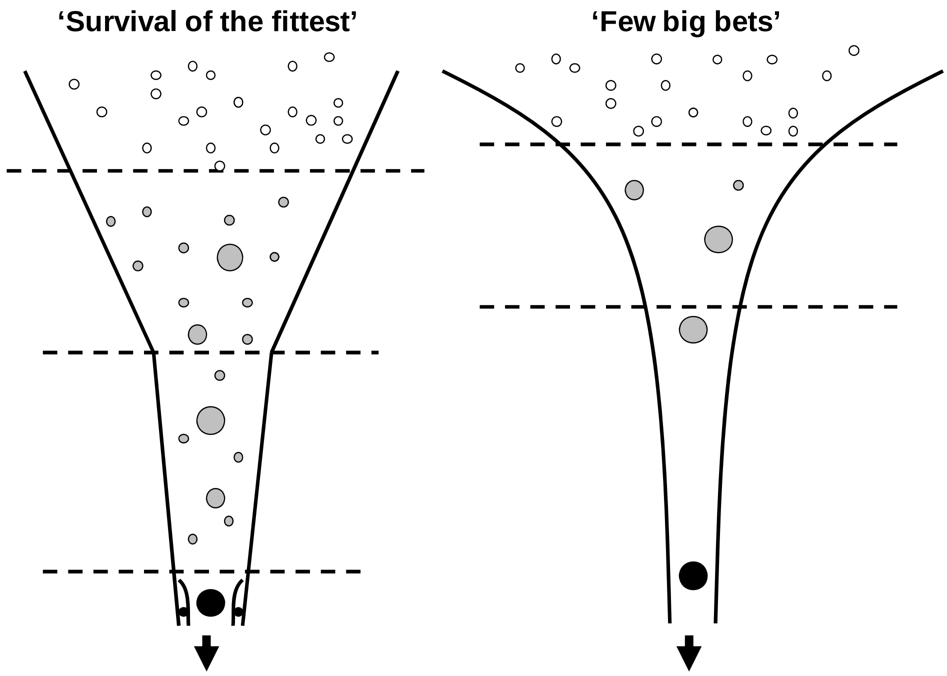

Figure 23: Two funnel types found in industry by Wheelwright and Clark (1992)

These two innovation funnel types are on the one hand what Wheelwright and Clark (1992) call a 'survival of the fittest' approach (left hand side in Figure 23) and on the other hand a ‘few big bets’ approach that bets on a single or few projects (right hand side in Figure 23).

According to Wheelwright and Clark (1992) the first one is found in R&D driven companies and they characterize it as a grass roots or bubble up approach. The essence of the survival of the fittest approach is that of hundreds of good ideas, only quite a small number ever become successful products. Firstly, carrying a new product development idea all the way from research through to market introduction is very expensive. Secondly, a company can generate a lot more ideas than it could ever sustain financially until market launch and could ever be absorbed by the market place. Thus at each screen the new product development ideas are reviewed systematically, based on current information and knowledge. Consequently, only the most promising ideas are approved for the next phases where additional effort will be invested to prepare these ideas for the next screen and to develop them further for eventual market introduction (Wheelwright and Clark, 1992).

On the contrary, the second funnel type is usually found in smaller companies or entrepreneurial start-ups and they characterize it as a top down model. The few big bets funnel type stands for taking an idea and backing it all the way to successful product introduction. While entrepreneurial start-ups use this funnel approach to bring a new product quite fast to the market, mature firms take more time than their smaller counterparts (Wheelwright and Clark, 1992).

2.2.2.3 Further considerations from literature

The funnel approach is also a crucial part of the stage-gate model. Unprofitable new product development ideas really need to get killed during the gate evaluations; otherwise the funnel becomes a tunnel (Cooper, 1996).

Yet, screened out new product development ideas do not need to be unprofitable or lacking in value proposition to leave the funnel. Sometimes they just do not fit the company. In that case, promising new product development ideas can be externalized in corporate ventures (Gemünden and Littkemann, 2007).

Furthermore, also sub-stages can look like a funnel by itself. E.g. the continuous design freeze can be displayed like a funnel. In that case, it is not new product development ideas that are selected or discarded, but for one idea, design degrees of freedom are reduced by freezing product aspects (Mascitelli, 2002).

2.2.3 Screening of new product development ideas

Many companies have to continually evaluate and select ideas aimed at expansion and diversification of the product line, ranging from minor changes to the introduction of an entirely new product (Hart, 1966; De Brentani and Droege, 1988). The above described funnel shape results from screening and reducing the amount of new product development ideas. Well-executed screening of new product development ideas is one of the most important factors for successful innovations (Dwyer and Mellor, 1991; Mishra et al. 1996).

2.2.3.1 Concept

In business, most new development projects have an initial screening. E.g. Cooper and Kleinschmidt (1986) found initial screening in 90% of the studied 252 new product development projects. Yet, it was rated as the weakest activity and the one most greatly in need of improvement in that study.

Companies with high new product performance undertake more idea generation and idea screening than their lower performing competitors (Barczak, 1995). Also Dwyer and Mellor (1991) found that initial screening contributed to a higher new product development performance regarding both profitability and sales in the studied 95 new product development projects in Australia.

The preliminary assessment can vary extremely in practice. Academics have found that it often takes only several days (Bösch, 2008). Yet in other cases the preliminary assessment can take years (Nixon, 1998).

Stevens and Burley (1997) analyzed and documented, amongst other things, the time spent on the screening process of venture capitalists. They found out that raw ideas of inventors are given only around 20 minutes of consideration each in the first evaluation. Only if they pass this first evaluation they are considered longer (around 4 hours). In the next step the ideas are looked at further with an analysis of the market need, business plan and management team checks. If an idea also survives that gate, further in-depth analyses are made before the venture capitalists submit an offer. Unfortunately, Stevens and Burley (1997) do not describe the tool use of the analysis process of these venture capitalists in their case study of 10 major venturing companies.

During innovations, top management faces high uncertainties related to position, continuation and stop of development projects (Jens, 1999). One general question at the first gate is whether it is uniquely the evaluating company that could succeed with this new product development idea (Bösch, 2008). Also, strategic alignment and availability of necessary competences is often checked at the first gate (Bösch, 2008). Screening should be like a quality control check at the gates, but that was found only at one third of the studied companies (Cooper, 2009).

The earlier an ineffective new product development idea can be eliminated, the more resources can be saved (Schmitt-Grohe, 1972). Thus Schmitt-Grohe (1972) indicates a two gate approach of screening ideas in pre-development. The first gate is a coarse screen of new product development ideas to eliminate ineffective new product development idea as soon as possible. The second gate is an economical analysis that should select the most promising ones from the remaining new product development ideas.

When go/no-go decisions for individual new product development ideas are made, innovation portfolio considerations also often play a significant role (Bösch, 2008). Screening of new product development ideas is often done by steering groups (Bösch, 2008) or top management (Cooper, 1990).

Furthermore, the completeness degree of new product development ideas is varying. Through this the information also becomes more complete and may even change through new knowledge (Schmitt-Grohe, 1972; Voigt and Sturm, 2001; Bösch, 2008). This notion of innovation as information acquisition process is picked up in subsection 2.2.4 further down. The completeness variation depends, besides other things, on the stage in which a new product development idea is and on its degree of newness. Thus one challenge in industry practice is that recently suggested, undeveloped and rudimental ideas are compared to very tangible, further developed ideas. This has to be kept in mind and the analysis process has to be adapted (Bösch, 2008).

According to Schmitt-Grohe (1972) the top management has to make the final go decision for the development start. He sees the development as costly and killing new product development ideas after development should be avoided as it wastes precious resources.

2.2.3.2 Screening criteria

When screening new product development ideas, evaluation may range from qualitative (e.g. use of judgment, intuition or hunch) to quantitative (e.g. rate of return, net present value or payback time) (Hart, 1966). Yet, in practice the rating on new product development ideas is a rather ambiguous process. Sometimes not enough information is available if too much detailed criteria have been used for screening ideas in the early pre-development phases (De Brentani and Droege, 1988; Bösch, 2008). Yet, using only few criteria has the danger to skip and miss essential information (Bösch, 2008). Thus Bösch (2008) recommends having several criteria categories with increasing depths. All of these categories are always checked, but the detailing of investigation per category increases for each gate.

Gate 1 is what Cooper describes a "gentle screen" (Cooper, 1990). The newly proposed idea is checked against a few key criteria that either have to be met or should be met to indicate or weigh the attractiveness of the idea.

> *"These criteria deal with strategic alignment, project feasibility, magnitude of the opportunity, differential advantage, synergy with the firm's core business and resources, and market attractiveness" (Cooper, 1990).*

However, in his opinion, financial and cost criteria are not part of this first screen. In the view of Schmitt-Grohe (1972) the first screen is low on information. Depending on the newness, quantitative information (e.g. production costs or sales figures) and qualitative information (e.g. usability of production know-how) are usually not available before development start or the efforts would be too high to build up this information. Thus he recommends having this screen based on expert opinion. The recommended tools for this screening are checklists and score-cards (Schmitt-Grohe, 1972). The checked characteristics should be hygiene factors. These are minimum requirements that have to be fulfilled at least. It is possible to handle these characteristics in a qualitative, quantitative or semi-quantitative way. According to Bösch (2008) the semi-quantitative way is on the rise in industry practice. These are then done with scoring models where qualitative declarations are translated to values. These values are then added to get an overall score to rate different new product development ideas (Bösch, 2008).

According to Cooper (1990) the screen in gate 2 is very similar to the one of gate 1. The idea is reevaluated with the help of the additional information gained since its last check. Compared to the first check, Cooper sees new evaluation criteria around marketing and financial issues. It is the first time that the financial return is considered according to Cooper (1990). This is done only quickly with the help of simple financial calculations. However, through this financial evaluation costs are also implicitly estimated. A multitude of information about the new product development ideas has to be available as a base for the second gate evaluation. Thus product concepts have to be completed in the view of Schmitt-Grohe (1972). He gives a recommendation how to structure the examination and selection of new product development ideas. For incremental innovations he sees the lead at marketing. New products are then developed, followed and integrated with the existing products. However, if innovations are more radical, a cross-functional team should carry out the first coarse selection and the economic analysis and the selection committee should be formed out of experienced employees (Schmitt-Grohe, 1972).

Carbonell et al. (2004) studied the correlation between new product development success and screening criteria. They also distinguished between incremental and radical innovations. They found that the importance of different criteria can vary from gate to gate of every stage in the new product development process. They state that strategic fit dimensions are the vital screening criteria in the first screening. Furthermore, they found that market opportunity criteria related positively with the initial screening in pre-development. They further found that at the rear pre-development, in front of the go-to-development gate, technical criteria screening significantly correlated with new product development success (Carbonell et al., 2004).

Yet, evaluation numbers of possible new product development can be part of strategic controversy and political debate in companies (Pavitt, 1990). Abandoning an ongoing new product development project may also be complicated, as companies fear to lose customers and demotivate employees (Varila and Sievanen, 2005).

2.2.3.3 Cost analysis

Some new product development ideas comprise future product costs (as one quality parameter) that do not correspond to the market need or customer value. The controlling effort in new product development funnels is to screen out these projects (Voigt and Sturm, 2001).

The second gate proposed by Schmitt-Grohe (1972) is an economical analysis. He sees it as the finer sieve that works as a filter to separate the most promising of the already pre-screened new product development ideas. In that stage predictions regarding income and expenditure are to be made. During that analysis he also looks at the future costs of the new product development ideas. However, he points out that in his view estimating the future product costs has often to be postponed until technical development is underway, especially for radical innovations.

Financial analysis is an "important part" (Cooper, 1990, p. 53) in the screening of gate 3 before development begins. It is based on market research, competitive analysis and concept testing of the stage before.

One approach to screening ideas can also be to evaluate them in an innovation portfolio. In this approach, only the most promising ideas are selected (Bösch, 2008). Yet, Bösch (2008) does not describe cost analysis on its own as being a selection criterion. However, cost analysis can play a part for estimating the value to customer and the net present value of new product development ideas (Bösch, 2008).

Cooper and Kleinschmidt (1986) studied 252 new product development projects in Canada. Overall, nearly two thirds of the studied companies conducted a business or financial analysis before moving into product development. They also found that in nearly a third of the cases cost and sales forecast were done before product development start.

2.2.3.4 Investment theory as a base for screening

Innovations are investments (Kaplan and Atkinson, 1998; Hauber and Schmid, 1999; Varila and Sievanen, 2005; Gemünden and Littkemann, 2007). At their start, they are connected with significant expenditures and risk. These investments are done in anticipation of future income. However, the time horizon for this future income is usually quite large. Thus product cost analysis during pre-development can also be seen as a problem of larger up-front investments for financial return under uncertainty (Schmitt-Grohe, 1972; Lindermeir, 1988; Bösch, 2008).

Innovation, like other business matters, is often a trade-off between some kind of risk and a connected possible return. Schneider and Miccolis (1998, p. 10) describe it as such:

> *"In a sense, the uncertainty and possibility of harm is the price we pay for a reward."*

Shareholder value is created when the return exceeds the costs, including risk, and the higher the achieved return per taken risk the more an investment is worth. This translates to higher stock prices of stock listed companies, as investors will pay a premium for a company that manages uncertainty more effective than others (Schneider and Miccolis, 1998). Thus sophisticated, but efficient management of innovations is important to the success of companies.

Investment in R&D and technology development is expected to be repaid in the future with sales from the new products; while cost, quality and cycle time efficiencies from improved processes (Kaplan and Atkinson, 1998). Schmitt-Grohe (1972) suggests using the internal rate of return for the detailed analysis of new product development ideas. Similar Bösch (2008) advocates to use the net present value to rate new development ideas in innovation project portfolios. Lindermeir (1988) uses the concept of innovation as investment for a quantifying valuation of innovations. However, she looks only at cash flows for this valuation, not at product cost and cost levels.

The company Schindler, a producer of lifts and stairways, is using a figure-of-merit evaluation at the gate before product development kick-off (Gassmann and Kobe, 1999). This figure-of-merit is an estimate of the ratio of future discounted income relative to the future discounted expenses. Together with this figure-of-merit, net-present-value, depreciation time, and risk are also taken into consideration.

The notion of innovation as investment can be enlarged to see it as a continuum of small sequential investments. Success is constantly evaluated and projects can be stopped if they seen to be unsuccessful. This notion also connects the idea of real options and the stage-gate model (Varila and Sievanen, 2005). At each gate the different new product development ideas are screened and a decision regarding continuing or not is made. This can be modeled with the real option approach.

However, incremental investment appraisal systems can undermine the ability to exploit innovations in a timely fashion (Baldwin, 1991). Companies do invest in R&D, but without using investment appraisal procedures. These procedures are firstly used for investments during the development process, e.g. for new product ideas or investments related to innovation. Thus investment appraisal tools can lead to the situation that a company will consistently postpone introductions. This is the case if a newly developed product would cannibalize existing products with high cash flows (Baldwin, 1991).

2.2.4 Uncertainty and information acquisition

Usually high uncertainties are attached to innovations, especially to radical ones (Deszca et al., 1999; Shenhar and Dvir, 1996). Innovations often do not have a predecessor and have a singularity that is higher than for e.g. investments in new production equipment (Lindermeir, 1988). The earlier during innovation the analysis of new product development ideas is done, the more data is based on assumptions and estimations. Thus a critical factor of success is to minimize risks (Schindler, 1999). Also, especially in radical innovations, market uncertainty will be carried over to the technical side and increase complexity and uncertainty for technical new product developments (Lindemann, 2008). This uncertainty is reduced through an ongoing information acquisition. The rest of this subsection focuses on this information acquisition view.

The innovation process can also be seen a process of ongoing information acquisition (Hafkesbrink, 1986; Srinivasan et al., 1997; Kotler and Armstrong, 2008). An innovation might start with a conceptual statement of needs, which are then translated to specific object specifications like shape, material, and production processes to be used. Thus the process starts with a high uncertainty and many unknown parameters, which are then clarified and determined during the development process (Srinivasan et al. 1997). A large part of the information acquisition occurs during pre-development (Moenaert et al., 1995).

Moenaert et al., (1995, p. 249) found that "successful projects have reduced, on average, as much uncertainty during the planning stage, as the unsuccessful projects have during the complete innovation cycle." Also Lynn et al. (1999) found a positive correlation between information acquisition and new product development success. Regular reviewing meetings are an effective way to share information and help overall information acquisition during innovation (Lynn et al., 1999).

2.3 Pre-development phases, its character and success

There is a large diversity of understanding and definitions about pre-development in literature. This section looks closer at the notion of pre-development. Firstly, time frames are defined for this thesis. Furthermore, specialties of the pre-development compared to other innovation phases are cited from literature. And finally, success factors stated in literature that are special to pre-development are noted.

2.3.1 Time classification and scope

Pre-development are the phases that lie before the actual development start of a specific innovation. This thesis follows the definition of Griffin (1997, p. 28) that **development "starts with the first spending of research and development money on physically developing the product" through design and engineering.**

Literature about pre-development is divers about its time-wise classification. Thus in the following, the different stages and phases in pre-development are presented from selected authors to clarify this time-wise classification in this work.

2.3.1.1 Basic and applied research

Some innovation models start with basic research (Wheelwright and Clark, 1992; Hauschildt and Salomo, 2007). Today many concept understandings and definitions of basic research exist between scientists. Basic research is often used to refer to research that is aiming at acquiring new knowledge rather than more practical aims (Calvert, 2006).

Basic research uses science to generate new knowledge that may or may not be applicable in later new product development projects (Calvert, 2006; Wheelwright and Clark, 1992). Zellner (2003) found that what 'basic research' definitions have in common is that they rely on some notion that the search activity is kept isolated from immediate commercial considerations and is usually independent of new product development ideas.

Applied research on the contrary uses specific methodological knowledge about experimental procedures and research techniques to gain specific propositional knowledge from current research and is less broad than basic research (Zellner, 2003).

Basic and applied research should be effective and several evaluation ratios and metrics do exist (Werner and Souder, 1997). However, it is important to notice that these metrics focus on cost budgets, which are left aside here as this thesis studies product cost analysis.

2.3.1.2 The front end of innovation

Koen et al. (2001) define the front end of innovation – quite largely – as the activities that come before the formal and well-structured new product and process development process. Similarly, Kim and Wilemon (2002) see the front end as the period between initial opportunity consideration and when an idea enters the formal development process.

Yet, this thesis follows the notion from literature that the front end is the first stage in which an idea is born (e.g. Cooper, 1990). Alternatively it also called Stage 0 or concept generation (e.g. Griffin, 1997). To state a precise start of this stage for this research, this thesis follows the definition of Griffin (1997) that **the front end of innovation starts when the idea for the product first surfaces.** Thus, the front end of innovation is the first stage of a development effort that focuses on a specific new development idea with the aim to launch this idea successfully in the market.

Koen et al. (2001) claim that there is hardly any concise understanding about the processes happening in their companies in the front end. Thus the front end of innovation is sometimes also referred as fuzzy front end (e.g. Kim and Wilemon, 2002).

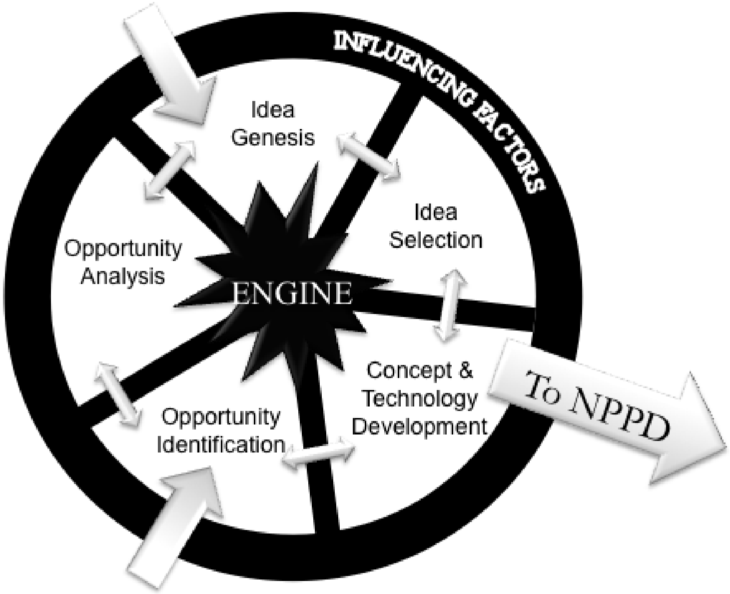

Figure 24: The front end of innovation and its environment according to Koen et al. (2001)

Idea generation often occurs before general requirements are set down, with high uncertainty, and at a point where customer requirements and technologies are still vaguely known (Ettlie and Elsenbach, 2007). Koen et al. (2001) distinguish five different front end elements that are also shown in Figure 24:

1. Opportunity identification
2. Opportunity analysis
3. Idea genesis
4. Idea selection
5. Concept and technology development

The first element is opportunity identification. In this element large or incremental business and technological chances are identified in a more or less structured way. The second element is the opportunity analysis. It is done to translate the identified opportunities into the business and technology specific context of the company. Here extensive efforts may be made to align ideas to target customer groups and do market studies and/or technical trials and research. The third element is the idea genesis, which is described as evolutionary and an iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside impulses, e.g. a supplier offering a new material/technology, or from a customer with an unusual request. The fourth element is the idea selection. Its purpose is to choose if or not to pursue an idea by analyzing its potential business value. Finally, the fifth element is what Koen et al. (2001) call the ‘concept and technology development’. It can be seen as the drafting and progressing of concept and base technology of a new product development idea. During this part of the front end the business case is developed based on estimates of the total available market, customer needs, investment requirements, competition analysis, and project uncertainty.

While idea generation is often done by scientists or technical people, it can also be the result of other activities according to Cooper (2006), such as:

- Strategic planning,
- Technology forecasting and roadmapping,
- Brainstorming or other creativity secessions,
- Scenario generation about future technological and market possibilities,
- Customer visits and feedback, or
- Company internal idea suggestion programs.

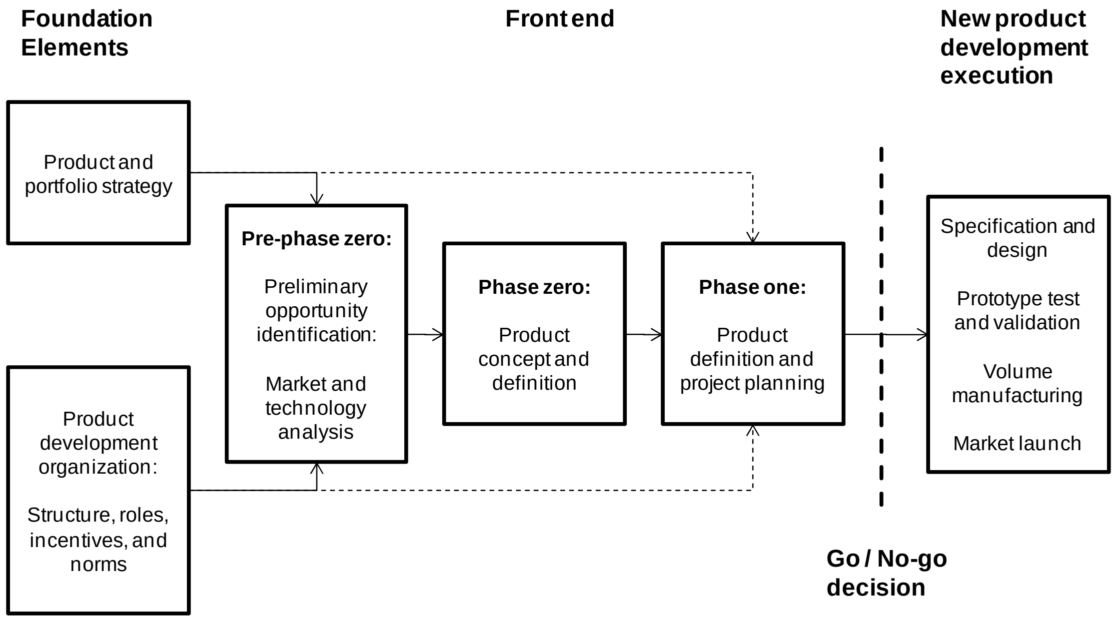

Figure 25: Model with systems view according to Khurana and Rosenthal (1997)

Another model of the new product development front end is presented by Khurana and Rosenthal (1997) and shown in Figure 25. Khurana and Rosenthal (1997) stress that not only the activities in the different phases are important to be understood; It is as essential to comprehend the interrelationships between them. In their view product strategy and portfolio plans should drive the entire new product development efforts. Furthermore the capabilities and competencies of the organization with its inherent assumptions about roles, communications, and culture provide the framework for the new product development. The front end itself is then subdivided in three phases. Pre-phase zero contains the semiformal recognition of a new product development opportunity. Phase zero is about the shaping of product concept and definition by a small group that can also include suppliers. Next, in phase one, the company assesses the business and technical feasibility, confirms the product definition and plans the further project activities (Khurana and Rosenthal, 1997).

2.3.1.3 Idea evaluation and planning

If an idea passes this first screen, it enters the first stage. Stage 1 incorporates a preliminary market assessment and its rough technical feasibility. In order to find out the potential of the idea, its total available market and its likely market acceptance, several rather inexpensive research activities are undertaken (Cooper, 1990). This stage can be named project evaluation stage (Griffin, 1997), concept level phase (Srinivasan et al., 1997), preliminary assessment (Cooper, 1990), and concept development phase (Ulrich and Eppinger, 2000). Griffin (1997, p. 28) states that project evaluation "starts when the product strategy and target market have been approved and the project has been given a 'go' to develop specifications."

Once this information is gathered, an idea is submitted to the check within the next screen – gate 2 – in Coopers (1990) model. If the new product development idea passes that gate, stage 2 is entered (Cooper, 1990). Stage 2 is the detailed investigation of the business case before larger investments in the (next) development phase are made. The idea definitions have to be narrowed down to give a clear picture and to ease the further evaluation of the idea on its market potential and feasibility. Market research, competitive analysis and concept testing are part of this stage before the check of gate 3 (Cooper, 1990).

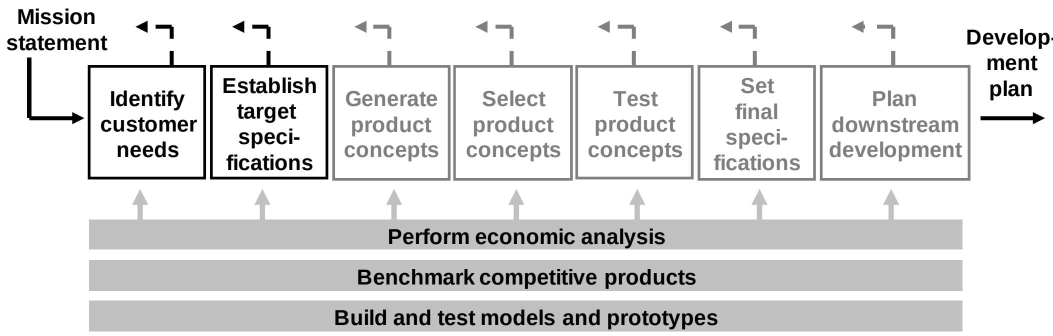

Figure 26: Pre-development sub-tasks according to Ulrich and Eppinger's (2000)

The model of Ulrich and Eppinger (2000) is shown in Figure 26. It shows different tasks that are usually performed between the planning and the system-level design stage in the model of Ulrich and Eppinger (2000). These are the stages that Ulrich and Eppinger (2000) call together with the preceding planning phase the front end. The first two tasks are the identification of customer needs and the establishment of target specifications. Yet, the other activities fall already in the development stage according to the definition of this work, as they already do physically develop the product.

2.3.1.4 Development begin

Development begin is the second boundary for this work. There the actual development of the product starts (Cooper, 1990). The aim of this stage is to develop product concepts into effective and practical physical products (Kotler and Armstrong, 2008). Development is a sequence of steps or activities that a company uses to envision, design, and commercialize a product (Ulrich and Eppinger, 2000). It starts when a company starts physically developing a new product development idea (Griffin, 1997). That is one reason why the development stage sees large rises in expenditures (Cooper and Kleinschmidt, 1993; Kotler and Armstrong, 2008).

In the development stage, study and research results are implemented into design and engineering to achieve the intended functions of the new product development idea (Wheelwright and Clark, 1992; Hauschildt and Salomo, 2007). The development process transforms ideas and concepts through detailed design and engineering, then tests and refines them and finally launches them commercially (Wheelwright and Clark, 1992; Hauschildt and Salomo, 2007). Many steps and activities in development are intellectual and organizational rather than physical (Ulrich and Eppinger, 2000).

Yet, generally describing the way in which companies develop products is problematic because different companies will adopt different processes (Slack and Lewis, 2008). The above described are some general traits. However, as the development stage is not in the focus of this thesis, readers that want a more detailed description about design and engineering in the development stage and later are referred to literature of that area.

2.3.1.5 Summing up on pre-development phases

As already pointed out before, this thesis looks at the activities before actual development start of a specific innovation. Yet, this time is actually separated differently in literature; often depending on the disciplinary and research background of the author.

Term	Authors	Definition	Similar to Cooper (1990)
Discovery	Cooper (2009)	"Discovery of new product ideas and opportunities through Fundamental research and technology development, voice-of-customer methods, strategically driven ideation, stimulating company internal ideation, and Open innovation"	Stage 0
Concept generation	Griffin (1997)	"Phase of product strategy and target market definition between idea discovery and gate to develop specifications"	Stage 0
Front end of innovation	Koen et al. (2001)	"Activities that take place prior to the formal, well-structured New product and Process Development or Stage-Gate process"	Stages 0(-2)
Fuzzy front end	Kim and Wilemon (2002)	"Period between initial opportunity consideration and when an idea is judged ready for development"	Stage 0-2
Preliminary assessment	Cooper (1990)	"Gathering of market and technical information at low cost and in a short time for a more thoroughly reevaluation of idea at Gate 2"	= Stage 1
Planning	Ulrich & Eppinger (2000)	"Activities starting from strategy with assessment of technology and market objectives, specifying target market, business goals, key assumptions and constraints"	Stage 0-1
Project evaluation	Griffin (1997)	"Phase from go for product strategy and target market until start of physical development of product"	Stage 1-2
Detailed investigation	Cooper (1990)	"Verification of attractiveness and product definition based on market research, concept testing and competitive analysis"	= Stage 2

Figure 27: Overview of different pre-development notions found in literature

Figure 27 compares the different pre-development notions and terms used of several authors. For comparison, these notions are all set into relation to the stage-gate model of Cooper (1990) shown in Figure 15 on page 26. One can see that Koen et al. (2001) and Kim and Wilemon (2002) use the term front end nearly synonymously for the whole pre-development. Yet, Griffin (1997) and Cooper (1990) separate pre-development in different stages. The model of Cooper (1990) is the finest cut, as it has the largest amount of stages in pre-development. Due to that fact and due to its popularity in business, the model of Cooper (1990) is used further on in this thesis.

2.3.2 Characteristics of pre-development

Srinivasan et al., (1997) note that quantitative manufacturing analyses are less well-developed in pre-development than at the detailed design level. Thus rather qualitative techniques are used to support pre-development. In their view the models used in pre-development are relatively non-quantitative because there is a multitude of paths to product concepts with specific features under study.

Because of its decision freedom, the front end gives one of the greatest opportunities to improve the overall innovation effectiveness. However, the flip side is that uncertainties are higher. The time span spent on the front end might be very small for some products, but larger for others (Kim and Wilemon, 2002).

It is in the front end where companies formulate a concept of the product to be developed and decide on whether or not to invest resources in the further development of an idea. It is the phase between first considerations of an opportunity and when it is judged ready to enter the structured development process (Kim and Wilemon, 2002).

According to Koen et al. (2001) there are clear differences between pre-development and the development process itself. The work in pre-development is more experimental, unplanned and can be more chaotic than during later innovation phases, which are more structured, controlled and goal-oriented. The uncertainties are higher and the date of commercialization of results is also vaguer in pre-development than in later phases. Seldom is the front end a process of purely sequential steps, completing each activity before beginning the next. In practice, activities may be overlapping and iterating in the front-end, as new information may become available over time (Ulrich and Eppinger, 2000). Thus the main differences between pre-development and later innovation phase characteristics are that the pre-development is less structured, more iterative, less formalized and might span over a long time until an idea is processed further (Ulrich and Eppinger, 2000; Koen et al., 2001; Kim and Wilemon, 2002).

2.3.3 Success factors in pre-development

Cooper (1990) and Dwyer and Mellor (1991) found several factors that contributed to a higher new product development performance regarding both profitability and sales. The contributing factors rooted in pre-development are:

- Initial screening

- Preliminary market assessment
- Preliminary technology assessment

Additionally, Cooper (1990) linked the quality of the execution of pre-development activities with a new product development success. Besides the above mentioned points he added the following activities to also be factors contributing to a higher new product development performance:

- Detailed market study / marketing research
- Business / financial analysis

The combination of R&D and marketing activities in pre-development is necessary for success in innovation projects (Moenaert et. al., 1995). In the pre-development phase the attention shifts from technology development towards the customer need (Voigt and Sturm, 2001). With this shift the customer needs should be translated into technical functionality. This can be done e.g. with conjoint-analysis, functional analysis and / or Quality Function Deployment.

Kim and Wilemon (2002) suggest several tactics how to manage the pre-development effectively. Some tactics are obvious, like to involve customers and suppliers, while others might be more subtle. As very many ideas are turned down during the front-end, a positive and motivational frame of mind and rewards have to dominate to mild disappointments, acknowledge and support. It might also help to appoint a knowledgeable individual (or team) as leader in pre-development. Furthermore it is very important to put up the right screening methods – not too soft and not too rigid. The first will lead to too few projects being killed and resources wasted, the latter will lead to too many ideas being rejected. The screening criteria often have to be varied from case to case (Kim and Wilemon, 2002). Additionally, different variations of an idea should be considered. These should then compete until the best product concept crystallizes. Finally it is also important to provide information systems and build up databases that allow R&D personnel to promptly check data on technologies, markets, other development projects and competitors.

According to Cooper et al. (1998) a good requirement capture is needed for successful innovations. This requirement capture starts in the front-end and continues during pre-development. This is a method of translating information and ideas into design briefs and specifications in the front end of innovation. It is essential if a company wants to capitalize on market-generated impulses for innovations. They give three steps during requirement capture:

1. Information gathering
2. Information transformation
3. Requirements generation

In the information gathering step the impulse from the market side can come from a constant monitoring of customer needs and requirements. One way companies are doing this is by using the results of market research agencies as input into the NPD process. Or it is employees with market contact that are bringing the information into the organization. Unfortunately this information gathering is usually done in an unstructured and unsystematic way. This leads to a subjective pre-screening by the person bringing the information into the organization, which could lead to a loss of opportunities, as chances are not recognized (Cooper et al., 1998). During the information transformation step the gathered information is processed and knowledge about the market is won. In the third step, the requirement generation, the won market insight is translated into one or several requirements, which are then reported. However, this is also too often a tacit process, where subjective opinions lead to wrong dismissal of data about the market.

2.4 Innovation and product cost

Product cost and cost related market issues are one of many contributing factors for succeeding with innovation (Mishra et al. 1996; Hax and Majluf, 1982; Hauber and Schmid, 1999; Gassmann and Kobe, 1999; Ernst, 2002). Product cost should be viewed as an input to innovation, not as an outcome of it (Cooper and Slagmulder, 1997). This section crosses innovation with one of its success-important characters – future product cost.

2.4.1 Growing cost importance in innovations

Different innovation generations after the Second World War have been identified in economic history by different academic researchers (Rothwell, 1994; Cooper, 1996). While Cooper sees three different generations, Rothwell classified the innovation types in five generations. The more detailed five generation concept is described here in the following.

Generation	Time frame	Competitive environment	Leading paradigm	Importance of costs
First generation	1950s to mid-1960s	High economic growth; Industrial expansion	Technology push	**Costs not in the development focus**
Second generation	Mid-1960s to early-1970s	Economic growth; Increase in productivity	Market pull	**Costs not in the development focus**
Third generation	Early-1970s to mid-1980s	Economic saturation and crises; Higher supply than demand	More critical innovation process with feed-back loops	**Strategy on cost reduction and cost control translates also to innovations**
Fourth generation	Early-1980s to early-1990s	Economic recovery; Focus on core competences	Integration and parallel development	**Cost management together with time and quality focus**
Fifth generation	Started in the 1990s	Stable but modest growth; Companies operating in networks	Incorporating inter-firm linkages	**Cost is an important aspect and analyzed as trade-off to time**

Figure 28: Summarizing overview of innovation process generations according to Rothwell (1994)

Figure 28 shows the different innovation types in the five generations that are classified by Rothwell (1994). In addition the last row presents the interest in cost management methods during these generations.

During the **first generation** the economic environment was one of large growth through industrial expansion, where demand might have even been higher than supply. At that time the industrial innovation process is rather linear, starting with a scientific discovery that is processed inside of companies and transformed to products that are then launched onto the marketplace (Rothwell, 1994). No significant cost management was made during the first generation innovation process.

In the **second generation** companies were still facing growth, but innovations were getting guided by demand side factors, changing to market pull innovations. In the second generation the industrial innovation process is still rather linear, but now starts with the potential market as a source of ideas (Rothwell, 1994). Also in the second generation innovation process, no significant cost management was used.

During the **third generation** supply capacity generally surpassed demand. At that time the innovation process is still a sequential process, but it now includes feed-back loops. It is the earliest generation that significantly incorporated cost management issues, as the strategy was focusing more on cost control and cost reduction (Rothwell, 1994).

However, after that – during the **fourth generation** – the economic environment for companies recovered and companies started focusing on core businesses and core technologies. At the same time product life cycles got shorter and time based innovation strategies became more important. Cost management was connected with quality and rapidness of developments (Rothwell, 1994).

According to Rothwell (1994) the **fifth generation** innovation process started in the 1990s with a stable, but modest economic growth. Companies incorporate a balanced view on strategic issues, networking, time to market, flexibility and manufacturing excellence. Costs are an important aspect, especially as a trade-off between development time and costs can be found. This trade-off is usually nonlinear, with costs rising over-proportionally when a company wants to accelerate its product development (Rothwell, 1994).

Summarizing, one can say that through the years the environment for innovations has changed. After the Second World War the importance of costs has grown as the markets have developed from a seller to a buyer market. Hand in hand with that, there has been a constant progress towards more market-need conscious innovations – one of these market needs being cost competitiveness!

2.4.2 Cost management

This section starts on a general outline of cost management before the innovation focus is taken up again.

2.4.2.1 A brief historical background

Many cost management models are known for over a hundred years, as they started being developed by engineers after the wake of the industrialization (Johnson and Kaplan, 1987). However, accounting principles have gained access to, and replaced earlier cost management procedures during the middle of the last century according to Johnson and Kaplan (1987). The focus was then shifting towards overheads and their calculation rather than investigating direct costs and efficiencies of processes and procedures. One major problem was the aggregation of cost data. In order to have fast and overall fitting financial data, the financial accounting principles aggregate many positions that can later not be separated and/or used for the cost/efficiency analysis of single processes.

However, the traditional cost management literature has focused on running processes and less on innovations. It has put cost management for innovation in the tray of tools to “support special studies” (Johnson and Kaplan, 1987, p. 228). Nevertheless, later through the enhanced perception of target costing in the 1990s (in the Western world), cost management focusing on innovation processes and new product development has gained more attention in literature (see e.g. Cooper and Slagmulder, 1997, or Davila and Wouters, 2004).

2.4.2.2 Cost management in general

In the industry cost management is often associated with short-sighted cost reduction programs, like general budget cuts and personnel reductions. However, the aim of cost management is to eliminate costs that bear no longtime potential of success (Voigt and Sturm, 2001). Thus especially in the field of innovations, a proactive cost management can be fruitful and is to be targeted.

Cost management focuses on cost reduction, continuous improvement and change and can be defined as the “actions by managers to satisfy customers while continuously reducing and controlling costs” (Horngren et al., 1994, p. 5). In contrast to that, traditional cost control systems “tend to be based on the preservation of the status quo and the ways of performing existing activities are not reviewed” (Drury, 2004, p. 943). As can be seen in the cost management literature (e.g. Dury, 2004; Horngren, 1994; Kaplan and Atkinson, 1998), there are different possibilities to influence costs of a product during the product life cycle. The core cost management concepts can be grouped into two different sets. The first set is cost management concepts that are connected to innovation and new product development activities. On the contrary, the second set is cost management concepts that are connected to running operations and offerings (e.g. Kaizen costing). As the focus of this thesis lies in the pre-development, only the first sets of cost management concepts are taken into consideration here. The cost management concepts for optimizing running production are not in the center of this work and a discussion of them here lies outside of the focus of this thesis.

2.4.2.3 Managerial use of cost information, decision making, and innovation

Through the focus on decision making, management accounting has over time increased the attention on how accounting numbers are used and why they are demanded (Demski and Kreps, 1982, Horngren et al., 1994).

Cost management has traditionally a focus on decision making, especially when it comes to efficiency related assessments. Traditional textbooks (e.g. Horngren et al., 1994, Kaplan and Atkinson, 1998, Baum et al., 2004, Drury, 2004) all more or less present traditionally several cost management tools as the compendium of that discipline and the relevant ones to this research are presented in the following in section 2.5.

According to Kaplan and Atkinson (1998, p. 222) there "are three important managerial uses of cost information. To:

- Understand costs so as to determine whether to make or abandon a product and to influence the nature of customer relationships
- Develop a cost basis for a price (as in cost-based transfer pricing or for a contract that calls for a cost-based price)
- Identify opportunities for, or the need to, improve product or process design and process operation"

Many managers in business argue that they cannot afford more analysis work in pre-development (Cooper and Kleinschmidt, 1986) or that too much is not good (Boutellier et al. 1997). Yet, here the same position is taken as from Cooper and Kleinschmidt (1986) that a company cannot afford not to commit resources to critical activities in pre-development, given the importance of new products, the amount at stake and the high likelihood of failure. Fast, light, and valuable tools are needed to support innovations (Boutellier et al., 1997; Schindler, 1999).

2.4.3 Companies, competition and innovation

This subsection focuses on companies and their competitive environment. It starts from a general strategic outset and then shows the importance of product costs for innovation.

2.4.3.1 Strategy, innovation and cost

Even so, cost management and the origins of its today's techniques are much older; one foundation is rooted in strategic management. Porter (1980) bundled up different strategies of how to successfully run a business. He divided the strategic approaches into approaches of:

1. Cost leadership
2. Differentiation
3. Specialization

Cost leadership is an approach that is based on the notion of the learning curve and a steady increase of efficiency to produce goods cheaper than any other market player (Porter, 1980; Hax and Majluf, 1982). This cost leadership is then used as a potential barrier to keep the competition out of a specific market. However, some empirical studies reject the idea of entry barriers into markets through learning curve effects (Lieberman, 1987). Yet, competitive costs can be crucial for all industries, not only if they compete on cost leadership (Cooper and Slagmulder, 1997; Nixon, 1998).

Schmitt-Grohe (1972) points out that product and industry specific parameters can have an impact on the product cost analysis during pre-development. The parameters that he points out are:

1. Amount of new products per year
2. Degree of technical novelty
3. Amount of competitors on the market
4. Effectiveness of advertisement

Thus company contingencies are also affecting the importance of product cost for innovation.

2.4.3.2 Importance of future product costs

Nowadays, new product development ideas have to compete on price early in the life-cycle and the cost of ownership to potential customers can play a vital role (see e.g. Nixon, 1998). Future product costs have the highest priority especially for new product developments targeting competitive markets. Thus the realization of competitive product prices and the attainment of target cost are essential (Boutellier et al., 1999). Product cost and price together with functionality and quality are crucial to a long time survival of companies (Cooper and Slagmulder, 1997).

Furthermore, cost targets are important. Cost targets can play a vital role for new product development ideas even though they are of distinguishing high quality and value and thus less part of price competition (Nixon, 1998). There is a need for more efficient innovations due to cost pressures on the market (Gupta and Wilemon, 1996; Werner and Souder, 1997). The earlier future product costs can be estimated, the better, as this information can then be used to manage cost actively (Becker, 1990).

In times where the new product development process is organized efficiently in companies, improvements in the performance in the pre-development phase can be vital for the success of companies in today’s market situation (Khurana and Rosenthal, 1998). Furthermore, in times of saturated markets, the cost aspect becomes more important, as products must be sold cheaper in order to reach new markets, which could economically not meet the expenses of the products so far. One possible answer to these cost pressures is to design new products cost efficiently and to avoid cost-inefficient lock-in decisions during the development stage. Also, the screening of new product development ideas should be done before costly procedures are started, as development efforts spend on ideas that are filtered out are otherwise wasted (Schmitt-Grohe, 1972).

2.4.3.3 Cost lock-in during innovation

One aspect that makes future product costs important in innovation is the lock-in effect. As decisions are made during the innovation process, different development possibilities are narrowed and also with that the uncertainty about the final structure and logic of a new product development. The other side of the coin is that there are lock-ins through these decisions if they cannot be reversed (Slack and Lewis, 2008). Many costs are designed in and cannot be avoided after the design stage "without redesigning the product. […] Consequently, effective cost management programs must begin at the start of the design phase of a product's life cycle" (Cooper and Slagmulder, 1997, p. 72).

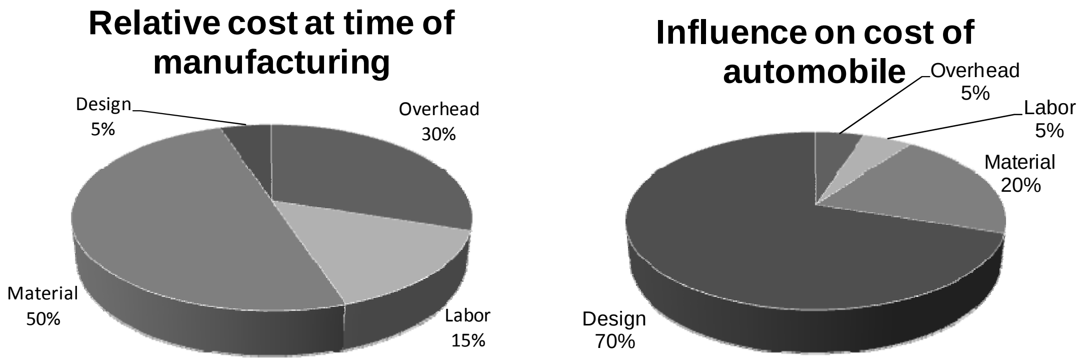

Figure 29: Relative cost and influence on cost of design according to Boothroyd (1988)

E.g. Boothroyd (1988) reports that studies at Ford Motors have shown that even though only about 5% of total cost of car parts are spent on the design activity itself, it determines about 70% of the total product cost of these parts. Others (Blanchard, 1978; Michaels and Wood, 1989; Schindler, 1999) speak of lock-in effects where 80% of the final product costs are locked through decisions made in the new product development phase and Cooper and Slagmulder (1997) cite even higher percentages (90-95%). The setback with lock-in effects is that changes cost a multitude of the cost for the initial right development (Voigt and Sturm, 2001). Similarly, the successfulness of an innovation depends partly on good concept development, as the following quote shows:

> *"Once an organization has committed to a future product's concept, most of the potential for change and improvement is gone from the project. If the concept is a bad one, if the product is difficult to manufacture or inappropriate for the desired user application, the project will run into problems – no matter how well integrated the team or how powerful the project leader" (Iansiti, 1998, p. 4).*

Franz (1992) sees the highest degrees of freedom to avoid costs is in a new design if no concept is frozen so far. In order to be able to carry out effective cost management programs, the right cost information has to be available for decision making. Thus one issue where management accounting can help in product development is to reduce uncertainty (Davila, 2000) and assist top management in decision making (Gemünden and Littkemann, 2007). However, top management might look at innovations after lock-ins happened and thereby too late (Wheelwright and Clark, 1992).

It is important to also show the designers the impact of their decisions on indirect costs (Franz, 1992). E.g. the amount of parts used for a new product will also influence the costs for sourcing and internal logistics. Yet, there are also critical voices against investing too much in the early development phases. Gemünden and Littkemann (2007) argue that even though the expenses are low and the cost and value efficiency is high, many new product development ideas are stopped before reaching the market. Successful innovations also have to bear the costs of the stopped ones. Thus it is an optimization problem regarding the optimal resource use in early innovation phases. Furthermore, it is a search and selection problem for solutions that are especially valuable to be realized (Gemünden and Littkemann, 2007).

2.4.3.4 Technology selection

A new product development idea might be realized through the use of different alternative technologies. The right technology selection can have a large impact on new product development cost optimization (Voigt and Sturm, 2001). The need for cost analysis methods and accurate cost data of new and emerging technologies is not new. Already 20 years ago, Laughlin (1989, p. K.2.1) stated that:

> *"Both government and industry perceive a lack of cost data and estimating methodologies to handle new and emerging technologies and acquisition strategies [… and that the…] scope and complexity of modern technology complicates the preparation of assigned analytical studies"*.

Through factors such as future production costs, technology selections influence potential profitability and marketing, as the example of Lorenz (2008, p. 10) shows:

> *"[…] the choice of packaging compounds and sterilization technologies influences the products' profitability and the optimal sales approach. […] Persons involved in product development and design regularly report that such cross-functional interdependencies and uncertainties cause enormous difficulties. Managers claim that there is only little structural support to handle these crucial but complex issues in the design process for market and technology innovations."*

Some companies work with corporate-level technology plans. These technology plans help linking strategy and new product development (Albright and Kappel, 2003).

Voigt and Sturm (2001) distinguish between technology development, pre-development and development. For the technology development they see a need for a filtering innovation and technology approach. This approach should include environment scanning and analysis and lead to a focusing of strategic opportunities.

The company Hilti uses a portfolio approach to compare its technologies under development against the technological possibilities of the competition. Besides other issues, future production cost levels also play a role here. (Bösch, 2008).

Seldom will a company have an all-embracing competence in every field of technology. Thus some companies join for strategic inter-firm technology cooperation, which has also the benefit of reducing uncertainty (Hagedoorn, 1993).

2.4.4 Product cost reduction in innovation

Even though the analysis and management of future product costs is important, there are several effects making the focus on this aspect laborious. Product cost is not the only dimension on which new product development ideas are competing on the market.

2.4.4.1 Conflicting dimensions in NPD

Innovations are developed in a field of many trade-offs. New product developments often show a clear "tension between focusing on technological innovation, product performance, time-to-market, and designing cost-effective products" (Davila and Wouters, 2004, p. 24). Usually there are several conflicting dimensions of new product developments that are difficult to be maximized all at once (Davila and Wouters, 2004, Everaert and Bruggeman, 2002). E.g. a ground breaking new product development will usually take more time-to-market than an incremental improvement of a product.

Figure 30: Conflicting dimensions of innovation according to Davila and Wouters (2004)

Trade-offs are usually plentiful and Davila and Wouters (2004) have selected four of them - costs, technological newness, performance, and time to market (see Figure 30). Even if cost improvement is stressed, this trade-off situation can hinder cost reduction when new product development engineers work under high pressure time constraints (Everaert and Bruggeman, 2002). In a broader view, management accounting can assist the management by providing information about possible potentials for cost and production time reduction, quality, but also softer factors like flexibility and usability (Gemünden and Littkemann, 2007).

2.4.4.2 Cost information and right cost optimization

The information analysis should provide data required to reduce uncertainty, as cost information collected in early innovation phases can be used for many purposes during pre-development, e.g. the ‘classical’ cost management use by the development team in the design stage, but also decision making by corporate management and the purchasing department. Davila and Wouters (2004) state that without appropriate over-spanning models of cost behavior, a sub optimization can happen that leads to higher overall costs. In that case the complexity of modeling costs of shared resources is high and managing costs is a task that also requires coordination around the developing team. Yet, if other parameters besides costs have a high importance, managing costs will also be a task that is carried out by more than just the developing team. These parameters can be of technical or market nature, short time-to-market and distributed knowledge in the developing organization (Davila and Wouters, 2004).

2.4.4.3 Cost reduction possibilities for different levels

During innovations the influence on costs can come from multiple sources according to Franz (1992). The influence can be exercised

1. On area level,
2. On activity level, and
3. On product level.

Area level cost analysis and management used to be and is still very important in industrial production settings. Its importance originates from history where the costs of manufacturing were the biggest and most important of all cost types (Franz, 1992). **Activity level** costs are analyzed and systematized through **activity based costing**. The advantage of activity based costing is a more accurate costing system for products and their production. Activity based costing can be defined as a costing method that focuses on activities as the elementary cost objects. It uses the cost of these activities as the basis for assigning costs to other cost objects such as products, services, or customers (Horngren et al., 1994; Franz, 1992). Activity based cost systems were described figuratively as an economic map of the operations of a company (Kaplan and Cooper, 1998). They expose the cost of activities and business processes for steering and forecasting the cost and profitability of individual products, services, customers, and operating units. **Product level** cost analysis and management focuses on costs that are directly or indirectly influenced by the new product development idea. Product characteristics, quality and price are determined dominantly through development and design. This includes more than the future production costs of a new product development idea. During the innovation process the sales channels, the logistic and sourcing concept and its respective costs will also be fixed. Furthermore, the costs for customer use will be determined (Franz, 1992).

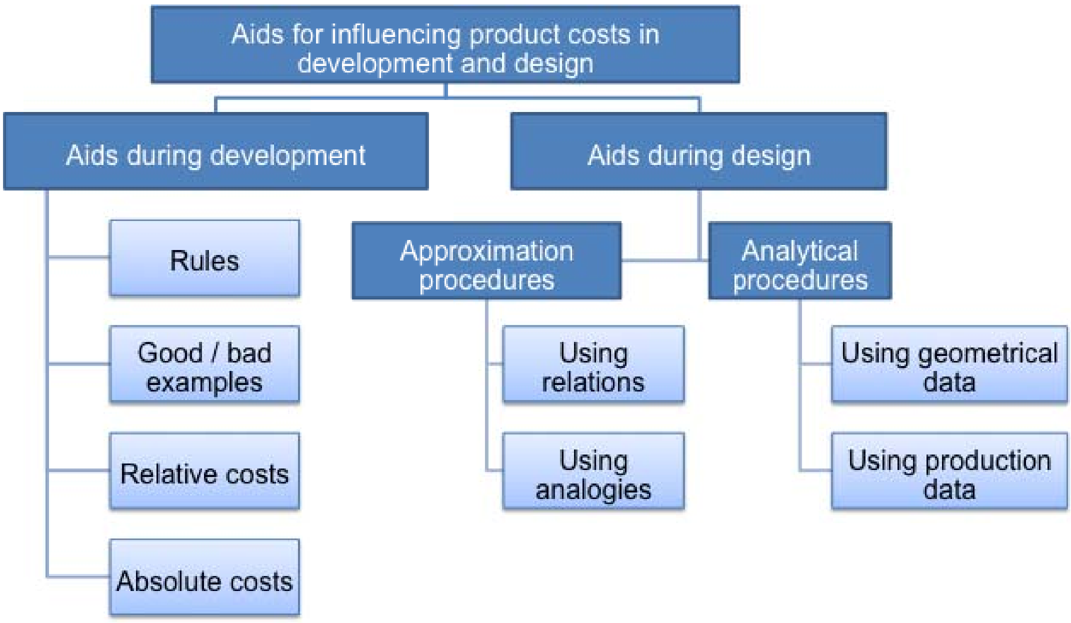

Figure 31: Influencing cost in development and design according to Franz (1992, p. 130)

During concept development Franz (1992) recommends several aids to influence costs. The left branch shown in Figure 31 illustrates four techniques suggested by Franz (1992). The first one is development rules. These rules are connections of constructive methods with cost data based on expert knowledge. These rules are used where numerical data is missing or where the effort of doing calculations is too high. The second aid is good / bad examples. These are examples that are similar to the rules previously described and used rather for illustration. The third technique is using relative cost data. This technique helps estimating costs by comparing the new product development with a similar object and its cost data. Catalogs with relative cost data can be used to inform developers and designers about cost efficient solutions for different design alternatives (e.g. alternative material or production methods). The forth technique is the use of absolute cost data. This cost data is based on units of standardized and / or purchasable components, subsystems and materials. Franz (1992) points out that this data should be up to date and preferably is available online to developer and designer. In summary, the first and second techniques use expert knowledge and rule of thumb, while the third and forth technique use cost databases.

On the left branch in Figure 31, techniques for influencing product cost during design are shown. A detailed explanation of these techniques is skipped here, as the design stage lies out of the focus of this thesis. However, it is interesting to notice that the suggested aids for development are in general lighter compared to the suggested aids for the design.

2.4.4.4 Platform planning, modules and cost

The third newness type mentioned by Wheelwright and Clark (1992) – platform development projects (see Figure 10 on page 19) – can also lead to improved developments. Davila and Wouters (2004) refer to so called ‘product-platform planning’ as a tool that looks at cost effective developments. This tool is an approach that incorporates future cost saving possibilities into design decisions, by allowing components, processes, and knowledge to be shared across a set of products (Davila and Wouters, 2004). Parts that can be designed in advance and then used as modules in other developments can help to simplify and streamline future developments. The attention of the development team is focused on several narrow scopes, rather than on an extremely large full-scope development. However, product-platform planning might also lead to over-design and thus the trade-off between effort and benefit has to be judged (Davila and Wouters, 2004).

2.4.4.5 Cost information support quality and uncomplicated models

Cost information has then also to be available and understandable for non-management accountants. Too late cost information support is equal to non-delivered support in fast pace new developments (Wieczorek, 1999). The quality of the information also has to be good. Otherwise, the results will be corrupt and not be usable or even misleading. In literature that is sometimes called the ‘garbage in, garbage out' (GIGO) paradigm (Chadwick, 2002). This paradigm stands for the notion that the quality of the output can only be as good as the quality of the input.

Additionally, gathered information can be used not only in the pre-development stage but also in the design stage of products. However, it is known that the development of cost models (data collection, data identification, data analysis and decision making tasks) is often lengthy and might require a high level of resources to reach an adequate result (Delgado-Arvelo et al., 2002) and that it might be too time and resource consuming during developments e.g. in high-technology industries (Davila and Wouters, 2004). Thus fast and easy to use methods should be set up. This is also found in past research. In general, companies use lighter tools for the analysis of possible future scenarios in the industry, than for analyzing their current business (Vinkemeier and von Franz, 2007).

2.4.4.6 Obfuscation and political debate

Reporting should avoid misplaced precision for somehow uncertain and vague matters (Cohen, 1996). Also, too sophisticated methods can lead to detailed number fallacy, as Bösch (2008) notes in respect to net present value calculation in pre-development. The potential fallacy results from the fact that detailed figures are calculated based on subjective estimations (Bösch, 2008). The underlying uncertainty is obfuscated through the apparent details of the number presentation.

It is noted in literature that company internal politics can contribute to the failure of an innovation (Crawford, 1977). Similarly, multiple concepts may be carried forward due to delayed – politically or emotionally difficult, but technically and economically clear – screening decisions (Srinivasan et al., 1997). Thus companies and 'internal entrepreneurs' have to be sensitive towards internal politics (Roberts, 2007). Even so the evaluation of possible new product development can be part of strategic controversy and political debate (Pavitt, 1990; Nixon, 1998); ultimately the market decides about success and profitability and thus the ability to satisfy the market needs better than the competition is essential (Pavitt, 1990). Thus, objective cost analysis and discussion during pre-development can also aid to avoid political power plays that lead towards the failure of an innovation on the market. Or even just make the innovation process more effective by objectively screening out ideas that would otherwise be carried out because of emotional or political pressures.

2.4.5 Creativity and cost control

There are only a few academic studies about cost consciousness during innovation and prior to the development stage. Shields and Young (1994) point out that this lack of research may be explained by the belief that the creativity of scientists and engineers should not be restricted by cost concerns prior to the development stage.

2.4.5.1 Creativity and importance of cost in innovation

Traditionally, designers of new products made their designs without their creativity being 'hindered' by cost considerations. Their prime focus lied elsewhere, mostly on functionality (Anderson and Sedatole, 1998). There seems to be a historic confrontational relationship between accountants and R&D personal and designers that might even have constrained the role of management accountants (Nixon, 1998). Accountants and manufacturing engineers have not been involved in product design decisions in this setting. The designer was seen as the 'creative artist', the manufacturing engineer as a 'technician' and the accountant as a "bureaucrat who compromises design integrity to save pennies" (Anderson and Sedatole, 1998, p. 223). Later, in order to change this, less traditional methods were introduced to the early product development procedures. The designers were called for using value engineering (sometimes together with target costing) for cost reduction or they were provided activity based costing data for their developments (Anderson and Sedatole, 1998). The importance of cost information in the innovation process has increased in the past and cost consciousness found its way into design.

Shields and Young (1994) identify a turning point of this cost consciousness during innovation. They indicate that, in contrast to the research work of R&D, the development work of R&D is put under strong product cost pressures. This issue is also repeated in the interviews that Shields and Young (1994) did. Some of the interviewed managers said that it is unusual that persons involved with basic research would be rigorously concerned with costs, whereas it is more frequent to observe a development engineer focusing on costs. However, Shields and Young (1994) also state that there is a changing view in companies with large R&D programs. There the view spreads more and more that all innovation activities should incorporate cost consciousness.

2.4.5.2 The controller as a neutral person vs. problems with cost controllers

The neutrality and background in economic evaluation can be reasons to include a controller into information gathering and decision preparation for the selection of new product development ideas, especially if the controller is a trusted person by the top management (Vinkemeier and von Franz, 2007). Managers in research and development and other technical areas might have excellent technical and technological knowhow, nevertheless a sober and economic look might help. A controller can 'digest' much cost data and avoid an information overload. Otherwise this information overload could lead in the worst case scenario to an 'analysis paralysis' where the company is unable to process the information amount to find the relevant issues (Pitkethly, 2006).

However, Vinkemeier and von Franz (2007) also warn that controllers might have a too short-sighted view and might be uncomfortable to handle the uncertainty and risk coming with innovations. Redfield (1951) also points out that two sights can collide when estimating future business: the sales manager's optimism and the controller's or production manager's conservatism.

2.4.6 Concluding summary

Summarizing, one can say that over the decades after the Second World War the importance of costs has constantly grown as the markets have developed from a seller to a buyer market. Yet, just cutting budget costs and personnel is the wrong way, as this is harmful for the long time business run of companies. Lowering costs through proactive cost management is a superior approach, focusing on correct decision making from the start on. Some managers in business might argue that they cannot afford more analysis work in pre-development; others might argue that cost considerations strain their creativity. However, the position of this work is that a company cannot afford to not commit resources to critical activities in pre-development, given the importance of innovation, the sums at stake and the high failure risk of innovations. This is valid regardless of the strategy of the company, but most crucial for companies trying to achieve a cost leadership in their industry. Thus efficient and valuable tools to support innovations are suggested in literature.

The realization of competitive product prices and the attainment of target cost are essential as efficient product cost and price together with fine functionality and quality are crucial to a long time survival of companies. Never the less, developments face lock-in effects. Cost is also only one dimension on which innovations are competing. Thus correct, understandable and usable information should be available on time to reduce uncertainty for correct decision making during the innovation process. The following section deals with literature about the tools used for product cost analysis during pre-development. It leaves the general overall patterns for innovation and cost of this section and one by one introduces the tools and their application in business.

2.5 Analysis tool classification

There is no established body of knowledge for the topic of cost information collection and analysis during pre-development phases as this area is a crossing of cost management and innovation research. However, there is a large amount of different methods that vary in comprehensiveness and special cost management focus. For analysis purposes management accountants can select "almost an infinite number of tools, methods, techniques, approaches, and other concepts floating around" (Clinton and Van der Merwe, 2006, p. 15). However, the focus can be narrowed down on concepts that are applicable for innovations, as the research focus of this work is on the purpose of assisting decision making during innovations for favorable designs. Thus tools and methods that are dedicated to assisting decision making to optimize already established and running processes are not considered further and the optimization of running processes (e.g. through kaizen costing) is not analyzed in the case companies. Furthermore, tools for this analysis can be divided into two categories according to Wieczorek (1999). The first category is tools that advert to product specific development contents. The second category is tools that advert to project management specific contents. This thesis concentrates on the first category of tools.

There are plenty of different names for the means of analysis researched in this work. E.g. tool, technique, method, system, procedure, concept and methodology are used variously and partly analogously (Brady et al. 1997; Clinton and Van der Merwe, 2006). This work chooses deliberately the term '**tool**' and follows the definition that **a tool is a document, a framework, procedure, system or method which enables companies to achieve or clarify particular objectives** (Brady et al. 1997).

In general a tool may be applied by particular individuals or groups within a company or may be used across the entire company (Brady et al. 1997). There also might be an overlapping of the particular analysis objective from several tools. I.e. the borderlines between the different tools are often blurred; however, the core ideas can be separated.

Furthermore, this work follows the differentiation of Brady et al. (1997) between specific and generic tools. However, for easier readability **the differentiation is named specific and unspecific here**. The information found and gathered with an unspecific analysis tool will tend to overlap for the information need of several new product development ideas. On the contrary, the information found and gathered with a specific analysis tool will be dedicated to one particular new product development idea. Thus for this research on product cost analysis during pre-development the differentiation of specific and unspecific analysis tools is defined as follows. **Specific analysis tools analyze primarily information regarding one particular new product development idea. Unspecific analysis tools gather information for an array of new product development ideas at a time.**

A second classification dimension is whether a tool provides general information or cost specific information about a new product development idea. In this work, the first is called a **general tool**, while the latter is called a **cost focused tool**.

2.5.1 General and unspecific analysis tools

Next, each subsection will introduce tools that were developed not specifically for cost management and/or innovation management, but which are nevertheless suitable for and supporting the cost information collection and analysis during pre-development. The next two tools are unspecific, as they analyze a range of information that is not specific to one new product development idea. Unspecific tools are less focused and provide rather general information.

2.5.1.1 Intelligence work

The first group of tools is called intelligence work. **Intelligence work** in the front end of innovation can be seen as a base for economic planning (Wheelwright and Clark, 1992; Vinkemeier and von Franz, 2007). It can be done as a potential market study, technology scouting or any other assessment of the business environment of a company. Intelligence work is carried out because comprehensive and timely information and knowledge is essential in generating new product development ideas (Hannula and Pirttimaki, 2003).

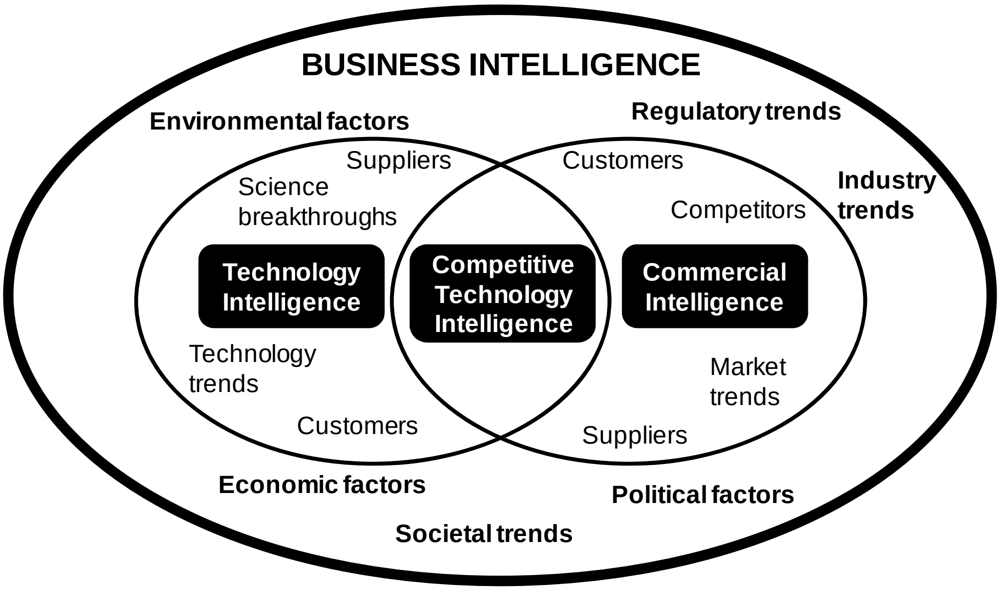

Figure 32: Environment of intelligence work according to Brenner (2005)

Intelligence work is sometimes referred to as business intelligence or competitive intelligence. However, the more universal and embracing term intelligence work is used in this thesis.

So what is intelligence work all about? There is no generally accepted conception of intelligence work in literature, but rather plentiful connotations of different aspects that authors wanted to highlight (Hannula and Pirttimaki, 2003). E.g.:

> *"We view business intelligence as knowledge and foreknowledge of the competitive environment to support decision-making with a primary emphasis to obtain early warning of new developments, capabilities, and strategies of competitors and potential competitors to support decision-making." (Brenner, 2005, pp. 6f)*

Intelligence work aims at early recognizing of trends and changes in the environment of a company. It can be used to start proper measures and actions in an anticipating way (Vinkemeier and von Franz, 2007). Intelligence work can be used in the opportunity-identification stage of new product development (Lilien and Rangaswamy, 2003). From a market perspective, intelligence work can assist in quantifying of feelings and motivations of potential buyers and help forecasting likely market acceptance (Cohen, 1996).

Thus intelligence work carries several aspects around gathering and processing information about the environment of a company. This thesis follows the definition of

Hannula and Pirttimaki (2003, p. 593) that **intelligence work is defined as organized and systemic processes, which are used to acquire, analyze and disseminate information significant to the business activities of companies.**

Intelligence work can roughly be divided into commercial intelligence and technology intelligence even though both are profoundly connected (see Figure 32). The first deals with economic matters, focusing on competitors, customers, markets, and suppliers. The latter emphases technological topics like science breakthroughs and technology trends (Brenner, 2005). Companies regularly use forecasting together with market assessment for their product/market strategy, but forecasting is also used often with technology assessment (Wheelwright and Clark, 1992). Commercial intelligence, which can be based on quantitative market research, uses structured methodology to collect data from potential customer samples and to generalize the results to a wider population (Cohen, 1996).

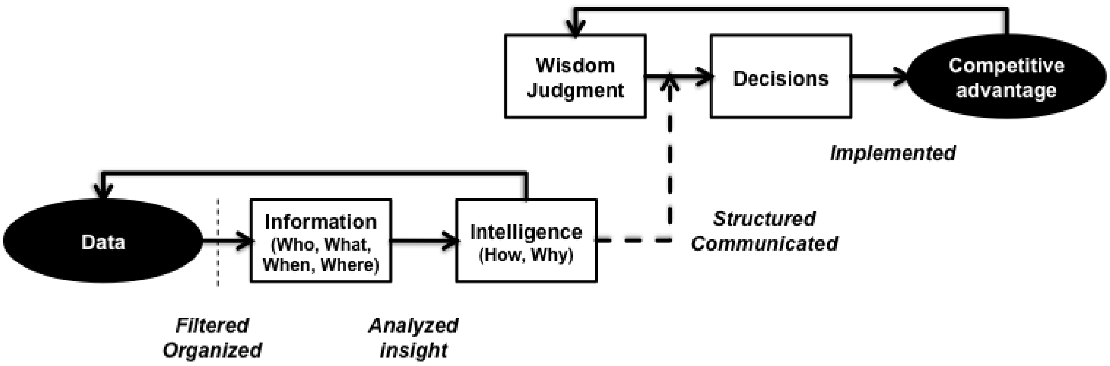

Figure 33: Intelligence leads to advantage according to Brenner (2005)

Figure 33 shows how intelligence work can lead to a competitive advantage by aiding decision making (Brenner, 2005).

One possibility for the intelligence work is that a management team ‘jumps’ through scenarios ahead into the future, e.g. ten years from now. It is important that the team actively takes a future position and is not only extrapolating the actual planning budgets (Vinkemeier and von Franz, 2007).

Another possibility of intelligence work is to monitor technology signals. Over the course of an innovation project of the competition, several signals can be monitored. These increase in intensity the further an innovation proceeds. First, discussions in gray literature and scientific papers arise. Later R&D alliances and joint ventures might be announced. After that patents are filed and process developments might be traced before new products get announced and launched on market

A further option for intelligence work is forecasting (Brenner, 2005; Pitkethly, 2006). Estimating future business is an essential and regular practice in business (Redfield, 1951). Forecasting can be used to analyze trends in the strategic environment of a company (Pitkethly, 2006). However, Redfield (1951) points out that no one can foretell the future exactly, and thus all forecasting includes guesswork. Furthermore, as guesswork is inescapable, one should reduce error to a minimum. The time horizon of forecasting can stretch from short-term (e.g. demand forecasting) to long term (e.g. strategic trends) (Vollmann et al., 1997; Pitkethly, 2006). Short-term estimates can be made through moving average forecasts, exponential smoothing forecasts, trend-enhanced forecasts, seasonally enhanced forecasts, and mixes of them (Vollmann et al., 1997). Redfield (1951) points out four main elements of forecasting:

1. Developing the groundwork
2. Estimating future business
3. Comparing actual with estimated results
4. Refining the forecast process

Thus it is very important to prepare data for forecasting, as one cannot figure out where one is going unless one knows where one has been (Redfield,1951). Furthermore, comparing the actual business with the estimated results is important to be able to refine the forecasting process. The actual techniques can be classified into five categories of basic viewpoints according to Vanston (2003):

1. Extrapolators
2. Pattern analysts
3. Goal analysts
4. Counter-punchers
5. Intuitors

Extrapolators analyze past trends and extrapolate them, as they believe that the future will represent a logical extension of the past. Somehow similar, **pattern analysts** believe that powerful feedback mechanisms in society, together with basic human nature, will cause future trends and events to occur analogous to past experiences. **Goal analysts** believe that the future is shaped by the beliefs and actions of a collection of individuals, organizations and institutions, like trendsetters and decision-makers. Thus they assess the long-term results of their actions. **Counter-punchers** believe that the future is shaped by unpredictable and random events and actions. Thus, a wide range of possible trends and events are monitored and a high degree of flexibility is maintained to react to developments. **Intuitors** are convinced that complex forces, random events, and actions of key individuals and institutions shape the future. Thus no rational technique is sensible, but one should gather as much information as possible, and then use intuition for the forecasting (Vanston, 2003).

One tool used by intuitors for long-term forecasting and connected to expert opinion is the so-called Delphi method (Vanston, 2003; Pitkethly, 2006). It was developed "in order to obtain the most reliable opinion consensus of a group of experts by subjecting them to a series of questionnaires in depth interspersed with controlled opinion feedback" (Dalkey and Helmer, 1963, p.458). Interestingly, an early experiment using a Delphi-style technique was carried out in 1948 in horse race betting in order to optimize the winning chances. Shortly thereafter, the Delphi method was brought into the scientific research world, where it started to be used in scientific forecasting (Gerstenfeld, 1971; Martino, 1980). Yet, forecasting is only a tool that can aid decision making, not substitute it. Thus companies have to employ forecasting wisely as support not replacement to managerial judgment (Vollmann et al., 1997).

A similar tool is war-gaming. War-gaming is predicting conflicting future situations and playing through these to derive measures and steps to be taken at present (Vinkemeier and von Franz, 2007). This simulation of conflicting future situations is a dynamic game that was developed for training top military personnel in the 19th century. War-gaming is based on the idea of competition. Managers playing it are separated in groups and each group plays a market role, e.g. a competitor, a customer or a regulating governmental body. Through analysis of these games and its dynamics, managers should realize the forces and approaches that shape the future market.

One more option for intelligence work is the so-called SWOT analysis (Brenner, 2005). It is a tool that originates from strategic management. SWOT is a tool that originates from the positioning school of competitive strategic management (Mintzberg et al., 1998). This stream of strategy was largely crafted by Porter (e.g. 1980). The acronym SWOT stands for four separate fields of analysis:

- Strengths,
- Weaknesses,
- Opportunities, and
- Threats.

These should show internally and externally, favorable and unfavorable factors of a company and its arrangement in the markets. The SWOT analysis was originally used to position a company in its competitive environment, but over time the concept has been applied to several other objects of analysis, e.g. a specific technology or product.

An analysis tool similar to the SWOT analysis is the PEST factors analysis (Pitkethly, 2006). The acronym PEST stands for the first letters of:

- Political,
- Economic,
- Social, and
- Technological.

Several actions can start from alerts that come from intelligence work. Brenner (2005) reports the reactions of the people alerted in the company Air Products. They are:

- 3% started licensing / technology acquisition
- 2% started joint development

- 9% called the inventor
- 41% incorporated the new knowledge to improve their project
- 31% addressed the competitive threat
- 50% searched for additional information
- 16% pursued the opportunity

Thus intelligence work can be a gateway leading to a new product development idea. Yet, if a new product development idea comes from some other source, intelligence work will be essential to assist its progress.

2.5.1.2 Roadmapping

A boat – even sailing at full speed – will not reach its destination if it is steered in the wrong direction. Similar innovations need a direction if the success of developments should be systematic and not only strikes of luck. Roadmaps are visual tools often based on strategic plan requirements and incorporate product attributes. Furthermore, they outline phases over time to achieve defined goals, development requirements, priorities, and defined evolution plans for new developments (Strauss and Radnor, 2004). On the example of technology roadmaps, Rinne (2004) explains the principal functions to be representation, communication, planning, and coordination of the roadmapped topic. Roadmaps can be used internally to locate the position and development direction of companies in their environment (Wheelwright and Clark, 1992). There are needs for roadmapping on different levels of organizations. One of these needs originates in the linking of strategy and operational issues, as roadmapping is linking strategy to product and technology plans (Albright and Kappel, 2003; Strauss and Radnor, 2004). This comes from the fact that operative planning and activities that translate strategic decisions into operative decisions are restricted by a multitude of variables rooted in the production of a company. As any production parameters must be taken into account, decisions made on intuition and past experience may not yield as good results as if roadmapping is used as a management tool for this purpose (Tan and Platts, 2004). One aim of roadmapping is the systematic identification and measuring of weak signals coming from the industry-specific supply chains. These weak signals are then processed further to new product developments and solutions (Vinkemeier and von Franz, 2007). These are typically created independently by people responsible for them and have to be connected. Roadmaps explicitly create the linkages between market needs, the competitive environment and the technology evolution and implementation plans (Albright and Kappel, 2003). Roadmaps can provide a time-directed representation of relationships between technologies and products, augmented with connections to market and other information (Rinne, 2004). Along the lines of the above statement, roadmapping is defined in this thesis as the **visual process of planning and displaying the timely evolution of new development idea attributes regarding goals, requirements and priorities.**

Roadmapping also fulfills several smaller functions. Besides linking product plans to strategy, it can be used to enable corporate-level technology plans, guide investment decisions, improve the communication of plans, help to focus on long-term and high priority topics, and be used for monitoring ongoing progress (Wheelwright and Clark, 1992; Albright and Kappel, 2003). At Philips Electronics product-technology roadmaps are used to gain a better integration of business and technology strategy already in the front end of innovation (Groenveld, 1997). GM used a mapping technique to evaluate the strategic positioning of the Buick Reatta car in a gap of the market (Lilien and Rangaswamy, 2003).

Roadmaps can also be used to show cost developments over time. They can be used to illustrate the cost structure over time. This can be done by volume levels, by relative performance, or by factors of production (Wheelwright and Clark, 1992). Albright and Kappel (2003) demonstrate how roadmapping is done at Lucent Technologies. One part of their roadmapping is a ‘forward cost model’ that is used to analyze the cost evolution of new technologies. This forward cost model is a roadmap that is based on an experience curve that helps finding probable developments and setting targets for prices and costs of new technologies. It is embedded in a multitude of different other roadmaps that show how a quantity of parameters develops over time.

2.5.2 General and specific analysis tools

The next two tools were also not developed explicitly for cost management and/or innovation management, but can be used for cost information collection and analysis during pre-development. Also, these two tools are specific, as they analyze specifically one new product development idea at a time. Specific tools are more specialized and provide mostly particular information for a distinct new product development idea or a narrow range of ideas.

2.5.2.1 Scorecard use

Scorecards assemble different qualitative and quantitative figures in a summary (De Brentani and Droege, 1988; Baum et al., 2004). Generally one can say that a **scorecard** is an overview of different important parameters that are analyzed together to give a coherent big picture for decision making. It is named like this as different dimensions are scored to give an overview and make comparison between different possible alternatives. Scorecards can help to make discussions more objective as they connect values or estimates of them to a specific situation under discussion. Furthermore, it is possible to weigh up the summary and evaluate the final score. However, the prominent balanced scorecard of Kaplan and Norton (1992) does not summarize to a final overall score, but leaves different area scores up to a qualitative evaluation. On the contrary the ‘weighted-point method’ (also called ‘linear averaging’) does. This method translates qualitative factors into quantitative ones and then uses weights for the different criteria (Timmerman, 1986). For innovations and their evaluation, the principle of using scorecards is based on the notion that qualitative criteria or factors are often better predictors of success than financial projections (Cooper, 2009).

Scorecard use is defined in this thesis along Baum et al. (2004) as **analysis through a weighted rating assessment system of different qualitative and quantitative factors that are aggregated with standardized and uniform levels of scale measurement to final scores for judgment.** Very often parts of the used scorecards in business are extremely industry-type specific (Chow et al., 1997).

Perhaps the most prominent scorecard is the Balanced Scorecard introduced by Kaplan and Norton (1992). The balanced scorecard was developed to communicate several dimensions that companies must achieve to compete with their core competences and innovation. It has four main perspectives that give a holistic view of the business of a company and its development. A different prominent scorecard is the 'Tableau de Bord' that was developed in the 60s in France (Baum et al., 2004). After its development it was used mostly by French and Canadian companies as a multidimensional performance measurement and management system. The company Schindler uses an innovation cockpit for steering and controlling its new product developments. Part of this cockpit is also a monitoring of the forecasted product target cost (Gassmann and Kobe, 1999). Like traffic lights, a forecasted overrun of target costs is shown in red, critical forecasted target costs are shown in yellow and forecasted target costs below the maximum allowable cost are displayed in green. Srinivasan et al., (1997) note that manufacturing checklists and expert judgment are used for concept selection during the concept level phase of innovations. These ask designers to rate the technological change or probable cost of alternative concepts.

These scorecards have in common that several factors and criteria are checked. These are grouped together to several categories. In general, the scorecard can be a simple listing of the different criteria with a score for each evaluation. However, this approach can be enhanced by putting different weights on the checked criteria. The evaluation scores are than added to a final score. This final score is used for the screening decision (Schmitt-Grohe, 1972; De Brentani and Droege, 1988). Either different new product development ideas are compared or there is a minimum score that has to be achieved (Schmitt-Grohe, 1972). For new product development ideas that are rather incremental, Schmitt-Grohe (1972) suggests that the weights and minimum final score are set according to company specific analysis results of successful and unsuccessful innovations. The scores can also be shown in a graphical way for each product. These product profiles can uncover weaknesses of a new product development idea and thus be the base for a targeted concept improvement (Schmitt-Grohe, 1972).

Another scoring model used in product development is Quality Function Deployment. Quality Function Deployment is a scorecard-based method to ensure several quality dimensions and to translate customer demands and wishes into design targets (Akao, 2004). Even so, it is mostly used in the design stage, Quality Function Deployment is also used as a tool to grasp the customer need in pre-development (Voigt and Sturm, 2001). Quality Function Deployment can also be used to reduce product cost while maintaining a balance with quality. This is referred to as cost deployment (Maekawa and Ohta, 2004).

Scorecards are also used as scoring models in pre-development for the display and screening of new development ideas in portfolios (Bösch, 2008). Some examples from literature are introduced next.

Schmitt-Grohe (1972) recommends a coarse screen of new product development ideas to eliminate ineffective new product development ideas as soon as possible. He recommends checklists and scorecards based on expert opinion for this screening. These scorecards check factors based on five main categories:

1. Probability of success
2. Development time
3. Development costs
4. Product demand in the long run
5. Turnover growth

In the scheme proposed by Schmitt-Grohe (1972) this screening does not involve any estimation of the future product costs of the new product development idea. However, he states that the scorecard measures can be enlarged to fit company or industry practice. Two further extensions that he recommends are to further check the availability of human resources and the patent situation.

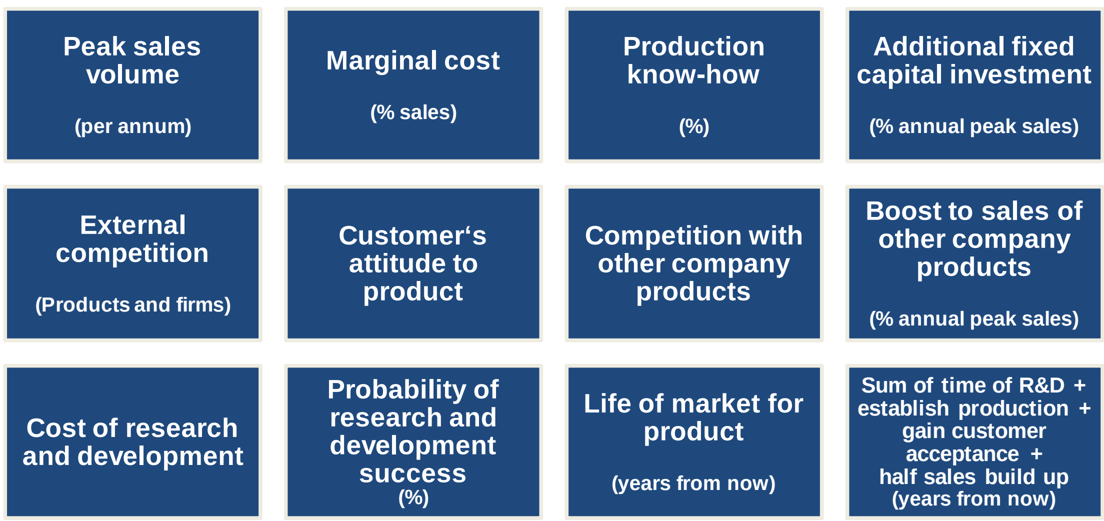

Figure 34: Product research and development ideas evaluation criteria according to Hart (1966)

One scorecard used as scoring model in pre-development is proposed by Hart (1966). It was developed for a company to assist the management in decision making. It checks twelve criteria in total (see Figure 34). E.g. the first criterion is the peak sales value, which is essentially an estimate about market size, market share and selling price. In total three criteria deal with cost estimates. Firstly, the model checks the marginal cost as a fraction of sales. Secondly, the additional fixed capital investment has to be estimated. These are the estimated cost for facilities and manufacturing equipment needed to produce the peak volume of sales. Thirdly, the future costs of the research and development work including overhead expenses have to be estimated. Furthermore, the model checks the customer's value perception in regard to quality and price of the product. If one runs into trouble estimating the marginal cost criteria, Hart (1966) recommends comparing the new product development idea with existing products, and their characteristics including sales volume, labor and material requirements. However, this is only possible for incremental innovations.

Portfolio analysis	Weighting	Scoring	Justification
A1 Market size What is the size of reachable future market?		Market size in Mio € -- - 0 + ++	
A2 Market growth What growth rates has the target market (inflation-adjusted)?		Real growth in % -- - 0 + ++	
A3 Potential future turnover How much additional turnover can be reached with the development (net of cannibalization)?		Additional turnover in % -- - 0 + ++	

Figure 35: Scorecard at Henkel according to Gerhardt and Knobel (1999, p. 90)

At the Henkel Company group a scorecard is used to rate new product development ideas and projects according to attractiveness. A part of this scorecard is shown in Figure 35. The attractiveness is measured in eight criteria:

1. Market size
2. Market growth
3. Potential further turnover
4. Potential further profitability
5. Differentiation potential
6. Sustainability of competitive advantage
7. Marketing resources
8. Contribution to eco-leadership

Similar potential risks connected to new product developments are evaluated with scorecards. The risks scorecard uses six criteria:

1. Technological know-how
2. Potential length of use
3. Competitive situation
4. Reliability of reaching technological targets

5. Reliability of reaching economic targets
6. Time-to-market

The projects are then classified according to its scoring on an attractiveness/risk matrix for a graphical overview, discussion and go/no-go decision making (Gerhardt and Knobel, 1999).

Strategic fit and importance	• Alignment of project with our business's strategy • Importance of project to the strategy • Impact on the business
Product and competitive advantage	• Product delivers unique customer or user benefits • Offering customer excellent value for money (compelling value proposition) • Differentiated product in eyes of customer/user • Positive customer/user feedback on product concept (concept test results)
Market attractiveness	• Market size • Market growth and future potential • Margins earned by players in this market • Competitiveness - how tough and intense competition is (negative)
Core competencies leverage	• Project leverages our core competencies and strengths in: • technology • production/operations • marketing • distribution/sales force
Technical feasibility	• Size of technical gap (straightforward to do) • Technical complexity (few barriers, solution envisioned) • Familiarity of technology to our business • Technical results to date (proof of concept)
Financial reward versus risk	• Size of financial opportunity • Financial return (NPV, ECV, IRR) • Productivity Index (PI) • Certainty of financial estimates • Level of risk and ability to address risks

Figure 36: A typical scorecard for gate 3 (go to development) according to Cooper (2009)

Figure 36 shows a typical scorecard and the evaluated criteria for the last gate before development start. In that gate meeting, the gatekeepers are using these six categories to rate new product development ideas. These gatekeepers are usually senior management. The scores are used to rank the ideas according attractiveness. The scores can be a weighted or un-weighted additional subcategory scores. Usually 60% of the maximal score is required for a Go decision (Cooper, 2009).

In the model shown in Figure 36, at least two categories deal indirectly with future cost of new product development ideas. The first category is about the product and its competitive advantage. Here a compelling value proposition is seen as important (Cooper, 2009). The second category is about financial reward in opposition to risk. Here the financial return figures consider calculations or estimations of future product cost (Cooper, 2009).

2.5.2.2 Uncertainty management

As stated in 2.2.4, high uncertainties can be attached to innovations. However, they are reduced step by step the further innovation proceeds. Uncertainty management tools can help to identify and manage the issues connected to reducing the uncertainty during pre-development.

In practice the terms uncertainty management and risk management are often used interchangeably to include the management of risk, opportunity and uncertainty (Olsson, 2006). Yet, in this thesis the term uncertainty management is deliberately used to illustrate that there can also be an upside attached to it.

Uncertainty management can be defined as the activity of taking care of, understanding, leading, handling, or being in charge of uncertainty (Olsson, 2006).

There are two main types of uncertainty – technical and market related. Technical uncertainty is related to the new product development idea meeting the required technical specifications and quality. Market uncertainty is the uncertainty around the commercial success if technical specifications and quality requirements are met (Smith, 1999).

Furthermore, two types of uncertainty management tools can be distinguished. The first concentrates on projects, the second on new product development ideas and portfolios of them (Olsson, 2006). The focus is on the latter for this work.

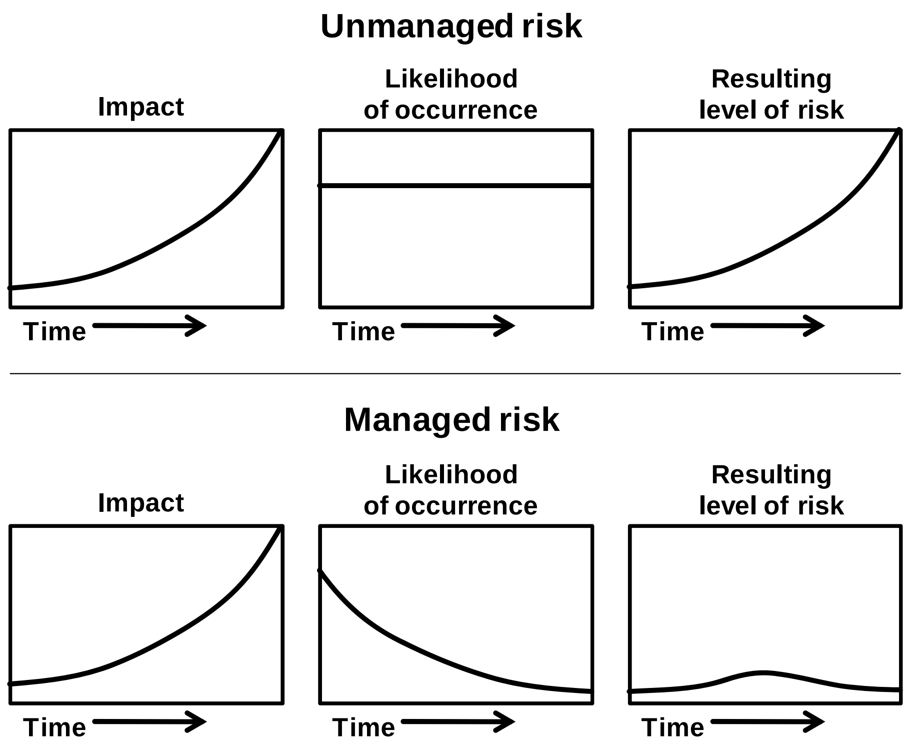

Figure 37: Unmanaged vs. managed risk according Smith (1999)

The lower part of Figure 37 shows the mitigating and damping effect that a reduction of the occurrence likelihood of a risk can have. In that case, the best way to manage the risk level is to manage its occurrence likelihood (Smith, 1999).

Basically all methods of a guided and structured management can be seen as uncertainty management (Young, 2007). E.g. risk identification can be made by creativity tools such as brainstorming (Smith, 1999). Similar Cooper (1996 & 1990) sees a structured and well-executed stage gate process as an uncertainty management tool. This can be seen as the wide view on uncertainty management tools. Somehow conversely, this thesis takes a more narrow view on uncertainty management tools for this classification. Uncertainty management tools in the narrow view are tools dedicated to reduce or handle uncertainty in data specific to product cost analysis during pre-development, like:

- Decision trees
- Scenario thinking/analysis
- Sensitivity analysis
- Using distributions for data input
- Triple-point estimates

The pursuit of new product development ideas is a multi-stage and multi-period endeavor that can also be modeled by **decision trees** (Schmitt-Grohe, 1972). E.g. Varila and Sievanen (2005) suggest decision trees for considering and valuating the variety of options for high-tech R&D projects.

Especially when the information state is blurred, tailor-made **scenarios** should be used (Lechner and Völker, 1999). Scenario thinking and planning aided Shell to be prepared for the oil crisis in the 1970s, setting itself apart from the competition (Senge, 1990). Intelligence work like forecasting and uncertainty management tools like scenario analysis can be connected. E.g. HP has developed a forecasting tool that uses three levels of uncertainty as a base for their cost estimations (Carbone, 2004). These levels are called low, base and high. E.g. the company can be sure that it will sell at least a specific amount of computers during the next analysis period even if things are not going well. This can be seen as a worst case scenario. The volumes of this worst case scenario can be used to have base contracts in purchasing that are fulfilled with a 100% guarantee.

The scorecards proposed by Schmitt-Grohe (1972) use several factors and criteria that are checked. However, if a factor cannot be estimated well, he suggests using **sensitivity analysis** for that parameter. This sensitivity analysis is to be carried out by varying the parameter under consideration. A new product development idea should also be further elaborated, even if a pessimistic approach on that variation leads to a positive overall outlook.

Basically, all quantitative data can be modeled as **distributions**. Schmitt-Grohe (1972) discusses a model that uses standard deviations of parameters for the analysis. Another possibility to describe the uncertainty of estimates is to use triple point estimates. This is done by estimating the worst case, the best case and the most likely outcome. These three different scenarios can then be used to qualitatively evaluate the matter under investigation (Turner, 1998). In the easiest way this is done by the above mentioned triple point estimates (minimum, most likely and maximum figures) and to evaluate them. More sophisticated methods can be based on commercially available special software. This is especially easy to apply if the uncertain data is available in spreadsheet form. It is done in form of a Monte Carlo analysis that compromises all entered elements of risk. In that analysis a comprehensive model of the situation is made that incorporates ranges referring each element of risk (Turner, 1998).

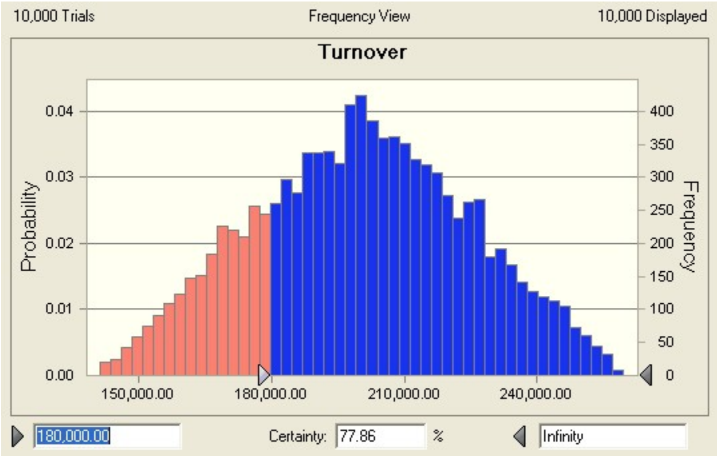

Figure 38: An example screen shot from the result of a Monte Carlo simulation

The model is then evaluated many times with the program and offers a distribution like the one shown in Figure 38, which is an example screen shot from the result of a Monte Carlo simulation. However, even though distributions can be used to model and demonstrate uncertainties, communicating distributions is perceived as more difficult by managers. Thus training and increasing the awareness of uncertainties in companies is important. Similar as for costs, uncertainty drivers and factors can be identified (Turner, 1998). Usually a perception of potential problems and their origin is already identified in an organization. Sometimes, solutions for these challenges are already known within the organization or by suppliers. Through that, the uncertainty for important decisions during new product developments is reduced. This leads ultimately to a mitigation of lock-in effects during the development process.

For the evaluation of new product development, ideas in pre-development can also use sensitivity analysis (Cooper, 1990; Varila and Sievanen, 2005; Bösch, 2008). With this approach the change of the results is analyzed when alternating different subjective estimations (Varila and Sievanen, 2005; Bösch, 2008). One or several estimations are varied and the changes in results are studied.

It is important to see uncertainty management as a cross-functional work, as most issues in new product development are cross functional. A specialized group will only focus on their specialty and skip important issues (Smith, 1999).

2.5.3 Unspecific cost analysis tools

In the last two subsections above general analysis tools for pre-development were introduced. On the contrary, this and the next subsection focus on tools particular to product cost analysis. The next two tools are unspecific, as they analyze a range of information that is not specific to one new product development idea.

2.5.3.1 Analysis of cost dynamics

Usually prototypes and products in early product life stages show much higher production cost than products that are already in later product life stages. Besides the fact that prototypes are often manufactured with different methods and materials, this is due to cost reduction efforts and optimization over time.

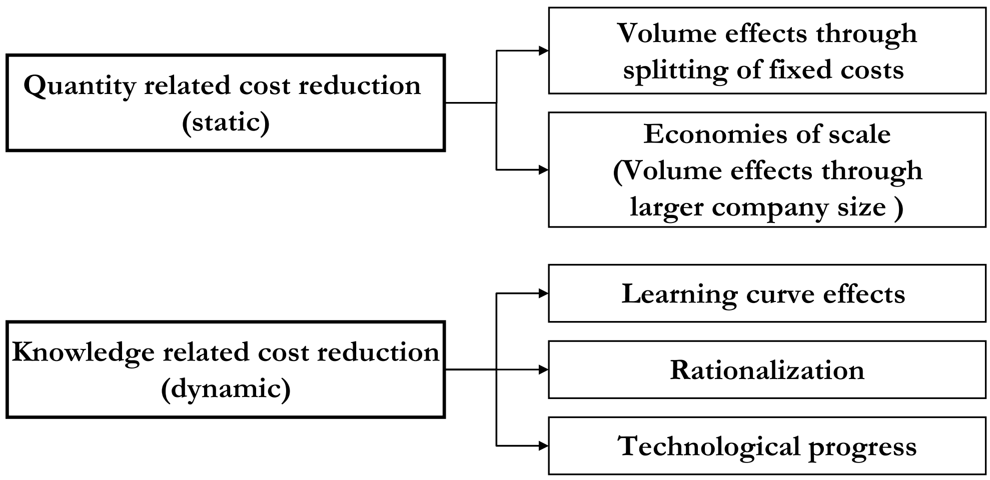

Figure 39: Scheme of effects for cost reduction (amended from Baum et al., 2004, p. 91)

Figure 39 shows different cost reduction schemes how they are presented in literature. There are static and dynamic cost reduction principles.

The two static cost reduction reasons (i.e. splitting of fixed costs and economies of scale) can easily be calculated, as these effects are static and come with higher volumes. This **volume effect** is achieved through a better utilization of secondary functions of a company (fixed costs, overheads) that are not directly related to production volumes. Thus the higher the production volumes, the lower the fixed cost share a single produced part has to bear (Baum et al., 2004).

Economies of scale also come from higher production volumes, but are related to the magnitude of the production (Chandler, 1990). Contrary to the splitting of fixed costs, economies of scale lead to an over-proportional increase of the output for an input increase. An example could be the higher purchasing power connected with high volumes, which leads to lower raw material prices (Baum et al., 2004). Similar different production technologies can show over-proportional increases of the output for an investment increase (Chandler, 1990). Economies of scale can have an important influence on how long an innovating company can hold a quasi-monopolistic market role (Walker, 1979). This is because following innovation is usually time consuming. If a company comes up with a radically new product development idea that succeeds on the market, the competition will need time to imitate that new technology. During the time that the competition needs to catch up, the innovating company can use economies of scale to fortify its position.

Furthermore, literature proposes several dynamic cost reduction types (i.e. learning curve effects, rationalization and technological progress). Technological development, kaizen efforts, redesigns and changes of underlying production technology fall into these categories. All have the principle in common, that there is a cost reduction, even though the annual volumes do not have to increase (Baum et al., 2004). One dynamic cause of cost reduction is the **learning curve effect**, which provides an empirical relationship between changes in direct manufacturing cost and the accumulated volume of production (Hax and Majluf, 1982). The learning curve is sometimes also referred to as experience curve (Lieberman, 1987). There is considerable empirical evidence for learning curves in a wide range of industries (Lieberman, 1987). The learning curve can be observed when the cumulative output increases, even though the annual volumes do not change (Baum et al., 2004). It was empirically found that these cost decreases are a function of cumulative output, rather than calendar time (Lieberman, 1987). The learning curve effect was firstly observed on the Wright-Patterson Air Force Base in Dayton/Ohio in 1925 (Baum et al., 2004). There the used time for air craft production processes decreased with the cumulative output through learning effects. The learning curve is a key tool to assist managers in judging competitive cost structures (Hax and Majluf, 1982). However, study results have been mixed about whether learning curve effects lead to the creation of entry barriers into markets. While some studies see it so, others find only quite low affirmation (Lieberman, 1987). In high technology areas, often companies bid for contracts which, if obtained, would lower their cost of units produced due to learning curve effects. For that, forecasting and projecting cost structure effects are essential (Hax and Majluf, 1982). Considering learning is an important factor in cost estimation, as initial fabrication and assembly can take up to five times longer than when it has become a routine task (Curran et al., 2003). Incorporating these effects, the lowered cost per unit are calculated and used during negotiation processes for bidding and winning contracts by passing on learning curve cost reductions to the customer (Hax and Majluf, 1982).

Technological progress happens through invention and conception of new and more powerful production technologies (Baum et al., 2004). These lead to lower cost for one produced product – independent of the annual volume.

Similar, **rationalization** leads to lower cost through increasing the efficiency of company internal processes. In this case the business of a company is planned according to scientific rules of management in order to achieve more efficient processes (Baum et al., 2004). Also this effect is independent of the annual volume.

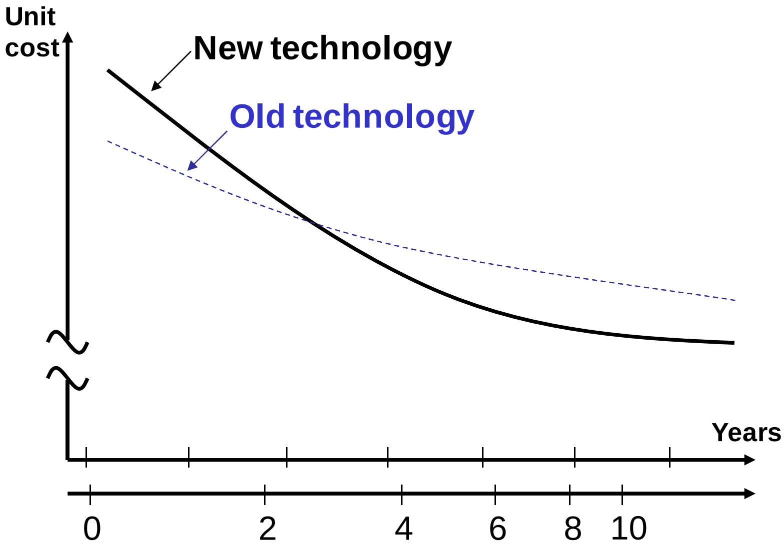

Figure 40: The dynamic view of technology choices (Illustrative example)

The learning curve has become a central concept in corporate strategic planning (Lieberman, 1987). Yet, it can also be applied to technology analysis. In Figure 40 a fictive example of two technologies with different cost reduction potentials is shown. Over time one technology might get cheaper, as there is a steeper learning and experience curve effect than for a competitive technology. That means that even if the costs of one technology are higher when a company gets to know that technology, the costs could decrease faster over some years so that the technology gets cheaper in the long run (see Figure 40).

The above described effects and their cost reduction effects can be calculated by analyzing the initial unit cost, the learning steepness and the amount of output doublings (Baum et al., 2004; Lieberman, 1987). Estimating these described cost reductions is referred to as **cost capability estimations** in this thesis. This can also lead to a target cost strategy of declining prices over time as described for the camera business of Olympus by Cooper and Slagmulder (1997).

Hax and Mijluf (1982) describe the analysis of cost dynamics through diagnosis of industry cost structures. This analysis contains determining the experience curve for each competitor in the industry. If the single experience curves are similar for all market participants, the market share of each competitor is crucial to assessing their strengths (Hax and Mijluf, 1982). However, if the experience curves are not similar for all market participants, identifying the different technologies in use can provide insights for the strategic positioning of a company in the business (Hax and Mijluf, 1982). In the latter case, investments in lower cost production technologies can lead to surpassing of learning curve effects.

In this thesis the analysis of cost dynamics is defined a bit broader than the use of Hax and Mijluf (1982) by using the differentiation of Baum et al. (2004) shown in Figure 39. **The analysis of cost dynamics is the diagnosis of variable cost structures that are influenced through knowledge related cost reductions of learning curve effects, rationalization, technological progress, and alike.** Analysis of cost dynamics is classified as unspecific, as it analyzes variable cost structures that are not specific to one new product development idea, but rather a range of technological possibilities.

The cost capability should be known to do the right decisions, including the decision to accelerate the decline. The most cost efficient technology at a given point of time does not have to be the most cost efficient in the long run and/or might neglect strategic aspects. Companies are using these cost capability estimations through internal rules of thumb (Baldwin, 1991). These rules of thumb are often stated as a performance goal, e.g. as price drop to 50 percent within 18, 24 or 36 months (Baldwin, 1991).

2.5.3.2 Cost database use

Franz (1992) suggests using cost databases as an aid to optimize cost of new product developments. In general, cost databases can be defined as records of detailed cost information based on a range of cost drivers or manufacturing variables (Yoshikawa et al., 1990). These can be catalogs with relative cost data or other databases that are also known as cost tables. These cost databases use up to date cost information about standard components, subsystems and materials. Once these databases are in place, this cost information can be used to evaluate a range of new product development ideas and thus is an unspecific tool. Thus **cost database use is defined as analysis of new product development ideas with databases of detailed cost information based on a range of tabulated cost information, cost drivers or manufacturing variables**.

According to Yoshikawa et al. (1990) cost databases are used by Japanese companies to project product costs assuming the use of different materials, different manufacturing methods, and different functions. In their opinion, cost tables can be used to improve cost effectiveness during all phases of the product life cycle, but especially before production begins. Traditionally the cost tables have originated from needs of the purchasing department. They have helped to negotiate better prices with subcontractors. However, the use has been extended to other controllable elements of production cost. With that the focus of the cost tables has also shifted. When cost tables were developed, they focused on production activities. Only later the focus shifted towards the functions or parts of products (Yoshikawa et al., 1990). The survey by Tani et al. (1994) found that the companies that use cost tables record usually costs for material (94,8%), purchased parts (94,8%), and direct processing (94,8%). However, still quite often cost data on overheads (82,3%), the depreciation of new investments (74,0%), and logistics (52,1%) was gathered. Less often data on development costs (39,6%) and trial production costs (36,5%) was also gathered.

The distinctiveness of cost tables against normal databases with cost information is their planned approach as well as preparation and maintenance. The cost information can be represented differently, but the specific value of cost tables is the sound approach in compiling them. Japanese management accountants maintain their cost tables accurately, to be able to provide help for cost based decision making by answering questions to “cost implications of alterative courses of action under consideration” (Yoshikawa et al., 1990, p. 30). They are reported to be used for what-if analyses. Also they answer cost implications of different designs (design cost tables). Furthermore, they aid to find cost reduction potentials of products in the production phase (manufacturing cost tables) and can help to make decisions about (dis-)continuation of product lines. Tani et al. (1994) found that cost tables are mostly prepared by departments that focus on development, design or production technology, but also by accounting departments. In Japan, cost tables are already used in very early stages of the new product development. A multinational company uses them together with target cost to screen out unprofitable new product proposals (Yoshikawa et al., 1990). Thus they have a good potential to be used in pre-development for the analysis of new product development ideas.

According to Yoshikawa et al. (1990) cost tables are put up gradually, based on the knowledge and insight of a company. They are based on a wide-ranging, multidimensional identification of the major variables that drive costs in the operations of that company, not only of the present design, but also alternative and future methods. However, the preparation of cost tables also needs a fair amount of resources. Yoshikawa et al. argue that the “analytical power of cost tables requires a full-time team of management accountants who must specify production activities and cost drivers, gather relevant cost data and then construct and maintain the cost tables” (Yoshikawa et al., 1990, p. 32). As an example they state that a factory with a workforce of 1,000 people, employs three management accountants to maintain cost tables full-time. In Japan cost tables are usually revised annually or semi-annually (Tani et al., 1994).

In general, one can say that the availability of cost information can be important for cost-based decision making in early stages of innovations. Cost tables codify and store cost information as databases. This information could later be used to evaluate new product development ideas, and make right decisions in early stages of innovations.

2.5.4 Specific cost analysis tools

This subsection presents three tools particularly focusing on product cost analysis. These three tools are specific, as they analyze explicitly one new product development idea at a time. Thus they are completely dedicated to the product cost analysis of one individual new product development idea.

2.5.4.1 Cost modeling and estimation

Accurate product cost estimation is critical in today's environment (Newnes et al. 2008). Cost estimations are part of pre-development and important for the evaluation in early screening (Cooper, 1990). It is seen as important to have accurate product cost estimations already at the concept design stage to support decision making (Ong, 1993; Srinivasan et al., 1997; Curran et al., 2005). There is a demand for reliable cost estimating across the industry. Some companies develop in-house spreadsheets while others rely on tight control or cost management during new product development (Newnes et al., 2008).

There has been some standardization work been done for the estimation of life cycle cost (EN 12973:2000 and IEC 60300-3-3:2004) that can be used for cost modeling and estimation. In order to make the right decisions in product development, cost information has to be available. The first possibility to estimate costs is to ask experts (EN 12973:2000). However, there are also several other cost estimation methods. E.g. the IEC 60300-3-3:2004 standard gives three methods to estimate life cycle cost:

1. Engineering cost estimation
2. Analogous cost estimation
3. Parametric cost estimation

The first is the '**engineering cost method**', where the driver for a special cost element is directly estimated by investigating the components of an asset one by one. Established cost factors, e.g. the current engineering and manufacturing estimates, can be used to find the cost of each element. However, the needed data might not be available in pre-development phases. The second method is the '**analogous cost method**', were cost estimations based on information from a comparable product or technology or historical data are used. This method provides a rather straightforward and brief instrument. It is easily applied to known components of the asset if actual data is available. The third given method is the '**parametric cost method**', which uses parameters and variables to build up cost estimating relations. These relations are usually equations where costs are estimated through some kind of cost function (that can be e.g. non-linear). However, in all cases of cost estimation the effort shall be justified by the information gain and increase (EN 12973:2000). Already in the 1970's, costs were estimated using parametric cost estimations for the 767 airplane at Boing (Anderson and Sedatole, 1998). The cost database for the 767 development was data derived from the 727 series. The number of labor hours per pound of specific sections of the 727 was taken and multiplied by the expected weight of the new plane section. That figure was then multiplied by a learning factor per plane generation and additionally a learning curve was estimated for the different numbers of planes (Anderson and Sedatole, 1998).

Cost modeling and estimation is a pair, as cost estimation demands the use of a prior developed cost model (Rios et al. 2007). In general, the primary function of cost estimation is the provision of reliable capital and operating cost assessments and information that can be used for decision making (Curran et al., 2005).

Cost modeling and estimation is defined along the above as follows. **Cost modeling and estimation work is representing and predicting cost factors, relations and drivers by investigating product details to provide approximated cost assessments and information that can be used for decision making.** These used product details can be product components, cost elements, information from historical data, comparable products or technologies, or parameters and variables. Cost modeling and estimation is classified as specific in this thesis, as it usually focuses on one single new product development idea at a time.

Cost estimators use a combination of logic, common sense, skill, experience, and judgment, to derive estimates that are timely, relevant, and meaningful (Rush and Roy, 2001). The accuracy of these estimates can be relatively high for incremental developments with traditional manufacturing processes of known products or product families. However, issues arise when products are new without any similar products or processes in place (Newnes et al., 2008). For the first, incremental developments in known areas, cost estimations can be done in real-time and on-screen during the design of a component (Newnes et al., 2007). However, for estimating the costs of new product developments, Roy et al. (2005) distinguish between currently used technology and new technology. Components using known technology are estimated with approved cost estimation relationships. The costs for components using new technology are approximated with analogous cost estimation of similar components from inside or outside of the company and industry.

Schmitt-Grohe (1972) recommends also using break-even analysis for the product cost analysis during pre-development. These require cost functions, which he sees as linear functions with a fixed cost part. In his view usually expert opinion is used for these cost function estimates. He points out a multitude of different options at this point regarding the final innovation characteristics. The uncertainty stretches over final product quality, distribution channels, marketing, packaging, and prices. Depending on the quality of the cost estimates, he suggests using alternative final prices for profitability calculations.

Srinivasan et al. (1997) suggest three different approaches for estimating costs during the concept selection phase of innovation to estimate the overall profitability. The first approach is subjective estimates of experts. The second approach is estimating the cost of attribute bundles for a sample of products and then estimating a function c=f(x) according to that information. The third approach is to do reverse engineering of competitor products and use that information for estimating a function c=f(x). Reverse engineering is also known as tear-down analysis and it is a process of disassembling products to analyze used materials, production and assembly (Srinivasan et al., 1997; Cooper and Slagmulder, 1997; Drury, 2004).

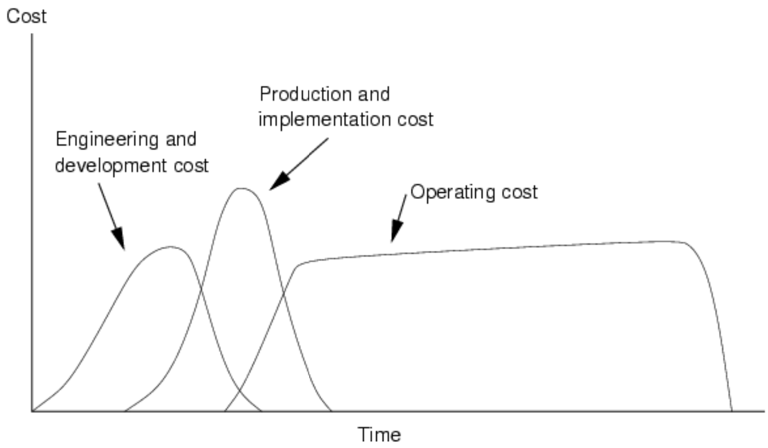

Figure 41: Different costs appearing in different parts of the product life cycle (amended from Woodward, 1997)

When analyzing alternatives in the pre-development state, **life cycle costing** is one possible method for cost analysis of these developments. The International Electrotechnical Commission (IEC) published a standard in 1996, which lies in the field of dependability management and gives recommendations how to carry out life cycle costing. In general, life cycle costs are the sum of all costs that are incurred during the life span of a product; starting with its development, manufacturing, and operation until scrapping or redeployment, as e.g. shown in Figure 41 (Woodward, 1997). Life cycle costing is defined as process of economic analysis to assess the aggregated costs of a product over its life span or portion thereof, through the process of estimating and aggregating costs (Kaplan and Atkinson, 1998; IEC 60300-3-3:2004). Life cycle costing is used predominately in the planning phase, where companies estimate the product’s cost over its lifetime (Kaplan and Atkinson, 1998). Life cycle costing is also called ‘cradle-to-grave costing’ and ‘womb-to-tomb costing’ (Horngren et al., 1994; Kaplan and Atkinson, 1998). Both terms are very descriptive and show that the costs of the whole life span are investigated.

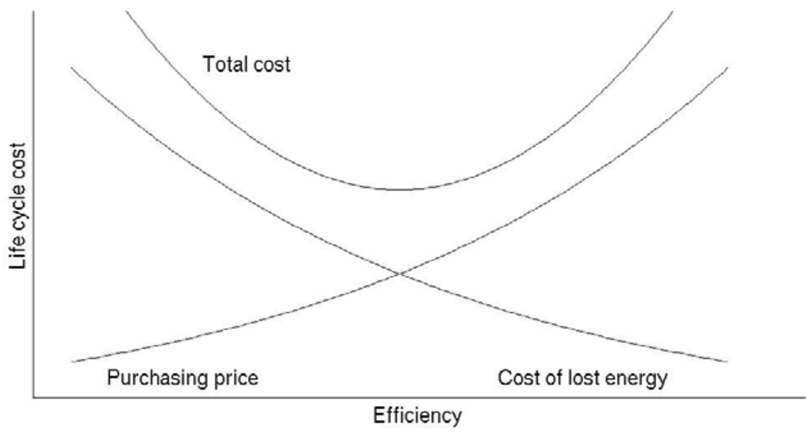

Figure 42: An example of a life cycle cost tradeoff (amended from Woodward, 1997)

Life cycle costing is a tool for finding the lowest life cycle costs by analyzing trade-offs. One example of that is shown in Figure 42. It shows a trade-off between price and costs of lost energy for a product that can have different efficiency levels. According to Kaplan and Atkinson (1998) life cycle costing is particularly important for developments with large planning and development cost (e.g. developing a new plane) or large product abandonment costs (e.g. nuclear power plants). In their view, there are three broad purposes of life cycle costing.

1. Develop a sense of the total cost associated with a product in order to identify whether it will be profitable to the company.
2. Identify environmental cost consequences connected to a development and direct the development efforts towards reducing or eliminating these costs.
3. Help to identify the planning and decommissioning costs already during the product and process design phase in order to control and manage these costs.

Life cycle costing has been a strong point of engineering economics for over 50 years and became popular in the 1960s when the concept was taken up by U.S. government agencies as an instrument to improve the cost effectiveness of equipment procurement. From that point, the concept has spread to the business sector, and is used in product development studies and project evaluations (Riggs, 1982). The life cycle costing concept was then taken up by management accounting. Park and Seo (2004) have found that companies are nowadays integrating life cycle cost analysis earlier in their product development as it gets a higher value in company policies.

Life cycle costing has to be distinguished from the product life cycle concept articulated in the economic literature (e.g. Levitt, 1965; Polli and Cook, 1969; Dhalla and Yuspeh, 1976; Kotler and Armstrong, 2008). The main idea of the product life cycle concept is that the type of products offered by a company shows a life cycle with a limited life time similar to the one of living creatures, from being born, to growing, maturing and finally dying. The product life cycle model is used to illustrate the sales volume of an object type through different market stages.

Furthermore life cycle costing has to be distinguished from life cycle assessment, which analyses environmental impacts of products. Earlier, this concept was also referred at as life cycle analysis (Webb, 1999) and life cycle thinking (Wiegard, 2001).

A further enhancement to traditional costing is reported by Cooper and Slagmulder (1997). They mention the computation of **perfect waste-free cost estimations**. These estimations are used to enhance the target costing process by showing the theoretical limit as a goal to aim for. According to Cooper and Slagmulder (1997) the perfect waste-free level is the cost level that is reached when all value-adding activities are performing as efficiently as possible and all non-value-added activities are removed. They also define a second waste-free cost level – the unavoidable waste-free cost. This second term is defined as the most aggressive short-term cost reduction goal possible for a product (Cooper and Slagmulder, 1997). According to these authors, the first waste-free cost level is the ultimate long-term goal of a lean enterprise that follows the cost leader approach. It is linked to the zero-defects objective in quality management. The second waste-free level is a nearer future cost target.

2.5.4.2 Target costing efforts

The initiative of searching cost reduction upstream into product development, together with its supporting systems and procedures, is called target costing or Genka Kiaku in Japanese (Kato, 1993). **Target costing** (also called target cost management) **is a set of activities aimed at attaining a cost target through means that assist the planning, development and detailed design of new products** (Tani et al., 1994). Target costing is a tool to determine maximum allowable product cost of a proposed product with specified functionality and quality, with the aim to meet future profit plans (Cooper and Slagmulder, 1997; Franz, 1992). Target costing is used during the planning cycle and drives the process of choosing product and process designs that will result in a product that can be produced at a cost that will allow an acceptable level of profit, given the product’s estimated market price, selling volume, and target functionality (Kaplan and Atkinson, 1998). It can take the control of future product cost early into the innovation process (Jens, 1999). Target costing is a strategic cost management system with several objectives around costs (cost reduction), quality (quality assurance) and time (timely market introduction) (Tani et al., 1994). Together with the newness of the product, it therefore takes into consideration the several trade-off dimensions that Davila and Wouters (2004) named the most important for innovations - costs, newness, performance, and time to market (see Figure 1).

There is an ongoing debate in literature, of which functions target costing teams most commonly represent - with a focus on team members from engineering (e.g. Tani et al., 1994; Dekker and Smidt, 2003) or with an important role of controllers and accountants (e.g. in Germany: Tani, et al., 1996). Traditionally it is specialists taking care of the target costing practices in companies. In a study of Japanese stock listed companies, Tani et al. (1994) found that over one third (37,6%) of the companies that were using target costing, had an office dedicated solely for target costing. Another 45 % had either a person in charge for target costing or another functional department taking care of the target costing procedures. However, the remaining 17,4% of the companies using target costing had no specific office or person in charge.

When target costing was taken up by western companies, they focused mostly on the calculation methods, i.e. first determining target costs and then calculating the allowable costs of product parts. This was due to the fact that when the interest in western countries grew, these calculation methods were the only focus of the first publications available in English language (Tani, et al., 1996). However, with later publications, the surrounding set of approaches also got clearer. Yet, the environment seems to play a role in the adoption of the tool. Target costing efforts were relatively more often used under circumstances of intense competition and high environmental uncertainty in the Netherlands (Dekker and Smidt, 2003). Hibbets et al. (2003) studied the role of the competitive environment and strategy on the adoption of target costing in a twelve company case study. They found that product differentiators are more likely to adopt target costing efforts than companies following other strategies like cost leadership. Additionally, they point out that a high company rivalry in the industry of a company will lead to a use of target costing in development.

Target costing combines company external and internal views (Voigt and Sturm, 2001; Kaplan and Cooper, 1998). The internal view is on a good organization of internal development procedures. The external view is on the market and the achievable market price of a development. Kaplan and Cooper (1998, p. 217) describe the idea of target costing as follows:

> *"At the heart of target costing is a very simple syllogism: Let the marketplace determine the selling price of the future product, subtract from this selling price the profit margin that you want to generate, and this figure yields the target cost at which the product must be manufactured. In target costing, the cost of a new product is no longer an outcome of the product design process; it becomes an input into the process."*

Thus, one principal idea of target costing is that costs are a criterion to the product development process and used during it. The target costs are derived by estimating a target selling price of a new product. It takes into consideration what customers are willing to pay and subtracts the desired profit margin from it. The use of target costing has several benefits. Through the development aim of staying below the target cost, competitive cost pressures of the market are transmitted to product designers and suppliers (Cooper and Slagmulder, 1997, Ewert and Ernst, 1999, Helms et al., 2005). Another central benefit of target costing is to avoid over-engineering. It helps to meet the customer demand and at the same time be profitable for the producing company (Butscher and Laker, 2000). Dekker and Smidt (2003) found that Dutch companies had independently developed practices that resemble target costing. They started to develop these through the pressures of the competitive and volatile environment they were operating in. Most of the analyzed companies claimed to use target-costing-like methods, but used different names for them. Similar findings are stated by Boer and Ettlie (1999) for U.S. companies.

The literature about target costing is rich in describing the practices in companies (especially in Japanese ones), in specifying the goals of target costing, in surveying the adaptation of this method, and on who exactly is involved in target costing efforts in organizations. However, a blank spot in literature so far is the earliness at which target costing is started to be used.

Another tool similar to target costing is **Design to cost** (DTC), which is used for cost effective planning and engineering. This is a tool that considers production cost goals already from the start of a development program. It does so by considering the estimated production costs as a performance parameter that shall be attained together with technical performances. The tool helps to keep the balance between costs, functional performance and schedule (EN 12973:2000). Similar to target costing, it establishes maximum allowable product costs connected with specified functionality and quality. Design to cost was developed by the US Department of Defense to encounter the constant cost overruns of larger armament programs. Since 1971 the US Department of Defense made it compulsory to use design to cost for each contract that is larger than 10 million USD (EN 12973:2000). Nowadays, design to life cycle cost (DTLCC) as a further development can also be used. It uses the same principles, but takes additional life cycle costs into account.

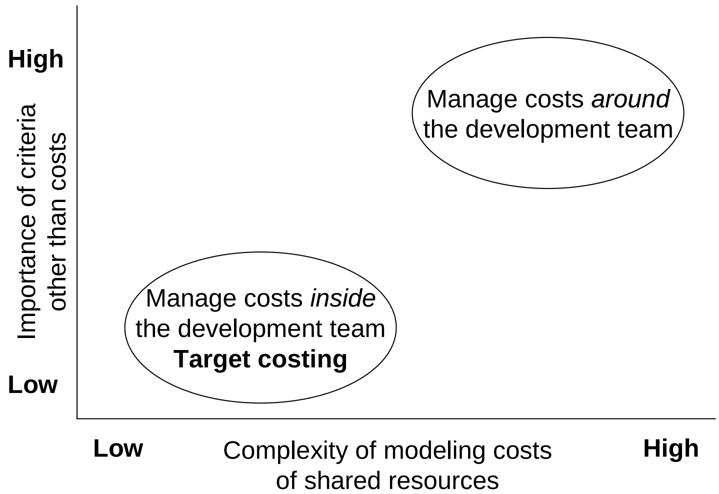

Figure 43: Cost management for different criteria and complexity according to Davila and Wouters (2004, p. 14)

Yet, there are also some **limitations** mentioned in literature on target costing. One is that target costing only could be too narrow for successful innovation management (see the graphical overview in Figure 43). There are several matters that have to be taken into account during innovation. Davila and Wouters (2004) group these into two main categories. One category is the complexity of modeling costs of shared resources. The other category is the importance of parameters different than costs (see Figure 43).

A further mentioned limitation is that target costing is best used with incremental developments, but is less suited when addressing the cost estimation of radical product innovations (Roy, 2003). This comes from the fact that target costing requires functionality and future cost breakdowns for new product development ideas. This is hardly possible for radical innovations, unless a special system for product definition and breakdown during these early stages is developed (Roy, 2003).

2.5.4.3 Value analysis work

Cooper and Kleinschmidt (1986) state that a high performance to cost ratio and economic advantages in the form of cost benefits to the customer are fundamental to new product development success. Also Vandermerwe (2000) states that a superior value at low delivered cost is essential to success on the market. This value can be described by the value to customer concept. According to Tu et al. (2006, p. 697), "**Value to customer** (VC) is the degree to which customers believe that they received products and services that are worth more than the price they paid." The value to customers is seen as essential to stay profitable in today's business environment (Vandermerwe, 2000). Karlsson and Ryan (1997) developed an analytical tool for rating new product development features according to their relative value and cost. Even though they use this tool for software development, it is essentailly transferable to all kinds of new product development ideas. Similarly, Ayag (2005) developed an analytical tool for evaluating conceptiual design alternatives of new product development ideas regarding value and cost. Both tools use the Analytic Hierarchy Process (AHP) for the customer value ranking. The Analytic Hierarchy Process is a multicriteria decision making approach (Saaty, 1990). It uses paired comparisions to arange factors in a hierarchic structure. It uses verbal judgements to rate these pairs against each other. These judements are then converted into numerical values and analyzed. However, in practice the Analytic Hierarchy Process can also result in inconsistent ratings by the customers (Karlsson and Ryan, 1997). Despite this, an average trend will usually emerge.

A concept related to the value to customer concept is **value analysis** which is also known as value engineering or functional value analysis (Drury, 2004). It is focused on reducing cost at constant or better quality and customer satisfaction (Stippel, 1999). This tool can be defined as a methodical approach to evaluating new product development designs with the intention of identifying other development possibilities that will improve the value of the development by achieving the same utility at lower cost. This value is defined as the ratio of functionality to cost (Kaplan and Atkinson, 1998). According to the ISO 15663-2:2001 standard, value analysis "is a technique that is particularly useful for the identification of cost drivers and subsequent option generation" (p. 28). Value analysis analyzes all parts of an offering, starting from the bill of materials up to the production type and equipment used. However, it focuses on the functions that are connected to high costs. It is a methodical approach that systematically analyzes the functions of a procedure or design. Subsequently, costs are attributed to these functions. By proper definition of the functions, it is possible to create a distance from the design and come up with alternative solutions (ISO 15663-2:2001). Value analysis work is rooted in investigations around the two main equations stated by Cooper and Slagmulder (1997, p. 81):

- Value = function / cost and
- Perceived value = perceived benefits / price.

In this work **value analysis work** is defined as **using one or a set of means that measure and analyze the benefit to cost ratio for a new development or components of it. It compromises both the technical oriented value analysis and the market-oriented value to customer notion.**

According to Kaplan and Atkinson (1998) the connections of value analysis to target cost are:

- Identification of improved product designs or even new product developments with reduced component and manufacturing cost at same functionality levels and
- Elimination of unnecessary functions that increase the product's cost and complexity

Value analysis starts with a detailed specification of the essential functions, an activity often called functional analysis (Kaplan and Atkinson, 1998). The result is a detailed specification, e.g. in diagram form. After that, it is analyzed how existing products achieve those functions, before new ways of achieving those functions are searched and analyzed. Consequently, the alternatives are rated, and, if possible, the best elements are taken from each of the alternatives to develop the proposed product design (Kaplan and Atkinson, 1998).

Another value analysis approach is presented by Timmerman (1986). He presents a tool called the 'cost-ratio method', in which prices are adjusted by the costs or benefits the client experiences according to the total cost of ownership principle. One example out of a business-to-business setting: If the cost of bad quality results higher inspection costs of 100€ and in rework of 1 000€ and the total purchasing value is 100 000€, the total quality cost ratio is (1 100€/100 000€=) 1,1%. The quoted price then has to be adjusted to reflect the total cost of ownership. In this case, there would be 1,1% of the quoted price added to reflect the cost of bad quality. The disadvantage of this method is that it requires a lot of cost data to evaluate the different criteria cost-wise.

2.5.5 Analysis tool summary

Several tool classes have been presented in the previous subsections. Some do have a more explicit cost focus than others. Yet, all these tools can be used to analyze new product development ideas during pre-development.

Tool	Definition	Specificity	Cost focus
Intelligence work	Organized and systemic processes, which are used to acquire, analyze and disseminate information significant to the business activities of companies	Unspecific	General
Roadmapping	Visual process of planning and displaying the timely evolution of new development idea attributes regarding goals, requirements and priorities	Unspecific	General
Scorecard use	Analysis through a weighted rating assessment system of different qualitative and quantitative factors that are aggregated with standardized and uniform levels of scale measurement to a final score for judgment	Specific	General
Uncertainty management	Tools used for taking care of, understanding, leading, handling, or being in charge of uncertainty	Specific	General
Cost dynamics analysis	Diagnosis of variable cost structures influenced through knowledge related cost reductions of learning curve effects, rationalization, technological progress, and alike	Unspecific	Cost focused
Cost database use	Analysis of new product development ideas with databases of detailed cost information based on a range of cost drivers or manufacturing variables	Unspecific	Cost focused
Cost modeling and estimation	Representing and predicting cost factors, relations and drivers by investigating product information to provide approximated cost assessments	Specific	Cost focused
Target costing efforts	Activities aimed at attaining a cost target through means that assist the planning, development and detailed design of new products	Specific	Cost focused
Value analysis work	Using one or a set of means that measure and analyze the benefit to cost ratio for a new development or components	Specific	Cost focused

Figure 44: Summarizing tool overview based on literature

Figure 44 shows an overview of these different tool classes and their definitions. On the right side of Figure 44, two characteristics of this tool class are stated. Firstly, it is shown whether the tool is analyzing information primarily regarding one particular new product development idea (specific); or rather analyzes information for an array of new product development ideas at a time (unspecific). Secondly, it is shown whether a tool provides general information (general) or mainly cost specific information (cost focused) about a new product development idea.

One has to bear in mind that there can be a possible overlapping in tool use. The application of one specific tool can also bring – besides its main use – information that can be used in other tool areas. E.g. most cost focused tools will also yield information that could be used in a more generic setting for intelligence work. Thus the borders between the different tools are not well defined, and to some extent, the boundaries between the various tools are fluid. However, the main idea and core concept have to be present and are checked for classification. E.g. cost modeling and estimation is specifically classified in this thesis, as it focuses on one single new product development idea at a time. On the contrary, more general cost modeling that precedes cost databases is not idea specific as it is based on a different idea and core concept, even though the actual modeling can be similar.

2.6 Case studies from literature

Several case studies report on areas related to product cost analysis during pre-development. The cases are studied regarding indications for this work in the next subsections. The last subsection gives a brief overview of the key findings.

2.6.1 Car development at Mercedes-Benz

This subsection is fully based on the case study of Hauber and Schmid (1999) that illustrates the Mercedes-Benz car development. Two different development project types are distinguished. The first type is focused on technology development, while the second type is focused on series development. The first type contains rather radical technology developments for several car generations, while the second focuses on the development of the next car generation.

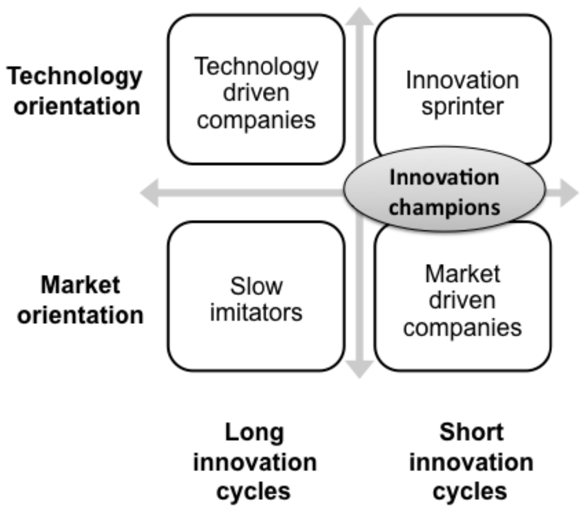

Figure 45: Types of strategic positions according to Hauber and Schmid (1999)

Hauber and Schmid (1999) distinguish car companies with on the one hand technology orientation and on the other hand market orientation (see Figure 45). The characteristics of market driven companies are short innovation cycles, a high focus on customer needs, a high prioritization of cost, and fashion trend awareness. Technology driven companies are characterized by technologically innovative products that result from relatively long innovation cycles. The success of this group resulted from a continuous generation and combination of unique innovative technologies. The innovation sprinter group is characterized by short innovation cycles. Innovation sprinters are usually the first to integrate newest technology in their products and bring it as first to the market. However, innovation sprinter products are usually technologically high class but are not conformed to customer needs. The new paradigm in the car industry is to move towards the field marked as innovation champions in Figure 45 (Hauber and Schmid, 1999). To reach the innovation champions position, new product developments are separated in technology development projects and series development projects. For series development projects Mercedes-Benz is using (besides other tools) target costing in combination with quality evaluation (Hauber and Schmid, 1999). Yet, the authors do not specify at which point in the development process target costing is started to be used.

Expenses for research and development are seen as investments at Mercedes-Benz. Thus innovations have to pay off. This potential payoff is evaluated through estimations of net present value and internal rate of return before taxes. The company group internal hurdle for new development projects is 12% internal rate of return for Mercedes-Benz (Hauber and Schmid, 1999).

One mentioned value driver of new development projects is to lower the future production cost, as there are lock-in effects in the automotive industry (Hauber and Schmid, 1999). This is checked regularly for series development projects. For technology development projects the focus is rather on the value creation contribution that a new technology can add to a future product and its customer value (Hauber and Schmid, 1999).

2.6.2 R&D management at DaimlerChrysler Aerospace Airbus

This subsection is fully based on the case study reported by Jens (1999) about the R&D management at DaimlerChrysler Aerospace Airbus (DASA). It highlights the importance of rooting research and development well in the business strategy and shows when and how cost analysis is started to be used. Strategic fit and a positive net value outlook are the main criteria of selecting ideas from a pool of R&D ideas at DaimlerChrysler Aerospace Airbus (Jens, 1999).

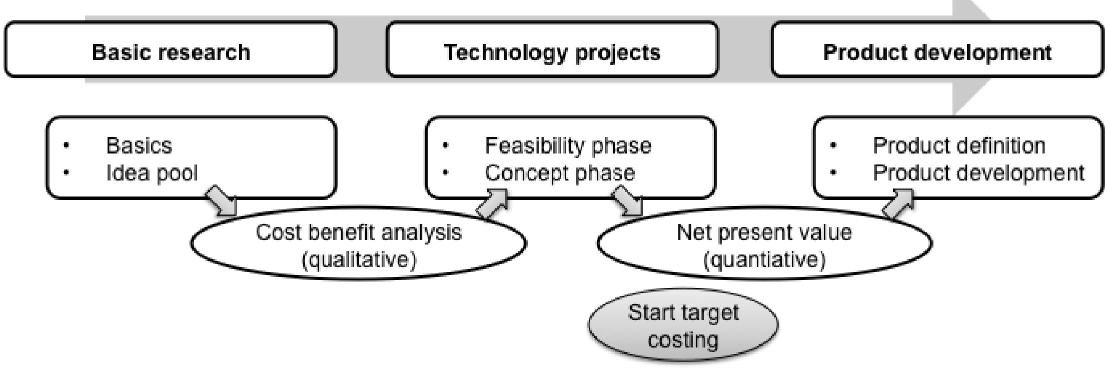

Figure 46: Qualitative vs. quantitative analysis of projects according to Jens (1999, p. 42)

At DaimlerChrysler Aerospace Airbus (DASA) new product development projects are classified according to three different categories (see Figure 46):

1. Basic research
2. Technology projects
3. Product development

In line with that classification, new development projects are ranked differently depending how far a project is from actual use in a product. New product development ideas that are still far from incorporation in a market product are analyzed qualitatively with a cost benefit analysis. New product development ideas that are near to market launch are evaluated through net present value or other cash flow based analysis. The cost analysis depends on in which category a new development idea is.

Firstly, new product development projects that fall into the product development category use target costing and a continual comparison of product part cost and product part benefits to the customer. The customer value is obtained through quality function deployment and set in relation to the estimated costs.

Secondly, new product development projects that fall into the categories of basic research or technology projects use parametric product cost modeling and estimation. These parametrical cost estimates are based on rule of thumb and experience from past developments. The screening of new development ideas is based on R&D internal prioritization for basic research projects. For technology projects, the new development idea screening is done through the attractiveness of the cost benefit analysis. Furthermore, the strategic and operative value of the idea for the company is used for rating and analysis.

2.6.3 A new generation machine innovation at CCM Ltd.

This subsection is based entirely on a case study reported by Nixon (1998). The case study focuses on CCM Ltd. that manufactures and markets continuous casting machines for non-ferrous metals. At the time of reporting the company had around 50 employees and additional sales agents. In the 18 years on the market, it set innovative standards in the technology of continuous casting through research and in-house development and design. Its competitive position is based on machines that are easy and economic to operate, low in investment, and capable of producing consistently high quality output. According to the top management, the business would probably quickly cease without a steady stream of new and improved machines. In 1995, 65% of the turnover came from products introduced in the last 3 years; in 1996 this percentage rose to nearly 90% (Nixon, 1998).

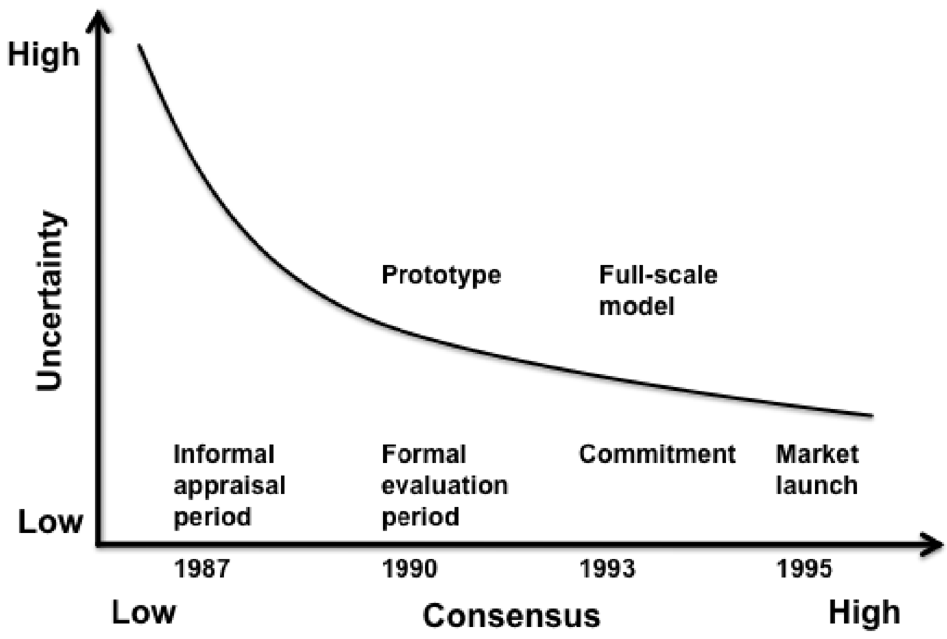

Figure 47: Uncertainty reduction and consensus building at CCM according to Nixon (1998)

Market information for new commercial and technological developments is used regularly. Formal meetings of employees and agents are held every two years to find and evaluate proposals for product extensions and for the development of new applications in existing and new market segments. The studied new product development idea is a miniaturization concept of continuous casting machines for a special high quality copper wire. Five separate technical problems were identified that required applied research and extensive development efforts. Thus, the technical risks were high. However, the market research showed an unfulfilled need for the new development idea and a potential market opportunity. The uncertainty reduction and consensus building over time is shown in Figure 47. Yet, at the same time as uncertainties were being reduced, the demand for CCM's primary business was declining and looking increasingly unattractive (Nixon, 1998).

No significant expenditure was made by the company on exploring ideas until their commercial viability was established. In total, the new development idea was discussed and explored informally for three years before a go decision at the first gate was taken and formal evaluation started (see Figure 47). The front end stage stretched between 1987 and 1990. During this time the new product development idea was evaluated with relatively informal, implicit, qualitative and subjective criteria. The principal data for evaluating the new product development idea was tacit knowledge, and distilled experience, which fit with the company's core technologies and the top management's views on acceptable risk. In the first stage the aim was to produce copper rod on a small scale with the desired quality attributes that were then tested by a potential customer for its characteristics. However, the construction of a small prototype in 1990 did not so far represent a commitment of the management to the new development idea. The construction of the prototype was part of a process of risk reduction and consensus building. It was an enabler to acquire technical capability at moderate expenditure. Also, the small prototype proved technological feasibility, but several technical problems were identified. These had to be resolved in order to assemble a full-scale machine. In 1993 the management felt sufficiently confident about technical feasibility and that a viable market existed. The top management also saw the prospect that the new product development idea could serve as a technological platform for a new generation of machines. However, this benefit was not quantified, e.g. with a real options approach. Yet, the top management claimed that this possibility was never forgotten. The company then acquired external funding for the development and convinced a customer to cooperate. This alpha customer also agreed to purchase the first machine, if certain pre-defined performance conditions were met. The agreement on the future machine price was deferred, as uncertainties were still too high. The targeted performance criteria were multiple, e.g. production speed, flexibility, and quality of output. However, one of the most important criteria was the cost per ton of copper rod produced. The small prototype and the collaboration with the alpha customer resulted in a very precise definition of the technical and cost targets. The following detailed design and development work on the full-scale machine were based on these targets. The financial controller was a part in the design and development work from the very outset. This was partly because the direct cost per ton of the copper rod output was a crucial design variable. One role of the financial controller was to weigh on the one hand operating costs and purchase price, and on the other hand profit contribution and cash flow requirements. The supervised costs were threefold:

1. Total budget development costs including consulting, testing and related overheads
2. Future product direct costs of manufacturing
3. Operating costs as cost per ton of output including maintenance

This cost type trinity required very close cooperation among design engineers, R& D team, manufacturing engineers, component suppliers, financial controller and the alpha customer. These costs also turned out to be the linking pin that integrated the different interests of the parties (Nixon, 1998).

The company used value engineering with cost driver analysis to balance the different cost dimensions. The financial controller assisted the designer in:

1. Production and operation cost trade-off evaluation of design possibilities
2. Standardization to reduce the time and costs of assembly and service
3. Minimization of the total number of parts
4. Design simplification for efficient manufacturing, assembling and service.

The overall development had an emphasis on customer value on top of cost. In order to achieve the cost and quality targets, further features that the customer valued and was prepared to pay for were added. The financial controller divided the target operating cost into labor, materials and operating costs. Furthermore, he also established the relative importance of these cost parts to the customer. The company also used failure mode and effect analysis (FMEA). This was of particular concern to the financial controller because machine reliability and after-sales service are important parts of CCM's competitive strategy. Furthermore, machine downtime would mean high idle costs for customers and a potential liability for the company (Nixon, 1998).

2.6.4 Target cost management at Leica Geosystems

This subsection is fully based on case study written by Schindler (1999) about the company Leica Geosystems, part of the Leica group and a sister company of Leica Camera. At Leica Geosystems a trend can easily be spotted. It is clear to everybody that the sales prices are determined by the market. Thus, the trend is that cost management gets more and more dominated by marketing and R&D departments. A traditional cost-plus calculation serves the purpose only in limited ways today (Schindler, 1999).

While budget controlling loses its importance at Leica Geosystems, controlling becomes more important in screening new product development ideas. This screening is done after clear criteria. The focus of these criteria is on evaluating the additional economic value that a new product development idea can offer (Schindler, 1999).

Leica Geosystems experiences lock-in effects. Shortly before the end of the product and process development, around 10% of total product cost have accrued, but already around 80% of total product cost have been determined (Schindler, 1999).

Leica Geosystems uses holistic target definitions of cost, time and quality. The company focuses its developments on market needs. They use conjoint analysis, Kano-models, quality function deployment and other methods to grasp customer requirements. It is seen as important to find out which features are valued by the customer, otherwise there is a risk of over-engineering (Schindler, 1999).

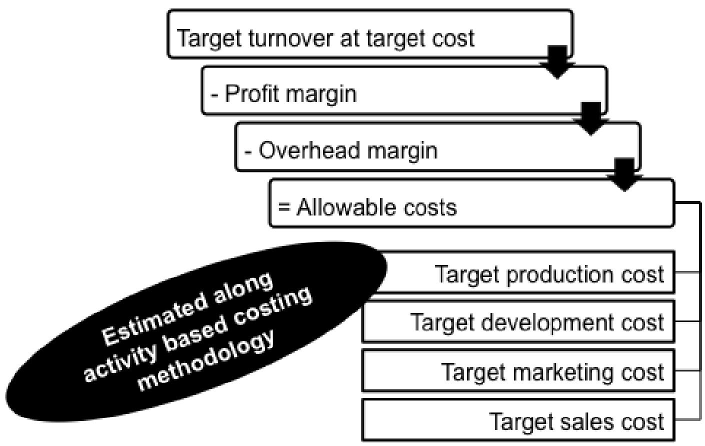

Figure 48: Retrograde calculation scheme for innovations according to Schindler (1999)

The calculation scheme used at Leica Geosystems is shown in Figure 48. It deducts profit margin and overhead margin from the target price to get the allowable costs. These are then further analyzed by forecasted actual costs that are derived in an activity-based style. Often there is a target gap between the allowable costs and the actual on the other side the forecasted costs. The guiding idea of this calculation is to find out what a product is allowed to cost and how the target cost can be reached. It replaces the older scheme of calculating what a product will cost and how to convince the customer to pay it (Schindler, 1999).

One lesson learned at Leica Geosystems is that 'rather be 80% sure to influence the right things, as to state with 100% certainty existing facts afterwards and too late' (Schindler, 1999). Thus one should proactively manage costs rather than to administer costs with hindsight.

In general the case does not state explicitly how the product cost analysis during pre-development is done at Leica Geosystems, as most of the described is done during the development phase (Schindler, 1999).

2.6.5 Target definition and controlling of development projects at Siemens ElectroCom

This subsection is fully based on case study written by Wieczorek (1999) about the company Siemens ElectroCom, part of the Siemens group. The company acknowledges that nowadays fast changes in science and technology also lead to faster product life cycles. An additional megatrend is that the amount and speed of exchanged information is growing exponentially worldwide. Furthermore, trade barriers are diminishing, leading to a never before seen globalization. This also affects customer-supplier relationships. Nowadays the company is analyzing the needs of its customers and the customers' customers more intensely to optimize the entire value chain. The company also looks for ways to achieve higher customer retention in a more and more unstable business environment (Wieczorek, 1999).

The above mentioned megatrends also impact the R&D of Siemens ElectroCom. It is becoming more difficult to maintain its lead in time and technology compared to its main competitors. There is a growth in the strategic relevance of technology monitoring and technology pre-development. These two are seen as important to have basis components for new products ready on time (Wieczorek, 1999).

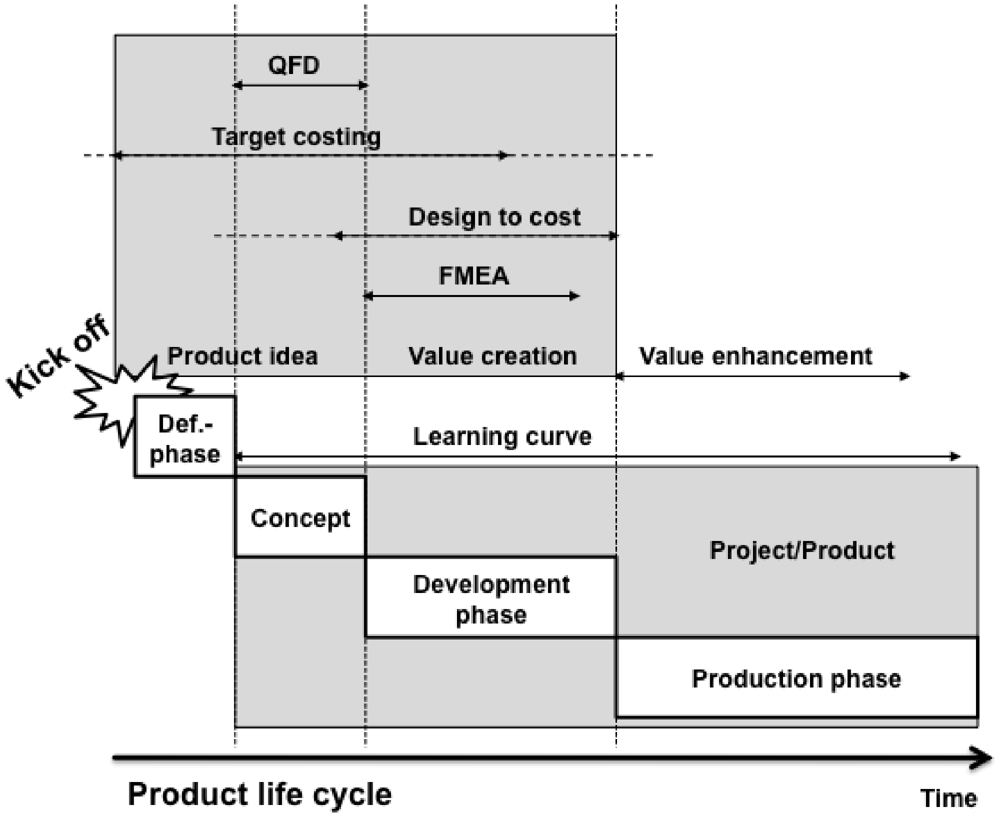

Figure 49: Tool use at Siemens ElectroCom according to Wieczorek (1999)

At Siemens ElectroCom target costing is started right in the definition phase (see Figure 49). Several parts of the target costing are done in the definition phase at Siemens ElectroCom. The first is the analysis and communication of the customer requirements. Another part is the analysis of competition and their products. It is seen as important to find unique selling points for their own offering. A further part is an economic analysis with an early estimation of future product cost in pre-development. With these estimated costs, Siemens ElectroCom does profitability analysis for single new product development ideas and compares different scenarios against each other. Another part is retrograde calculation to analyze different cost pools. Also, one part of target costing at Siemens ElectroCom is quality function deployment. It is done to derive the allowable costs for the different product functions. The systematical execution of these parts results in several alternatives regarding technical solution, profitability, costs and position relative to the competition (Wieczorek, 1999).

Already in the first innovation phase, called definition phase, Siemens ElectroCom starts a market oriented cost management. It analyses the market and wants to gain understanding about customer requirements. Furthermore, the company already starts estimating component costs in the definition phase. The general aim is to find the optimum between customer requirements, technical solution and product cost. This challenge is seen as complex and interdisciplinary. Several repeating steps are used to find this optimum. First, there is a target analysis that is based on target costing results. Then alternative technological solutions are created and rated according to their potential value. Ultimately, the results are checked and corrected if they are not satisfactory (Wieczorek, 1999).

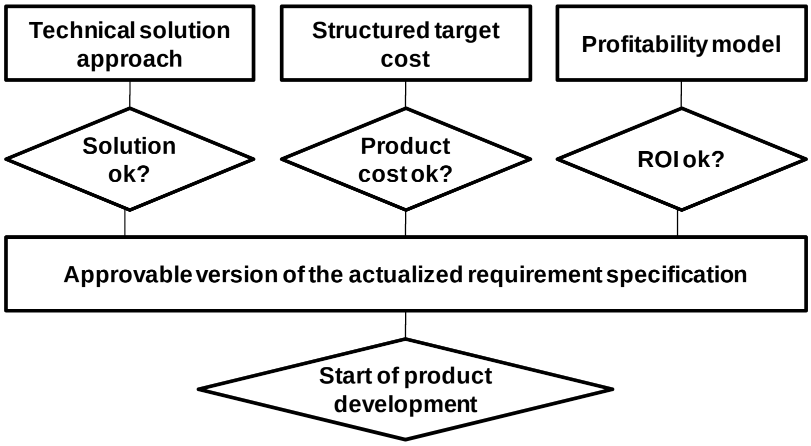

Figure 50: Checks before product development start according to Wieczorek (1999)

Figure 50 shows different parameters that are checked before a new product development idea can proceed into the actual development phase. When checking the product cost it is seen important to have comparable cost models for several production locations. A clear cost stewardship on component and product level is also seen as important. Furthermore, the controlling department has to constantly supply product cost estimates in a timely fashion to support the innovation (Wieczorek, 1999).

The case of Siemens ElectroCom shows that product cost analysis is already done during pre-development in some companies. The company starts using target costing already in pre-development and evaluates product cost estimates for their go decision in the development stage. However, the described case study does not explain the tool use in pre-development in detail.

2.6.6 Cost dynamics and Miller Lite beer

The Miller Brewing Company was founded in 1855 by Frederick Miller. In 1966 the ownership majority was bought by W. R. Grace & Co. Later in 1969 Philip Morris purchased the company for USD 130 million[2]. Under the ownership of Philip Morris it introduced successfully the Miller Lite beer in 1973. According to Hax and Majluf (1982) the assessment of the industry cost structure, learning curve effects, and low-cost technology investments partly explain the success of this market introduction. At the time of the entry the beer industry was seen as an aging industry. In line with Porter (1980) “entry into an aging industry is regarded as a highly unnatural and unproductive strategy” (Hax and Majluf, 1982, p. 59). Nevertheless, the success of Phillip Morris was based on a coherent set of strategies, which also included heavy investment in new and efficient production facilities (Hax and Majluf, 1982). Also, the new beer was an innovative product with a high potential market. Together with

[2] Source: http://en.wikipedia.org/wiki/Miller_Brewing_Company.

impressive marketing[3] and distribution, it succeeded in the market as it followed a completely different experience curve than its competitors (Hax and Majluf, 1982). In 2002 Philip Morris sold Miller to South African Breweries for USD 3.6 billion worth of stock and US$2 billion in debt, with Philip Morris retaining a share of 36%[4].

2.6.7 Value oriented project selection at BASF Pharma

This subsection is fully based on the case study written by Lechner and Völker (1999) focusing on the company BASF Pharma. The company uses the discounted free cash flow concept for the evaluation of its new product development ideas. This concept is based on the notion that the value of a company equals the sum of the discounted free cash flow surplus that can be attained with its business activities. Thus a new product development idea is to be rated positively if it creates a positive discounted free cash flow. Every new product development project that has a positive net present value contributes to a value increase for the company. However, simply the analysis of the net present value is not enough to rate new product development ideas. Thus it is seen as beneficial to model adapted scenarios, especially because of fuzzy data situations. Furthermore, it is not only the profitability, but also the general volume and a short payback time that matter. Furthermore, a project might create options for follow-up projects that also have to be taken into consideration (Lechner and Völker, 1999).

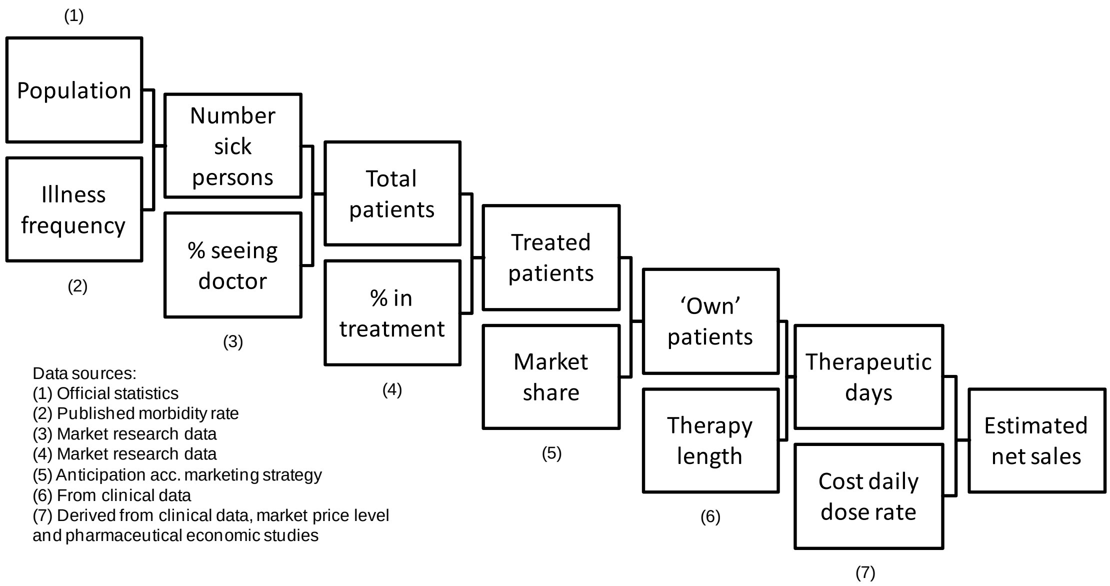

Figure 51: Determination of anticipated product net sales according Lechner and Völker (1999)

BASF Pharma aims for an as objective as possible evaluation of new product development ideas. Thus is uses the net present value as a guiding principle and focuses on a cash flow oriented approach. The company starts evaluations during the development stage 'Clinical phase II', which follows the first phase. Only then is one

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[3] Miller Lite's advertising campaign was ranked as the 8th best advertising campaign in history by the Advertising Age magazine (Source: http://en.wikipedia.org/wiki/Miller_Lite).
[4] Source: http://en.wikipedia.org/wiki/Miller_Brewing_Company.

able to generate the large amount of data needed for the evaluation. At this point data is available that can be used to make a product determinable and describable in its markets. E.g. it is needed to know the profile of pharmacological effects, its derived therapeutic indication, and also the forecasts of daily dose rates. This information can then be used to make first price and production cost estimates. The base calculation scheme used for the sales estimation is shown in Figure 51. The calculation scheme uses the volume of the market, market share, and price estimates, based on estimated daily therapeutic costs. Additionally marketing tools are used. These tools are the SWOT analysis and key value driver analysis. The new product development idea is also compared to the medical criterion standard[5] as a benchmark. This comparison evaluates and benchmarks the new drug under development regarding medical effectiveness, tolerance, application form, length of therapy, and other factors (Lechner and Völker, 1999).

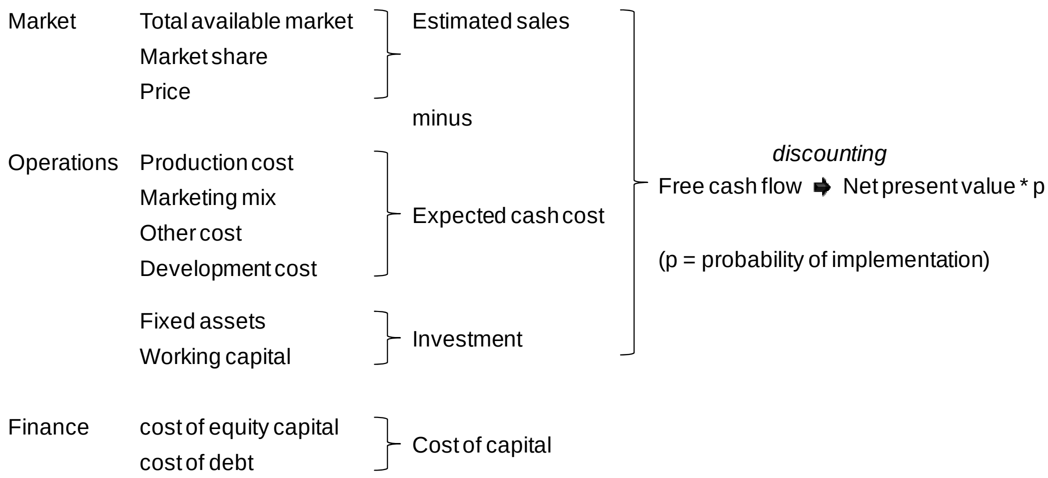

Figure 52: Calculation of expected project value according Lechner and Völker (1999)

Figure 52 shows an overview how the evaluation number is calculated. The production costs are estimated on the basis of standard values by using indicatory calculation schemes and the average daily dose rate. Also, the marketing costs are planned that result from the targeted marketing mix. Furthermore, other cash-out like investments are also taken into consideration if they are necessary. The calculated net present value is further multiplied by an estimated probability of implementation. At BASF Pharma this probability is p<0,15 for projects in the second development phase and 0,3<p<0,5 for projects in the third development phase (Lechner and Völker, 1999).

[5] The criterion standard is also referred to as gold standard in the medical field. It refers to a medical diagnostic test or benchmark that is regarded as definitive. [See also http://en.wikipedia.org/wiki/Gold_standard_(test)]

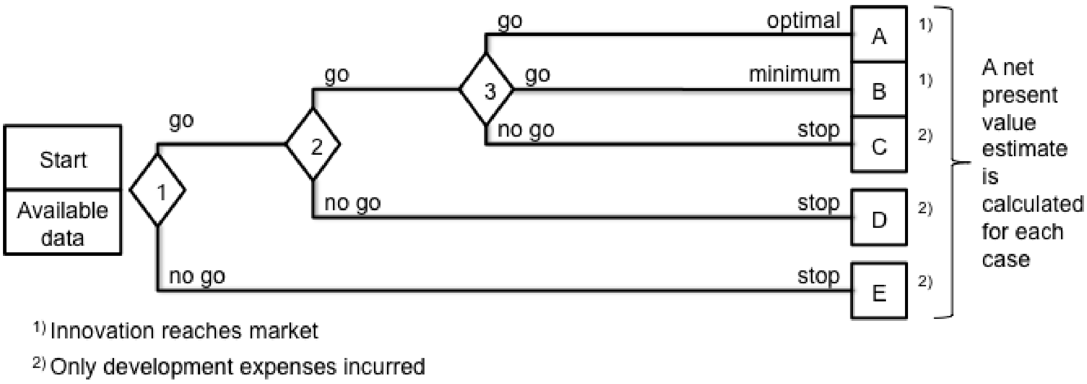

Figure 53: Evaluation decision tree according Lechner and Völker (1999)

Each new product development project contains uncertainty. Thus, BASF Pharma evaluates different scenarios. These scenarios are shown in Figure 53. The overall net present value for new product development ideas is based on the evaluation of different branches of the decision tree. For each branch a net present value is calculated. These values are then multiplied by the estimated probability for each and then added to get the overall score. This evaluation also displayed a positive side effect in that the discussion of new product development ideas became more objective and fact based. The company also found that risks and opportunities were better weighted and made 'computable' (Lechner and Völker, 1999).

Furthermore, BASF Pharma acknowledges that R&D projects also have an option character. Often these projects offer one the possibility to later introduce further new products or line extensions. Yet, the use of option pricing similar to financial options is not followed. That comes from the fact that the transferability of financial theory to R&D projects is seen as limited. R&D projects are not traded on markets and thus there is no market assessment as it would be for financial products. Nevertheless, the company is also taking options into consideration when rating new product development ideas. However, this consideration is qualitative and not added to the quantitative estimation (Lechner and Völker, 1999).

2.6.8 Business development and controlling at Hilti

This subsection is entirely based on the case study written by Bösch (2006). The Hilti group is a leading, worldwide operating group of companies that produces and markets high quality products for the construction and maintenance industry. It is mainly selling directly to the professional user. In total, over 15000 employees work for Hilti in 120 different countries.

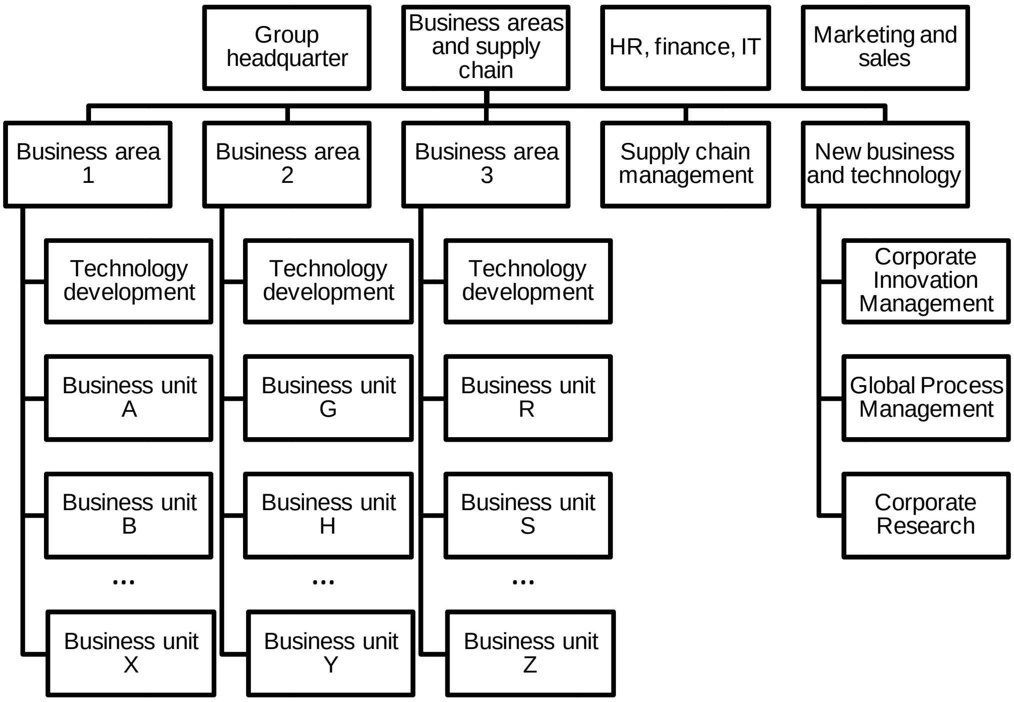

Figure 54: A part of the organizational chart of Hilti according to Bösch (2006)

Figure 54 shows a part of the organization of Hilti. The company has three main business areas. Each business area has one technology development unit and several business units. The business areas are at the product group level; the business units are at product level. Additionally there is a new business and technology division besides the three business areas. This new business and technology division is responsible for R&D. This division is further split up in the corporate research unit, the corporate innovation management unit and the global process management unit. The units of the new business and technology division serve the business areas and are compensated by internal transfer pricing (Bösch, 2006).

	Basic research	Applied research	Technology development	Product development
Goals of that phase	Breakthrough in basic sciences (e.g. materials)	Breakthrough in applied Hilti-systems	Module design Cost optimization Quality and durability	Design and handling Sourcing Product development
Executing unit	Universities Private research institutes	Hilti research Universities and private partner	Hilti pre-development Universities and private partner	Hilti development Suppliers
Requirement to pass gate to next phase	Proof of physical feasibility	Proof of system-feasibility	Proof of technical feasibility	
Estimated technical feasibility	0-65%	65%-90%	90-100%	100%

Figure 55: R&D at Hilti according to Bösch (2006)

Figure 55 shows different steps of the research and development approach at Hilti. The applied research is situated in the corporate research unit. The aim of this applied research is to understand the effect for Hilti for discovered and understood scientific effects. On the basis of that, technology development at the corporate research unit should advance technologies in such a manner that they could be applied to product modules. Also the product costs are optimized in the technology development stage. This is done in a tradeoff with quality and durability. In the ideal case the technical feasibility of a technology has to be 100% certain before it is moving into the product development stage. This product development stage is then located at the different business units. It is the responsibility of the business units to develop products and market them (Bösch, 2006).

Overall, work of the corporate research unit is guided by the demand of the technology development units of each business area. In that case the technology development units are the internal customers of the corporate research unit. However, a part of the applied research is one without internal customers. This is done with the focus of working on technologies whose applicability is still very far in future. There the aim is to gain insight and elaborate the relevance for Hilti (Bösch, 2006).

Each business unit has its own innovation strategy that is derived from the top-down formulated corporate strategy. The corporate strategy is based on the on the concept of “Champion 3C”. The 3C-concept stands for customer, competence, and concentration. The customer notion stands for the idea that Hilti wants to be the best partner of the clients and that customer needs are driving Hilti’s action. The competence notion stands for leading innovation, comprehensive quality, direct customer relationships, and effective marketing. The concentration notion stands for focusing on markets where Hilti will achieve and hold a leading position. The overall strategy of R&D is reported by the corporate innovation management unit. This corporate innovation management unit is one further part of the new business and technology division (Bösch, 2006).

Product managers of the different business units accompany new product development ideas through the product development process as well as the entire life cycle. The continuous involvement of these product managers lowers interface problems at the different innovation process phases. These product managers also act as the voice of the customer during product development (Bösch, 2006).

Hilti also employs Business Developer and Controller for the corporate research unit, the technology development units, and product development. Regarding innovation these Business Developer and Controller provide several services for the different business units:

- Project controlling
- Reporting on project over-spanning level
- Decision support about potential new product development projects
- Support regarding go/no-go decisions of running projects
- Information support for strategy updates

Regarding the **project controlling**, a cockpit-chart is created monthly. This cockpit-chart is a short status report that also shows possible challenges, the cost situation, and progress of a new product development. This reported cost situation contains both budget costs and future product costs. For the creation of this cockpit-chart the Business Developer and Controller supports the new product development project manager (Bösch, 2006).

The reporting on **project over-spanning level** is based on a budget-focused analysis. Here the Business Developer and Controller helps the management of the different business units to control actual vs. planned costs (Bösch, 2006).

The Business Developer and Controller also assists regarding the decisions about **potential new product development projects**. Each business unit has a committee that decides which new product development ideas should be developed into projects. This committee analyses new ideas in specially scheduled meetings. One part of this analysis is the potential future profitability of new product development ideas. For this analysis the Business Developer and Controller prepares an analysis that answers the following questions:

- How large is the total available market (TAM) for the new product development idea?
- What will be development and future production cost for the new product development idea?
- How is the demand expected to develop on the market?
- What activities of the competition are to be anticipated?
- How many pieces of the new product development idea can be sold within 1 and 3 years?

If possible new product development ideas are compared to existing products. The comparison analyses especially if the new or added customer benefit justifies the expenses for development and market launch (Bösch, 2006).

Regarding **go/no-go decisions** of running projects the Business Developer and Controller helps analyzing new product development ideas on gate reviews. At Hilti only one new product development idea at a time is analyzed in a gate review meeting. The go/no-go decisions are made by the guiding committee of the business unit that also contains the Business Developer and Controller. The analyzed criteria depend on the innovation stage in which a new product development idea resides. However, they usually contain at least the technical feasibility and the potential profitability of the development (Bösch, 2006).

The Business Developer and Controller provides information support for **strategy updates** to the business areas. Information about the different projects of the business units are summarized at business unit level. This summary is the base of the innovation project portfolio that is regularly checked. Furthermore, the Business

Developer and Controller assists in market information search. The aim of this market information search is to understand the market better for the definition of strategy and innovation roadmaps. These innovation roadmaps show the future development aims and directions for the next years and handle the following questions:

- Which products should be introduced to the market?
- Which customer needs are addressed with the developments?
- How much turnover and profit is to be generated with the developments?
- Which markets are to be targeted?
- Which activities and projects are needed to succeed in the future development aims?

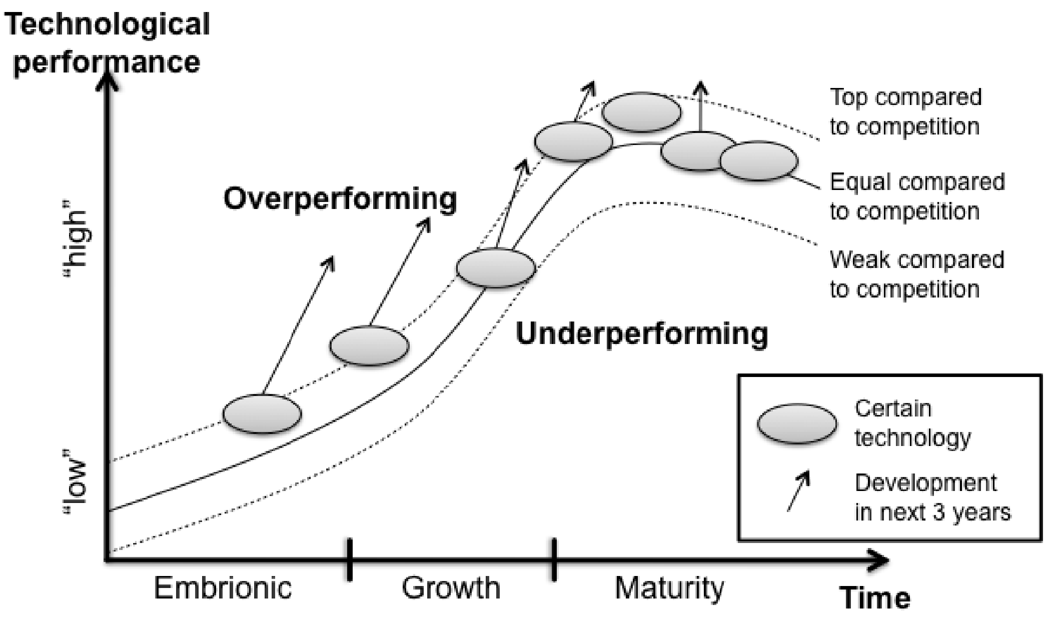

Figure 56: Example of a technology portfolio according to Bösch (2006)

Other Business Developer and Controllers also assist the technology development units of each business area. Besides budget and time control, the Business Developer and Controller helps in optimizing the technology portfolio of the different technology development units. An example of a technology portfolio is shown in Figure 56. The technology portfolios are based on the analysis of the potential of different technologies. Furthermore, the relevant technology position of Hilti compared to its competitors is estimated. As this requires an all-embracing technological know-how, the analysis is done by the management of the technology development units. A characteristic S-curve is used as a basis tool for these technology portfolios. It is then charted on a graphic representation over the relative technological performance and the maturity of a technology. The continuous line in Figure 56 shows the average state of knowledge of a technology. Top companies that are leading in a technology and its knowledge are moving above the solid line. Low-performers are moving underneath the solid line. All these estimations and positions are based on the expert opinion of Hilti. As a guideline, Hilti wants to be positioned as good as possible for all technologies that are seen as important for a product to stand out on the market based on quality and performance. Several analyses are made after roadmapping all technologies of a business area on this S-curve. One analysis aims at finding underperforming technologies in the technology portfolio in order to improve them. Furthermore, it is analyzed if the technologies of the company are represented in all phases of the technology life cycle (Bösch, 2006).

As stated above, Business Developer and Controllers also assist the controlling of the whole new business and technology division by maintaining a cockpit-chart for the division. Through maintaining a cockpit-chart the business and technology division has three main blocks that are measured or estimated:

- Build enabling elements
- Create enthusiastic customers
- Create a better future

Competences and processes are in focus in the block of **building enabling elements**. It checks e.g. how many competences are available in comparison to an ideal situation. Furthermore, the quality of processes in the business and technology division and other issues are rated.

The block of **creating enthusiastic customers** focuses on single research projects. It checks the effectiveness of the projects, i.e. whether the projects of the corporate research unit satisfy the expectations of the business units. Also the budgeted cost and time are checked.

The '**create a better future**' block stands for the notion that enough interesting and valuable ideas should be available. It also checks whether the research is evenly distributed between the different business areas and the maturity of the different technologies (Bösch, 2006).

Last but not least, the corporate innovation management unit is the hub where data from the business units, the technology development and the corporate research are converging. The corporate innovation management unit is consolidating the data of the different units to give a picture about the past performance and innovation planning. Regarding the past performance, this consolidated data is analyzed with six key ratios:

- On time delivery
- Sales share new products
- Time to market
- Total cycle time
- Profit share new product
- Introduction sales of new products

Regarding the innovation planning, the aim is first and foremost how the future sales of new products are going to develop in the next 3-5 years. The portfolio balance is also checked regarding technology risk, innovation newness and market differentiation. The strategic orientation of the innovation portfolio is also regularly checked.

On top of the aforementioned, the corporate innovation management unit offers company internal innovation consulting at Hilti (Bösch, 2006).

2.6.9 Summarizing the case studies from literature

In the last subsections seven case studies from literature are described. They all have in common that they at least partly deal with product cost analysis during pre-development.

Case	Authors	Key findings	Specific on cost analysis in pre-development?
Mercedes-Benz	Hauber & Schmid (1999)	• To improve its R&D performance two development types are established • The first development type is technology development projects; the second development type is series development projects • The first focuses on value creation • The latter uses target costing, aiming at lowering future production cost	To a low extend; little description about analysis in pre-development
DaimlerChrysler Aerospace Airbus	Jens (1999)	• New product development ideas are firstly analyzed qualitatively with cost benefit analysis; later with net present value or other cash flow based analysis nearer to market launch • Basic research and technology developments use parametric product cost modeling and estimation, based on rule of thumb and experience from past developments	To some extend, but little description
CCM Ltd.	Nixon (1998)	• Based on unfulfilled customer need as potential market opportunity with high technical risks • Idea generation phase stretched over several years • First screen with tacit knowledge, distilled experience, fit with core technologies and risk evaluation • Found alpha customer before development start • Multiple performance criteria as development requirements • Very precise definition of the technical and cost targets (future product cost and operating costs) at development start	Yes, but little description about first idea screening criteria; focus on development stage
Leica Geosystems	Schindler (1999)	• Screening new product development ideas according to added economic value • Use target costing, conjoint analysis, Kano-models, quality function deployment	Partly, use of pre-development vs. development phase blurred
Siemens ElectroCom	Wieczorek (1999)	• Does technology monitoring, technology pre-development and product cost analysis in pre-development • Aiming at optimum between customer requirements, technical solution and product cost • Target costing efforts and market oriented cost management are started in definition phase • Economic analysis with future cost estimation in pre-development	Yes, but little description and no detailed explanation of tool use in pre-development
Miller Lite beer	Hax & Majluf (1982)	• Strategic and innovative cost dynamics use • Edge over industry cost structure through learning curve effects, and technology investments in new, efficient and low-cost production facilities • Completely different experience curve that its competitors	Moderately, pre-development practices not covered in detail
BASF Pharma	Lechner & Völker (1999)	• Uses discounted free cash flow concept for new product development idea evaluation • Together with decision tree and a 'light' real options approach • Uses scenarios modeling • Determined calculation scheme for first price and production cost estimates	Moderately, well explained calculation scheme, but analysis hardly covered
Hilti	Bösch (2006)	• Business Developer and Controller for decision support for potential new product development projects and go/no-go decisions • Project controlling about budget costs and future product costs • Aid for technology management	Partly, but not in main focus

Figure 57: Overview of studied literature cases and key findings

The studied cases give a pre-understanding regarding the research questions of this work, but do not answer them so far (see Figure 57). The richest case descriptions are found in the article of Nixon (1998) and the doctoral thesis of Bösch (2006). However, in Nixon (1998) the product cost analysis is focused on the development stage and Bösch (2006) takes more of a helicopter view focusing on the role of his developed controlling management performance measurement system.

Nevertheless, the cases show that product cost analysis during pre-development is done in the industry. However, the cases also show that there is a need to study the practices in more detail. This is done in the empirical part of this thesis further down.

3 Methodology

3.1 Qualitative vs. quantitative and deductive vs. inductive research

Generally, the key issues in research are from where to gather which kind of evidence and how to interpret it correctly to answer the declared research question. There are two radically different approaches to research – qualitative or quantitative. Depending on which one you choose the research design will be different. As the names suggest, quantitative studies rely on quantitative information (i.e. numbers and figures), while qualitative studies base their accounts on qualitative information (i.e. words, sentences and narratives) (Blumberg et al., 2005). In his book about qualitative and quantitative approaches in research design, Creswell (2003) describes how the research questions and hypotheses should be derived for these different approaches to research. On one hand, in quantitative studies, the researcher will state hypotheses. These are predictions the researcher derives from theory or experience about relationships among variables. These predictions are then tested and either confirmed or falsified. A third possibility is that it is not possible to make a statistically sound decision about the validity. Creswell (2003) gives three main uses of hypotheses:

1. Comparison of variables/parameters
2. Relations of variables/parameters to each other
3. Description of response to independent, mediating or depending variables.

Depending on the matter under study the research question will be either a null (stating the inexistence of a relationship) or an alternative hypothesis (stating that the outcome will be in favor of one alternative).

On the other hand, in qualitative studies, the researcher will in most cases state research questions to show what his study should answer. Qualitative data is useful for understanding the rationale or theory underlying a setting, while quantitative data can reveal relationships that are not evident from a mere qualitative study (Eisenhardt, 1989). Creswell (2003) recommends to have a central question and to associate sub-questions, which then should be answered in the research investigation, an approach taken in this thesis.

As the taken research approach is an in-detail investigation of tools, methods and mechanisms in pre-development, a quantitative approach that presumes predictions about relationships from theory or experience is less useful in this research. Instead, this thesis looks at challenges of innovations, different (cost) analysis tools and their use during pre-development. In general, the analyzed research material is not homogeneous. Important contingencies might be found through a detailed study, rather than a quantitative approach.

A further point enforcing a qualitative research approach, rather than a quantitative one is that the terminology used might not be familiar to mangers. The research is near to the daily business that companies are facing during the management of innovation. This makes mailing surveys failure prone as different methods articulated in academic literature might not be known to managers by the academic name, even though they are using them.

However, taking an overall qualitative research approach does not mean that no analysis based on quantification could be used. Miles and Huberman (1994) believe that too much quantitative-qualitative argument is in essence useless. They argue that both are needed to understand the world. Besides the limitations of a questionnaire-based survey stated above, qualitative approaches can also use quantification strategy for sense making.

3.2 Research strategies and design

One of the main challenges in the process of writing a thesis is to assess, choose and work with a methodology. This section explores possible research methodologies and strategies that could be applied to answer the research questions introduced in a suitable and methodologically rigorous manner. The objective of this section is to present an overview of existing methodological concepts and to define the research paradigm and strategy used in this thesis.

Strategy	Form of research question	Requires control over behavioral events?	Focuses on contemporary events?
Experiment	How, why	Yes	Yes
Survey	Who, what*, where, how many, how much	No	Yes
Archival analysis	Who, what*, where, how many, how much	No	Yes/no
History	How, why	No	No
Case study	How, why	No	Yes
* what questions, when asked as part of an exploratory study, pertain to all five strategies			

Figure 58: Relevant situations for different research strategies according to Yin (1989, p. 17)

Yin (1989) gives an overview of five selected research strategies and their relevant situations (see Figure 58). It would be difficult to set up an **experiment** for the above stated research question, as it would require control over behavioral events of the studied phenomena. This is a setting that is usually not feasible in management research, as the subjects under study –managers – tend to be powerful and busy people. Thus an experimental setting to answer the stated research question would not be practically feasible.

As no archive with relevant data could be accessed, **archival** analysis is also not feasible in this setting to answer the sought after research question. Similarly, a **historical** study would not be beneficial for this research as a contemporary setting is desired to reflect the latest findings and contingencies. Thus out of the five presented research strategies in Figure 58, only the survey and the case study strategy remain.

According to Yin (1989) if results of a specific event or phenomenon are the researched topic, **surveys** will be favorable over case studies, especially if a tested theory is predictive about certain outcomes. On the contrary, Yin (1989) argues that 'how' and 'why' questions are more explanatory and likely to lead to the use of **case studies** as preferred research strategy. Additionally, Langley (1999) notes that a case study research will lead to more subtle nuances to be discovered and included than in a questionnaire-based study. According to her, the research will be thicker and can lead to more meaningful and potentially more powerful explanatory variables.

The research underlying this thesis elaborates why and how cost information is used in pre-development phases. Moreover, this research deals with cost management concepts and methods that are likely to not be fully familiar to many managers working in innovations (as representatives of the study population). Furthermore the sophistication of use will be different in different companies. Therefore the validity of the results of a survey would be doubtful. E.g. my own past experience has shown that managers could easily mistake the concept of target costing with some other practice. Thus, in order to get reliable data, a deeper understanding, and to be able to answer the research question, a case study approach was selected.

In the footnote of the overview presented in Figure 58, Yin (1989) states that in the case of an explanatory study, 'what'-questions can be supplemented to all research strategies. This is also done in this thesis. This thesis is not only focusing on the how and why, but explores new areas of cost management in pre-development phases.

Type	Focus	Starts with	Mean
Case study acc. to **Yin** (1989)	Confirm/falsify theory	Theory development	Individual & cross case conclusions
Case study acc. to **Eisenhardt** (1989)	Build theory	Research question identification	Develop constructs & compare to literature
Constructive approach acc. to **Kasanen** et al. (1993)	Solve problems	Problem identification	Construction of models, plans etc. & application (market test)

Figure 59: Contrasting theoretical contributions of selected methods

Hand in hand with the qualitative approach of this thesis goes the aim of this thesis to build up a higher understanding of the tools, methods and mechanisms in pre-development. There are several approaches to case study research. Furthermore the constructive approach, a method developed in the field of management accounting, could be applicable. Some major points of these three methods are presented in Figure 59. As one can see, the focus of the three methods is slightly differently. While the case study approaches according to Yin (1989) and Eisenhardt (1989) both are connected to either theory testing or building, the constructive approach from Kasanen et al. (1993) aims mostly at problem solving. When it comes to theory, Sutton and Straw (1995) clearly state that references, data, lists of variables, constructs, diagrams and hypotheses are not theory by themselves. All these points have to be processed further to build theory. As this thesis aims not at solving a specific problem, but at developing a proposition for a new tentative theory, the constructive approach according to Kasanen et al. (1993) is not used.

When comparing these two approaches one can see an essential difference. Yin (1989) assumes that a tentative theory can be derived from literature before the start of a case study. The case study is then used to test this tentative theory with the empirical material provided by the case study. Thus, in the approach of Yin (1989) the theory is stated in the beginning as a 'blueprint of the research', Eisenhardt (1989) attributes that neither theory nor hypotheses should be used in the beginning 'to maintain theoretical flexibility'. The theoretical flexibility can be a strong motivation to choose this approach, if novel findings are the aim of the research like it is in this thesis. A general strength to case study research and especially of the approach of Eisenhardt (1989) with its flexibility, is that the likelihood of generating novel theory is higher than in other research approaches. Instead of starting with a theoretical construct like Yin (1989), the approach of Eisenhardt (1989) increases the likelihood of a new theoretical revelation (Eisenhardt, 1989). Another strength of case study research is that constructs that result from the research are more likely to be measurable and easier to confirm or falsify than otherwise derived theoretical constructs. Furthermore, theory crafted through case study research is more likely to be empirically valid (Eisenhardt, 1989). All these strengths are more likely to be found in case studies exercised with the approach of Eisenhardt (1989) rather than Yin (1989), as the first develops theory only at later stages, while the latter develops the theory as a first step. For the reason of this crucial difference, the case study approach of Eisenhardt (1989) is chosen for this thesis.

Nevertheless, there has also been a critical voice regarding the case study approach of Eisenhardt (1989). Dyer and Wilkins (1991) would like to see a richer description of fewer cases. However, this work incorporates both positive aspects. Several cases are researched and richer descriptions – in form of quotations – are included. This is possible because this thesis is not as much restricted in pages as a scientific journal article would be.

3.3 Contingency analysis, determinism and managerial choice

One main question often used for theorizing is 'why is something like it is' (Sutton and Straw, 1995; Daft, 1985). In this case contingency theory can provide valuable answers.

The second research question asks why the product cost analysis during pre-development is done the way it is. This question is one example of a possible strive between 'contingency approach' (e.g. Lawrence and Lorsch, 1967; Donaldson, 1996) and 'strategic choice' (e.g. Child, 1972). Simplifying and shortening the matter a great deal, one can say that that this question is part of a larger question set that deals with what forces shape the organization of a company.

Supporters of the **contingency theory** see a connection between the environment of a company and how a company is shaped. The environment "shapes its strategy, technology, size and required innovation rate. These contingency factors in turn determine the required structure" (Donaldson, 1996, p. 2). On the contrary, supporters of the **strategic choice** view state that managers running organizations can choose freely about strategies and structures (Donaldson, 1996). The notion of 'strategic choice' is here renamed to '**managerial choice**', as to fit the frame of this thesis that lies in management accounting and not strategy.

In its basic description, contingency theory is based on the principle of theoretical formulations. These theoretical formulations associate contingent variables with the environment, organizational characteristics, and decision-making style in which they are identified (Donaldson, 1996; Drury, 2004). In the context of this thesis the question is how the analysis practices during innovation are arranged and why it is like that. One possibility is that the analysis style depends on several characteristics of the specific company and environment in which it is operating in. Another possibility is that managers can chose freely.

Several contingency factors have been analyzed and identified in studies (see Donaldson, 1996, for a selective review). Contingencies can be the variable characteristics when looking at a multitude of several companies. However, for one company itself, these variable characteristics are actually fixed to a certain extent (Pavitt, 1990). Companies cannot completely freely change their underlying business and the dominating business logic (e.g. if the business is rather product or process oriented). Otherwise, they would have some penalties in the form of cost, inefficiencies or new knowledge to acquire. The approach to the market, rather specialized or rather broad with diversified products, is also usually set to some degree. Thus these sluggish and slow-variable distinct features are typical company characteristics for the companies.

Already over 25 years ago, contingency theory has been accepted in the field of management accounting (Otley, 1980; Drury, 2004). Shifting to innovation research, a multitude of factors can affect innovation practices and it is unlikely that there is a general formula for successful innovation that can be used by all companies regardless of the situation they are in (Tidd, 2001). However, according to Tidd (2001), contingency theory helps to create improved understanding how context affects innovation. Tidd (2001) also argues that contingencies cannot determine everything, as this would dictate certain management and there would be no choice of the company leaders anymore. Thus he argues that contingencies constrain, rather than fully determine the operations and (best) practices for companies and the respective environment they are working in.

This thesis analyses a set of case companies to talk about cost management during pre-development phases. However, it is difficult to claim that the findings are universally applicable as there are always different conditions attached to a specific situation in which some cost management tool performs better than in others. This is based on the idea of the contingency theory postulated by Lawrence and Lorsch (1967). Thus, when it comes to theorizing the findings, the contingency theory approach should be used. Langley (1999) is arguing similarly when stating that there is a trade-off between accuracy and generality.

In management accounting research prior to the employment of contingency theory approaches, researchers assumed that a – for all organizations alike – fitting management accounting information system design could be discovered. However, the contingency theory approach supports the idea that there is not one 'best' design, but that 'it all depends' upon the situational factors. These situational factors represent the contingent factors (Drury, 2004). In the words of Eisenhardt, building evidence "occurs through constant comparison between data and constructs so that accumulating evidence from diverse sources converges on a single, well-defined construct" (Eisenhardt, 1989, p. 541) and this construct will be dependent upon the situational factors according to the contingency theory.

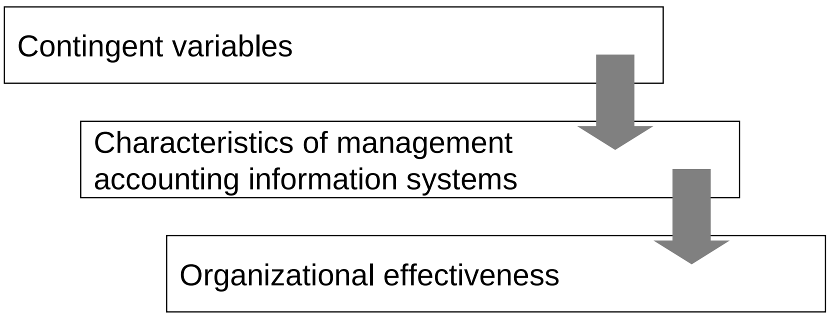

Figure 60: The contingency theory framework applied to management accounting according to Drury (2004)

The framework shown in Figure 60 represents the simplified chain of argumentation used in the contingency theory framework. In this framework the contingency variables of the first box are assumed to influence the design of the management accounting information systems (box 2) that are e.g. used for preparing decision making. Furthermore, contingency theory implies that in the end the organizational performance or effectiveness depends on the level of fit or alignment between the contingent variable and the management accounting information system (linkage between the second and third boxes in Figure 60) (Drury, 2004).

3.4 Setting up the field study

These methodological considerations stated above are the base for the further work in this thesis. With these as a base the field can be entered for the study that is described in the following.

3.4.1 Getting started

The chosen case study approach starts with an initial definition of the research question (Eisenhardt, 1989). This has already been done in subsection 1.2. This thesis follows the recommendation of Eisenhardt (1989) and does neither spell out a predominant theory, nor hypothesis for the research to be taken. This is done in order to retain the theoretical flexibility. However, the methods and tools introduced in the literature overview about cost management tools are kept in mind in order to provide a better grounding of the construct measures during the research (as it is suggested by Eisenhardt, 1989).

This thesis is founded in empirical research conducted as a research project during 2005-2007. During this research project, the focus has gradually moved from the beginning of the development phase towards the front end of innovation and basic R&D.

3.4.2 Case selection

The study of future product cost analysis during pre-development lives from the analysis of companies. This intersection of innovation management and management accounting is enriched to a high extend by company developments. This is due to two facts. The first is that management accounting has been driven for quite a long time by company developments (Johnson and Kaplan, 1987). The second is that the latest academic developments have not been applied widely outside of simplified academic settings. Thus a dependency on company developments is evident in the history of management accounting.

Furthermore, studying a single company would allow a very detailed description of the procedures of this company. However, studying several companies would increase the likelihood of discovering new practices, allow cross-company patterns to emerge and provide more generalizable findings (Eisenhardt, 1989). Thus a multiple case study is chosen as approach to this study.

3.4.2.1 Selection criteria

According to Eisenhardt (1989) the selection of cases is an important aspect in theory building from case study research. Generally, there are two different possible approaches to case selection; random sampling and theoretical sampling. Random sampling tries to create a representative sample of the study population, for example, a vote analysis. The aim of random sampling is to be demographically representative. On the contrary, theoretical sampling tries to look for specific characteristics in order to learn about what kind of influence these have on the researched topic (e.g. the R&D spending on the intensity of cost management in pre-development). The aim of theoretical sampling is to choose cases according to theoretical reasons rather than statistical ones. According to Eisenhardt (1989) a random selection of cases is possible, but neither necessary nor preferable.

During the study, several cases are added for further study, until a closure is reached. Eisenhardt (1989) states that the ideal point for stopping adding cases is when theoretical saturation is reached. This is the case when the marginal learning is minimal because the researcher is observing phenomena seen before. This is the case in this thesis. Adding cases was stopped as the marginal utility of the research was going down and a lack of novelty in the cases was apparent. As there was a limitation of time and resources, i.e. one researcher, the addition of supplementary cases was stopped once the total of seven case companies was reached. The core cases with which the analysis was started were Dali, Kandinsky and Warhol. The other four cases joined in while the interviews for these core cases were already on-going.

The research is done as a seven-company multiple case study. The sample selection aimed to cover several central aspects. The first and perhaps most important was that the company should be engaged in innovation activities. The second aspect was to achieve differences in the size of the companies under study. Three medium sized companies (turnover between 10 and 100 Mio Euro) were studied, while three other companies can be classified as very large companies (turnover over a billion Euros). No small companies were included in the study, as the innovation activity and the amount and effort of cost management made in the pre-development was estimated as being rather low, and the companies would not have met the first criterion. The third criterion was to get a differentiation of business to business (B2B) vs. business to consumer (B2C) companies. Two of the studied companies are operating in a B2C environment. However, one of these companies operates in both B2C as well as B2B markets. Furthermore, it was attempted to gather a diversified industry sample, i.e. companies operating in different industries. However, as five of the seven case companies are partly or fully operating in the telecommunication industry there might be a bias towards its business type and its operating logic.

Name	Dali	Duchamp	Kandinsky	Lichtenstein	Miro	Van Gogh	Warhol
Company size	Large	Very large	Medium	Medium	Very large	Medium	Very large
Turnover [€]	100m to 1bn	> 1 bn€	10 to 100 m€	10 to 100 m€	> 1 bn€	10 to 100 m€	> 1 bn€
R&D spending per turnover	0 to 1%	1 to 5%	5 to 10%	> 10%	1 to 5%	5 to 10%	> 10%
EBIT per turnover	0 to 5%	> 10%	negative	negative	5 to 10%	5 to 10%	> 10%
P/E ratio[1]	0 to 15	15 to 30	0 to 15	n/a[2]	15 to 30	n/a[2]	n/a[2]
B2B/B2C	B2B	B2B & B2C	B2B	B2B	B2B	B2C	B2B

[1]Earnings reported for 2004 in relation to average stock price 2005
[2]Fully consolidated into a holding company that is stock listed

Figure 61: Classification of case companies

An overview of the case companies is shown in Figure 61. As a pointer for the R&D activity the R&D spending per turnover is included in the overview. Additionally the earnings before interest and tax (EBIT) per turnover are used as an indicator for profitability. To relate the company to its performance on the stock market, they are also classified by price per earnings ratio. However, in three cases this is not possible as the company is part of a larger group.

3.4.2.2 Case overview

This section presents details of the seven case companies. To retain the confidentiality, the different case companies were assigned names of artists (Dali, Duchamp, Kandinsky, Lichtenstein, Miro, Van Gogh and Warhol). The companies are presented in alphabetical order in this section.

- **Dali** is operating in a business-to-business (B2B) environment and produces mechanical and electronic parts and modules for the telecommunication, medical and automotive industries. It is a large sized company that operates globally in four continents. The company traditionally has a manufacturing focus, as it grew through manufacturing excellence. The case company is using up-to date manufacturing technologies and methods.
- **Duchamp** operates in both business-to-business (B2B) and business-to-consumer (B2C) environments in the telecommunications industry. Duchamp is an international company, operating mostly in Europe.
- **Kandinsky** operates in a business-to-business (B2B) environment and designs, manufactures and markets electronic products in the telecommunication, healthcare and other industrial industries. It operates globally in four continents and is classified as a medium sized company.
- **Lichtenstein** operates as a venturing organization in the business-to-business (B2B) field. It is a part of a larger company operating in the electronics industry. Lichtenstein itself is classified as medium sized company.

- **Miro** operates in a business-to-business (B2B) environment and manufactures and markets chemicals and industrial services connected to these industries. The company is classified as a very large company.
- **Van Gogh** operates in a business-to-consumer (B2C) environment and designs, manufactures and markets electronic products connected to a sport and health theme. Van Gogh is classified as medium sized company.
- **Warhol** operates in a business-to-business (B2B) environment and designs, manufactures and markets electronic products connected with telecommunication equipment. Warhol is classified as a very large company.

3.4.2.3 Method of data collection

The data was mostly collected through semi-structured face-to-face interviews, company websites and reports, corporate organizational charts and product development records. Interviews were the prime data gathering method due to practical reasons of confidentiality. For the case companies the content of their new product developments were to be kept strictly confidential, while the methods of new product development practices were not classified as strictly. Thus the researcher was not allowed to investigate the original documents of the company's new product developments, e.g. business plans or feasibility studies, as that would have meant too much disclosure of the actual content of these new product development ideas. Rather, the used methods were discussed and documentation about the company's processes during new product developments was studied. As Eisenhardt (1989) suggests, the researcher was opportunistic to use all available information available to him. Thus whenever possible, further documents were also used. These were often organizational presentations about different methods and innovation procedure time lines (e.g. company records in the form of MS-Power Point presentations, organizational flow charts, checklists, scorecards etc.). Furthermore, the researcher asked the interviewees to present or draw their company's stage-gate model in the beginning of the first interview. This was done in order to clear out the time line of when which kind of cost management related action was taken. In some cases, additional quantitative cost information was gathered during or after the interview. This information was usually connected to a specific innovation case and used to give a better insight.

First contacted → Case companies in order of date of the first interview → Last contacted

	Kandinsky	Warhol	Dali	Lichtenstein*	Miro	Van Gogh	Duchamp
1st interview	Senior manager in duty of sales and customer relations	Senior new technology purchasing manager	Director (R&D) + Director (concept development) + Project manager (technology assessment) + Production manager [1]	Senior manager (business development) [1]	Managing director [1] (research center)	R&D director [1]	External consultant working for Duchamp[1]
2nd interview	Vice president (New technology development)	Chief design engineer	Director (concept development)	Managing director of the venturing unit	Head of one business unit	Cost engineer (R&D and manufacturing)	Director (concept development of innovations)
3rd interview	Chief design engineer + Project and key account manager	Senior new technology purchasing manager	Director (concept development) + Project manager (technology assessment)		Managing director [2] (research center)	R&D director [2]	Director (idea suggestion system)
4th interview	Vice president (New technology development)	Chief design engineer	Director (concept development)				Director (concept development of innovations) + Director (idea suggestion system) [2]
5th interview	Vice president (New technology development)	Managing director (research center)					
6th interview	Vice president (New technology development)						

* Additionally a manager was interviewed' that had taken over a spin-off venture project from Lichtenstein, but who is not actually working at Lichtenstein

[1] Written out hand notes, not recorded

[2] Double checking of findings, not recorded

Figure 62: Interviewee position overview

An overview of the different interviews in each company is shown in Figure 62. The interviews were made in a semi-structured interview style, and usually recorded and transcribed (except where indicated differently). In cases where the interviewed managers would have been uneasy and disturbed by the recording, i.e. in some first meetings, notes were written down per hand during the interview and enriched shortly after the interview. The semi-structured interview style was chosen, as the goal was to get a rather thick description of different situations and tools in pre-development phases from the interviewed managers. Usually the discussions went quickly into the researched subject as publicly available information on the companies was collected from their websites and annual reports. The length of the interviews usually lasted from one to two hours. In one case, an interview lasted only 45 min (2nd interview at Lichtenstein), while on one other occasion a meeting lasted a whole afternoon (1st interview with Dali). The cases are arranged in the order of the first interview date. In total the interviews were conducted in the time frame from September 2005 to December 2006. The written findings were fed back to the interviewed managers for confirmation and comments.

3.4.3 Research and study towards theorizing

There are many ways of creating knowledge about the world but not all might be scientific. In order to create knowledge through research in a scientific way the results have to be supported by empirical reality. Furthermore, the results have to be found in a scientific and rigid manner (Abnor and Bjerke 1997).

Eisenhardt (1989) states that inductive researchers usually use a multitude of different methods to analyze cases. As rationale for this, she argues that different data sources allow triangulation and provide a stronger substantiation of constructs and hypotheses. Triangulation can be defined as a convergent validation of several methods and research facets (Jick, 1979). It is seen as a method to ensure the validity of research in social sciences.

Even though Glaser and Strauss (1967) propose a joint collection and analysis of empirical data to uncover patterns and other discoveries, Eisenhardt (1989) claims that this is often not possible to a full extend. However, she recommends having at least some degree of overlap, as it was done in this thesis. Coding and first analysis was already started before the first interviews of the last cases were made.

Langley (1999) identifies several strategies for theorizing. One of these strategies is what she calls a **narrative strategy**. It is the structuring of detailed narratives from the collected raw data. This strategy should yield a thick description that will often produce a ‘déjà vu’ feeling. However, this approach is limited in the amount of cases to be used. Nevertheless, according to Langley (1999) it is used by many researchers also as a first stepping stone into further detailed research.

Another strategy is what Langley (1999) calls the **synthetic strategy**. This synthetic strategy is a sense-making strategy that uses whole processes as units of analysis. Global measures are used to describe and explain these processes. In a next step these measures are used to compare different processes and to identify regularities. These regularities will form the basis of a predictive theory that relates process characteristics to other variables.

A third strategy is the **visual mapping strategy.** According to Langley (1999), this strategy can be useful for the development and verification of theoretical ideas. This strategy contains visual graphical representations that are especially useful for the analysis of process data. It displays several dimensions simultaneously usually over a time axis. These graphical representations are usually a summary of different incidences. One approach to generate a more universal understanding is comparing several of these illustrations. These can then crystallize to 'causal maps' that can lead to a more general theory (Langley, 1999).

When using the narrative and the synthetic strategy, the data analysis was carried out with a **conceptually clustered matrix** (Robson, 2002). This was basically done by structuring the empirical data in tabulated fields and categorizing them. These categorizations were done for each case in itself, but on a template that evolved during the research. I.e. when a pattern or finding was detected, the other cases were also checked according to it and the new categorization was also introduced to the other cases. The understanding was build up by constantly checking the empirical data case for case and cross-case. Also the following instruments were crafted to enrich the understanding and grasp possible findings from the total data set.

Once the analysis yields results the next step towards theorizing after the within and cross-case analysis is to **shape propositions using the insights of the analysis findings** (Eisenhardt, 1989). The central idea is the constant evaluation of possible theoretical conclusions and their fit to the data. This step is depicted by Eisenhardt (1989) as the 'sharpening of constructs'. This sharpening of constructs is done by crafting a construct definition and building evidence that assesses the explanation power of the construct definition in each case. This is done through comparison between case data and possible findings to get a valid construct (Eisenhardt, 1989).

3.5 Crafting instruments regarding tool use

This section looks at the actual research analysis of the empirics. First, general research analysis instruments are configured. A process that Eisenhardt (1989) calls 'crafting instruments'. The different analysis methods – or 'instruments' in the words of Eisenhardt (1989) – are defined in the following subsections, in order to craft the instruments regarding the analysis of the found tool.

3.5.1 Tools and their first use

The motivation for this study is to understand how product cost analysis during pre-development is practiced in industry today, as this has received little attention in the literature so far. A first step towards this study is to use the visual mapping strategy according to Langley (1999) to model the found cost analysis during pre-development (see Figure 63).

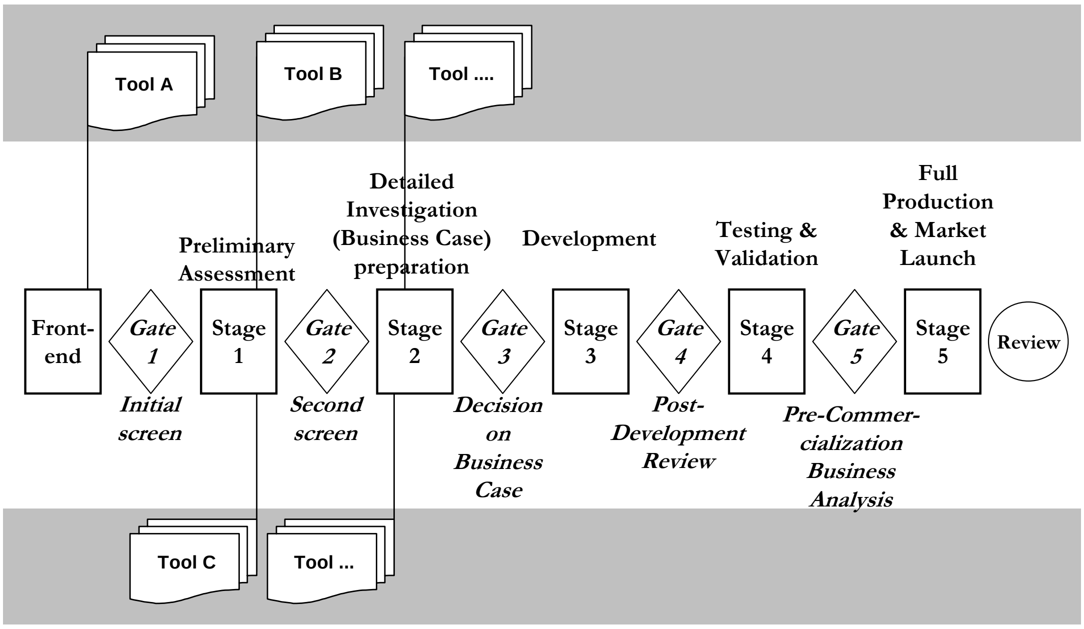

Figure 63: An exemplary overview of first time tool use

Each section about one individual case company starts with a graphical overview of the different tools the company reported to use in the pre-development phases. As shown in Figure 63, the overview illustrates when the analyzed company is using what kind of tools the first time in the course of their (standard) NPD process. As many companies use a stage-gate model for their innovation processes, the different tools are shown as 'flags' and the 'flag poles' connect the tools with the respective innovation phases in which the company is using it for the first time.

Additionally the different found tools are described in more detail in the within-case analysis for the different case companies. This is done to illustrate how found tools are used in business settings. This specific tool use description follows the order that is presented in the literature overview.

3.5.2 Normalizing the pre-development tool use

In order to analyze the first time tool use of the companies, the term 'normalized pre-development tool use' is used. This normalized first time deployment of the different found tools is used in the analysis below.

In this thesis the normalized pre-development tool use is defined as the standardized first time use of a tool. It is standardized to three possible values for the pre-development:

1. Front end (or shortly front)
2. Middle
3. Rear end (or shortly rear)

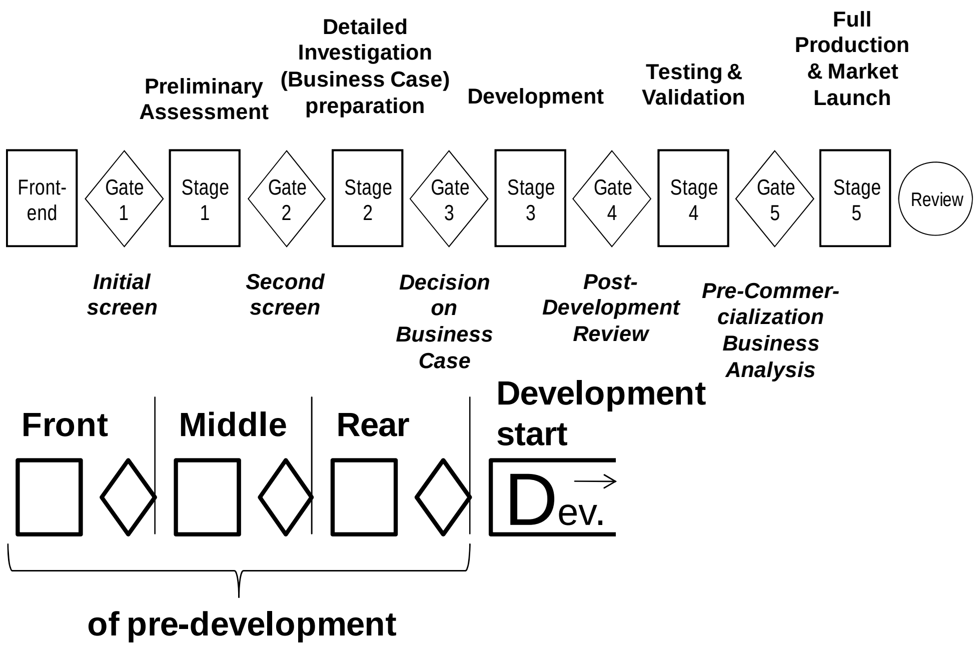

Figure 64: Normalization of first time tool use in pre-development

The normalized pre-development tool use is derived as follows: As shown in Figure 64, the distance between the front end of innovation and the detailed design start for a specific product was split and distributed over the above mentioned three values. This means that e. g. a method found to be used in the front end of innovation would be assigned the value ‘front’. However, a method found in the development stage would not get any value assigned, i.e. not be taken into consideration for this research. As stated in the literature review in subsection 2.2.1.1, companies can have several stages in pre-development. **For this analysis the value ‘front’ always means the front end of innovation. On the contrary the value ‘rear’ always means the last stage before development start. The stage or stages in between are given the value ‘middle’** (see Figure 64). In the case that a company uses only two stages before development start, the first is called front and the second is called rear as it is the last stage before the actual development start. This approach is deliberately chosen to ensure a consistent notion in the further analysis.

Further down, the normalized first time use of tools for the different case companies are described in detail and set in relation to other company specific parameters. The in-detail analysis is carried out in the first sections of the cross-case study (chapter 4.7.7).

3.5.3 The relative cost tool importance

The tool use during pre-development phases varies from company to company. Thus different companies organize their future product cost analysis differently. In order to analyze this, specific cost tools have the ‘relative cost tool importance’ calculated.

To calculate the relative cost tool importance, first the tools are classified into two main categories: to be more general (see subsections 2.5.1 and 2.5.2) or to be cost focused (see subsections 2.5.3 and 2.5.4).

	Number cost focused	Total tool used	Rel. cost tool importance [%]
Case 1	3	6	50%
Case 2	2	5	40%
…	…	…	…
Case n	x	y	=x/y

Figure 65: Relative cost tool importance for the compared case companies

In the second step the relative cost tool importance is calculated for each case company by dividing the amount of found cost focused tools by the sum of the cost focused and more general tools found in the pre-development phases (see e.g. Figure 65).

The minimum this figure can be is 0%. This is the result if a case company does not use any cost focused tool in its pre-development analysis. On the contrary, the figure can also be 100% if all tools found in one company during the pre-development are cost focused tools. If all possible tools are found, the number will be 56% (i.e. five cost focused tools out of nine tools in total).

3.5.4 Specificity and cost focus

For the analysis, the different tools found in the seven case companies are categorized according specificity and cost focus in section 2.5.

The first distinction is the **specificity of one tool.** There are two types of tools. The first is classified as **'unspecific'** (see subsections 2.5.1 and 2.5.3). Unspecific analysis tools gather information for an array of new product development ideas at any given time. The second is classified as **'specific'** (see subsections 2.5.2 and 2.5.4). Specific analysis tools analyze primarily information regarding one particular new product development idea.

The second distinction is **whether a tool provides general information or cost specific information** about a new product development idea. In this work, the first is called a **general tool** (see subsections 2.5.1 and 2.5.2), while the latter is called a **cost focused tool** (see subsections 2.5.3 and 2.5.4).

3.5.5 Summary of crafted instruments regarding tool use

Before 'entering the field' a case study researcher should craft 'instruments' according to Eisenhardt (1989). In this section several of these instruments regarding tool use are introduced and defined for the empirical analysis of the found tool in the following chapters. Figure 66 gives a summarizing overview of these instruments.

Instrument	Description	Values
First time tool use	Visual mapping through graphical overview of reported company tools	Flags indicate first time use
Average pre-development tool use	Normalized first time tool use	• Front • Middle • Rear of pre-development
Specificity	Whether a tool gathers information for an array of ideas (unspecific) or regarding one particular idea (specific) at a time	• Unspecific • Specific
Cost focus	Whether a tool provides general information or cost specific information	• General • Cost focused
Relative cost tool importance	Amount of cost tools used relative to the number of all tools used in the pre-development phases	All tools have cost focus = 100% to No tools have cost focus = 0%

Figure 66: Overview of crafted methodological instruments regarding tool use

In total five instruments regarding the tool use study are shown in Figure 66. The first is a graphical overview (first time tool use). The second normalizes the first time tool use in three different phases of pre-development. The third uses ratios for particular aspects of tool use (relative cost tool importance) that give an aggregated view of the found tool use in pre-development. Finally, the fourth and the fifth deal with the tool analysis itself.

3.6 Crafting instruments regarding organizational contingencies

This section also looks at the actual research analysis of the empirics by 'crafting instruments' (Eisenhardt, 1989) regarding the organizational contingencies of the case companies. These instruments are necessary to uncover whether company contingencies shape the product cost analysis during pre-development.

3.6.1 Company characteristics

Above the instruments were crafted regarding the analysis of the found tools. Yet, that looks only at a part of the picture. The possible company characteristics of the case companies must also be crafted for this work.

Company characteristics, e.g. the size of a company, can be organizational contingencies (Drazin and Van de Ven, 1985; Pavitt, 1990; Tidd, 2001). Thus the analysis below will look at the following company characteristics[6]:

- Turnover as a proxy for company size
- R&D spending per turnover as a proxy for the R&D activity and intensity of the cases
- Earnings Before Interest and Taxes (EBIT) per turnover as a proxy for the profitability of the case companies

[6] Reported in the annual reports of 2005.

- P/E ratio[7] as a proxy for the stock performance and outlook from investors on the case companies
- Whether the business of a company is based on goods or services

Company characteristics				
Company size	Small	Medium	Large	Very large
Turnover	< 10 m€	10 – 100 m€	100 m€ - 1 bn€	> 1 bn€

R&D activity and intensity				
R&D spending per turnover	0% to 1 %	1% to 5%	5% to 10%	> 10%

Profitability				
% ratio of EBIT to turnover	negative	0 % to 5%	5% to 10%	> 10%

Stock performance				
P/E ratio[2]	negative	0 to 15	15 to 30	> 30

Figure 67: Classification scheme for the different case company characteristics

The different categorizations and its boundaries for the company classification are shown in Figure 67. An overview of the different cases and their classification according to that scheme is presented in Figure 61 above when the different case companies are introduced.

For understanding the tool application in pre-development, different angles are taken to study the use of the case companies by crossing the company characteristics with the different tools usage ratios. This cross-case analysis further down (in chapters 4.7.7 and 6) is done in order to analyze and discuss the possible influence and explanatory value of the different company characteristics as boundary conditions. This part of the study method seeks understanding about contingencies of the tools that companies are using regarding the second question of why future product cost analysis during pre-development is done the way it is. The question is whether the company characteristics in which the different cases are embedded are governing the future product cost analysis during pre-development and to which extend, and in which relation.

3.6.2 Companies' innovation style

Innovations can be market or technology driven (Ulrich and Eppinger, 2000; Hauschildt and Salomo, 2007). This distinction can be used to classify companies in the analysis according to their prevailing innovation style. In accordance with the explanation stated in the literature review (see subsection 2.1.1), **the innovation style**

[7] Earnings reported for 2004 in relation to average stock price 2005.

is determined by the focus, the initiative and the highest newness intensity of the targeted innovations. Two different innovation styles are distinguished in this thesis:

- Technology driven innovation approach
- Market driven innovation approach

For the **technology driven** innovation approach, the focus, initiative and the highest newness intensity lies in the technological area. Technological and production aspects are in the center of attention. This technology driven focus and newness intensity of innovations will be characterized by large changes in the following points according to Hauschildt and Salomo (2007):

- Newly developed technology underlying the innovation
- New technology substitutes hitherto-used technology to a large extent
- New design uses very little of the hitherto-used engineering
- Using novel technological components

Technological and production aspects are in the center of attention for technology driven innovations.

For the **market driven** innovation approach, the focus and the highest newness intensity lies in marketing the new product development idea. This market driven focus and newness intensity of innovations will be characterized by large changes in the following points according to Hauschildt and Salomo (2007):

- New customers are addressed
- Novel customer needs are targeted
- New sales channels are developed
- Cooperation with new partners regarding the sales market is needed

Market aspects are the focal point for market driven innovations throughout the whole innovation process. Technological aspects of market driven innovation are rather different and can be changing greatly during the innovation process. Sourcing and production play a minor role in the innovation conception.

3.6.3 Idea initiative

The idea initiative can also be differentiated (Hauschildt and Salomo, 2007). It is distinguished whether the initiative for a new product development idea comes either from

- Discovery by chance
- Institutional idea search and development
- Customer led innovation
- Idea suggestion innovation programs
- Improvement and byproduct recycling search

This distinction is taken from the classification in subsection 2.1.1. In the analysis the idea initiative of the different companies is checked and the prevailing initiative is selected.

Some innovation is based on discovery by chance, e.g. by finding a chemical formula by chance that behaves in a certain exploitable way. Another initiative for innovation is institutional idea search and development. This stands for a planned and constructive search of several possibilities based on research, strategic analysis and alike. Innovation from the third initiative category can come from the customer impulses and is named customer led innovation. The fourth initiative category is idea suggestion innovation programs that are based on ideas submitted by employees. The fifth initiative category is improvement and byproduct recycling search. This happens if a product is defective and has to be modified or if the production of a product leads to a side product that can be exploited further, e.g. in the chemical industry (Hauschildt and Salomo, 2007).

3.6.4 Innovation funnel type

According to Wheelwright and Clark (1992) the treatment and screening of new product development ideas during pre-development is dependent on the innovation funnel type of a company. Thus the product cost analysis during pre-development of the different case companies could be affected by the innovation funnel type that they use.

In subsection 2.2.2.2, the two characteristic innovation funnel types of Wheelwright and Clark (1992) are introduced (see Figure 23 on page 33). One is called the survival of the fittest funnel and the other is called the few big bets funnel. In the analysis further down these two funnel types are used as an organizational contingency to find out whether this funnel type influences the product cost analysis during pre-development.

3.6.5 Technological uncertainty

Theory suggests that uncertainty can be a driving force in the design and use of management accounting systems (Davila, 2000). Thus it is possible that uncertainty could explain why future product cost analysis during pre-development is done the way it is. In order to get an operational method for analysis, the well crafted and described concept of technological uncertainty from Shenhar and Dvir (1996) is used (see Figure 12 on page 20). It categorizes the technological uncertainty into four categories from ‘A, low-tech’ to ‘D, super high-tech’.

The analysis below also uses the technological uncertainty of Shenhar and Dvir (1996) as an organizational contingency to find out whether it influences the product cost analysis during pre-development.

3.6.6 Summary of crafted instruments regarding organizational contingencies

This subsection summarizes the crafted methodological instruments (Eisenhardt, 1989) that look at the different organizational contingencies. The following Figure 68 gives a summarizing overview of these instruments.

Instrument	Description	Values
Company characteristics	Company characteristics as potential organizational contingencies for tool use	• Turnover • R&D spending per turnover • Earnings Before Interest and Taxes (EBIT) per turnover • P/E ratio • Products vs. service industry
Innovation style	Innovation style as potential organizational contingency for tool use	• Technology driven • Market driven
Idea initiative	Idea initiative as potential organizational contingency for tool use	• Discovery by chance • Institutional search & development • Customer led innovation • Idea suggestion programs • Improvement & byproduct usage
Innovation funnel type	Shape and type of the innovation funnel as potential organizational contingency	• Survival of the fittest • Few big bets
Technological uncertainty	Technological uncertainty as potential organizational contingency for tool use	• A, low-tech • B, medium-tech • C, high-tech • D, super high-tech

Figure 68: Overview of crafted instruments regarding organizational contingencies

In total five instruments are shown in Figure 68. All instruments deal with organizational contingencies that could explain the specific tool use of the companies due to organizational contingencies (e.g. company characteristics). These instruments are used in chapter 6 further down.

In the next step the analysis is then carried out for the different phases of the pre-development to see a pattern. The field is entered according Eisenhardt (1989) with these instruments crafted in the sections 3.5 and 3.6. To some extent these instruments combine qualitative data and quantitative figures for the analysis further down to achieve a synergistic view of evidence, as recommended by Eisenhardt (1989). The tools used and their characteristics are mapped for each stage and each company to uncover tool use patterns in the pre-development phases.

4 Within case analysis

As Eisenhardt (1989, p. 539) clearly states, “analyzing data is the heart of building theory from case studies”. She recommends that the analysis is started with a within-case analysis, before one should start to search for cross-case patterns. This chapter takes the detailed records of each case and compresses them to a description of the case according to the guiding themes of different subsections.

The general structure of the following case company subsections in this chapter is divided into three parts with guiding themes for each of the case companies. The first part (4.x.1) gives an introduction to the case. The second part (4.x.2) provides an overview about the cost information analysis process of the different case companies. The third part (4.x.3) introduces the tools found in the case company and looks especially at the role of cost information in the tool use. Furthermore, other successive subsections highlight interesting findings.

4.1 Dali

4.1.1 Introduction to the case

From the insight gained through the discussion and interviews, one can see that a good manufacturability of new technologies and products is still seen as one of the most important goals in R&D. The case company uses cross-functional teams in their innovation activities already in early stages. The two analyzed new product development projects were to a large extent technology-driven. As the company is increasing its R&D activities there was a significant rise in R&D expenses.

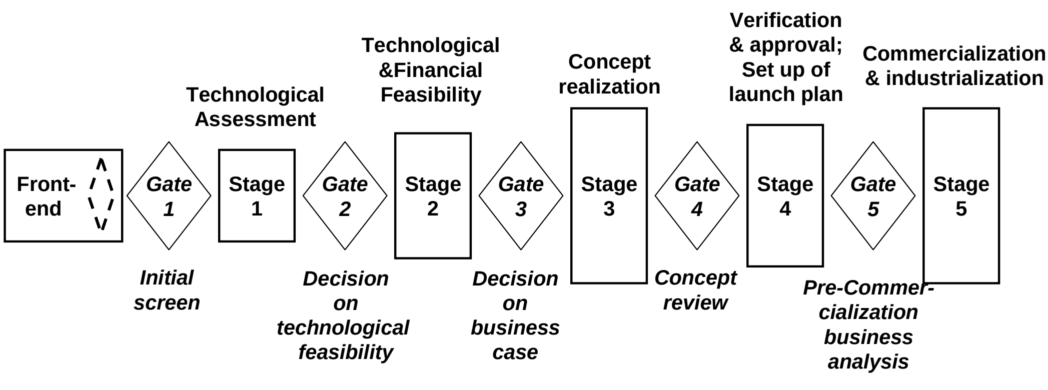

Figure 69: Stage Gate model of Dali

Even though it is not shown on corporate charts; the person reviewing proposals already pre-screens the ideas according to rough feasibility and strategic fit. In stage 1, information about the technological feasibility of the analyzed new product development idea is gathered. The focus is on the technological feasibility, less on the financial feasibility. In this stage, the R&D team is looking for feasible production concepts in order to find the most appropriate technologies or manufacturing approaches so that the technologies to be used may be clarified. Once this is done, the company has a review meeting where the board decides on the new product development proposal. If this board decides that the idea exploitation should proceed, it is defined what information should be gathered and what practical steps should be done in the stage 2.

In stage 2, usually the technological feasibility is further checked, but financial aspects are also now taken into account. This is the first time that costs, potential market volumes and pricing issues are addressed actively and evaluated. The technological analysis moves away from the own technology assessment of stage 1 and is more directed to evaluate competing technologies of other players in the market – something that could be named competitive technology intelligence work. The company uses a template for the feasibility study where gathered information is filled in. Parallel to the work on the feasibility study, the writing of a business plan is started.

Gate 3 consists of a review meeting, where the board of directors decides about whether to proceed to the development stage (stage 3), to kill the effort, or to evaluate the idea further in order to get more information. Gate 4 is a concept development examination, before the launch plan is worked out (stage 4).After Gate 4 the marketing department takes over the responsibility.

Due to its focus on technology-lead innovation, innovations at Dali are classified as mostly **technology driven** (see 3.6.2). According to the interviews, the idea initiative at Dali comes predominantly from **institutional idea search and development** rooted in structured and strategic business development (see 3.6.3). The funnel type of Dali is classified as using a **survival of the fittest** approach (see 3.6.4). Dali is classified as **medium-tech** in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5).

4.1.2 The cost information analysis process of Dali

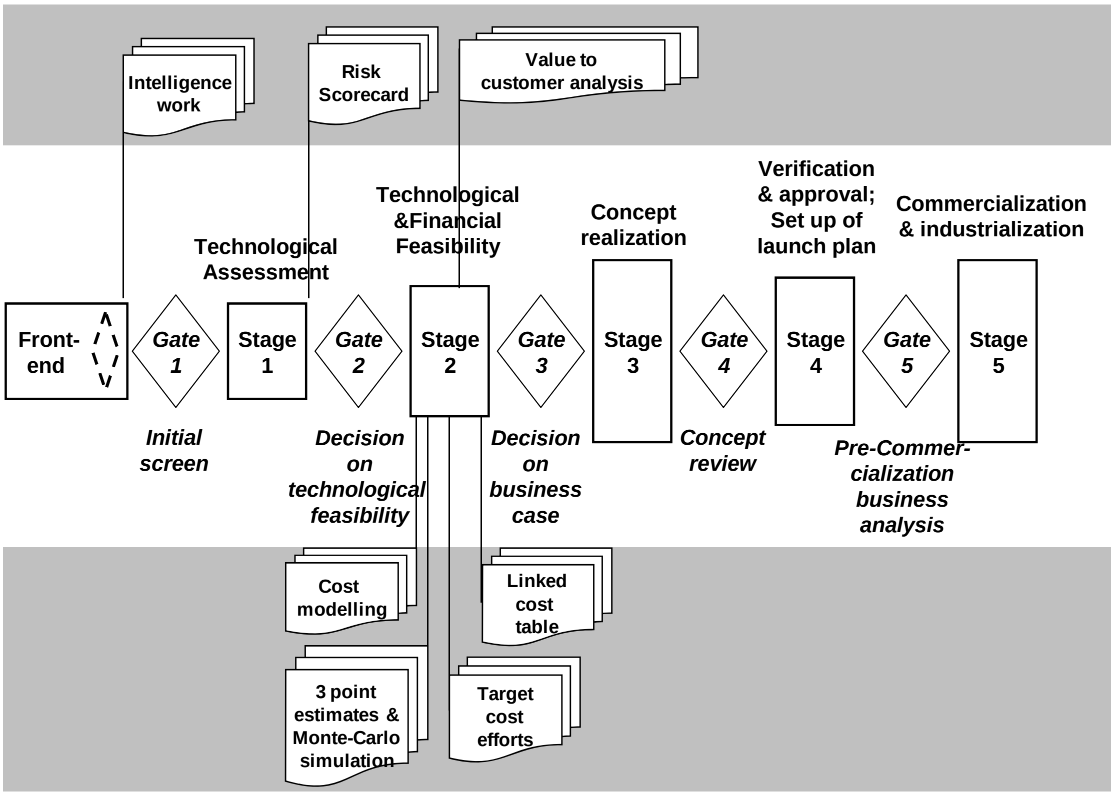

Figure 70: First time tool use of Dali

As shown in Figure 70, Dali is using **intelligence work** in the form of business intelligence together with results from regular teardown studies in the front end. In stage 1 Dali starts using a qualitative risk **scorecard** to evaluate new technologies and new product ideas.

In stage 2 Dali is using **value analysis** and has incorporated a system of allowable costs and target profit calculations similar to the paradigm of **target costing**. For their **cost modeling and estimations** Dali is using different types of costing templates in pre-development. These are either made ad-hoc or a large cost table is used. This cost table is linked to the internal ERP-system, which can be seen as a **cost database**. In more radical new technology and product developments Dali is enriching the value analysis by total cost of ownership analysis for the end customer of products, where the new solution could be used. And last but not least, Dali uses **uncertainty management** tools. These are triple point estimates and Monte Carlo simulations to analyze and judge new product developments together with a scenario analysis integrated in the cost database program.

Intelligence work	Unspecific	General	**Front**
Roadmapping	Unspecific	General	**-**
Scorecard use	Specific	General	**Middle**
Uncertainty management	Specific	General	**Rear**
Cost dynamics analysis	Unspecific	Cost focused	**-**
Cost database use	Unspecific	Cost focused	**Rear**
Cost modeling and estimation	Specific	Cost focused	**Rear**
Target costing efforts	Specific	Cost focused	**Rear**
Value analysis work	Specific	Cost focused	**Rear**

Figure 71: Dali's unified tools use in pre-development

After the normalization of the stage gate model according to the scheme presented in Figure 64, one can see the different tools and their first time use at Dali in Figure 71. It is interesting to see that in the front end, the tool use is concentrated on one unspecific tool, while later the center of attention migrates towards the use of specific tools.

Generally, one can say that in the case of Dali, mostly human expertise based methods and a preliminary risk assessment are made in the front end of innovation and stage 1. Only if a new technology and product proposal has passed gate 2, more quantitative methods are used to further evaluate the idea.

4.1.3 The role of cost information within the found tools

In the front end Dali uses business intelligence together with expert opinion. Already at this stage, costs can play a role in the market data the company is using for its intelligence work. In the next stage the company is using scorecards for finding critical issues that have to be checked for new product developments. Managers at Dali are aware that the scoring is based on guesswork, which might not reflect reality very precisely and through that has a limited meaning. Yet, in total, the tool is seen as a valuable tool by the company.

In the rear pre-development, the importance of cost information rises significantly. At this point in time Dali starts using costing templates which are linked to a cost template. This cost template is connected to the ERP system of the company and thus very detailed. The cost estimations of how much the new product development idea would cost if produced in high volumes are in the focus of the analysis. Due to more specialized production methods, sales and production volumes have an impact on future production costs. This also affects the analysis during pre-development as the following two examples show. The interviewed director for New Concept Development and IPR at Dali states:

> *"The current market price is for very high volumes. It means that the cost target needs […] to be equal. […] We can see how near we can come [to the*

> *market price]. But of course we know that before we are coming there, we have a certain kind of loss in the very beginning. […] We calculate first a […] higher price when we start and [take] the price erosion in our calculation.”*

Dali is looking at the potential market and using value analysis to estimate allowable costs. The company has incorporated a system of value analysis, allowable costs, ‘back-costing’ and target profit calculations similar to the paradigm of target costing in the feasibility study phase in the rear of pre-development before development kick-off. At the same stage regular target costing is started. Additionally, the company is doing idea specific teardown analysis in order to follow the development of competitor’s products, find improvement possibilities and try to evaluate the cost structure of the competition. Also in this teardown analysis, the role of cost information is very important. If a new product development idea has a comparable functionality similar to the product of the competition, the own cost estimates are benchmarked with the cost information of the solution of the competition. Additionally Dali is using uncertainty management tools in the form of triple point estimates and Monte Carlo simulations.

Summarizing, one can say that the role of cost information for the found tools is strongly increasing in importance through the pre-development stages. Dali has a high focus on costs in their new product development idea analysis once it processes through to the rear of pre-development.

4.1.4 Misleading tools and numbers

Managers at Dali are skeptic about the validity of estimates that come in the disguise of too sophisticatedly calculated numbers regarding the use of Monte Carlo simulations for cost analysis in pre-development. One interviewed manager at Dali acknowledges that the information handled contains mostly estimates. These show a certain kind of variation. In order to make the assumptions behind best guesses more reliable, managers use triple estimates. These triple estimates are based on the most likely, the worst and best case. The company sees the benefits, but also the limitations of simulations based on the Monte Carlo method in pre-development. They used it to evaluate new product portfolios, but are hesitant to use it for the profitability calculations of a specific new technology. For the latter, the past has shown that feeling too confident about simulated numbers conceals the uncertainty that comes with estimations and this can be misleading.

4.2 Duchamp

4.2.1 Introduction to the case

The interviewed managers of Duchamp see technology as an enabler for business. As the company itself is selling services enabled by new technologies, they might develop or adapt technologies and then use field trials to develop products and services on this platform. In this way new technologies get a strategic aspect where decisions about strategic directions are taken without being able to fully specify how the final product or service based on a new technology will look like. Due to the nature of the business in which the company is operating in, they are using field customer tests to fine-tune their offering during the development phase. The stage gate model of Duchamp is shown in Figure 72.

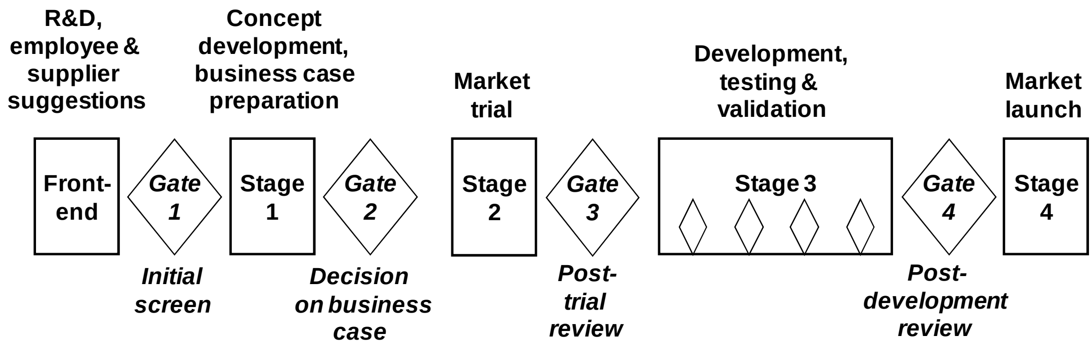

Figure 72: Stage Gate model of Duchamp

The R&D work of Duchamp is directed towards strategic growth areas. Generally the research efforts of the company are centered on applied research topics rather than basic research and organized in programs/campaigns. In each program there are several projects running on the program theme. Even though the R&D efforts are targeted at developing own products and services, some developments might lead to spin-offs or intellectual property rights (IPRs) that are sold. The company is trying to locate large new business areas for innovations as the director in charge of the employee suggestion process clarifies:

> *"I think the most important thing […in idea development] is the customer. What is the value for customer and what is the customer need, and how to evaluate that. That is one thing. And then the other thing is that we would like to get ideas which might be big from business point of view […]. They might be very difficult to implement from technical point of views, but then they would really bring value to customers; so not incremental steps to our existing [… products and services], but really looking [at] something totally differently, which means that we would maybe have to change our processes to make it happen, but then it would bring value to customers."*

The company is using a strategic portfolio approach to manage their products and find areas of new product development for their front end. The company is using product life cycle analysis and market share vs. growth matrices (also called Boston Consulting Group matrix) to identify the need for change and progress.

Furthermore the director of the idea suggestion system of Duchamp also explains that it is important to focus on what one wants to do and the size of the ideas (scalability). Yet, the organization is open to more radical ideas, as long as it is beneficial for the company:

> *"I think [it is] very important when you do something […that] you have to look what you really are looking for. What kind of ideas, for what you are looking. First thing first, that's why we have themes. […] Okay. Then the second question is, do we want to have small ideas, meaning from business point of view, so […] quite incremental ideas, or are they really something which could bring, let's say significant growth or growth possibilities or business opportunities for us. And then of course for us the interest is in big business opportunities. Because if we do some small change in [our existing business…], of course it could be good for customers, but maybe it would not bring us lots of revenue. So you have to keep in mind what you are looking for."*

The director in charge of the employee suggestion process of Duchamp states on the screening of ideas:

> *"Most of the ideas are such that they have already been identified by our other organizations. […] So, then we might know already some of those ideas, and then we clearly can say okay, this is identified, we don't go any further, because that's already in the process somewhere, so you can drop quite many ideas based on that. "*

At Duchamp the first gate in the suggestion system approach is very light on analysis. The checks are mostly targeting on whether a similar idea has already been evaluated and/or whether it is in development. The interviewed director further explains:

> *"If you think that you have now good ideas, let's say for example three ideas, which you want to give [to be considered by the] management; then how to inform management that you should do something with this. And that is, I think, the tricky part. […] We have ideas coming from many sources, so these ideas what are coming out from here, these 1-2-3, there might be many competing."*

On the contrary, the second gate is heavy. Many ideas compete for the attention of the top management. Thus the analysis as a preparation for this top management screen is also heavier. One reason for this is to get the higher management interested in new ideas as they get many business issues presented and new ideas are competing for the attention of the management. Thus at Duchamp the biggest step in tool use is before the heaviest gate in the middle of pre-development.

When looking at the survival rate of ideas in the employee suggestion panel, a heavy first cut can be seen (from 40 submitted, only about three ideas are taken to the next gate, e.g. 7,5%). There are many ideas to be screened in the front end and the resources for the analysis during pre-development phases are limited. In the twelve months preceding the analysis around 460 ideas (around 40 ideas per month) were submitted to the employee suggestion system and reviewed by the managers in charge at Duchamp. Ideas that were already evaluated before are eliminated out of these.

After that the ideas are grouped together with similar ones and evaluated. After this process, usually one to three ideas reach the next gate and are presented to the management board in a monthly meeting.

Duchamp’s innovation style is classified as **market driven** due to its clear customer focus (see 3.6.2). Even so, Duchamp also has an institutional idea search and development; the focus for this research lies in its idea suggestion program as idea initiative. Thus Duchamp’s idea initiative is defined as **idea suggestion** based (see 3.6.3). The funnel type of Duchamp is classified as using a **few big bets** approach (see 3.6.4). Due to the complexity of its business and therefore their innovations, Duchamp is classified as **high-tech** in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5).

4.2.2 The cost information analysis process of Duchamp

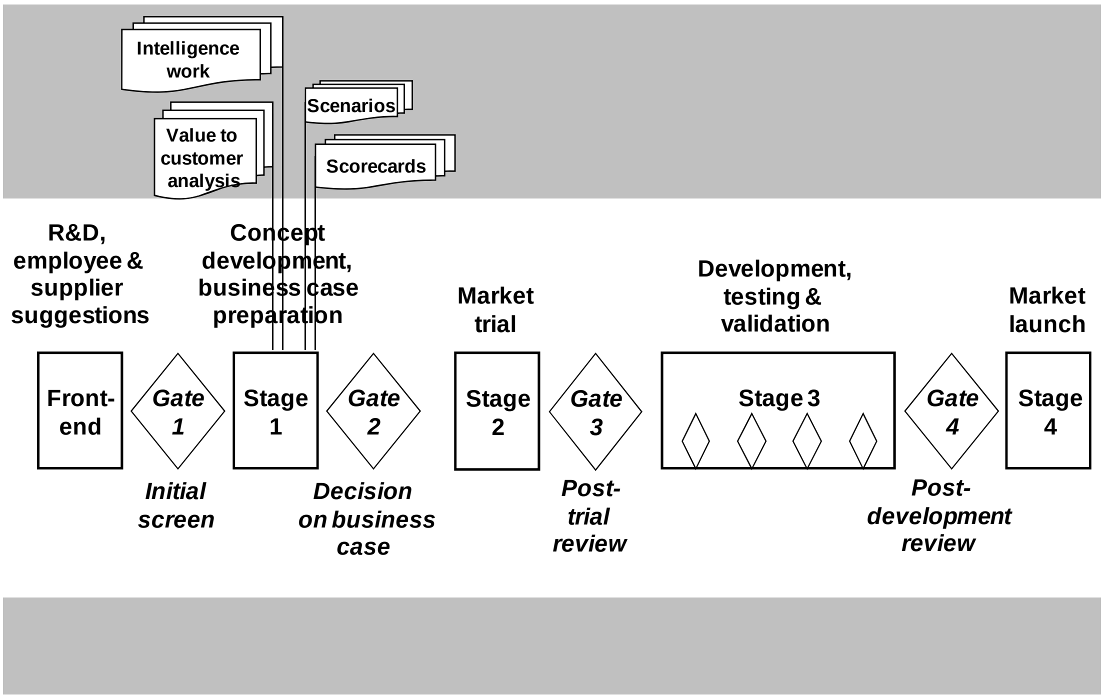

Figure 73: First time tool use of Duchamp

The first time tool use of Duchamp is shown in Figure 73. Duchamp uses **intelligence work** along with expert opinion to evaluate its new ideas in the middle of pre-development. At the same stage the company is using potential pay-off checklists as **scorecards**, which are primarily used to evaluate whether a new product development idea has the potential to pay off and secondly about whether it is technologically feasible. The employees reviewing ideas are rating ideas according to guidelines. The scorecard also involves **value analysis work**. Furthermore, Duchamp uses scenarios as a tool for **uncertainty management** in this phase.

Intelligence work	Unspecific	General	**Middle**
Roadmapping	Unspecific	General	**-**
Scorecard use	Specific	General	**Middle**
Uncertainty management	Specific	General	**Middle**
Cost dynamics analysis	Unspecific	Cost focused	**-**
Cost database use	Unspecific	Cost focused	**-**
Cost modeling and estimation	Specific	Cost focused	**-**
Target costing efforts	Specific	Cost focused	**-**
Value analysis work	Specific	Cost focused	**Middle**

Figure 74: Duchamp's normalized tool use in pre-development

One can see the different tools and their first time use at Duchamp in Figure 74 after the normalization of the stage gate model according to the scheme presented in Figure 64.

4.2.3 The role of cost information within the found tools

At Duchamp, new product development idea reviewing in the first screen is done with the help of guidelines and expert opinion of experienced employees based on business and technology intelligence. New information from business intelligence leads to updates in the business estimations of the early stages or is stored until needed. The managers in charge of the evaluation are estimating the technical feasibility, the potential turnover for the company and the value for the customer. However, the used guidelines still allow a larger amount of personal judgment and **costs are not in the focus of the analysis**.

Duchamp uses a standardized pay-off checklist in the middle of pre-development for their new product development evaluation. The most important factors judged are (1) the alignment with existing resources of the company, (2) the potential turnover, (3) the future feasibility, and (4) the potential value to the customer. **However, costs are not specifically checked with this pay-off checklist.** It is interesting to notice that Duchamp is primarily interested in whether a new product development idea has the potential to pay off and then secondly about whether it is technologically possible. Yet, costs are not checked explicitly, but rather a business stake in the total available market (TAM) is estimated.

Duchamp is doing value analysis work in the middle of pre-development. If no additional value to the customer can be seen, an idea will not be developed further as the director in charge of the employee suggestion process states:

> *"Customer values and needs are the most important. […] Because if they do not have a need and a value, why would they use it? Even though […] it would be very easy for us to implement it from a technical point of view."*

Duchamp is aware of rough target prices, but the company is not carrying out target costing efforts in pre-development. As a reason for this, the interviewed director in charge of the concept development states that **cost estimation is too hard to perform**. Furthermore, a target price might be too difficult to set up according to the manager from Duchamp. The market prices have been fluctuating in a broad range in the past and the company is a price taker on the market that has little power to influence the pricing of its industry.

Starting from the middle of pre-development on, Duchamp is also using scenarios in several ways during pre-development. First, they are evaluating business directions through several scenarios and second, they use it to facilitate discussions during pre-development phases. Through these scenarios, the company finds that judgments about new product developments and their analyses during pre-development are facilitated.

Summarizing, one can say that the future product cost analysis during pre-development phases of Duchamp is marked by the effect that Duchamp finds it very hard to estimate its costs. Furthermore, a price target for target costing is seen as difficult to set up and the company is described as a price taker on the market. Thus **the analysis of new product development ideas compromises only very little investigations of costs. Instead of the cost level itself, the relative value as benefit per expenditure is checked attentively. If no additional value to the customer can be seen, an idea will not be developed further.**

4.2.4 Uncertainties of future costs of processes as a limitation

Duchamp is not using any cost modeling in the evaluation of new product development ideas in the pre-development phases. Its director in charge of the concept development says:

> *"For example one huge bottleneck is […a significant part in the delivery system]. Before checking you may not know how big work something is. It may sound very little, but due to the structure of the system it could be quite big work, and there is other activities competing with new products as well, because you have links to marketing campaigns […] and these have to be taken into account […] as well."*

Thus there can be a large uncertainty connected to innovations due to existing processes that might not be able to handle a higher workload resulting from new product developments. These can have a serious impact on the cost structure of the new product development idea as the example stated above shows and this will also affect the product cost analysis during pre-development.

4.2.5 Need of pre-development cost analysis vs. limited resources

The director of the idea suggestion system of **Duchamp** states:

> *“We try to focus the idea hunting, because we have noticed that if you put [out the word for the] idea channel saying only ‘give ideas’, then we get ideas from here to here. So it’s impossible, we do get lots of ideas, but we get too many, and they are too stretched – so it is like fishing, you want to have certain kind of fish, you pick up a certain kind of net, and then you go for that kind of fish. So what we are doing, we are running themes, so we try to find something which is interesting to the company and to our business unit at the present moment, and then we say that we have, are running now this theme, please give ideas to this theme, which is whatever it is. Then we get more focused ideas. […] We don’t get now hundreds of ideas, we might get 20 or 30 ideas, but they focused now to the certain theme or idea, which is, I think, better.”*

Thus in a general innovation approach the focus on themes to get ideas in one direction is seen more valuable. Furthermore with that approach it is also easier to cover with the analysis workload.

4.2.6 Tools have to be familiar to be used at all and correctly

For the first assessment of an idea, **Duchamp** is using the expert opinion of experienced employees. The director of the idea suggestion system at Duchamp states:

> *“Basically it is up to the person who is doing it [the screening]. We have some guidelines, but it is the experience of that person. He or she cannot be very young or inexperienced. He or she has to have some kind of a broad kind of looking, he or she has to know also what we have done previously,[…] have we tried that before, and if it was successful or not, what was the reasons and so on.”*

He acknowledges that the process is quite open to personal judgment. Also he states that the first check relies heavily on experience.

The director for innovation concept development of **Duchamp** points out that the tools have to be familiar to the employees if they should use them correctly:

> *“You can have different scenarios about its possible success, there may be parameters […], the time schedule, […] and you have several options, and then of course about the revenue and volumes. […] If you are used to work with scenarios, you normally use them more, but if you have never used scenarios, it’s difficult. We do have some, what could be called as innovation tools that are available for people; some, guidelines how to use them. [… Also] we have a couple of people who are more used to use them, so they act as kind of support pool if needed, sometimes they can act as an activator, run workshops, and then the project people can just participate; […] in order to make sure it goes very good.”*

4.2.7 Misleading tools and numbers

The director of the idea suggestion system at **Duchamp** also states the following difficulty for the value to customer analysis:

> *"What we first were trying to put on the customer value [… was] the value, for example in numbers. […] But these are very difficult, because what does one mean? What does three mean? If you say […] the customer value for this idea is three, and I look [at] something else and I decide it has a customer value four. Are they in the same scale? Then we would have to define on a very detailed level what one means, what two means. So I think it is the best […] to, in a way, look that somehow in a bigger scale, no value, yes value, maybe value. But of course there are overlappings. [laughs]"*

Similarly his colleague, the director for innovation concept development, is also skeptic about the validity of estimates that come in the disguise of too sophisticatedly calculated numbers:

> *"I do not believe very much in, for example, that type of methods that you give different measures, you have lots of questions and then you have numbers from zero to ten and then you calculate and get a result, for example 67. What does it mean for you? So […] of course they help you in decision making, but you cannot make decisions directly with those things. It is always kind of intelligence and intelligent decision supported by industry knowledge and information. […] For example if you think about new business opportunity, there might be a kind of barrier that it has to be big enough. That is still easy to say, meaning that if it is not big enough, then it is not worth the activities. […]* ***There have been different models, computer aided or then huge criteria and different values and even different weights of parameters; and the more it becomes mathematical in the model, the more you miss the point, because in a way those models expect that you have facts and then you begin to calculate. And then you, in a way, forget that they weren't facts.****"*

Thus the explained paradox is that the more sophisticated a model is, the more it misses the point in pre-development in the opinion of the interviewed managers. The sophistication conceals the imminent uncertainty coming with the estimates on which the analysis is based.

4.3 Kandinsky

4.3.1 Introduction to the case

According to the interviewed managers, one of the highest quality criteria of Kandinsky is the reliability of its products. However, through a global cost competition the value of the product for the customer is another major criterion, along with elevated flexibility to meet customer demands. Many of their development efforts focus on custom-designed versions of the main products. Another big part is

R&D which is in line with the R&D activities of the main customers. Only a small amount of R&D effort goes into radically new technology and product developments. While the mainstream new product development projects are very customer oriented and are composed mostly of application engineering, this study looks at some more radical innovations that are more technology driven.

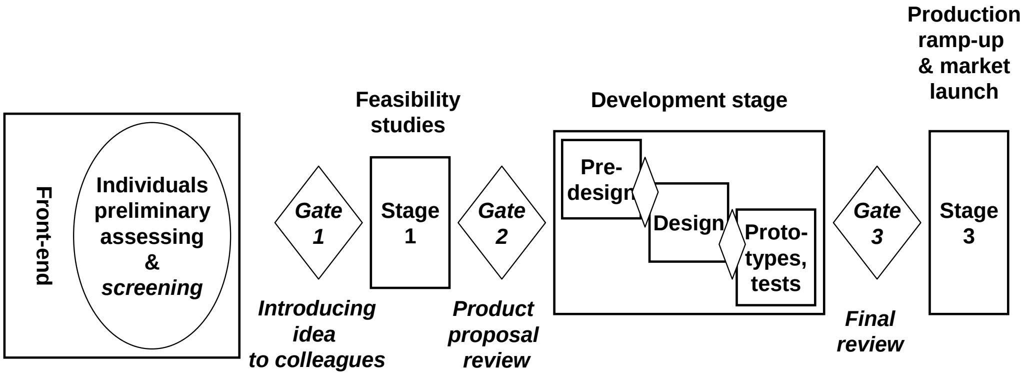

Figure 75: Constructed Stage Gate model of Kandinsky

Kandinsky has three product development centers, each in another continent. Even though Kandinsky has an execution sequence for its incremental product development process, they are not using an explicit Stage-Gate approach to manage their radical development efforts. However, for the studied cases, a stage-gate was constructed by the researcher for this thesis, which is shown in Figure 75. In the front-end, individual employees are looking for new ideas and are screening the environment. The different ideas are assessed by each individual on their own. The first real gate is to present the idea to colleagues for feedback. The company internal discussion might lead to recognition by senior management that will allow and fund preliminary feasibility studies. After an idea passes this assessment, an idea is discussed further and different cost estimations and cost development calculations are made to evaluate the potential of new ideas. The company uses a mix of parametric and analogous cost estimations for deducting prices for incremental innovations or new designs in pre-development. The parameters relate usually to the functionality of the product under study.

Kandinsky's innovation style is classified as **technology driven**, due to its focus on technological improvements in products and manufacturing processes (see 3.6.2). Kandinsky's idea initiative steams to the largest extend from **institutional idea search and development** (see 3.6.3). Regarding the funnel type, Kandinsky is clearly using a **few big bets** approach (see 3.6.4). Furthermore, Kandinsky is classified as a **medium-tech** company in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5), as the used technologies are state of the art, but limited in scope.

4.3.2 The cost information analysis process of Kandinsky

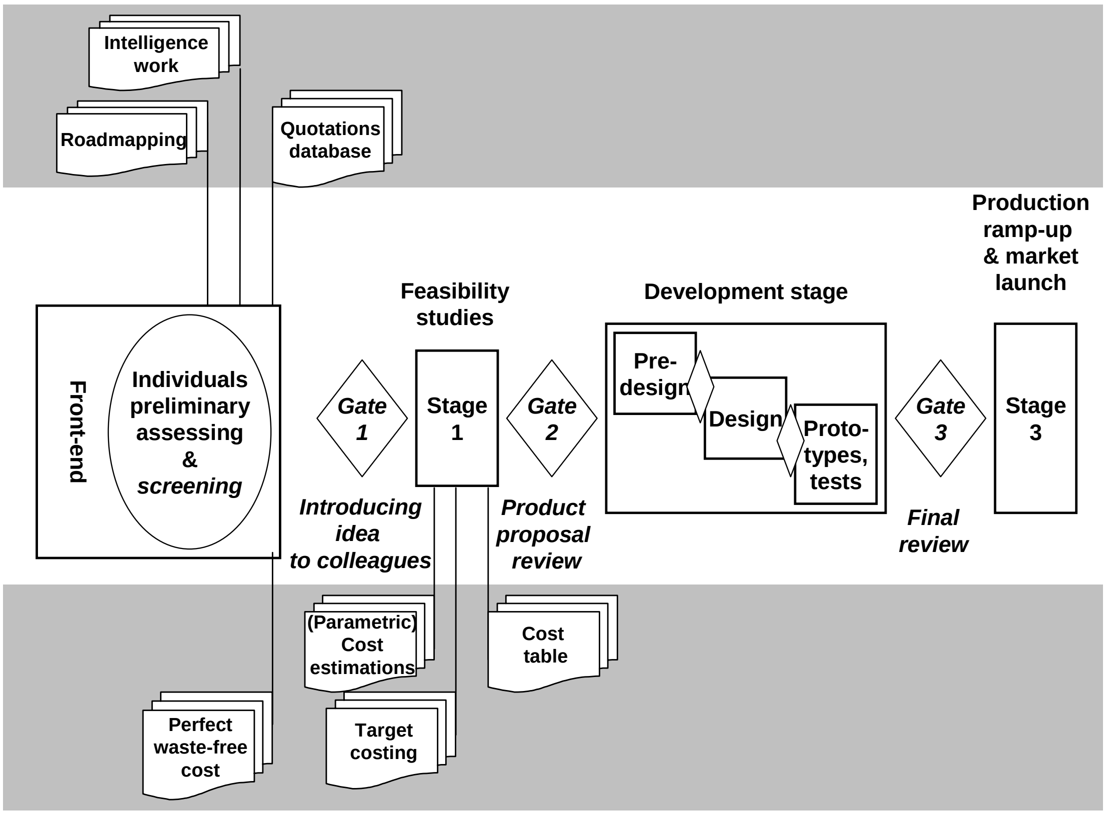

Figure 76: First time tool use of Kandinsky

In the front end Kandinsky uses **intelligence work** and **roadmapping**. The intelligence work is centered on technologies and other information gathered by employees. The roadmapping routines also include cost information. With this information, employees at Kandinsky try to pick technology alternatives that they think are likely to have the lowest costs for their new product developments. Through this they identify new technology alternatives to drive the costs of their products down. Some cost considerations in the front end are based on a quotations database, which can be seen as a **cost database**. Additionally to the quotations database, Kandinsky has an information system for component and material costs in another cost database. This is a system of different cost tables which the employees can access through their intranet. In this cost table, price information about purchased materials and components is stored. Furthermore a senior manager for new technology development is using perfect waste-free cost calculations, which can be seen as a kind of **cost estimations**. This analysis is done, so that he can judge the theoretical minimum of costs to fulfill a function. Once an idea is further evaluated, the studied company uses parametric cost estimations and **target costing** 'inspired' analysis together with cost tables, before a new product development idea is reviewed by management in the rear of pre-development.

Intelligence work	Unspecific	General	**Front**
Roadmapping	Unspecific	General	**Front**
Scorecard use	Specific	General	**-**
Uncertainty management	Specific	General	**-**
Cost dynamics analysis	Unspecific	Cost focused	**-**
Cost database use	Unspecific	Cost focused	**Front**
Cost modeling and estimation	Specific	Cost focused	**Front**
Target costing efforts	Specific	Cost focused	**Rear**
Value analysis work	Specific	Cost focused	**-**

Figure 77: Kandinsky's normalized tools use in pre-development

After the normalization of the stage gate model according to the scheme presented in Figure 64, one can see the different tools and their first time use at Kandinsky in Figure 77. It is important to notice that the stage-gate model of Kandinsky has only the front end and one additional stage before development start. According to the definition in 3.5.2, the stage before development start is counted as the rear end stage of pre-development.

4.3.3 The role of cost information within the found tools

In the front end of innovation Kandinsky uses technological intelligence and scouting done by engineers informing themselves about new product developments in the industry. **The first analysis** is driven through personal interest and discussions with colleagues, but **focuses mostly on technological parameters and less on costs**. However, **later** during the preliminary assessment the idea is discussed further and **different cost estimations and cost development calculations are made to evaluate the potential of new ideas**. When it comes to the evaluation of technologies new to the company, the technology development of Kandinsky makes a cost trade-off evaluation with experts in the front-end. Sometimes suppliers are involved and their opinion towards cost trade-offs is taken into account. A senior manager for new technology development at Kandinsky has developed a product cost calculation that could be labeled 'perfect waste-free' cost analysis. These are calculations about the theoretical minimum of costs to fulfill a function.

Roadmapping is used for technology management in the front end at Kandinsky. **For its roadmapping efforts the company tries to anticipate the 'cost roadmaps' of the customer, i.e. how much is the customer willing to pay in the future for a certain functionality.** There is a clear connection to target costing, as the company later uses the generated information for target costing calculations together with these cost roadmaps.

In the rear pre-development Kandinsky starts using a mix of parametric and analogous cost estimations for deducting prices for incremental innovations or new designs. The parameters relate usually to the functionality of the product under study. For radical innovations, the cost modeling of new technologies is made when the need for it is seen. In that case mostly parametric cost estimations are made.

The company uses **cost driver analysis** during pre-development to investigate the cost structure and actual costs of their products and purchased components.

Furthermore, **Kandinsky starts target costing with interdisciplinary teams in the first stage after the front-end.** With a certain target profit in mind the managers add the costs and targeted profit margins in their feasibility studies. In the case that the targeted profit margins cannot be realized, developments are started to improve the cost situation.

Additionally Kandinsky starts using cost databases from the front end on that are maintained to reduce the uncertainty connected to innovations. This can either be a general purchasing cost database or a personally updated quotations database. The information gathered in this quotations database is also used for roadmapping purposes through trend extrapolation.

Summarizing, one can say that there are two reflective and distinct roles of cost information:

Firstly, the company wants to find out the feasible market price for its innovations. Together with the cost roadmapping the company uses the gathered information for a light version of target costing calculations. However, managers at Kandinsky lack a specific cost goal provided by their customer, but the company does not want to develop solutions that are too expensive. Thus Kandinsky tries to anticipate the 'cost roadmaps' of (B2B) customers.

Secondly, Kandinsky's focus of cost analysis is to evaluate purchasing costs and to find innovative ways to achieve requested functionalities with some new method or way that turns out to be cheaper or more efficient than before. The role of cost information is to provide the background for this search of a better alternative.

4.3.4 Radical vs. incremental innovations

The interviewed chief design engineer of **Kandinsky** states the following on how he does the cost estimations for incremental developments in an application engineering style at Kandinsky:

> *"My way to work is […to] write the block diagram of the whole […special system component] and […] I have experience [for] several blocks and I roughly know what the block costs. […] Sometimes I must write the semantic diagram, when the solution is very new; and I know the price of the components; I get them from our key books material system. And sometimes it*

is very difficult to know what will the price of the components be in the future. And I discuss with our material guys and we try to calculate it and […take into consideration the] dollar level and so on. It is quite complicated."

Thus, at Kandinsky the cost estimation for application engineering works well for known components, but is more difficult for new ones.

When starting developments for a customer, the time is so pressing that no time for cost evaluation remains and the approach for the solution should be already decided as an interviewed project and key account manager from **Kandinsky** states:

"[Our] customer's developing schedule is that tight that […] everything should be more or less clear. You cannot [take] too big risks during the product development, because the schedule is one of the most critical issues at that time, during that the customer is also doing the product development […] in system level and we are trying to support their schedule. There you cannot do much [of] any new testing. Only some minor issues to be decided, but the basic ideas are fixed. […] And that must be cost effective from the schedule point of view and also something can be done there, but mainly the basic ideas are fixed in the front end technology thinking."

The Vice president new technology development of **Kandinsky** sees it similar that time to market is the most important and thus proven solutions are preferred. However, cost reduction programs including more experimental solutions could be launched later:

"Sometimes […] the customer has really a pressure to go to market. So they do it in the way it works, and even if there is good ideas how it could be done better, you just don't do it and risk the program. […There have been cases where] very soon after the first project has been launched, then after that another cost reduction project is already starting with little bit more resources to think how it should have been done based on the experiences on these first guys."

The interviewed project and key account manager of **Kandinsky** also further states that required design changes hinder a better cost management during the application engineering:

"That is one of the biggest challenges […], when [our] customer is doing their product development at the same time as we are, they are doing it at a system level and we are doing it from our unit level. And the customer realizes [that] some changes [are] needed to the specifications and we need to start again and we do not have possibly time enough to do all the optimization from the costing point of view. […] And the challenges come from fluctuating specification and trying to keep up the schedule. Costing, cost structure is more or less based on this front end thinking and technology development and

then in the pre-design phases, when you fix the basic ideas […] And then the next option comes only after the first revision has been released to production and you can start developing more cost effective products based on the next specification."

4.3.5 Need and challenges of pre-development cost analysis

The following quote is from an interviewed project and key account manager from Kandinsky:

> *"From the volume point of view then sometimes it is also good see the volumes first and then, if that particular product has gone [to be] a huge or big volume product then you can start the optimization product development a bit later, but if only 20 % of our projects goes to production and if only 20 % of those 20 % are big volume products, then it is not too cost effective to use all the resources for all products, but that can be focused better on those critical products, if we have seen that okay, now this seems to be successful product, […] the future is promising and then we should start redesign and cost reduction, optimization developing project pretty soon after the first revision has been ramped up to the production."*

This quote is about not spending too much effort on early cost optimization, as only roughly 4% of the development projects are actually going to be sold in large quantities. Similar is the view of the interviewed Vice president new technology development at Kandinsky:

> *"I think there is possibility to reduce costs [… after market launch]. That is my feeling, because […] in real projects there is always so many compromises and you want to be on the safe side because of the schedule and this kind of things."*

Thus the reality for cost optimization seems to be that often it is not practicable as there are other constraints that are valued more important. A company could deliberately intend to save unnecessary effort.

However, this loss of cost optimization can be significant as this additional quote from the Vice president new technology development shows:

> *"I mean, if you think that you just make a conservative design and you are [in a] little bit [of] hurry and you do it like that and then if you think that you really do it how [it would be cost optimized] and use all the methods to get the costs down, I think that you can [achieve up to] 20 to 30 % [cost savings]."*

This significant loss of cost optimization could be one factor leading to a failure of a new product development idea on the market.

Additionally, wrong cost estimations based on feelings can happen in the view of the Vice president new technology development at Kandinsky:

> *"There is potential how the things go that now we say that okay, we have to increase […the performance of a product]. And you think no no no, it costs, but then actually in reality actually, when there is a really-must for engineers to do something, like there is some regulations […], then suddenly whoops. When it's a must, it goes and the cost is not changing so much. So I don't say that the people are lazy or somehow, but they are not just prioritized to do these things, before it is really a must."*

Summarizing, one can say that challenges for the cost analysis during pre-development are that developments are not cost optimized as other points are seen more important by the designer and that many new product developments do not succeed on the market.

4.3.6 Need of pre-development cost analysis for technology selection

Kandinsky experiences high uncertainties in respect to the final chosen production method in the front-end for radical new innovations. Hand in hand with that goes the uncertainty of future product costs, as they are dependent on the used production method. This is not the case for incremental innovations. In this case the used technology is not changed and the installed production equipment base is used. The interviewed Vice president of new technology development at Kandinsky prefers flexible technologies that can produce the new product development at a low cost. However, this would require a higher initial investment:

> *"I think the way to go is that the system has to be upgradable, so easy to start with low CapEx and then when you have the revenues, then you invest a little bit more, but I think it is an open question."*

When it comes to the evaluation of new-to-company technologies, the technology development of company Kandinsky makes a cost trade-off analysis in the front-end. The Vice president of new technology development at Kandinsky then analyses the perfect waste-free cost. He further explains:

> *"I think that then you need also […to] risk a little bit […], maybe do some investment. […] I am sketching […] these new technologies […]. Actually this [special technology] is very cheap, but investments for this production line, the development, it is […] quite expensive actually […]; so you always end up with this dilemma that this is now how to save the cost where we are. Then you need to invest a little bit."*

Thus he sees potentials for new, low cost technologies. However, these technologies require an upfront investment. This is one point where the cost analysis during pre-development should help communication and decision making.

4.4 Lichtenstein

4.4.1 Introduction to the case

Lichtenstein is a company that focuses on venturing. Lichtenstein takes up ideas that can come from internal or external sources. These ideas can be brought externally to the company or they can be strategic developments. These developments start from special focal points, e.g. a crossing point of two technologies or markets. The approach described by the managing director of the venturing unit reminds the researcher of the tactic taken by the innovation approach TRIZ. TRIZ is an acronym for a theory of inventive problem solving (in Russian: Teoriya Resheniya Izobretatelskikh Zadatch) and means that certain principles are systematically used to find new product or process innovations (Brostow, 2006). The company is also generating business ideas based on mega trends in society. They are analyzing these trends and start business development projects based on these findings to uncover possibilities and limitations of new business ideas. Similar the company uses different key concepts and market trends that are evaluated to find out how that could result in a business idea. The result of this analysis in the front end is which segment to enter and how to proceed. After that, the case company is searching for an entrepreneur and launches the idea as an operative project. Once the team leader is appointed, he can decide independently how to use his budget, e.g. whether or not to outsource some development work or not.

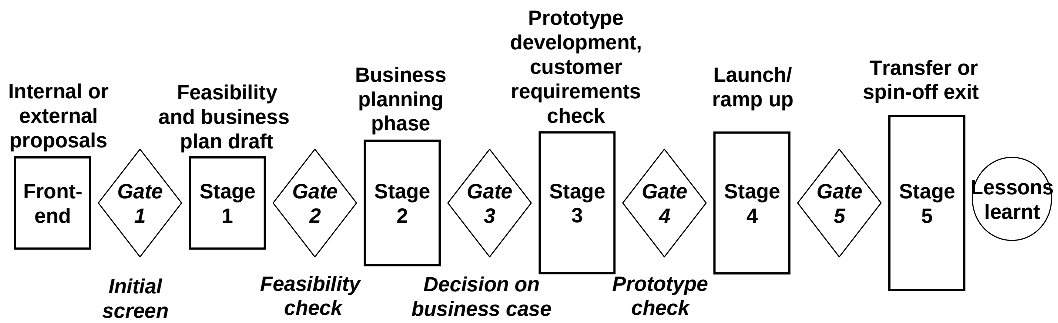

Figure 78: Stage gate model of Lichtenstein

Lichtenstein's stage gate model differs significantly from the one found in conventional, non-venture companies as the stage gate model ends with an exit as soon as the first (alpha) customer is found. After that the idea is transferred to another business unit or it is spun-off, either by selling it completely or establishing a joint-venture. The company focuses on ideas that have a very high potential, i.e. a high total available market (TAM) estimation for the future.

In the middle of pre-development a feasibility study is conducted and a business plan draft made. The rough ideas from the front end are investigated further and crafted into the business plan draft. In this case the company already computes the first 'rough' cost estimates. The middle of pre-development has been described as taking around three to six months. The rear of pre-development comprises business planning.

Here the first cost and revenue estimates are elaborated and refined. This stage has been described as typically lasting six to eight months. In the third stage development starts and a prototype is usually developed. This prototype is then used to check the solution against the customer requirements and make alterations. This stage has been described as typically lasting around six months. The fourth stage is the launch or ramp-up phase and lasts usually between six and eight months. After this stage there is a final review before the venturing company exits the development.

To exploit these ideas, several small teams are working on different topics. It is seen as important to have frequent reviews for their work. These are conducted monthly and named operations reviews. Additionally, there are also more strategic decisions made in longer time intervals, e.g. every ten months, where the new budgeting and planning is made for the next longer time interval. The milestones of a project are also discussed during these strategic decision making sessions. In the operations reviews, the different business ideas are evaluated and their position in the stage gate is checked. These reviews are on an operative level, i.e. how the product is running according to the budgeted plan. If it is seen that a project will not fulfill certain milestones in the near term, it can also happen that the project is terminated after an operational review. However, usually the go / no-go decisions, whether to proceed on a project or not are made in the strategic decision making sessions.

Additionally, Lichtenstein uses templates in the middle of pre-development to be more effective, according to a senior manager in charge of the business development. They try to ‘recycle’ as much as possible in order to avoid rework and learn from past experience. These templates are used for the information collection about the different innovation ideas.

Lichtenstein is classified as **market driven** company (see 3.6.2) due to its focus on marketing, new sales channels and customers to achieve large market capturing innovations. Due to its venturing approach the company focuses on routine, strategic new product development idea generation and thus shows an **institutional idea search and development** initiative (see 3.6.3). Lichtenstein is classified as using a **few big bets** funnel type (see 3.6.4). Lichtenstein is classified as a **high-tech** company in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5).

4.4.2 The cost information analysis process of Lichtenstein

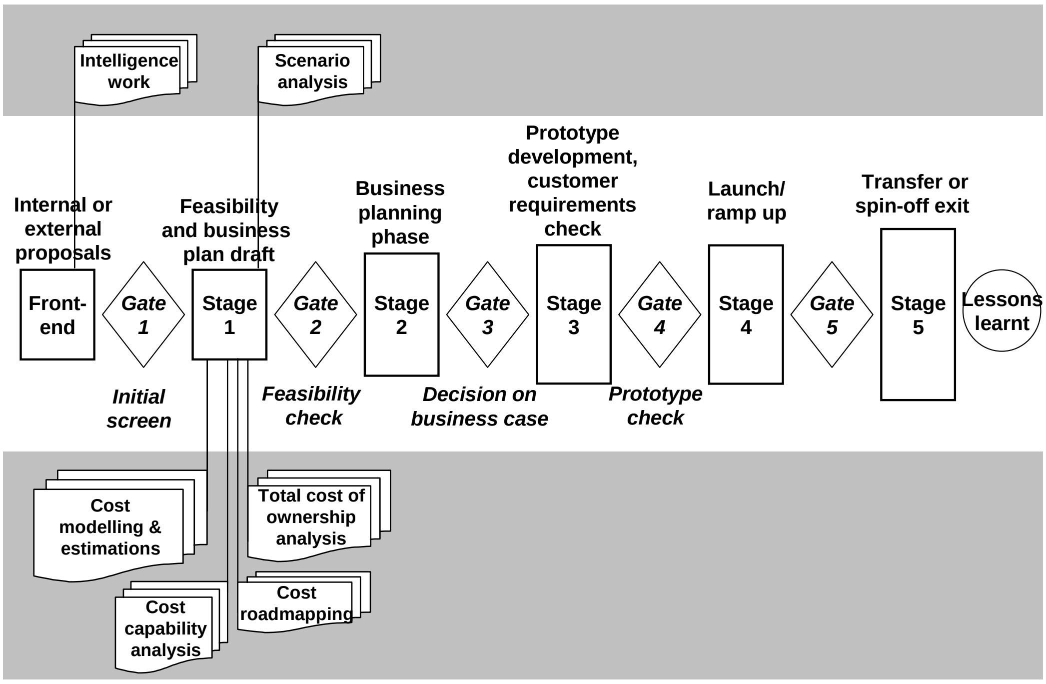

Figure 79: First time tool use of Lichtenstein

In the front end Lichtenstein is using **intelligence work** focused on business matters to evaluate its ideas with a high total available market (TAM). Once an idea passes the first screen it is exposed to several tools. In the first stage after the front end (stage 1), a feasibility study is conducted and a business plan draft made. In this phase the company already models and computes the first **cost estimates** with parametric and analogous methods and models life cycle costs. Additionally to this cost estimation, **roadmapping** is done that also includes cost figures. Furthermore, Lichtenstein is evaluating the **dynamics of costs** through a cost capability analysis. The **value for customers** is also investigated through a total cost of ownership analysis. This analysis is enriched by scenarios as an **uncertainty management** tool and later also by some use of triple point estimates. The intensity of the analysis with these tools is increased the further an idea proceeds.

Intelligence work	Unspecific	General	**Front**
Roadmapping	Unspecific	General	**Middle**
Scorecard use	Specific	General	**-**
Uncertainty management	Specific	General	**Middle**
Cost dynamics analysis	Unspecific	Cost focused	**Middle**
Cost database use	Unspecific	Cost focused	**-**
Cost modeling and estimation	Specific	Cost focused	**Middle**
Target costing efforts	Specific	Cost focused	**-**
Value analysis work	Specific	Cost focused	**Middle**

Figure 80: Lichtenstein's normalized tools use in pre-development

After the normalization of the stage gate model according to the scheme presented in Figure 64, one can see the different tools and their first time use at Lichtenstein in Figure 80. A big step up in tool use can be seen between front end and middle of pre-development.

4.4.3 The role of cost information within the found tools

In the front end Lichtenstein is carrying out intelligence work. However, the focus is centered not on costs, but rather on the potential market value of an innovation. It is only in the middle of pre-development that cost analyses start. Then Lichtenstein starts using cost roadmapping in order to meet the need of the target market. The managing director of Lichtenstein sees it as important that the cost trends of new ideas are taken into account especially in pre-development. He warns that if the cost development is not taken into account the new ideas might be rejected by the market quite soon.

Lichtenstein starts estimating and modeling costs in the middle of pre-development. It does so with the help of parametric and analogous methods and models life cycle costs. However, during project execution, the costing efforts are focused more on a variance analysis of cost budgets for the development tasks than on life cycle costs of the found solution. As the managing director explained, in the short run the budgeted costs are not to be exceeded, even though the project costs are unimportant in the long run. What matters in the long run are turnover goals and cost benefits for the customer.

Together with most other tools, Lichtenstein also starts analyzing the dynamics of costs. Lichtenstein's cost roadmapping in the middle of pre-development aims at meeting the need of the target market. Similar like the roadmapping effort, analyzing the dynamics of costs is done to develop ideas that are (cost) competitive on the market. In the view of the managing director of Lichtenstein it is important to be cost aware and take cost erosion into account. If the future cost development is not taken into account, managers could get a rude awakening when trying to market an innovative idea. As can be seen in Figure 79, Lichtenstein also uses many other cost estimation or costing tools. Thus the worry of the company of not developing past the market is encountered by analyzing the costs of new product developments.

Lichtenstein uses value analysis in the middle of pre-development and in later stages the value for customers is investigated. With this approach, cost benefits for the customer are seen as the most important in the long run for innovation evaluation. This and turnover goals are seen as vital to the overall success of the new product development. Lichtenstein is working on one to two strategic topics per year. These are the anchoring points for new product development ideas, which are then checked upon for potential of success. Two of these potentials for success are related to cost issues. The first potential checked is if the company itself can get a cost leadership position in a market. This cost leadership can be significant in corporate success, e.g.

in rising markets in emerging countries. Additionally Lichtenstein checks whether the new idea can offer a significant cost benefit to the client. The company looks for cost related potentials for their clients. I.e. a new product development that increases the productivity of the client, so that the client will get cost benefits through deploying the new product development.

Lichtenstein starts using uncertainty management tools in the middle of pre-development in the form of scenarios. These scenarios contain triple point estimates – the best, the worst and the most likely case. The intensity of the analysis with these tools is increased the further an idea proceeds and can also include cost analysis.

Summarizing, one can say that Lichtenstein starts analyzing costs with several tools from the first stage after the front end on. The role of cost information is elevated as costs are seen as crucial to meet the need of the target market and cost analyses should be taken into account from the early stages of innovation on.

4.4.4 Too low future product cost estimates

The senior manager in charge of the business development of **Lichtenstein** states an interesting issue. He has encountered the situation where early future product cost estimates seem usually too low to be compared to the final product cost of a new product development idea. In his view, costs are usually higher than expected as there are many indirect cost sources that are not taken into account in the beginning. He metaphorically described this as '**small rivers**'. These small rivers are small sources of different unexpected costs that then add up to large amount. One example is that an idea needs more marketing effort then estimated beforehand. Another example that he gave were patents and connected intellectual property rights which can cause unforeseen additional costs. **Regarding avoiding or better estimating these cost his opinion is that there are less 'unforeseen rivers' the better the management understands the cost implications of the business.** Thus in practice, cost analysis might be further optimized during innovation.

4.4.5 Pre-development cost analysis need vs. limited resources

The managing director of Lichtenstein explains that they had a business plan competition that was disestablished. Lichtenstein realized that it is actually 'complete nonsense' to have 800 business plans per year, if one needs to revise them all. Then the whole organization would be evaluating business plans, instead of establishing business. That would miss the point of venturing and new product developments in his view. Thus, quite naturally, there is a limited capacity for the cost analysis work during pre-development. Overall, the available analysis work capacity has to be used efficiently.

4.5 *Miro*

4.5.1 Introduction to the case

Miro is undergoing a strategic change from a product oriented to a customer solution oriented company. According to the interviewed head of R&D, the company is moving away from a mere industrial company that only supplies products, towards a supplier of added (industrial) services. Furthermore he stated that the main competitive advantages are seen as mostly connected to the delivery process and customer service, not the sold products themselves. The products are only the base for the operational excellence with which the company wants to succeed on the market.

The company used to focus R&D and start innovations with a view on products that the company could produce and then tried to find customers for these new product developments. However, the new approach starts with market inputs that guide the R&D efforts from now on. Thus, the customer base plays a very important role for new product developments during idea generation. This customer base has to be taken into account as there may be problems with the commercialization of ideas at later stages. The company has tried to create new products for totally new customer areas, but found it very difficult to convince customers to adapt the new product. Even though the performance and value of the new product was described as looking very good, the problem was that new customers did not know the company so far. Through this, the credibility at the customer interface was not built up and it was hard to get into business with the new products. New idea developments usually show a faster time to market when the customer base is known. On one hand it is easier to find a first customer that is prepared to test the new product development. However, on the other hand, a new product development with a 'waiting' customer comes faster to market, as there is what the interviewed head of one business unit described as 'some pressure' on R&D. Additionally, the search for a new customer and the above mentioned credibility challenge will also slow down the commercialization of a new product development idea. Thus one can say that the company finds it easier to enlarge its business through new products for already served markets.

Similar, the location of the customers throughout the world played an important role. If the sales channels and logistics were not built up, the company found it more difficult to market new ideas.

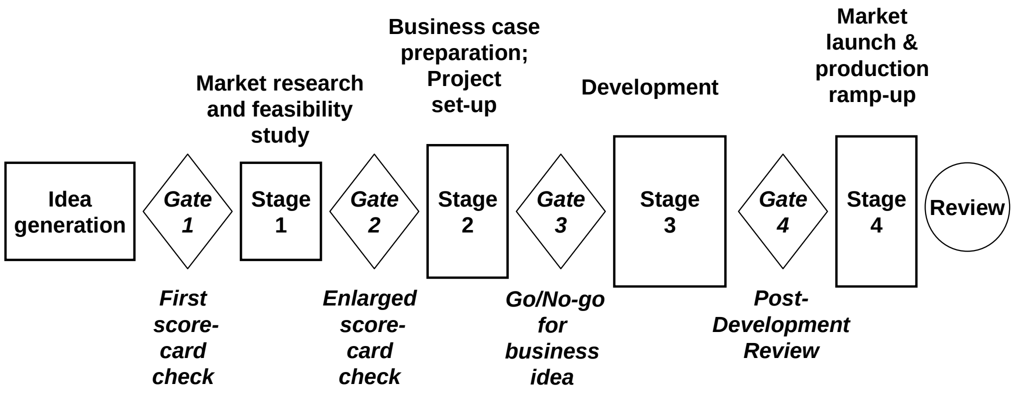

Figure 81: Stage gate model of Miro

Figure 81 shows the stage gate model of Miro. The interviewed head of one business unit explained that gate 1 can be passed without any larger R&D work in order to save money. The investment in the initial analysis before the first screen is kept intentionally low. The information gathered comes from literature or knowledge available inside of the company. The effort of research conducted on a business idea increases from gate to gate.

The second screen involves the same issues checked in the first one, with additional criteria to be checked. Furthermore, the interviewed managers stressed that there has to be a commitment of the key employees to the business idea. Additionally, an entrepreneurial spirit in the front end is seen as important. During the detailed investigation in the rear of pre-development (stage 2) the aim is to clear out the uncertainty connected to the business case, the targeted customer base and the business potential of the idea. As the interviewed head of one business unit explains further, the time to market is usually dependent on the products under consideration. If the new product development idea can use the existing infrastructure it will be potentially faster ramped-up as if the infrastructure and production facilities have to be built up first.

Even so, Miro wants to change itself to a more market focused company in the future, it is clearly a **technology driven** company at the time of research (see 3.6.2). Through its R&D, Miro also has an institutional idea search and development, yet its idea suggestion program is dominant. Most new product development ideas are evaluated through this scheme. Thus Miro's idea initiative is defined as **idea suggestion** based (see 3.6.3). The funnel type of Miro is classified as a **few big bets** approach (see 3.6.4). Miro focuses on continuous incremental to complex innovations. For Miro it is important to stay within the same sales channels, as it is otherwise too difficult to get new business of the ground. Due to the nature of its core business, Miro is classified as **medium-tech** company in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5).

4.5.2 The cost information analysis process of Miro

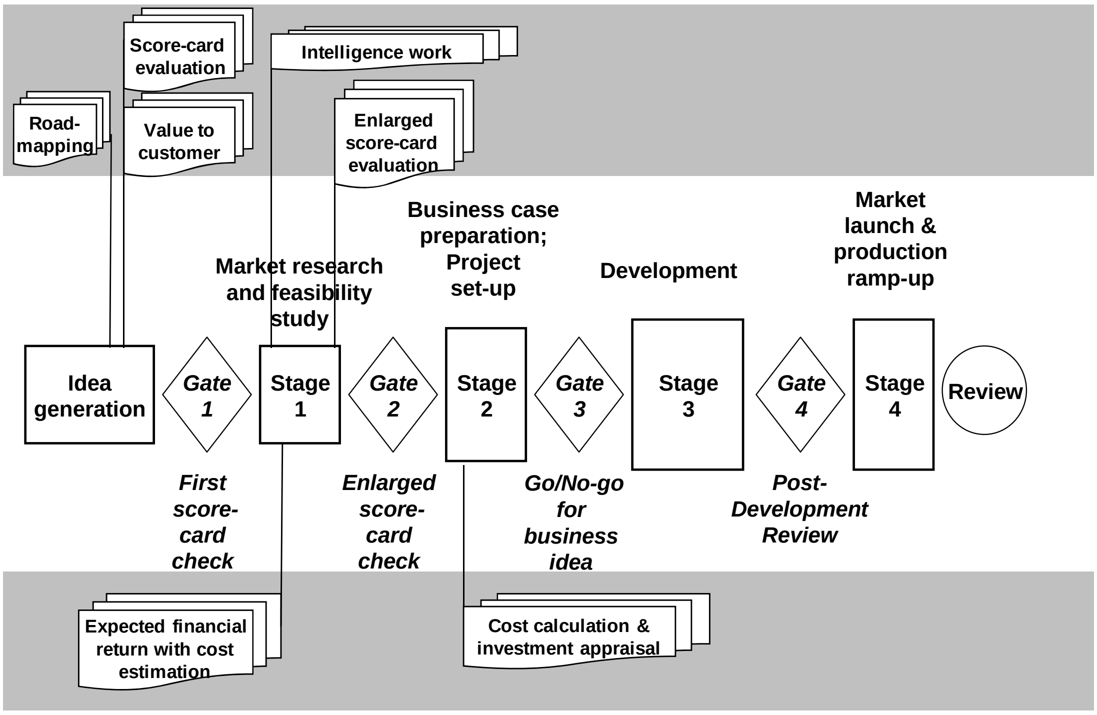

Figure 82: First time tool use of Miro

At the start of its innovation process, Miro uses **roadmapping** tools during its idea generation in the front end. At Miro, ideas that come out of the front end have to pass an initial test to be assessed further in the first stage. This is done with the help of a **scorecard**. This check is done by a project team dedicated to innovation, assisted by a network of experienced experts. Besides other aspects, Miro also embedded a **value analysis work** in this scorecard.

If the idea passes this test, it is analyzed in more detail with the help of **intelligence work**, e.g. by using a SWOT analysis to rate potential new ideas in the middle of pre-development. Miro is doing its first product **cost estimations** in the middle of pre-development. These are then carried out in more detail and with a higher sophistication in the rear pre-development.

Generally the interviewed head of the corporate R&D center pointed out that it is very important in the evaluation of new product ideas that there will be synergies between the newly proposed product idea and currently manufactured products.

Intelligence work	Unspecific	General	**Middle**
Roadmapping	Unspecific	General	**Front**
Scorecard use	Specific	General	**Front**
Uncertainty management	Specific	General	**-**
Cost dynamics analysis	Unspecific	Cost focused	**-**
Cost database use	Unspecific	Cost focused	**-**
Cost modeling and estimation	Specific	Cost focused	**Middle**
Target costing efforts	Specific	Cost focused	**-**
Value analysis work	Specific	Cost focused	**Front**

Figure 83: Miro's normalized tools use in pre-development

After the normalization of the stage gate model according to the scheme presented in Figure 64, one can see the different tools and their first time use at Miro in Figure 83.

4.5.3 The role of cost information within the found tools

The evaluation tool that dominates the early evaluation at Miro is the scorecard that the company employs to rate new product development ideas. This scorecard was developed to reflect the assessment criteria that Miro found useful and wants to be evaluated. They span a wide spectrum from strategic fit, over technological and marketing issues to the potential financial return and also cost issues.

In the middle of pre-development the product cost are estimated for the first time. Before that, only budget costs for the development are investigated. The cost estimations were described as simple, usually based on the bill of materials. Additionally logistic costs are included and the investment costs are estimated through analogical cost estimations from past experience. The further the new idea development proceeds, the more accurate the cost estimations. In cases of rather incremental developments that are launched to already served markets and potential customers, projects can be evaluated very fast with the help of investment appraisal methods, like the net present value and return of capital calculations. **Generally, the interviewed manager explained that whether or not life cycle costs are calculated for a customer solution depends on whether the customers are sensitive to prices or not.**

In support of the value analysis work, Miro checks whether a new product development idea generates a potential cost advantage for the customer and for how long a potential competitive advantage could be held against the competition.

Miro starts using **business intelligence** in the middle of pre-development. It depends on the business segment and research unit, how much these tools are used and whether cost issues are also included in this business intelligence analysis. The company also involves experienced managers, technology experts and other experienced experts for this analysis. Generally it is up to the project team that follows an idea to choose whether or not to use business intelligence and to which degree.

Similar, Miro starts using **roadmapping** in the front end, but leaves it up to the evaluating employees whether this tool is also used for analyzing cost developments.

4.5.4 Challenges of product cost analysis during pre-development

A challenge that Miro faces is that technical oriented employees are not doing cost estimations if they are not required to do them and if they do not get any support for it. It is difficult to get researchers to do cost estimates, as the managing director of a research center at Miro states:

> *"We started to do it so that we linked this business person; so we have had always somebody from business side involved in the project. So he or she was responsible to think that okay; that we have a viable business concept […] and [through that] also these cost calculations will be done. Because in practice these […researchers] don't make any cost calculations without somebody really pushing them to do that, and they probably not always have the ability to do the cost calculations in our […] industry. Because it is not easy to take into account how much the production is, raw material availability, and raw material cost and production cost and all the marketing and trades and also what […] the value of the product to the customers [is]."*

Thus it is very complicated for technical oriented employees to estimate the business potential because of uncertainties connected to volumes, costs and markets.

That is why case company Miro is involving business experts in new product development teams. These are either experienced managers involved in innovations or networks of experts. Both are used to evaluate ideas as the head of one business unit explains:

> *"We have also this kind of network where these ideas are evaluated […with] experienced persons. For example in our business area we have an R&D network through which all the ideas go, or the projects are discussed. And their expertise is used to check that okay, it is okay. But not very deeply […]. It's related partly to the process. And also the idea generation is related to that […]. We have […] an R&D coordinator who collects all the ideas and has a portfolio, project portfolio, and there […] we evaluate them as a whole and compare projects and that way try to use this experience to, or expertise to evaluate how good they are, what kind of project they are, do the right resource allocations, what are the probability of success, and so on."*

The evaluation has to be done by senior, knowledgeable and experienced persons. The involved business experts have a good understanding about the cost structure of present products. This should ensure that there are no hidden costs that are discovered in later stages of a new idea development. Furthermore, these experts have a higher understanding of what is the value of the product to the customers.

Thus the used tools have to be familiar to the employees to be used at all and correctly during pre-development. If employees are running into troubles of using the tools correctly, they are aided by more experienced colleagues in the case of Miro.

4.6 Van Gogh

4.6.1 Introduction to the case

Van Gogh employs five to ten managers that are dedicated to product management and that are specialists in a specific business field. Similar to these product managers, the case company has employees dedicated to project management in innovations. Together, the product and the project manager are guiding new product ideas through the innovation process. On one hand, the product managers provide the strategic direction and idea, what should be developed. On the other hand, the project managers are taking care of the operative development of innovations. This combination reminds of a matrix organization, where the product manager has more power in the front end and the process manager is more administrating the later development stages. The company employs one controller for production and R&D. He is the key contact person for product and process managers if they need any cost based information. The product managers that ‘own’ the ideas in the front end can contact several different departments in a very easy fashion, something that was described as “very low barriers between […] departments” by the controller of production and R&D.

Van Gogh has a structured stage gate process approach to manage the different stages during innovation. At every gate there is a cross-disciplinary meeting with people from manufacturing, software development, quality control, etc. During the meeting these participants have to agree that the idea fulfills the criteria for their respective field, so that the idea can move on into the next stage.

The case company Van Gogh distinguishes two different types of R&D projects:

- Product developments
- Platform developments

In the case of product developments several sources of innovations can be differentiated before the ideas are taken to the business opportunity check:

1. Industrial design upgrade and usability improvement
2. Market feedback
3. New technology
    - Own research & development
    - Ideas injected by business partners

They vary in scope and risk. The first type – industrial design changes – improves an existing product by changing the look and feel of a product and/or usability. The second type is coming from customers, trade partners, business partners and after-sales or similar contacts. Most innovations come from market impulses that are channeled through the product managers for their respective market and business field. These innovations are using known technology or show only incremental technology changes. However, new technology based new developments can also happen through two origins. New technology based innovation can firstly come from own R&D efforts or secondly from outside of the company. For the partnering solution they can be either only a rough sketch or a complete pre-engineered module that is then overtaken. The director of R&D explained that these kinds of innovations usually are caused by a technology push. Yet, there are also cases of radically new products coming from a market pull. This can be seen as the most risky innovation type as the company is facing uncertainties connected to the technology and the market at the same time.

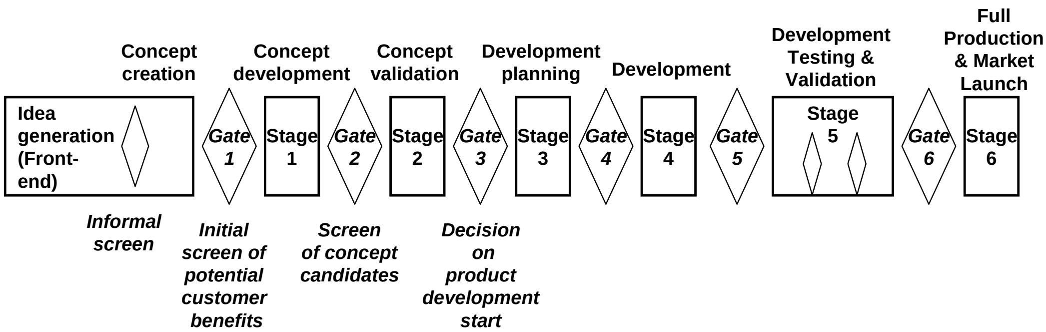

Figure 84: Stage gate model of Van Gogh

The stage gate model of Van Gogh is shown in Figure 84. The effort about research conducted on a business idea increases from gate to gate. For the first formal gate (gate 1) where ideas come out of, the front end product manager that is proposing the idea, has to sketch the idea and its potential on a one page overview. This analysis is still carried out mostly by managers in duty of product lines with the help of the marketing department. This changes in the middle of pre-development (stage 1); here, the new product idea is taken over by an innovation project manager. The effort undertaken rises for the evaluation happening in the second gate (gate 2). The initial one page overview is extended into a four page report that is more detailed, e.g. about the competition. In some cases market reports from external consultancies can be used. These reports are used to identify the competition in the targeted market. Furthermore, the total available market (TAM) is analyzed. For feasibility studies the company then estimates the market share it could acquire from this total available market.

The front end is a systematical idea generation process, using the technology push or market pull approach. However, there is no rigid system set up. This is perceived by the company as constraining creativity and killing ideas too early. Employees that have ideas would ideally drop an email to the director of R&D. There is no software based, e.g. intranet, solution dedicated especially to introducing and describing new ideas so far. The process is more based on informal contacts, e.g. water cooler discussions, or official reporting structures, e.g. emailing the director of R&D. Another idea generation possibility is the product managers of Van Gogh. They provide the strategic direction and idea of what should be developed.

When an idea goes further into the innovation funnel, it is then handed to project managers. These people are taking care of the operative development of innovations. They are deciding about make or buy decisions and whether to locate the production near the headquarters or in a low wage country. Furthermore they are also doing the cost management in early stages of innovation, by analyzing the cost structures of new product ideas, according to the planned bill of materials for this product. The controller for production and R&D is the key contact person for product and process managers if they need any cost based information.

At Van Gogh most innovations come from market impulses through Van Gogh's product managers and the company has a clear customer focus. Technology lead developments are possible. Thus the innovation style definition is that Van Gogh is a company with **market driven** innovation (see 3.6.2). However, this definition is not as clear-cut as in the other cases. Furthermore, Van Gogh is classified as a company showing an **institutional idea search and development** innovation initiative (see 3.6.3).

The director of R&D described the innovation process as turbulent and iterative up to gate 4, but then rather streamlined from stage 4 on. Thus the borderline between innovation styles can be seen as the decision at the product development start. The new product development funnel of the case company is shaped according to the **few big bets innovation funnel type**. This means that the company has a lot of ideas in the front end of innovation, gathered by product managers. However, the first screen eliminates many ideas right away. This process might not even be explicit, but tacit. The product manager discusses the ideas with his colleagues and evaluates himself whether or not to present the idea to the steering group in the first gate. Even though the controller for production and R&D pointed out cases where the new product developments were stopped at a very late stage, just before market launch, the tendency is towards an early screening.

Due to the nature of its business and its clear focus on core markets, Van Gogh is classified as **medium-tech** company in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5).

4.6.2 The cost information analysis process of Van Gogh

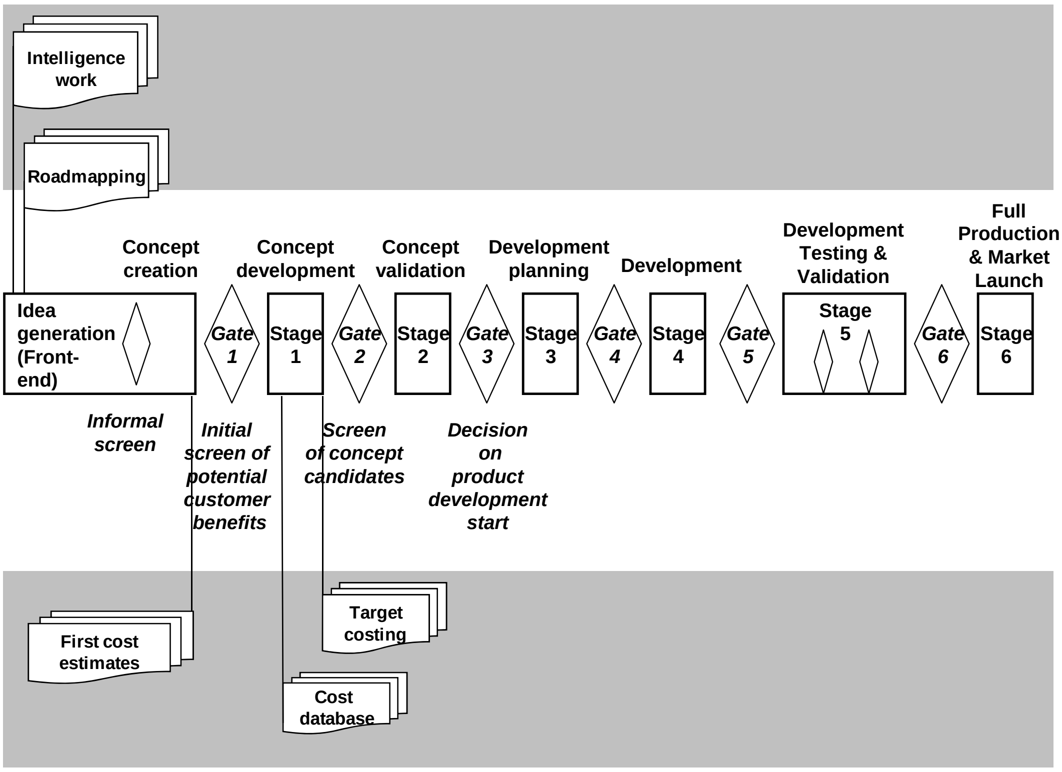

Figure 85: First time tool use of Van Gogh

As can be seen in Figure 85, Van Gogh uses **roadmapping** and **intelligence work** already in the front end to identify possible new product ideas. After a first implicit screen by the product manager, whether or not the idea could be interesting to the company, he will seek opinions from peers that have deeper expertise in different fields than him. The intelligence work is multifaceted. It is about new technologies, but also about potential market success. Additionally, Van Gogh is already making its first **cost estimates** in the front end. These are then deepened in the next phase. After the idea generation in the front end there is a first informal screen with discussions with experts. The product manager will use rule of thumb and first guesstimates that he then summarizes on one page and presents to a steering group that makes the first go/no-go decision. If an idea passes through this gate, the product manager passes the idea over to a project manager that will take the idea through the innovation process. In stage 1, Van Gogh is starting **target costing** efforts. Furthermore it uses **cost databases** in that phase. Concluding, one can say that the company is not using too many tools but the utilized tools are used already in very early phases for the first time.

Intelligence work	Unspecific	General	**Front**
Roadmapping	Unspecific	General	**Front**
Scorecard use	Specific	General	**-**
Uncertainty management	Specific	General	**-**
Cost dynamics analysis	Unspecific	Cost focused	**-**
Cost database use	Unspecific	Cost focused	**Middle**
Cost modeling and estimation	Specific	Cost focused	**Front**
Target costing efforts	Specific	Cost focused	**Middle**
Value analysis work	Specific	Cost focused	**-**

Figure 86: Van Gogh's normalized tools use in pre-development

After the normalization of the stage gate model according to the scheme presented in Figure 64, one can see the different tools and their first time use at Van Gogh in Figure 86.

4.6.3 The role of cost information within the found tools

Cost information plays a significant role in several tools that Van Gogh is using in pre-development phases. **Van Gogh starts cost modeling and estimation already in the front end, when the company computes the first financial estimations.** Already in that stage, a product manager is estimating potential sales deducted from market data. He uses cost information from running products, taken from cost databases that are connected to the company's ERP system. For that he is assisted by the controller of R&D and production, who can retrieve historical information on prices of purchased items of several years. **The cost modeling of the company is based on records of old products for the costs of raw materials, taken out of their ERP system.** The cost information is then used in parametric and analogous cost relationships for the early cost estimations of its new product ideas that are not radically new. The cost analysis is intensified when a new product development idea moves up the innovation process.

In the first stage after the front end Van Gogh starts using target costing efforts. The company uses a target costing approach by setting a recommended retail price already during pre-development and staying with costs and profit margin underneath this price target. However, when using this tool the company is not making an allowance for any cost erosion that could come from economies of scale and learning. With these (target) cost estimations the product manager is also computing first profitability calculations to estimate the potential profitability of the new product idea. This information is then used to screen the different new product development ideas.

Van Gogh starts using cost databases in the first stage after the front end. It uses cost tables that are built on top of information stored in their ERP system. In this way the company uses always the latest cost information in its cost estimations and calculations for the evaluation of new product ideas.

The innovation process of Van Gogh starts with intelligence work in the front end and uses expert opinion during pre-development. Even so, cost issues can be dealt with during this intelligence work; the analysis of cost information is not an explicit part of this intelligence work. Similar the roadmapping practices of Van Gogh do not normally include cost analysis.

There is a limited capacity for the cost analysis work during pre-development. E.g. it was pointed out that the analysis for cost dynamics is not done because of a limitation in manpower to do so. Even though there is a need of pre-development cost analysis, this analysis faces limited resources. Thus, the available work capacity has to be used efficiently overall.

4.6.4 Cost controller to facility cost analysis

Van Gogh is using a dedicated cost controller during innovation. This controller for R&D and production is the facilitator to use available cost information in pre-development. He computes historical trends of component costs and passes the information further in an aggregated way to other managers. The computation of the needed cost information is not straightforward. At the moment, the company has to first run a report in their ERP system and then import the figures to a spreadsheet where they are processed further. Other managers probably would not have the competences and time to transform the raw cost data into the needed information. Thus he can be seen as a connecting point and linking pin between the data and the project managers that use the data.

4.7 Warhol

4.7.1 Introduction to the case

Due to the nature of Warhol's business they are facing very long research developments. There might be research based on technologies that will result in products only in ten to 25 years ahead of time. In these kinds of research efforts, costs only play a role as budgets for research spending. The company is challenging the market leader on its main operating area and tries to actively gain more market share. It operates globally in all continents and the R&D activity is spread over several sites internationally.

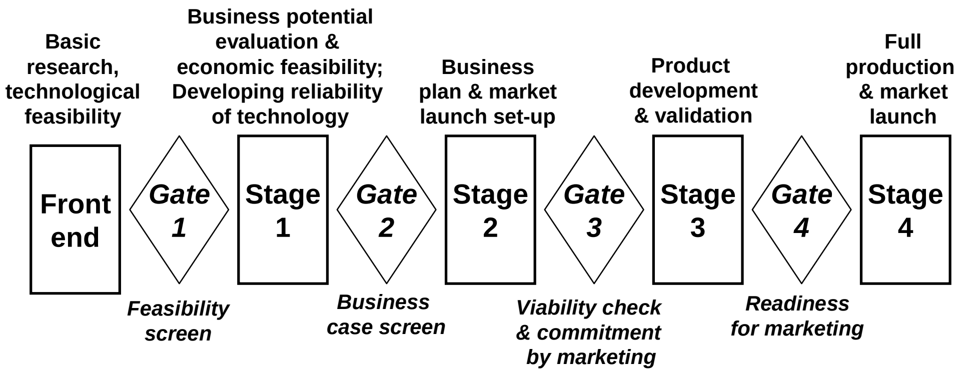

Figure 87: Stage Gate model of Warhol

In the view of the researcher the stage-gate process of case company Warhol can be divided in three different sections compromising of different stages. The first section contains the basic research and technological feasibility proofs that are done in the front end. The second section contains the stages one and two, where applied research and development efforts are undertaken to elaborate and refine the new product development ideas. The third section compromises the stages three and four, where new product development ideas are developed and made ready for market launch. During stage three the uncertainty of the final design is eliminated until the point where all specifications are frozen. In stage three the product design and integration is done. Furthermore, the manufacturability of the developed product is tested and first pilot production runs are made towards the end of stage three. Finally, in stage four the production is ramped-up and the product is launched on the market. The following analysis of this case focuses on the stages from front end to stage two.

Regarding basic research and technology transfer, the managing director of a corporate research center explains the technology transfer from basic research to the development departments as follows: Once the developers are brought into a project they are starting to absorb the technology issues, but also the market impulses at the same time. They also look at the market needs and address strategic issues. This is usually done with the help of technology roadmapping as a portfolio management tool. Thus the development teams need people with many different backgrounds in economics and technology. This is not the case in the research division, where employees usually have a strictly technical background. As the director of the research center describes it, the researchers working for him are not interested in the economic issues, but mostly in the technical feasibility and reliability of new product developments.

In the rest of pre-development, new product development ideas are elaborated and refined. In the middle of pre-development (stage 1) the business potential of a new product development idea is evaluated and the first base concepts and main product architectures are selected. As the interviewed chief design engineer explains, the technical feasibility of the new idea is checked after the technology transfer from the research center. In this time employees of both the research center and the development team are working together. With the basic knowledge available by them, the economic and technological feasibility of the new product development idea is also analyzed and evaluated. Before a new product development idea passes through to the next stage it is checked on a plethora of different criteria. These contain if the requirements of the new product development idea can be solved by the proposed technical solutions and whether they are economically feasible. Furthermore, scheduling, timing, resource spending and budgets are checked. At the same time the phases of the next stage are planned and prepared.

At the rear pre-development (stage 2) the uncertainty of the exploitation of a new product development idea or technology is further reduced. The business plan is set-up and the market launch planning is done on the marketing side. Furthermore, the resources and requirement specifications are analyzed and set.

Innovations at Warhol are generally **technology driven**, thus the innovation style is classified accordingly (see 3.6.2). Furthermore, Warhol's idea initiative is clearly rooted in **institutional idea search and development** (see 3.6.3), as innovations are based on scientific research and planned well ahead before market introduction. Warhol is clearly using a **survival of the fittest** funnel type for their innovations (see 3.6.4).

New product developments at Warhol are targeting radical to disruptive innovations. Incremental innovation can also happen, but they would by-pass the pre-development and go straight to concept or product development. Thus Warhol is classified as **high-tech to super high-tech** company in terms of the technological uncertainty according to Shenhar and Dvir (1996) (see 3.6.5).

4.7.2 The cost information analysis process of Warhol

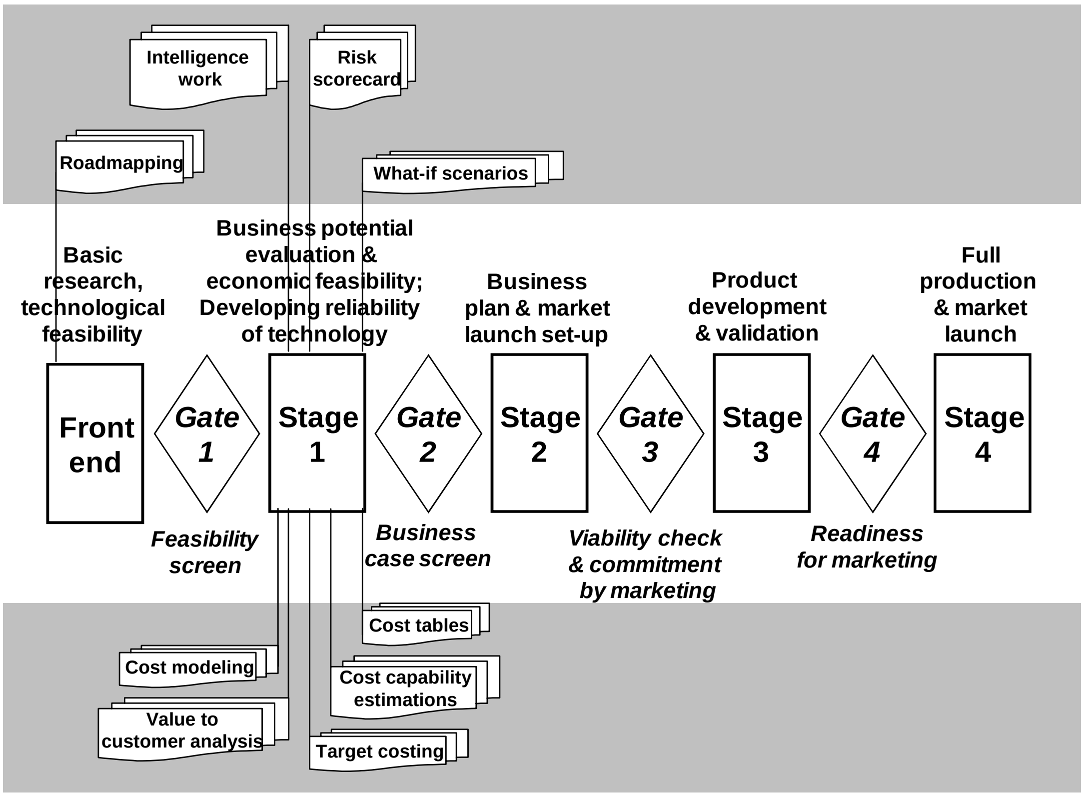

Figure 88: First time tool use of Warhol

During pre-development Warhol uses several human expertise based methods. In the front-end, Warhol uses **roadmapping** to manage its basic research. All other identified tools and methods are used in the middle of pre-development (stage 1) for the first time in an appreciable amount, as can be seen in Figure 88. In the middle of pre-development Warhol uses methods of **intelligence work** and expert judgments together with business intelligence. Furthermore, the company is using **scorecards** to evaluate risks at that stage. Additionally Warhol starts **modeling costs** and estimating the cost capability of new product developments. Through its cost capability estimations of new technologies Warhol **analyses cost dynamics**. This is also when Warhol starts using **target costing efforts** together with **value analysis work**. Warhol is also using **cost databases** and **uncertainty management** tools in the nature of what-if scenarios for its feasibility studies. This is done to check whether new product development ideas should be developed further. And last but not least, the company uses **cost databases** in the form of cost tables already in this early stage of innovation.

Intelligence work	Unspecific	General	**Middle**
Roadmapping	Unspecific	General	**Front**
Scorecard use	Specific	General	**Middle**
Uncertainty management	Specific	General	**Middle**
Cost dynamics analysis	Unspecific	Cost focused	**Middle**
Cost database use	Unspecific	Cost focused	**Middle**
Cost modeling and estimation	Specific	Cost focused	**Middle**
Target costing efforts	Specific	Cost focused	**Middle**
Value analysis work	Specific	Cost focused	**Middle**

Figure 89: Warhol's normalized tools use in pre-development

After the normalization of the stage gate model according to the scheme presented in Figure 64, one can see the different tools and their first time use at Warhol in Figure 89.

4.7.3 The role of cost information within the found tools

Warhol starts using is **roadmapping** in the front end. Once interesting technologies are identified, Warhol tracks these with forecasting and trend analysis. Furthermore, market trends are tracked with volume forecasts and scenarios to establish market development roadmaps.

Warhol starts using **intelligence work** in the middle of pre-development. The company is open to new ideas of all kinds, but cost information still plays a minor role.

Furthermore, Warhol is evaluating risks in a **scorecard** approach with a customized list with different risk items. The risks might include items like schedule risks, risk of cost overruns, resource risks and risks connected to intellectual property rights, but not specifically the (target) costs of a new product development once it is in production.

However, at the same time Warhol starts **modeling and estimating costs** in the middle of pre-development. Managers in Warhol are interested in which kind of cost level per functionality can be achieved with a specific technology or technology generation. They are doing this by analyzing the trade-off between costs and functionality. Whenever possible, managers at Warhol try to quantify the benefits, disadvantages and costs of different design solutions as accurately as possible. This cost modeling uses the information gathered during the basic research and later R&D activities. In pre-development, the cost modeling is seen as a preparation work to make the right basic technology choices. However, due to the uncertainties attached to it, it resembles cost scenario modeling; mapping out possible cost settings and developments. This cost modeling is usually not done by the development engineers themselves, but by the new technology purchasing unit that feeds the cost information to the development unit before technology selections are made.

The company often faces technology choices about which technology to integrate in a product under development. One parameter in this selection is the cost level that can be reached with a certain technology. In order to estimate how the costs connected to certain technologies will develop over time, **Warhol starts analyzing cost dynamics in the middle of pre-development.** Managers of Warhol try to estimate the cost potential of competing technologies for several years ahead through expert judgment by combining elements from roadmapping and target costing. The costs that are roadmapped, are the unit production cost connected to certain technologies. It is used in planning purposes in order to hit the targeted price level of the new product that is developed. This combined use of tools is described further in subsection 4.7.7.

Warhol starts using **target costing efforts** in the middle of pre-development. The first rough estimates are then made to analyze the feasibility of a solution. In this effort target costing is made down to component level. However, subsequently a gap analysis is performed to identify improvement possibilities. Once a proposal passes the feasibility analysis the target costing effort is stepped up to get as much information as possible for the development phase.

Additional to their target costing efforts, Warhol starts using **value analysis** from the middle of pre-development on. The analysis is less on costs, but rather whether the existing customer base would appreciate new product developments and how much the potential market price could be.

Warhol developed a **cost database** routine rooted in the concept of cost tables for new product development projects to determine and manage costs for several main components of the end product. The method uses a detailed model of price/cost drivers and a database of old price quotations for deriving price estimates of purchased components. The database is constantly updated by requesting virtual quotes from several suppliers with a purchasing scope of several years. The base for the detailed price/cost driver model was made through modeling the production process of the purchased component and thus recognizing the variable parameters affecting the production cost. Additionally, Warhol is also using cost databases and information for mechanical and electronic components and modules. In these cases the different component solutions show a certain degree of standardization and are comparable.

Warhol starts using **uncertainty management** tools from the middle of pre-development on. It is done with the help of volume forecasting and scenarios, but focuses less on costs. Additionally, Warhol is analyzing different alternatives through what-if scenarios from several angles to discuss different development options and their impact, e.g. on costs. In these scenarios, cost plays an important role. Besides the required functionality and other specifications, costs are one target that has to be balanced with the other ones.

When asked what the most problematic issues are in the front end, the interviewed chief design engineer working in Warhol answered that it is the **uncertainty about future cost evolvement**:

> *"Of course the prediction of the future; that is the most problematic. And actually it may impact to the decision-making quite a lot that at stage zero [if] people say that this is too expensive. And if you don't have the capability to predict how the cost will evolve, you may not get that proposal through. […] For people it is very difficult to […understand] on day zero that for example a product […] may ramp up after three years or four years from now, and they have to make [the] decision […whether this is] worth doing. […] For that it is difficult to find correct data."*

The estimation of the cost situation of a new product development can be a critical issue in decision making and has a predictive view on cost evolvement.

4.7.4 Cost pressure origins, challenges and need of cost awareness

The following quote from the senior new technology purchasing manager of Warhol shows his opinion that some pressure to design for costs is also essential if costs should be optimized:

> *"As long as cost isn't the pressure, then the design is never optimized for it. And that includes the supply base design as well."*

Regarding the importance of cost analysis in pre-development, the interviewed chief design engineer of Warhol explains:

> *"We could have three different examples. One is for example this kind of mainstream products. And there is a huge cost pressure from the [direct business customers] all the time, because of the competition. […] Then there is this […special new system development] example, that there is a market impulse and it comes through the different […special key technology] standards competing again. And there you need to be able to hit the price points that the other competing technologies can provide. Then this third example, which had, or would have big impact on the […customer's] OpEx and CapEx and implementation expenses, […] there we may have a little bit more room for the technology cost. But anyway, the cost awareness is there that we always have to compare with the competing solutions for that original […customer] problem. So […] you cannot survive without cost awareness."*

He also states that:

> *"It may in reality be so that depending on your awareness, you may choose, at the beginning you may choose a higher reference point, because you know that the slope will be or there may be some disruptions and it may be easy to change the technology later on. […] So it is not always the lowest reference point that should be targeted, but […] you have to think about the whole lifecycle. And this is quite hard for people to understand that the cheapest one is not the cheapest one in the long term."*

Thus there are several cost pressure origins. These are leading in the direction that, new product developments – besides certainly many other issues – should be cost optimized. Yet, what sounds logical and easy in theory can be problematic in real business life.

4.7.5 Effective technology selection is more important than efficient design

The following quotes show an interesting aspect in the appreciation of cost modeling and analysis in the pre-development. The first quote is from the interviewed new technology purchasing manager of Warhol:

> *"Cost data, […] it is very dynamic and it changes a lot. […] Especially in the case with technologies not on the shelf, there is no price for them. The only way to really get the cost information is by doing some kind of modeling work and estimations based on our know-how of the process and likely cost of such a future component. […] At later stages, when there is more information available and suppliers, they've got products, they've got a price tag for them, then all kinds of people will get the information from the suppliers."*

However, one would think that the cost modeling of potential new technologies and estimating the costs of 'such a future component' would lead to much work and effort going to the waste bin. This can be either because this technology is not finally chosen or because the new product development would later not sell in high volumes. So why is Warhol prepared to spend the effort of modeling the cost of new technologies? One possible explanation would be that Warhol could optimize the costs early in the development projects. However, this is not the case as the following quote of the interviewed chief design engineer from Warhol shows:

> *"But there may be also such cases that we just have to develop technology that we don't have. […] And that was only just such case that we looked what is technically feasible, and of course having in mind what is feasible from economic point of view as well. And we have developed the first generation of that solution. It may not be the cost-optimized, but the reason for that can be also that the specifications are not so settled yet, so that we […] expect that there will be also further development on that side. And that means that you cannot choose the cost optimum from the kind of device stand point of view."*

Thus the reality for cost optimization seems to be that often it is not practicable as there are other constraints that are valued more important. So it seems that the development often cannot be fully cost optimized for the first generation development at Warhol. Yet, why is Warhol prepared to spend the effort of modeling the cost of new technologies, but do not fully optimize the costs during the development stage before market launch? It seems that **cost modeling work has to be done for several alternative technologies before the concluding technology selection.** Even though much of it goes into the waste basket, the benefit of modeling the costs of new technologies in the pre-development is seen greater than the effort spent on it. When it comes to the development on the contrary, the cost optimization is left aside as other constraints are valued more important. However, if the new product development is successfully established at the market, cost redesigns will be made. Also the cost modeling before the technology selection will be rougher and more of an estimate of magnitude than a precise cost calculation.

This has to do with the lock-in effect that the technology selection brings with it as the quote of the interviewed chief design engineer from Warhol shows:

> *"This is the making point when the technology is selected to be designed into product, and this means that it is very hard to change it, because it costs resources, it costs time."*

On another occasion he states regarding the cost capability analysis of new technologies:

> *"Cost capability, yes, at each phase. […] Specifically it is [done] in this front end decision-making milestones. When you have in a way passed […the go-decision for development] or started the development, you don't follow that much, because you have chosen the technology and you are moving ahead. If you change your plan in between, you never get ready."*

So summarizing, one can say that an effective technology selection is felt more important than a cost efficient design straight for the first generation of a new developed innovation. Even though much of the analysis work done before the technology selection is useless after the technology decision; it is seen as a 'worth doing' effort by the above analyzed companies. They want to choose the right technology before lock-ins happen. For later detail design during the development phases, these lock-in effects seem not so extreme. These products get redesigned later on.

4.7.6 Roadmapping and trend analysis at Warhol

Warhol is doing extensive **technology roadmapping** in pre-development to manage their technology portfolio. The time frame for these roadmaps is around three years and more into the future. The input comes from research and intelligence work. It can originate from external or internal sources. This roadmapping is done for planning purposes and to identify areas that have to be further elaborated or where the development has to be accelerated as the interviewed chief design engineer explains:

> *"…in [an] ideal case, the outcome of the applied research projects or technology feasibility studies or technology intelligence, […] would provide information for our roadmap. Because […] unless there is total disruption in […a targeted market or] technology, […] the research results would create something into our roadmaps. Or we could identify from our roadmaps that for example for […a certain process or technology] need, we can say that we know how the world is evolving until three years from now. […] Then we would identify from our roadmaps that now we don't know what is going to happen [after that time period], so […the unit needs to] make some research on this and that area. That is how research is mapped into this technology […]. The whole thing is more or less technology management, and this is the technology roadmapping and architecture - reference architecture management."*

Furthermore they collect information from different sources and concentrate it into internal reports that are shared in the different departments of Warhol, as one chief design engineer points out:

> *"[For] technology roadmapping […Warhol uses] technology forecasting or technology trends analysis and such activities. […] We buy some analyst company reports and we do work by ourselves. […] When being in contact with our vendors and suppliers, […] we of course gather a lot of information, and every now and then we try to […] synthesize that information and create [an] understanding for us that where is the market or where is the industry going. […] Such activities [are] bundled in the strategic process, […which incorporates a] business environment outlook, or kind of prediction of the big trends or mega trends. And a lot of that kind of activities happen; so in various parts of the organization, whether it is in research or by ourselves [in development]."*

Thus Warhol is carrying out **forecasting and trend analysis** for interesting technologies. These activities span over both, technological and business matters. **Furthermore, managers at Warhol are doing a trend analysis to understand the dynamic development of the performance and cost of different technologies.** Similar, industry trends are analyzed. This information can then be used to compare technologies and to position the company compared to the competition. The company is analyzing the maturity of technologies to evaluate whether or not it would be better to invest into a new technology or remain with the conventional one for the next product generation as the interviewed chief design engineer explains:

> *"Actually we are doing some trend analysis […] and it feeds our understanding of the technology capability […], where the industry is moving,*

and it helps to […] position ourselves. This is then the key questions on technology trends that we try to understand. And it is about the investment, or the kind of traditional S curve that we need to know where are we; […] is the technology saturating or maturing, and when to invest to the new S curve, and always looking [at] the impact of the performance."

In the next step technology and market roadmaps are combined. The knowledge about new technology developments and the market trend and volume estimates are then brought together for further analysis of the new product development proposal case. In the case the further development of an important technology is uncertain, research projects to explore new technological possibilities are initiated. The findings of these projects are then used in further roadmapping and technology choice decisions. Similarly, the competences of suppliers are roadmapped and used in supplier selection as the chief design engineer further explains:

"There [are] still these technology maps and upward research projects and it brings significance into our business technology roadmaps. For that we need to have this kind of supporting functions, and it means doing technology intelligence, feasibility, technology specification evaluation, technology selection, and […] we are screening for other vendors. So technology selection and vendor selection [is] then based on our supply line management strategies; […] who are our recommended suppliers and what is our strategy regarding each specific area."

4.7.7 Combined use of tools

In subsection 4.7.3 the novel combination of tool elements is already mentioned. This subsection will look closer at this combination. On top of roadmapping and trend analysis at Warhol, the company has further developed these tools to include figures that are blurry in the beginning, but are to be refined during the R&D process as a senior new technology purchasing manager explains:

"If you're pitching a technology towards the […] release in three years' time, then you can say that roughly speaking it needs to come at this [cost] level. So it is still using target costing […] and it's more fuzzy, so not so sharp. The closer you get to the product launch, the more certain you can be about the target costing. But you still use some [estimates] for target costing in the early stages as well. You're using a rough guess, you're saying the price erosion […] will be roughly […X] % per year.[…] You can do […] a rough cut, then you have to structure your architecture and component choices such that it will meet that kind of very rigorous target. So I think there is this form of target costing as well before […development], but done with a more general understanding."

In the middle of pre-development, Warhol is using the approach of target cost that can be described as follows: Warhol uses estimates from cost roadmapping based on expert knowledge and compares these to target cost estimates. In the case that developments might take several years until production ramp-up, it is important for Warhol to know how the costs connected to certain technologies will develop over that time. The roadmapped costs are the unit production costs that can be achieved with a certain technology. In this early stage when the costs are still too high, the company estimates the future point on which it could start the development with traditional target costing. Like this, Warhol uses estimates and vague figures from cost roadmaps and experience curve effect to unite them over a time axis. For further discussion this novel tool use combination will be referred to as **directional costing** in this thesis.

Directional costing is described as a future cost analysis and tracking procedure performed before the start of specific new product development procedures, aiming to map costs and functionalities that are the base for later target costing when new product development programs are started.

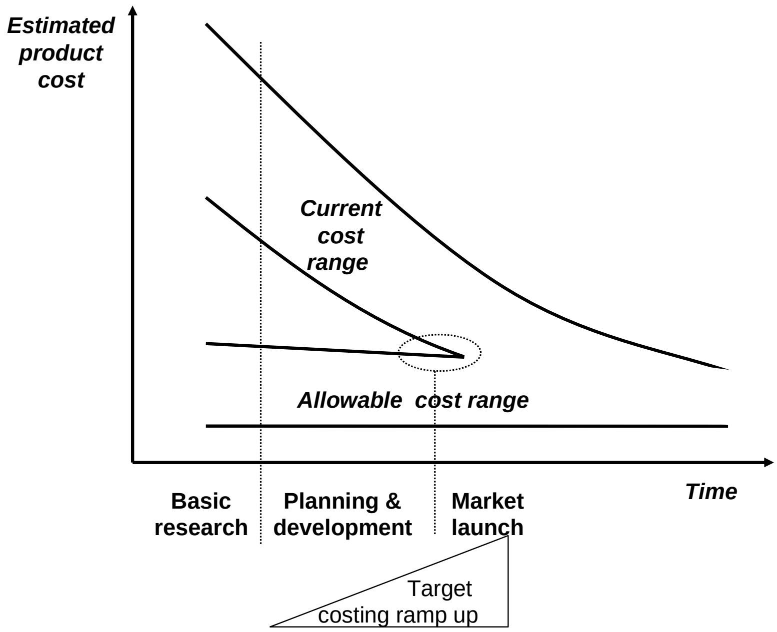

Figure 90: The concept of directional costing

A figurative outline of directional costing is shown in Figure 90. As stated above, Warhol is using a tool prior to target costing that is a fusion of several tools. This procedure contains elements of forecasting, trend analysis, roadmapping, cost estimation, cost capability analysis (analysis of cost dynamics over time) and target costing. Directional costing is done to understand the dynamic development of the performance and cost of different technologies and to be aware of future development possibilities several years before a development process (with target costing) is started.

Furthermore, one point is worth making a note of. In the ongoing debate in literature, of which functions target costing teams most commonly represent (see 2.5.4.2), the case study of Warhol indicates clearly that directional costing is carried out by engineering team members; however it is also supported by purchasing experts from the sourcing department.

5 Analysis of general and cost tool use

Next, an overview of how the different tools are used is given. This chapter presents an overview of the different tool usage in the case companies to manage early innovation. In the following of this chapter the use of tools found in the case companies will be described in more detail.

5.1 Intelligence work

5.1.1 Overview

- **Dali** uses information from a variety of sources, ranging from consulting reports to information stored internally in databases, enriched by expert opinion and judgment.
- Similarly, **Duchamp** is using business and technology intelligence and updates its information and estimations as soon as new information is available. Employees of Duchamp can find reports and business evaluations in the intranet and also receive support from experts.
- **Kandinsky** uses technological intelligence and scouting done by engineers in their field of interest, covering mostly technical aspects, but also economic ones.
- **Lichtenstein** uses intelligence work to support idea creation and evaluation, e.g. through analyzing how different market trends can lead to new business.
- **Miro** also uses business intelligence, but starts it in the middle of pre-development. For their business intelligence, Miro uses technology experts and experienced managers of the targeted business areas are involved.
- **Van Gogh** uses intelligence work that covers both sides: the technological and the business related. For the analysis of the potential market success the opinions of experts are used. In this way, more information about challenges connected to the new product idea is gathered.
- In the middle of pre-development **Warhol** uses technological and business intelligence work together with expert judgments from experienced employees or company external sources. The gained knowledge is usually stored in reports and roadmaps, which are then used for the analysis of new product developments.

5.1.2 Intelligence as a base that is readily available

Intelligence work can be used to map the environment of a company and is a base for the analysis during pre-development. Intelligence work is commonly started to be used in either front end or middle of pre-development as a base for the further work as a quote of the interviewed chief design engineer of **Warhol** shows:

"Business intelligence – yes, certainly that is the fundament. […] It is always there; needs to be always there. That is our main bread and butter."

He further explains:

"We do [use intelligence information], so we buy some analyst company reports and we do work by ourselves. […] When being in contact with our vendors and suppliers, […] we of course gather a lot of information, and every now and then we try to put it, kind of synthesize that information and create understanding for us that where is the market or where is the industry going."

The location of the intelligence work material can be spread several locations, as the director of concept development at **Duchamp** makes clear:

"We do have some type of business market intelligence. […] It is not exactly centralized, but there are not many places where that exist, and that information will be used, and of course here we do have some universities and other partners that provide some information that will be used, depending on the case and the part of organization."

His colleague, the director of the idea suggestion system, further clarifies:

"We have a separate unit, big unit, […and] in our intranet we have separate, if I call it pages, where they put [intelligence information]; they buy from several consultant companies reports on what is happening in the industry. Technical reports and evaluations and business evaluations and so on, […] We can use those, no problem. […] We can use that information, that is totally available for us."

However, the use of employees during pre-development depends on the need and desire to use it, as one head of a business unit of **Miro** explains:

"Of course it depends on the researcher too and this business person who is involved, if he uses [the] business intelligence available or not. But it is not so that you must utilize these tools."

5.1.3 Summary

All studied companies are using intelligence work in pre-development. Furthermore, four of the seven companies are using intelligence work in the front end of innovation; the other three start using it in the middle of pre-development. In five of the seven cases intelligence work is used together with expert opinion to judge new product development ideas and aspects connected to them. The companies are using information from a variety of sources. The information gathered is usually stored inside the organization, sometimes explicit, sometimes tacit. All companies use a balanced mix of business and technology intelligence. However two companies stand out: Kandinsky has a tendency to cover more technical issues through their scouting and Duchamp has a tendency to cover more business issues in their intelligence work.

5.2 Roadmapping

5.2.1 Overview

- **Kandinsky** creates cost roadmaps in order to anticipate the future value of different functionalities to their customers. These roadmaps are then used in the target cost considerations of Kandinsky.
- **Lichtenstein** also uses cost roadmapping in order to meet the needs of the target market. For this, the cost development of products and parts are analyzed in the middle of pre-development.
- **Miro** uses roadmapping to break its business and technology strategy down, to communicate it to their employees and guide developments. These roadmaps can be enriched by specific development targets set by the top management.
- **Van Gogh** uses strategic roadmapping for identifying possible new product ideas and to ensure that the developments are leading in the right direction.
- **Warhol** has the most sophisticated roadmapping practices. The company uses roadmapping to grasp, store and refine technological and market information over several years and uses this tool to manage their technology portfolio. In their roadmaps, employees of Warhol are carrying out trend analysis to understand the dynamic development of performance and cost of different technologies. These are compared to market data. If both are different, research efforts are conducted to bring the technology costs down to a feasible level. Warhol also uses roadmaps for volume forecasts, market development scenarios and early supplier involvement.

5.2.2 Benefits and limitations

Roadmapping work helps to develop in the right direction. One interviewed head of a business unit at **Miro** says that:

> *"But normally we even may have a project and R&D persons nominated to do that kind of […] roadmapping, and we have defined the targets that you have to innovate something for this. So this comes from strategy."*

There is also a connection with the intelligence work described above as the quote from the interviewed chief design engineer of **Warhol** shows:

> *"And in ideal case, the outcome of the applied research projects or technology feasibility studies or technology intelligence […] would provide information for our roadmap."*

Furthermore, the interviewed cost controller for R&D and production of **Van Gogh** says that the company would like to increase the use of roadmaps for further strategic alignment:

> *"Yeah, we have those road-mappings to those new areas. […] But I think that we are even today […doing] this ad hoc thinking. […] But I think that we have to do better those plans and also roadmaps […]. We think that our current situation is not the best. But we think that these things run okay, but we think that if we want to improve we have to do things different way."*

The above examples show that roadmapping often has a connection with strategy work and intelligence work. During pre-development a multitude of different aspects can be roadmapped. The vice president for new technology development at **Kandinsky** describes also a technical performance roadmap:

> *"And then for each of these functions; […] each of them is making this kind of […] functional roadmap. Where we are and where they want to go."*

Additionally, he translates these technical performance roadmaps into business value:

> *"Myself, I am thinking and calculating, and euros and dollars are here in these roadmaps."*

And he uses it to communicate possible future developments:

> *"I have [a] sort of technology roadmap, where I have the market price for the products […]. Market price, [… versus two industry specific and important performance indicators], these are the three parameters. [The roadmap shows…] what is now the market level, and then […] some kind of price erosion. [… It shows that] we won't survive in five years, because we are already in some cases over the sort of bulk market price, but then I show that with these innovations, with different kind of technology steps, like optimized components, optimized topologies and optimized packaging, with these steps actually we can go on to make that 40 % gross margin in this business. This is sort of the message I have been giving."*

The interviewed senior new technology purchasing manager at **Warhol** states:

> *"Normally the way the programs would start is that there is some kind of roadmapping that goes on to begin with. […] We've got some roadmapping activity, and this is typically done at a system level and there might [be] some product level done as well, in case some feasibility study is starting. […] And you can [have] some various small research projects, which are contributing to the information for roadmapping."*

However, he adds:

> *"[In] theory […] you should see a nice cascade of roadmapping proposals, then dribbling feasibility studies and once they are looking good, then the*

project will start. [However,] quite often what happens is that there is a very short phase for the feasibility study. There is a certain impulse to make something and the guys, more or less, they're very quick in starting a project. And during the program specification stage it stretches and stretches, because there is a lot of iterations as they try and find their way to what is really going to work."

If employees or management want 'things to get started' there can be a challenge with starting innovations fast - maybe too early. Thus it is a challenge in the front-end of innovation that employees might be rushing in the beginning without doing enough pre-work to research and evaluate a new product development idea and its requirements. In this case, it can come to the above described iterations that could be avoided or streamlined with prior roadmapping.

A limitation described by the vice president for new technology development of **Kandinsky** is that roadmaps have a limited use for them as it is impossible to know innovation made outside of the company in advance:

"It's very hard to get some not invented here kind of stuff in the roadmaps."

So there can be a limited use for roadmaps that deal with new product developments outside of the company.

5.2.3 Summary

All case companies but Dali and Duchamp are using roadmapping as a tool in the front or middle of pre-development. Information is collected from different sources and concentrated into internal reports that are shared throughout the company. As developments might take several years until market launch, it is important to know how the costs connected to certain technologies will develop over that time. A very important aspect is the communication of and the alignment with strategy for innovation projects. However, roadmapping works best with data from within the company or publicly available information (e.g. from conferences). It is less suited to anticipate the development of other companies, as the base-information is hardly available.

5.3 Scorecard use

5.3.1 Overview

- **Dali** uses scorecards to evaluate risks of new technologies by checking a list of critical issues. Dali's scorecard is a template that is continuously filled and which includes a scoring. First a light version of this risk scorecard is used, but once a development proceeds further, the risk study is made in depth.
- **Duchamp** checks several points for new product developments with scorecards as templates. However, the interviewed managers at Duchamp point out that the scoring and ranking of ideas can be problematic. For that

qualitative judgment and an extended framework, grasping the big picture, has to be used.

- **Miro** has centered its entire evaluation of new product ideas on a scorecard scheme. With this scorecard it checks several dimensions of strategic fit, technology and business feasibility. Miro sees this scorecard as an efficient way to screen new product development ideas as it can be used very lightly and is suitable to very early phases of innovations.
- **Warhol** is using a scorecard to evaluate its risks. It is used from the first stage after the front end on and is custom-made for each project from a general list with different risk items.

5.3.2 On the analysis and screening done by submitting employees themselves

Ideas submitted by employees at **Miro** are screened by the submitting employees themselves as the first gate. This gate is described as very light. The reason for this kind of screening is the motivational factor for the employees, rather than a strict screening as the director of one research center describes it:

> *"This first stage is also quite light, not very heavy. […] People are satisfied when they have to do something with their ideas, […] when they create [an] idea; they get that kind of feedback that they can play around a little; because it motivates them to make more ideas. And then here the next stage, […] these are still proposals here, not accepted projects into our system. So that acid test only, how we call it, it only tells that okay, we have the potential, but we don't know yet how economical it is. So and afterwards we decide that okay, you can put here maybe one week's work to test something. Make first tests, so is it viable or not. Then during that second stage here, […] we ask everybody to make sales estimates, we ask them to make calculations, like net present value calculations, […] you get also gross margin there. And then we can evaluate […whether it has the potential to be] profitable for the business."*

5.3.3 Scorecards as decision aid

The screening system of new product development ideas at Miro is heavily based on a scorecard system in the front and middle of pre-development. However, this in only a standardized first step as the director of one research center at **Miro** further explains:

> *"Okay, but the idea is much more than only to check that. We are saying that always before we start anything, we have to have two items. One is the business commitment, meaning that they are involved and they have evaluated what kind of value creation possibilities we have in the new idea, so meaning that they must say that okay, there should be some kind of customer value for the new idea, otherwise we don't proceed here."*

Similarly, an interviewed director in charge of the concept development at **Duchamp** says that scorecards can only support decision making, but are limited in their power to analyze new product development ideas in pre-development:

> *"I don't believe very much in for example that type of methods that you give different measures, you have lots of questions and then you have numbers from zero to ten and then you calculate and get a result, for example 67; what does it mean for you. […] Of course they help you in decision making, but you cannot making decisions directly with those things."*

5.3.4 Summary

Four out of seven case companies are using scorecards in pre-development. Out of that, two companies (Dali and Warhol) use scorecards mostly for risk analysis to check the feasibility of new product developments. On the contrary, two other companies (Duchamp and Miro) use scorecards mostly to evaluate the strategic alignment and the attractiveness of new proposals. Thus the case companies using scorecards do so mostly to get a fast and refined overview of the attractiveness of the new proposal or its attached risks. It is important that the scoring dimensions are well described and understood similarly by all employees working with the scorecard. The earliest use of scorecards found is to employ them directly for the evaluation of new product development ideas in the front end (Miro). Already at this stage Miro gathers and analyzes cost information.

The above comments on the limitations (see 5.3.3) show that a scorecard itself is only a way to embed other analysis during pre-development. It standardizes the way of analysis, but the scoring itself can lead to ambiguity and thus should not be used mechanically.

5.4 Uncertainty management

5.4.1 Overview

- **Dali** is using triple point estimates and Monte Carlo simulations for the analysis of their new product developments. Managers estimate the most likely, the worst and best case for several critical points and run a simulation to analyze the distribution of likely outcomes.
- **Duchamp** uses scenarios to analyze possible business strategies and to facilitate discussions during innovation phases.
- **Lichtenstein** analyzes different scenarios to check the plausibility of their estimates. These scenarios contain also triple point estimates for the best, the worst and the most likely case.
- **Warhol** uses what-if scenarios to discuss different development alternatives. Regarding uncertainties attached to costs of new product developments the

new technology purchasing unit of Warhol models cost scenarios, mapping out possible cost settings and improvements. Furthermore, the company uses volume forecasting and scenario thinking during their analysis of factors affecting demand.

5.4.2 Benefits and limitations

Uncertainty management tools facilitate to get a grip on data. The challenge of the uncertainty is present at **Lichtenstein**, as generally the uncertainty connected to venturing is one challenge that management faces in the front end of innovations. The senior manager in charge of the business development of the venturing unit worries the uncertainty coming from marketing and distribution channels and he sees that even more important than the uncertainty of costs. Thus it seems logical that they are using uncertainty management tools. Yet, e.g. **Kandinsky** points out volume uncertainty as a challenge in pre-development, but does not use uncertainty management tools.

The director of concept development at **Duchamp** talks about its use and benefit to get a broader understanding in pre-development:

> *"You can have different scenarios about its possible success, there may be parameters that, about which, [like the] the time schedule, you are not [sure], and you have several options, and then of course about the revenue and volumes […] Then it could be one way to create the most likely case, and then use that as a basic assumption when you're doing those calculations and studies, but still have other alternatives."*

Similarly, the interviewed chief design engineer of **Warhol** points out:

> *"We may do alternative scenarios for the business case, so the kind of target and […] medium, high and low; and that is in a way giving some indication that where are we between the decision making points and – but in a way not crunching such statistical numbers."*

Thus the benefit is to evaluate several alternatives when the pre-development analysis incorporates too much uncertainty on several aspects. Furthermore, it is described as a tool without too much 'number crunching', so it is seen as a rather qualitative tool.

5.4.3 Summary

Four out of the seven case companies are using tools that can be grouped as uncertainty management tools. According to the case studies, uncertainty management is not used in the first screen. That means that the companies are not concerned towards reducing the uncertainty with these tools in the front-end, but only in the later pre-development when it comes to more detailed analysis and decision making.

Three companies are using scenarios to evaluate business directions to facilitate discussions during innovation phases and as a part of their corporate planning. The companies using scenarios in pre-development find that the use of scenarios facilitates new product developments and their decision making centered on them. Two companies are using triple point estimates. Furthermore one company is using Monte Carlo simulation additionally.

5.5 Cost modeling and estimation

5.5.1 Overview

- **Dali** is using parametric cost estimation in its costing templates together with either manually entered cost data or cost data out of their ERP system. The cost modeling follows the production of their products, but also uses batch and product level costs from activity based costing.
- **Kandinsky** uses a mix of parametric and analogous cost estimations for deducting prices for new product developments. If the development is a radical innovation the case company uses mostly parametric cost estimations. Furthermore, Kandinsky uses cost driver analysis to investigate the cost structure and actual costs of their products and purchased components. 'Perfect waste-free' product cost calculations, which compute the theoretical minimum of costs to fulfill a function, are sometimes done in the front end.
- **Lichtenstein** uses parametric and analogous cost estimation in the middle of pre-development. The company derives component and usual technical development costs from the experience with old products. Furthermore, it also models life cycle costs and cost benefits for customers in the middle of pre-development.
- **Miro** uses parametric cost estimations in the middle of pre-development that are refined later. The first cost estimations are usually based on the planned bill of materials of a new product development, but also include product level costs. In some cases Miro also models life cycle costs.
- **Van Gogh** computes the first cost estimations already in the evaluation for the first gate. These are later refined using parametric and analogous cost relationships. For the estimation of unit level costs, the company uses ERP system records of old products. Additionally, batch and product level costs are evaluated.
- **Warhol** starts using cost modeling in the middle of pre-development using information gathered during basic research and later R&D activities. The cost modeling task is carried out by specialists rather than employees specialized in technology.

5.5.2 Incremental vs. radical innovations

Modeling and estimation facilitate assessment and quantification of cost issues. The following two quotes are about estimating costs of product parts that are integrated into new product developments. The first one is from the interviewed chief design engineer of **Warhol**, explaining the cost estimation in an example of a rather radical innovation on a system level:

> *"In the first example, the research project has gone into the component level: so they […] analyzed the main components; so their existing or […] known component prices, and also [did a] kind of gap analysis that where are the areas we should improve. […] And that analysis is bringing some knowledge that where […] is the […] cost of the component. So in this case it has been quite precise. Of course I'm certain these […were] not analyzing so thoroughly the performance requirements or not going into very details, but kind of rough analysis of the requirements. But okay, that has been the outcome of the research project. And now the research results have been brought into the business unit, […] and there we try to make [the] next step of the preciseness of the performance analysis. […] as deep and as precise as possible, [...] and depending on the knowledge of the people as well."*

The second quote is from the interviewed vice president of new technology development at **Kandinsky**. It is about the cost estimation in an example of a rather incremental innovation on a component level as supplier for larger clients:

> *"The plan is that everything is clear and we have a goal here, but of course there is a lot of quotations, you have to give a quotation and then you don't know if it's accepted or not. Sometimes it happens that we give a quotation and then [the] customer rejects us and then we thought that we were too expensive and the case is lost, but then after six months they come back and actually the other calculated it wrong and could not do it or the solution did not work. So this fuzzy front end is a little bit difficult for technical people like myself."*

Thus the challenge of estimating costs is complex in both cases for radical system level developments and incremental innovations system component level developments. However, the quotes also show that there is a difference in the targeted preciseness of the cost estimation. The first cost analysis for the radical innovation is described as a 'rough analysis' that gives indications for further analysis work in additional, following research projects. Yet, the cost analysis for the incremental innovation can also be rather difficult, as it has to be more precise and is done in an application engineering style.

5.5.3 Types, aims and benefits

The modeling of costs can have quite diverse aims. The managing director of **Lichtenstein** is saying that they are modeling business cases and the cost of their solution. Furthermore, they are modeling what the costs of today's solution is and what the savings potentials are, especially to evaluate and show the cost benefit for the customer, once he is using their product.

In long running technology developments, cost modeling in the ideal case and other cases can be significantly different as the interviewed senior new technology purchasing manager of **Warhol** explains:

> *"So then when we come to the front end, innovations and […that] kind of things, then it suits the formal mainstream [research and development] process pretty well, because we were trying a lot of the cost modeling and things into these early research phases, and then they would help us make the right decisions in roadmapping stage and then give some good information for the feasibility studies, for the cost estimations, for the product when they put all the elements together. It suits that kind of courses. It doesn't suit so much this other process here, which might be pulling new technologies [in an ad hoc way…] and there really isn't any time to do modeling for this. The best you can do [in the ad hoc way] is just try to negotiate it in the traditional style and hope for the best price. But [that] isn't a structure that encourages this kind of early modeling work."*

He further adds to the benefit of cost modeling in pre-development:

> *"So I think that if we can encourage this kind of early [technology cost] modeling approach and get some validity there and even use that to help these guys in the informal process to chose the right thing from the beginning and find, [and] de-risk it, then it will help their approach as well as the formal approach. So I am quite convinced that the more information […] we get about the right choices for the technology cost progression, the more flexible it is going to be to the business."*

Thus, there are different approaches to cost modeling in pre-development. Furthermore, the cost modeling in pre-development is seen as beneficial for long running, well structured development projects that prepare information on different alternative technologies in advance, so that this information is then available before the final technology selection and lock-in.

Furthermore the interviewed senior new technology purchasing manager of **Warhol** states:

> *"So if […] information is fed through, it is already modeled and worked out and then we go back to this formal process, where it comes through from the beginning, then the engineers do not need to go and bargain about it, because*

> *they've got good cost models that they can do their decision making about their designs in an early stage in a correct way, and there is less hassle around the price levels."*

He continues:

> *"And also because the suppliers are being cooperating earlier, everybody understands what the real price is, in terms of the end result. So the negotiation pressure is reduced and there is more genuine cooperation."*

Thus additional to the benefits of having information before technology selection, cost modeling in pre-development makes client-suppliers cooperation easier.

As Van Gogh has rather incremental innovations they can use cost data from old production records as a base for their modeling. The interviewed cost controller for R&D and production of **Van Gogh** describes their production cost modeling as follows:

> *"Our cost modeling works in our SAP system, because there is our old history data, because SAP, they have so huge those databases. They can take like three years in history data, and then we can think that how those material costs are going. And then we have one very good tool in SAP, it is like this cost estimate, what gives right way the what is our costs. And there is very nicely, there is information [about…] material cost in that product and labor cost and also in overhead costs. Normally our project managers, the like a lot of that SAP information."*

He continues about the cost modeling and estimation method:

> *"We use this activity-based costing, and we use that […] when we direct our costs. And this activity-based costing is, it is something like four years old. Before that we used only this percent allocation. Then the percent allocation, it is not good in all the cases."*

5.5.4 Intellectual property rights make cost modeling difficult for new innovations

The following quote from the senior new technology purchasing manager of **Warhol** has to be seen in the light of a system innovation that also requires integrating several new technologies from suppliers into the new product development:

> *"So then when you're doing your cost modeling, there is always some kind of estimation about the value of the performance aspect. So you find another line creeping in there, which is just generally called IP [(intellectual property)], which is know-how or trade secret or whatever of the company, which they are trying to put evaluation on. So then that gives a premium on their component over another similar but less well performing component. So that is a bit tricky. And there really is not any source for that data and the supplier will put*

their evaluation on it, but the market will determine the real value of that. If people buy it, then the suppliers will feel justified, that we put the right price tag. If no-one buys it, then they will understand it is not […] and they will have to drop it. It is difficult to get the real cost data for that kind of [new developments offered by suppliers].”

The quote of the senior new technology purchasing manager shows his struggle to estimate costs of system components that should be purchased from some supplier. What he labels as the add-on prices for intellectual property (IP) by suppliers is seen as a problem in cost estimation in pre-development.

5.5.5 Technology communality can override isolated cost modeling

“Then there is some things that we are now struggling with is that […] we try to look [at] communality, where it is rational. So it may be that one project chooses this technology and other chooses this. And […] somebody could say that there would be an even lower entry point with maybe better [cost development] curve. But it may be that if you choose this family of technology, in the long term the total cost is better than just making individual decisions on selecting the technology. So it also comes to this product family thinking that what is the technology base; […] would be better if it is more similar […] across the products and across product lines. It is like in [the] car industry that they are not designing the tire bolt each and every time for each product, they take those from standards. But still in our industry our engineers tend to invent their own bolts again and again.”

This quote from the interviewed chief design engineer of **Warhol** shows that technology communality might let you choose technology that is not the cheapest for one special case. Instead synergies in technology selection should be used as the standardization might not be used enough otherwise. However, this indicates that the overall cost optimization is looked for, not a sub-optimization of system parts that would lead to higher overall costs.

5.5.6 Freedom from cost restrictions in research

Another limitation of the early use of cost modeling in pre-development is mentioned by the interviewed chief design engineer of **Warhol**:

“It is maybe two-folded: that one is to research or search for the technical solution, and it maybe just technology driven. And then the other, related to decision-making, is to predict the cost, cost evolution or the cost of the technology. And maybe, in most of the cases we are not […] concentrating our research effort on that. It is more concentrated on the technical solution. But then, when going into the […business development] milestone phases, then we will get more the cost or the economical analysis there. And maybe that is

good and intentionally done so that new ideas can come up from research; and if those are not put down because of the expected cost or that kind of restrictions."

Thus there might be an intentional freedom from cost restrictions in research in order to allow more creativity. However, there will be a shift after basic research towards more cost interest as soon as a new product development idea becomes pre-development. When this happens, the cost modeling and estimation work is going up at Warhol.

5.5.7 Summary

All case companies except one (Duchamp) are using some kind of cost estimation or modeling in pre-development. One of the analyzed companies (Van Gogh) starts formulating its first cost models already in the front-end of innovation.

In the analyzed companies, the cost modeling is either fully or at least partly done by specialists. Furthermore, cost modeling in pre-development is sometimes enriched by also including other costs from a total cost of ownership perspective (Lichtenstein) or life cycle costs (Lichtenstein and Miro).

There is a difference between the analysis for incremental and radical innovations in the targeted preciseness of the cost estimation of future new product developments. The first has to be precise and is done in an application engineering style. The latter is described as a 'rough analysis' that gives indications for further analysis work and is used in technology selection. However, incremental innovations can also use cost data from old production records as a base for their modeling, a trait that radical innovations do not have.

The cost modeling in pre-development is seen as more beneficial for long running, well structured development projects that prepare information on different alternative technologies in advance, especially in front of technology selections.

However, cost modeling and estimation in pre-development can also have constraints. Uncertainties of future costs of processes can be a limitation. They can be a hindering point to cost modeling and estimation in pre-development as the case of Duchamp shows. Intellectual property rights can also make cost modeling difficult for new product developments. Cost modeling in pre-development can also be limited in use if there is a technology communality that has to be taken into account. In addition there might be an intentional freedom from cost restrictions in basic research to allow more creativity.

5.6 Target costing efforts

5.6.1 Overview

- **Dali** has incorporated a system of value analysis work, allowable costs, 'back-costing' and target profit calculations similar to the paradigm of target costing in the second stage after the front end. First the company analyses what the value of a solution is to their customer or to the end customer. From that the allowable market price is deducted. They then calculate the estimated manufacturing costs and add a profit margin. In a final step allowable costs and estimated costs (including the targeted profit margin) are compared to each other. If the targeted price is unlikely to be reached by the new solution, it has to be altered or it is dropped.

- **Kandinsky** tries to find out how much the customer is willing to pay in the future for this function. In the next step costs and targeted profit margins are added and compared to the allowable market price.
- **Van Gogh** has different end-customer price level for different products under development. During development and design the costs of a product are estimated and must stay below a target price minus a targeted profit margin.
- **Warhol** is using target costing efforts already in the middle of pre-development. The company investigates the acceptable market price for new product developments as early as possible with the help of market intelligence and/or market strategy. Warhol then uses cost roadmapping together with the analysis of cost dynamics which are compared to cost target estimates. If these estimated costs are too high Warhol uses gap analysis to identify improvement possibilities to align its development to the target costs. In some cases Warhol analyses which kind of cost level per functionality can be achieved with a specific technology or technology generation for planning and decision making. This information can then be transferred to different kinds of roadmaps of a company.

5.6.2 Benefits, limitations and connection to roadmapping

Target costing efforts help to develop for the market. The chief design engineer of **Warhol** gives details on a radical development example and how it was processed:

> *"For such products we know that what is the kind of price point or the price target of the end user market, so that what would be the retail price. Then from there we calculate backwards, what is the […gross] price [to the merchant or wholesaler], and backwards what is the price that we should hit. And actually it goes even further, because […] we know the component prices, so what is the component price of the vendors. And that is exactly what happens that we have analyzed the current state of the technology and calculated the cost. And for example in this case we have noted that we cannot hit the price point with the current technology. Then, the next step has been that we are considering that can we reduce some functionality, or can we somehow optimize the performance of the products, so that we would not be obliged to use such high-performance process, high-performance engines*

inside that product. And so, that is exactly what happens. It has happened in this case in the very early phases of the research as well, and that has been […] one of the research topics that where […] and how to find the technology or what is the technology that satisfies that cost target. […] In this example […] we gathered the understanding that we cannot [meet] the price point with […] today's technology, and now […] we are predicting that what happens when the Moore's Law goes ahead."

Thus Warhol uses target costing efforts and cost modeling to analyze the feasibility of technology developments. Target costing can lead to the insight that the aimed-at cost level cannot be reached. That triggers a process of evaluating what can be done if these cost are not feasible. In that case it was functionality reduction or performance optimization.

The target costing approach in pre-development is described as more uncertain as in other later innovation phases after development project kick-off by the interviewed senior new technology purchasing manager of **Warhol**:

"Then the other thing which is coming up is the actual technology possibilities, what cost level can be achieved with the coming technologies."

Furthermore he states:

"So you've got to start looking at those things and saying okay, well, how will the available technology position in the actual price. Well, then that has become into play with the target costing and the strategy and the business model feature, so there is an interaction here [in pre-development], which is a lot more vigorous than what goes on later in the [product development] programs, because there the target costing is done rather saying okay, we must bring the product here and we will design such a product that we will get a price. Well, it is not that clear in the early stages. We can say, this is the general target and we've got to find a business model that will give us the possibility to make it business with this level of payment and how do we structure that. It might be that the technologies coming through do not give the answer, it is not possible to do it by that route and it will have to be done by another route. So there is, I would say, [a] more complex discussion going on."

Also for Warhol the target costing efforts are connected to business models and strategy in more radical innovations.

For less radical innovations, the vice president new technology development of **Kandinsky** explains:

"In the roadmaps the development time for [a special custom made product…] should go down to four months and then again it should be based on these platforms. And then we just modify them and test that everything is

okay. Then when it goes to […] new technologies, I think again it is based on this what we assume the cost will be and then […] when we pick these technology alternatives we are trying to beat this cost target. And then we sort of identify […] this kind of newer alternatives to get the costs down. […But] of course not the whole production technology; it does not have to change over one night."

Thus there might be a limited use for target costing approaches for incremental developments as the development time is short and developments should be platform based. However, for less incremental developments, target costing efforts in pre-development might lead to new technological opportunity seeking. In that case technology alternatives are taken to reduce costs. However, more radical changes need also more time.

Besides these described benefits and limitations, target costing efforts can also lead to contra-productive situations. There can be damages to supplier relationships through unrealistic negotiations as the interviewed senior new technology purchasing manager of **Warhol** describes:

"In some cases engineers get very obsessed about cost management, because in the business case the project does not survive without the cost being at a certain level. And rather than try and find clever engineering solutions to get the cost down, they'll spend a lot of time bargaining with the suppliers, often unreasonably so. To the point, you know, they are asking for prices, which are not practical and which might cause damage to the supplier relationship, if they continue that way. […] It is kind of out of control in that case."

5.6.3 Summary

Four out of the seven case companies are using target costing efforts to manage their pre-development. Generally the sample companies using this approach see target costs as an important factor that has to be evaluated relatively to the potential market price of an innovation. Besides feasible costs of the market (target costs) the found practices all circle around product and production technologies. One further interesting practice found (at Warhol) is a cost and functionality trade-off analysis that is later used for target costing.

5.7 Value analysis work

5.7.1 Overview

- **Dali** is using value analysis work to estimate allowable costs as a base for target costing efforts. Before the appraisal of new product developments at the rear of pre-development the company analyses what the value of a solution is to their customer or to the end customer. In radical new product developments

Dali sometimes analyzes the total cost of ownership for the end customer for products, where the new solution could be used.

- **Duchamp** starts doing customer value analysis in middle of pre-development. The customer value of new product developments is seen as crucial for Duchamp. If no additional value to the customer can be seen, an idea will not be developed further.
- **Lichtenstein** investigates the value for customers through a total cost of ownership analysis in the middle of pre-development. Even though cost budgets play a short term role in the new product developments of Lichtenstein, the company focuses on the cost benefits for the customer.
- At **Miro**, ideas that come out of the front end are assessed with the help of a scorecard in which besides other aspects also a value analysis is embedded. Unique or at least very valuable benefits to their customer are essential for a new product development idea to pass the first gate.
- **Warhol** uses value analysis work in its roadmapping and target costing efforts in the middle of pre-development. The value of certain developments is analyzed through market intelligence and through analysis if there is already an existing customer base that would appreciate the new product development and be prepared to pay for it.

5.7.2 Benefits and application of value analysis work

The director of the idea suggestion system at **Duchamp** says:

> *"I think the most important thing […] in ideas is the customer. What is the value for [the] customer and what is the customer need, and how to evaluate that. That is one thing. And then the other thing is that we would like to get ideas which might be big from [a] business point of view. […] They might be very difficult to implement from technical point of views, but then they would really bring value to customers; so not incremental steps to our existing services, but really looking something totally differently, which means that we would maybe have to change our processes to make it happen, but then it would bring value to customers."*

For him the customer need and the value of a new product development are very important and thus the analysis of this customer value is essential.

Also at other companies value analysis work is done. The interviewed head of one business unit of **Miro** states:

> *"So that there are a couple of people evaluating and trying to find, what is the value to customer. Mainly business people [are analyzing…] that kind of issues."*

He explains also:

"We have […] these business persons who [… have an] understanding of what kind of cost structure we have with present products, and also they should have [an] understanding what is the value of the product to the customer, and what is the pricing methodology. And also what problem has been that many business people also easily think that okay, price of product is the cost of, production cost of product plus something, and not thinking about value to the customer. But that has been changed, I hope."

Thus also for Miro the value analysis work is important. However, the interviewed manager sees it also as a possibility to ask for a market price according to the customer value that might be higher than just the production cost plus some premium.

Yet also a strong connection to costing can exist as the following both quotes from managers working at Warhol show. The interviewed chief design engineer of **Warhol** points in the direction of life cycle costing and low life cycle costs a value to the customer:

"If it is a group of many different things we can have […], which part is […] gonna bring added value to the customer. So we really try and think carefully and […] put ourselves in their shoes and try and do the kind of calculation that they will have to do internally […] and so you could say that we do in that sense some kind of lifecycle costing."

Similar the interviewed senior new technology purchasing manager of **Warhol** sees a connection to a total cost of ownership analysis:

"Yeah, that comes then to this total cost of ownership, like basically you are looking at the total benefit for the customer, so that seems to be the driving [theme …]; value to customer analysis basically. You're trying to do that."

5.7.3 Summary

All except two companies (Kandinsky and Van Gogh) are using value analysis. In three cases this is done as a preliminary effort towards target costing in order to stay below the allowable costs of the market. In all cases it is started to be done during the middle of pre-development. Furthermore, it is interesting to notice that Miro used to start innovations with a view on products that the company could produce and then tried to find customers for these new product developments. However, they found out that this leads into many problems that can be avoided if one focuses straight away on potential customers. Thus Miro incorporated a value analysis. According to managers at Warhol there are connections between value analysis work and life cycle cost and total cost of ownership analysis.

5.8 Analysis of cost dynamics

5.8.1 Overview

Only two companies are using the analysis of cost dynamics in pre-development.

- **Lichtenstein** is evaluating cost dynamics through analyzing and estimating future cost erosion for different new product development ideas. Lichtenstein sees it as critical to investigate the cost capability in order not to develop past the market.
- **Warhol** traces the cost dynamics by carrying out trend analysis to understand the dynamic development of the performance and cost of technologies that could be used for new product developments. This tool that they are calling cost capability analysis is investigating the slope of the cost development and projects these against the market requirements. Beside other issues, this is done in order to not miss the right market entry time. This tool is part of what is called directional costing in this thesis – a fusion of forecasting, roadmapping and target costing.

5.8.2 Reasons for analyzing cost dynamics in pre-development

The chief design engineer of **Warhol** sees the benefit in using the analysis of cost dynamics in pre-development on knowing what kind of (cost) drivers have an effect on the cost reduction gradient for which technology:

> *"One interesting issue is that, now that if we think that we have that entry [cost] level, then the awareness of that for a certain technology [would be to know] which are the drivers that are affecting […] this slope. That would be important to understand when making that technology selection. Part of the modeling is or should be to […] find out the key drivers in each of the technologies and try to understand the differences as well."*

He further continues:

> *"The slope is important, and then also the prediction that if this is a totally new disruptive thing; normally it is very high cost, but then you need to have the kind of estimate that where does it end when the time goes on and where is it when we are here. This is also challenging. […] It is again about this that if some technology have different curves that they make [a] decision based on today's thing and they say that we are not using this technology; although if you were aware that all the time when you are ramping up you would be with this technology, you would be here [at lower cost]. And that is the challenge, how to get these long-term predictions on the technology cost capability; and making this visible to people, and that would affect a lot on decision making."*

Thus he sees it as important to know the cost decrease potential before technology selection, especially in the case of technology enabling radical developments. As also the quote of his colleague in section 4.7.7 shows.

5.8.3 On importance, position and limitations in the innovation phases

In the view of the senior new technology purchasing manager of **Warhol**, it is vital in the pre-development to choose the right technology with a cost decrease potential as you are out of the market otherwise due to long developments (caused e.g. by longer software development times):

> *"The hardware resources are very stable or in declining [relative importance] and the software resources are becoming extremely important, more and more so. Yeah, so I think the world is changing and one of the issues is that if you have, if you use a relevant form of approach here and it kind of gets stalled by the software availability, and you have not really thought about what is going on with price development and the things that you are choosing, then you might find yourself stuck [with the problem] that the market has moved on. You have developed a certain idea in mind and a certain price level, but by the time you get to deliver it, it's changed. And if you have not chosen or carefully chosen technologies such that you know that the prices will go down to follow the market, then you might find out that you have [to] go through the whole hardware development again, because the […] product you developed it is no longer any good, it is not competitive."*

The following quote of the interviewed chief design engineer from **Warhol** is interesting to become aware of the position in the innovation phases in respect to the question about the arrangement of tools:

In subsection 4.7.5 the quote of the interviewed chief design engineer from **Warhol** is interesting to become aware of the position of the analysis of cost dynamics in the innovation phases. He sees this analysis as most important in pre-development before technology selections. Once technologies are chosen the analysis gets less important as changing technologies would mean losing development time. He continues about the impact of cost awareness in technology selection:

> *"It is exactly that if you have that increased awareness or awareness that which are the drivers and which are the predicted slopes, then in the early phase you can make a lot difference, and the difference comes through the technology selection."*

Thus the cost capability analysis work is done at Warhol mostly in pre-development and less after technology lock-ins. The information is valuable especially before the technology selection and it is needed up-front of that. The information has a lower value after the technology selection, as a change in underlying technology would endanger the innovation time table.

Another quote is from the interviewed cost controller for R&D and production of **Van Gogh**. He states regarding the analysis of future cost erosion (that the company is not practicing):

"We are so small that we don't have so many persons to analyze all of those things."

Warhol is classified as a very large company, while Van Gogh is classified as medium sized company. Even so the interviewed cost engineer for R&D and production states that it is the size of the company that is the limiting factor, another possible explanation could be the newness of the innovation. In the quotes of Warhol cost modeling of new technologies is seen especially important for technologies that are either new-to-the-world or where there is no cost for these technologies available so far. Yet on the contrary, Van Gogh does not deal with such radical innovations.

5.8.4 Summary

The analysis of cost dynamics is done only by two case companies (Lichtenstein and Warhol). Both use it to look ahead and anticipate whether a development idea might be cost wise feasible after a certain development time.

Out of the situation found at Warhol one can say that the analysis of cost dynamics is a task that is done by experts on this field. This restricts the earliest possible use if there are many different new product development ideas to be evaluated. Furthermore it is more beneficial for radical than for incremental innovations. Also cost capability estimates are less interesting and important once the design of a new product development idea is locked, as specification changes would mean that parts have to be redesigned, leading to higher costs and/or that the development delays. This could be one explanation why it is used only by two case companies.

5.9 Cost database use

5.9.1 Overview

- The cost database used by **Dali** is based on their ERP system. It is a database of tabulated costs linked to an investment appraisal calculation program. On unit cost level it contains the purchasing prices of raw materials and moving averages of direct costs. On batch level the cost table contains assembly costs and on product level it includes machinery investment costs. Besides it function to store information, the cost table can be used for the analysis of different scenarios.
- **Kandinsky** has intranet-accessible cost databases for component and material costs. Additionally the company maintains a cost database derived from former quotations made. During pre-development the company uses information from these cost databases to analyze and evaluate new product development possibilities.
- **Van Gogh** is another company that uses their ERP system as cost database. The cost information is aggregated manually before its use in the feasibility

studies of new products. Additionally historical price information of purchased items can be used to analyze price trends.

- Besides cost data being stored in several ways in the organization, **Warhol** developed a method based on the concept of cost tables especially for new product development projects. It is based on an auction system and is carried out for special development project or to scout new technological possibilities on the market. The method uses a detailed model of price/cost drivers and a database of old price quotations for deriving price estimates of purchased components and is constantly updated.

5.9.2 Benefits and limitations

Cost databases help using existing knowledge. The opposite of using cost databases is that designers ask ad-hoc quotations during the development activity. However, this can be difficult and can lead to bloated cost structures by not cost aware employees as the following quotes show and is thus not recommended by the quoted managers.

Kandinsky has a culture of open communication about costs as the interviewed chief design engineer says:

> *"We have very open information on the cost. Everybody [inside the company] can know, [and] download the cost development [of our] materials."*

However, for new material that is different. The chief design engineer thinks that the cost information for new components should go through the purchasing department otherwise experience has shown that the estimates are too low between decision made and later purchases:

> *"I think that we have [a] problem with new components. We do not know exactly what is the volume price. And then the buyer is [a] very important person. He can ask [the] price from [a] supplier and he can think is this price exactly good. Typically component suppliers say to the designers some sum, some price. Typically the price is too low. Very good components and very low price and you can take it. [… However] typically designers do not have experience in the price level […] some people have it, but I think that young guys do not have it."*

The situation is similarly seen by the interviewed senior new technology purchasing manager of **Warhol**:

> *"Engineers will be approaching suppliers directly, discussing the pricing and so on. So […] it can be quite out of control, because of course the suppliers can offer something with a higher price, and if you accept it, then they'll do it. And if the people, who are asking for this are not very discerning about the price level and are more interested in the technical things, then they just take*

the given price and put it into their spreadsheets. Then you end up with a cost structure much higher than it ought to be."

Thus Warhol prefers to have specialists getting costs for new product developments and store these in cost databases. Like this technical employees can focus on technical issues and use cost data provided by other functions, as he also states:

"The technical guys will be looking at the […] efficiency and meeting a standard requirement, all of the technical items. They won't necessarily have their eye on that cost and price erosion thing, but that is one of the reasons for having a sourcing function."

However, this approach has also a setback. The senior new technology purchasing manager of **Warhol** also states as a limitation that this can collide with some internal power play in the start, but for the smoothness of the project advancement it will help in the long run:

"If you talk to these business units, they will say oh, we think it is more flexible, if we are not tied down to your earlier choices of suppliers and technologies. We want the flexibility to choose whatever we want. But it does not give necessarily the benefits that they think they get. It comes more down to a question of who is in charge and who decides and all of the social parameters that actually dictate the starting phases of the program, rather than the durational ones that engineers like to talk about."

5.9.3 Summary

Cost databases are used by four out of the seven case companies. In general cost estimation and the codification of costs go hand in hand. This can also be seen by the fact that all companies using cost databases are also doing cost estimation and modeling work in pre-development. Two of the companies are using cost databases built on their ERP system and thus are using old records to estimate cost trends. Also old quotes are stored as cost information and a further going approach is taken by Warhol that evaluates the potential cost of new technologies by receiving and using quotes that are valid in the future.

As already stated above in the section dealing with cost estimation, the engineering cost estimation method can be used well if the bill of materials of a new product development idea is similar to the one of an existing product. In this case a cost database built on top of the EPR system (like the ones used by Dali and Van Gogh) allow cost records of similar running products to be used.

5.10 Aggregated first use of tools per pre-development stage

During pre-development, a new product development idea is evaluated and analyzed with several tools. In this section these tools and their use in the different companies are presented.

			Front	Middle	Rear	*Sum*
Intelligence work	Unspecific	General	**4**	**3**	**-**	***7 / 7***
Roadmapping work	Unspecific	General	**4**	**1**	**-**	***5 / 7***
Scorecards	Specific	General	**1**	**3**	**-**	***4 / 7***
Uncertainty mgmt	Specific	General	**-**	**3**	**1**	***4 / 7***
Cost dynamics analysis	Unspecific	Cost focused	**-**	**2**	**-**	***2 / 7***
Cost database use	Unspecific	Cost focused	**1**	**2**	**1**	***4 / 7***
Cost modeling & estimation	Specific	Cost focused	**2**	**3**	**1**	***6 / 7***
Target costing efforts	Specific	Cost focused	**-**	**2**	**2**	***4 / 7***
Value analysis	Specific	Cost focused	**1**	**3**	**1**	***5 / 7***
		Sum	***13***	***22***	***6***	
		Cumulative sum	***13***	***35***	***41***	
					Avg.	***4,56 / 7***

Figure 91: First use of tools per normalized pre-development stages

Figure 91 shows at which point of time during pre-development how many companies are using which tool for the first time. The values in the 'front' column indicate the aggregated tool use in the front end of pre-development. The 'middle' column shows the amount of tools used for the first time in the middle of pre-development. Along with this scheme, the 'rear' column shows this for the rear end of pre-development. Thus Figure 91 shows the popularity of the different tools used for product cost analysis during pre-development. The tool use of all companies together is shown according to the normalized pre-development tool use (see methodology in subsection 3.5.2 on page 124).

The most popular tool is intelligence work; it is done by all case companies. Five companies are using roadmapping to present and analyze technical, market and cost information in pre-development. Four out of seven case companies use scorecards to get an overview of the attractiveness of the new proposal and its risks. Similarly, four case companies use uncertainty management tools - scenarios, triple point estimates and Monte Carlo simulations. However, only two case companies are doing an analysis of cost dynamics in pre-development. Cost databases are used by four companies to handle and store cost data in pre-development. All but one case company use cost modeling and estimation in pre-development. Four companies see target costs as such an important factor during innovation that they start using target costing efforts in pre-development. And last but not least, value analysis work is put into use in pre-development by five case companies.

Intelligence work, roadmapping and scorecards tend to be started to be used rather early in pre-development. Uncertainty management and target costing efforts tend to be started to be used rather later in pre-development.

Concluding one can say that cost modeling and estimation is the most popular cost tool in pre-development. The least popular cost tool in pre-development is the cost dynamics analysis. The cost tools used by the companies in the front end are cost modeling and estimation, cost databases, and value analysis work. Target costing efforts in pre-development are found in four out of the seven case companies in pre-development stages. This means that target costing, which is a long-established cost management tool used in development phases, is used by some companies already to some extent in pre-development phases.

6 Cost analysis approaches and patterns

This chapter looks at the tool use during the cost information analysis in pre-development. Compared to the chapters before, this chapter looks particularly at cost focused tools. It takes a cross-case perspective to indicate why companies are shaping the analysis process the way they do. This is done in order to expose patterns relevant for the cost information analysis process during pre-development.

6.1 Cost tool use per company

This section looks at how the cost analysis during pre-development is made. It investigates the cost tool use per company in more detail. The first subsection looks at the amount of different tools that the companies are using in the pre-development phases. Subsequently, the first time use of cost tools is aggregated and studied for all seven case companies. Then a short summary of the found cost analysis approaches for the different cases is made. Following this, the tool use is analyzed for steps in intensity for each company.

6.1.1 Amount of tools found per company

This subsection looks at the number of different tools that the companies are using in the pre-development phases.

	Amount of tools	Cost tools only
Warhol	9 / 9	5 / 5
Dali	7 / 9	4 / 5
Lichtenstein	6 / 9	3 / 5
Kandinsky	5 / 9	3 / 5
Van Gogh	5 / 9	3 / 5
Miro	5 / 9	2 / 5
Duchamp	4 / 9	1 / 5
Avg.	**5,9 / 9**	**3,0 / 5**

Figure 92: Overview of the amount of tools found per company

The found tools are counted for each company and shown in Figure 92. There the amount of tools is compared to the maximum amount. For all tools the maximum amount is nine, for cost tools the maximum amount is five. The higher the amounts stated in Figure 92, the broader the analysis of a company in pre-development. This is due to the fact that the analysis will be broader as different additional categories are covered. A company with broader tool use will look at the analysis during pre-development from several angles.

As one can see, the overall amount of tools used and the amount of cost tools used follow a similar pattern in Figure 92. The maximum number of analysis tools is used by Warhol. Warhol is using tools in every category (nine out of nine) and thus also all cost tools (five out of five). Therefore Warhol is carrying out the broadest analysis in the sample. Following, Dali uses overall seven tools and four cost tools in pre-development. Lichtenstein deploys six tools, out of which three are cost tools. In total three companies (Kandinsky, Van Gogh and Miro) are using tools that span five categories. Yet, Kandinsky and Van Gogh use three cost tools, while Miro is using only two cost tools in pre-development. Overall, Duchamp uses tools in four categories, out of which one is a cost tool. The average tool use during pre-development is overall 5,9 tools per company. For the cost tools the average tool use during pre-development is three cost tools per company. None of the companies are using tools in less than four different categories. One company (Warhol) stands out from the other case companies, as it covers all nine analysis angles.

6.1.2 Overview of general and cost focused tool use

Figure 92 in section 6.1.1 shows the amount of general and cost focused tools found per company. This section shows a detailed full overview of the found first time use of general and cost focused tools.

	Intelligence work	Roadmapping	Scorecard use	Uncertainty management	**Cost dynamics analysis**	**Cost database use**	**Cost modeling and estimation**	**Target costing efforts**	**Value analysis work**
Dali	Front	-	Middle	Rear	**-**	**Rear**	**Rear**	**Rear**	**Rear**
Duchamp	Middle	-	Middle	Middle	**-**	**-**	**-**	**-**	**Middle**
Kandinsky	Front	Front	-	-	**-**	**Front**	**Front**	**Rear**	**-**
Lichtenstein	Front	Middle	-	Middle	**Middle**	**-**	**Middle**	**-**	**Middle**
Miro	Middle	Front	Front	-	**-**	**-**	**Middle**	**-**	**Front**
Van Gogh	Front	Front	-	-	**-**	**Middle**	**Front**	**Middle**	**-**
Warhol	Middle	Front	Middle	Middle	**Middle**	**Middle**	**Middle**	**Middle**	**Middle**

Figure 93: First time use of general and cost focused tools per case company

Figure 93 shows when which case company is using which tool for the first time in pre-development. It gives a cross-case overview of the tool use derived from the findings presented within case description of chapter 4. It provides the full overview of the first time use of general and cost focused tools for the different case companies, and serves as a starting point for the next subsections in this chapter.

The **cost focused tools** and their starting during pre-development are shown in **bold** in Figure 93. Next, the use of these cost focused tools in the different case companies is summarized briefly.

Dali uses cost tools only in the rear pre-development. At this stage Dali has a high focus on costs in their new product development idea analysis. The company uses cost modeling and estimation in their cost templates. The latter are connected to cost databases. Furthermore, Dali starts target costing activities by estimating allowable costs and making target profit calculations. Additionally, Dali is using value analysis work.

Duchamp starts using value analysis work in middle of pre-development. However, the analysis does not include cost modeling and estimation. The given reason is that Duchamp finds it very hard to estimate its costs. Thus managers at Duchamp state that it rather focuses on estimating costs relative to the value to the customer.

Kandinsky is starting to use cost modeling and estimation in the front end of innovation. Also the use of cost databases is started in the front end. Cost analysis work is further increased with target costing efforts. Kandinsky's analysis has two major aims. First, finding out the feasible market price for its innovations and second, evaluating innovation alternatives in the search of a cheaper and more efficient solution of customer demands.

Lichtenstein starts estimating and modeling costs in the first stage after the front end. It uses parametric and analogous methods and models life cycle costs. In this stage Lichtenstein also starts value analysis. In the same stage the analysis of cost dynamics is begun. The aim of this analysis is to be cost aware and take cost erosion into account.

Miro starts with a value to customer analysis in the front end. At Miro the product cost are estimated in the first stage after the front end for the first time. The cost estimations are usually based on expected bill of materials, logistic costs and investment costs.

Van Gogh has a very prompt approach towards cost information analysis. Already in the front end, Van Gogh starts cost information analysis with first cost modeling and estimation. This is done for their feasibility and profitability estimations of new product development ideas. The company uses cost records of previous products for their cost modeling in the first stage after the front-end. These cost records can be seen as a cost database. The cost information is then used in parametric and analogous cost relationships for the early cost estimations. The cost information analysis is also the base for Van Gogh's target costing routines that are started in the first stage after the front end.

Warhol starts analyzing cost information actively from the middle of pre-development on. Warhol is modeling and estimating costs to find out which kind of cost level per functionality can be achieved with a specific technology or design. In the pre-development phases, the cost modeling is seen as a preparation work to make the right basic technology choices. Thus Warhol analyses the cost level that can be reached with a certain technology. Furthermore, Warhol starts analyzing the dynamics of costs in order to be able to estimate the cost potential competing technologies for several years ahead. Also, target costing efforts down to the component level are started in the first stage after the front end. Later a gap analysis is made to further identify improvement possibilities. Value analysis is also started in the first stage after the front-end. Furthermore, Warhol uses cost databases to analyze and manage costs for several main components of new product developments.

Companies starting cost tool use in		
Front	3 / 7	43%
Middle	3 / 7	43%
Rear	1 / 7	14%

Figure 94: Start of cost tool use during pre-development

Figure 94 shows that three companies are starting to use cost tools in the front end. Similar, three companies are starting to use cost tools in the middle of pre-development. And finally, one company starts using cost tools in the rear pre-development.

	Front	Middle	Rear	Biggest step in
Kandinsky	2	-	+ 1	Front
Miro	1	+ 1	+ 0	Front/Middle
Van Gogh	1	+ 2	+ 0	Middle
Warhol	0	+ 5	+ 0	Middle
Lichtenstein	0	+ 3	+ 0	Middle
Duchamp	0	+ 1	+ 0	Middle
Dali	0	+ 0	+ 4	Rear

Figure 95: Location of the biggest cost focused tool use step for each company

Figure 95 shows when how much **cost focused tools** are starting to be used. The last column indicates where the biggest quantity of new tools is started to be used. One can distinguish four approaches by the companies. The first approach has the biggest step in tool use in the front end. **Kandinsky** is doing so. Secondly, for **Miro** the steps are by one tool in the front and one tool in the middle of pre-development. The third approach has the biggest step in the middle of pre-development. This is done by the largest group of four companies (i.e., **Van Gogh, Warhol, Lichtenstein** and **Duchamp**). The forth group contains only of **Dali**. It has the biggest step in the rear of pre-development.

The biggest step in absolute figures is made by **Warhol** in the middle of pre-development. This can be traced back to the pre-development stage gate approach used by Warhol. In the front end the focus is on technology development, where employees usually have a strictly technical background. After the first gate it changes to more business analysis. These analysis are carried out by development teams with backgrounds in technology and economics. With this knowledge available, the cost tools are used. Thus in the case of Warhol the big step in tool use can be explained by the changing background of the employees working on the new product development idea.

6.2 Cost tool use and organizational contingencies

This section looks at possible clues **why** the cost analysis during pre-development is done the way it is. It investigates the relation between cost tool use and company in more detail.

6.2.1 Number of cost tools used

It is interesting to analyze whether company characteristics are governing the number of cost tools used for the cost information analysis during pre-development. If there is a connection, this could answer the second research question of 'why cost information analysis is done the way it is'.

	Cost tools used	Turnover	R&D spending per turnover	EBIT/ turnover (%)	P/E ratio	B2B/B2C	Goods vs. Service
Warhol	**5**	Very large	>10%	>10%	n/a	B2B	G
Dali	**4**	Large	0-1%	0-5%	0-15	B2B	G
Kandinsky	**3**	Medium	5-10%	neg	0-15	B2B	G
Lichtenstein	**3**	Medium	>10%	neg	n/a	B2B	G
Van Gogh	**3**	Medium	>10%	0-5%	n/a	B2C	G
Miro	**2**	Very large	1-5%	5-10%	15-30	B2B	G/S
Duchamp	**1**	Very large	1-5%	>10%	15-30	B2B&B2C	S

Figure 96: Number of cost tools used vs. company characteristics

A first overview of cost tool use against the company characteristics is presented in Figure 96. The companies with medium sized turnover all use three cost tools in pre-development. Yet, the group with a very large turnover is split in two with Warhol using five and Duchamp using one cost tool during pre-development. Thus the **turnover is not linearly interrelated to the pre-development cost tool use** of the different found tools. Furthermore, the turnover is an indicator for the size of a company. Thus it follows that the cost tool use in pre-development is not dependable on the company size in the studied cases.

Also, neither the **R&D spending per turnover, nor the EBIT per turnover demonstrate any strict relationship** with the total number of studied tools used in the predevelopment. The **P/E ratio shows a negative association** with the use of cost tools in pre-development. The higher the P/E ratio, the lower the amount of cost tools used. However, in total, only four data points are available for this analysis. The **business-to-consumer indication** shows little kind of order relative to the number of tools found, but it is **tentative in the lower range**. If a company is in the **service business indicates tentatively that the amount of tools found is lower** than for companies selling goods.

	Cost tools used	Innovation style	Idea initiative	Funnel type	Technological uncertainty
Warhol	**5**	Technology driven	Institutional	Survival of the fittest	High-tech to super high-tech
Dali	**4**	Technology driven	Institutional	Survival of the fittest	Medium tech
Kandinsky	**3**	Technology driven	Institutional	Few big bets	Medium tech
Lichtenstein	**3**	Market driven	Institutional	Few big bets	High-tech
Van Gogh	**3**	Market driven	Institutional	Few big bets	Medium tech
Miro	**2**	Technology driven	Idea suggestion	Few big bets	Medium tech
Duchamp	**1**	Market driven	Idea suggestion	Few big bets	High-tech

Figure 97: Number of cost tools used vs. organizational contingencies

Figure 97 shows the cost tool use against further organizational contingencies.

The third row of Figure 97 shows the innovation style of the different cases. Companies with a technology driven innovation style tend to use more cost tools in pre-development. However, Miro which also has a technology driven innovation style, uses less cost tools in pre-development than other companies with market driven innovation style. **Thus, there is no clear indication that the innovation styles influences the amount of cost tools used in pre-development.**

Similarly, the last row of Figure 97, displaying the technological uncertainty, indicates **no clear connection between the technological uncertainty and the amount of cost tools used in pre-development.** The technological uncertainty does not influence the number of cost tools used in pre-development, as there is clearly no pattern to be seen in Figure 97.

On the contrary, when analyzing the **idea initiative, a clear sorting can be seen** in Figure 97. All companies using an institutional search and development approach use more cost analysis tools in pre-development than companies using an idea suggestion program based initiative. Both companies with the idea suggestion style (Miro and Duchamp) have the lowest cost tool use.

Similarly, a clear sorting can be seen regarding the innovation funnel type of the different case companies cost tool use (see Figure 97). Thus the funnel type seems to affect tool use. This is a finding towards the question 'why cost information analysis is done the way it is'. The approach to innovation, expressed through a different development funnel style, impacts the cost information analysis process in pre-development. Companies using the few big bets funnel type create a multitude of ideas that are then sharply reduced to a few in the first screen. In contrast, companies using the survival of the fittest funnel type keep many ideas running parallel to each other and then select at later stages the most promising ones. The latter approach seems to correlate with a higher amount of cost tools used during pre-development.

6.2.2 The relative cost tool importance

As a next study step the relative cost tool importance is calculated for all cases. It can be used to analyze how the different companies organize their future product cost analysis in pre-development relative to the overall number of tools used.

	Total tools used	Cost tools used	Rel. cost tool importance	Turnover	R&D spending per turnover	EBIT/ turnover (%)	P/E ratio	B2B/B2C	Goods vs. Service
Van Gogh	5	3	**60%**	Medium	>10%	0-5%	n/a	B2C	G
Kandinsky	5	3	**60%**	Medium	5-10%	neg	0-15	B2B	G
Dali	7	4	**57%**	Large	0-1%	0-5%	0-15	B2B	G
Warhol	9	5	**56%**	Very large	>10%	>10%	n/a	B2B	G
Lichtenstein	6	3	**50%**	Medium	>10%	neg	n/a	B2B	G
Miro	5	2	**40%**	Very large	1-5%	5-10%	15-30	B2B	G/S
Duchamp	4	1	**25%**	Very large	1-5%	>10%	15-30	B2B&B2C	S

Figure 98: Relative cost focus of tools vs. company characteristics

Figure 98 shows the calculated relative cost tool importance of the different case companies. Furthermore, Figure 98 looks at whether company characteristics are governing the relative cost focus in tool use. The relative cost tool importance is not linked to the turnover and thus the size of the company. Neither is the R&D spending per turnover as an indication for the relative innovation intensity. Also the profitability measure of EBIT per turnover does not show a relationship with the relative cost tool importance in the found tools. There is **some kind of order in the P/E ratio compared to the relative cost tool importance**. The companies with a lower relative cost tool importance have a higher P/E ratio than the others. Yet due to the limited data it is hard to tell how significant this order is.

The relative cost focus measure is not linked to whether a company is selling mainly to other businesses (B2B) or directly to consumers (B2C). However, **the relative cost focus ratio is linked to whether a company is in the service business or produces mostly goods**. The goods focused companies do show a clearly higher relative cost tool importance percentage.

	Rel. cost tool importance	Innovation style	Idea initiative	Funnel type	Technological uncertainty
Van Gogh	**60%**	Market driven	Institutional	Few big bets	Medium tech
Kandinsky	**60%**	Technology driven	Institutional	Few big bets	Medium tech
Dali	**57%**	Technology driven	Institutional	Survival of the fittest	Medium tech
Warhol	**56%**	Technology driven	Institutional	Survival of the fittest	High-tech to super high-tech
Lichtenstein	**50%**	Market driven	Institutional	Few big bets	High-tech
Miro	**40%**	Technology driven	Idea suggestion	Few big bets	Medium tech
Duchamp	**25%**	Market driven	Idea suggestion	Few big bets	High-tech

Figure 99: Relative cost focus of tools vs. organizational contingencies

Figure 99 shows the calculated relative cost tool importance of the different case companies. The case companies are arranged in an ascending order of the relative cost tool importance figures.

The third row shows the innovation style of the different case companies. There is **no connection between innovation style and relative cost tool importance** in pre-development, as the different case companies are mixed.

Similarly, the last row in Figure 99, presenting the values for the technical uncertainty, does **not show a connection between technical uncertainty and relative cost tool importance.**

However, the fourth row of Figure 99, illustrating the idea initiative as a potential organizational contingency against the relative cost tool importance, shows a clear division between the case companies. Similar to Figure 97, the two companies with the idea suggestion approach also have the lowest relative cost tool importance. On the contrary, the companies having the institutional search and development idea initiative paradigm show a higher relative cost tool importance in their product cost analysis during pre-development. **Thus there is a tendency for the idea suggestion program initiative to have a lower cost focus in the pre-development analysis; relative cost tool importance and idea initiative seem to be connected.**

The next row in Figure 99 shows the potential connection between the calculated relative cost focus and funnel type. For this analysis the companies have to be grouped in three clusters. The **cluster I** contains the companies Van Gogh and Kandinsky. Both companies have a few big bets innovation funnel type and tend to focus strongly on costs during its analysis in the pre-development phases, as the relative cost tool importance is 60% in both cases. **Cluster II** includes the companies Dali and Warhol, both having a survival of the fittest innovation funnel type. Dali has a relative cost tool importance of 57%, as it uses four cost focused tools out of its seven tools in the pre-development phases. Warhol is using all nine tools and thus has a relative cost tool importance of 56%. Their focus on costs is balanced in the analysis. Finally, **cluster III** is made of the companies Duchamp, Lichtenstein and Miro, all again having a few big bets innovation funnel type and a rather low cost focus in their analysis. Lichtenstein uses three cost focused tools out of six tools in total, equaling 50% relative cost tool importance. Miro shows a relative cost tool importance of 40% and thus also has a lower than average focus on costs for its analysis during pre-development phases. Duchamp has a value of 25%. Thus, in this analysis Duchamp ranges on the lowest place in the overview. As stated in the methodology in subsection 3.5.3, if all possible tools are found, the relative cost tool importance is 56%. Thus a balanced relative cost tool use is around this value of 56%. If the percentage is higher, costs are stressed more; if the percentage is lower, costs are stressed less in the analysis during pre-development. Therefore, cluster I companies tend to focus more on costs in their product cost analysis during pre-development than cluster II companies. On the contrary, cluster III companies tend to focus less on costs in their product cost analysis during pre-development than the balanced cluster II companies. **Thus one can say that companies with a survival of the fittest innovation funnel type tend to have a balanced relative cost tool importance. Yet, the position of the companies having a few big bets innovation funnel type cannot be explained so far.** Thus one has to look further for explanation, which will be done in the next subsection.

6.2.3 Pricing approaches and cost analysis during pre-development

This subsection looks at the question whether different approaches regarding customer’s cost sensitivity guide the cost analysis during pre-development.

At **Miro** the role of cost analysis during pre-development is dependent on the customer as the head of one business unit explains:

> *“We try to evaluate in quite early stages what is the role of our product in the customer’s costs. And if it is very important, then we evaluate that in early stages. If it is only minor, […than] that it is not really an issue.”*

On the contrary **Warhol** is not distinguishing the price sensitivity of customers. All customers benefit from cost decreases according to the senior new technology purchasing manager of Warhol:

> *“I think all the customers are price sensitive. […] You know anyway that the [cost] curve will continue to go down just from a general market condition. So it is not really about pitching it to customers who are paying more to start with and then [others…] a little bit later. Everybody is gonna be paying around the same amount here and everybody will be migrating to lower prices later.”*

Similar to Warhol, **Dali** also has cost sensitive customers, as the director for New Concept Development and IPR of Dali explains:

> *"We have a certain kind of erosion, yes. We think that the price is coming down and also our learning curve and cost is coming down. So that is some kind of estimate […] We need to know exactly how to improve the learning curve. […] And of course we can first start to sell a little bit by loss or try to get some better price, but why should [our] customer be willing to pay [… for] our learning in very beginning. [One major customer…] is not that kind of company. So it means that we need to calculate a little bit loss to that total investment first."*

Furthermore, when deriving target costs for products based on new technologies Dali is orienting itself on the current market price of similar solutions:

> *"The current market price is for very high volumes. It means that the cost target needs […] to be equal. […] We can see how near we can come [to the market price]."*

The situation of **Kandinsky** was described very similar to the one of Dali. Thus these cases are comparable.

Yet, companies can deliberately have different end customer prices targets. According to the R&D director of **Van Gogh**, the company designs the different developments for all their business areas according to three different, but clearly defined final customer price segments. The first area targets the premium customers, the second one the middle and the third one the beginner and low price customers. This distinction is already made in the front end.

Quite different to that, **Duchamp** sets its end customer prices only very late in new product development process, as the Director of concept development of innovations at Duchamp says:

> *"In a way in each phase you have to update […] your latest view […]. With the information that is available and with assumptions you have, you have a certain revenue estimate. And the more you go towards that direction, the more you should have information and then it will be updated […], but the pricing decisions will be done quite late in exact prices."*

Thus there are several pricing approaches that could influence the tool use during cost analysis during pre-development.

	Relative cost tool importance	Using target costing efforts in pre-development	Description
Van Gogh	60%	yes	Target price segments are fixed right from innovation start
Kandinsky	60%	yes	Cost sensitive customers; market price can be derived by similar products on the market
Dali	57%	yes	Cost sensitive customers; market price can be derived by similar products on the market
Warhol	56%	yes	Cost sensitive customers, aiming at radical innovations
Lichtenstein	50%	no	Generally cost sensitive customers, aiming at rather radical innovations
Miro	40%	no	Some customers are not cost sensitive, while some are
Duchamp	25%	no	Customer prices are set very late in development process

Figure 100: Tool use vs. customer cost sensitivity and point of pricing decision

These above mentioned cases are brought in an order in Figure 100, starting with **Van Gogh**, as the company structures its developments according to clearly defined final customer price segments right from the start. Then comes **Kandinsky** and **Dali** that acknowledge that their customers are cost sensitive. Additionally **Kandinsky** and **Dali** are under strong market pressure, as similar solutions exist on the market. They are both setting up target costs based on the current market price of similar solutions. **Warhol** and **Lichtenstein** also acknowledge that their customers are cost sensitive. However, both are targeting at rather radical innovations. Different to this, at **Miro** the cost evaluation is done dependent on the cost sensitivity of the customer. They have customers that are seen as rather cost sensitive, while costs play a minor role for other customers. And finally **Duchamp** is not establishing the end customer prices until late in the new product development process.

As can be seen in Figure 100, this order also shows a relationship with the relative cost tool importance figure and the use of target costing efforts in the pre-development. Also in this overview, the two companies with the idea suggestion system approach show the lowest values.

Through the approach of target price segments that **Van Gogh** is taking, the use of target costing efforts in pre-development is understandable, as it can be seen as an extension of this approach. Also, it is apparent that **Duchamp** is not using target costing efforts during pre-development, as the customer prices are only set later and would be a requirement for a target cost approach.

The pair of **Dali** and **Warhol** is distinct from **Miro**, even though it is not so clear cut as for Van Gogh and Duchamp. The first two acknowledge having price sensitive customers and thus are using target costing efforts in the pre-development. On the contrary, Miro has at least partly customers that are not very cost sensitive. For these customers, cost issues are not checked thoroughly during pre-development. Furthermore, Miro is not using target costing efforts in the pre-development.

Summarizing one can say that:

1. If a company is using an approach of target prices segments, it is likely to use target costing efforts for analysis in the pre-development. Yet, if a company is not establishing price targets in the pre-development, target costing efforts cannot be used in the cost analysis during pre-development.
2. Furthermore there seems to be an effect of the customer's cost sensitivity on the cost analysis during pre-development. The more sensitive a customer is, the higher the relative cost tool importance will be and the more likely it is to find target cost efforts during pre-development.

6.2.4 Organizational contingencies and cost analysis

There are several company characteristics that give clues why the cost analysis during pre-development is done like it is. Miro and Duchamp both show a low cost tool use during pre-development. There are several company characteristics that set them apart from the other companies. Miro has partly a service business approach; Duchamp is mostly in the service business. Duchamp and Miro both also have an idea suggestion approach to innovation. Thus there is a tendency for service business and idea suggestion approach innovation style companies to have a lower cost focus in the pre-development analysis.

Furthermore, the development funnel type a company uses can have an impact on the cost analysis in pre-development. The patterns regarding the innovation funnel type in Figure 97 and Figure 99 suggest that the style of the development funnel and the style of the tool use go hand in hand. If a company has a 'survival of the fittest' funnel approach it is more likely to implement more cost analysis tools in pre-development. On the contrary, a company with a 'few bets' approach is more likely to use less cost tools in average in pre-development.

Moreover, pricing approach and customer's cost sensitivity can play a role in the use of target costing efforts during pre-development. On the contrary, companies that determine prices only very late in the new product development process are likely to not apply target costing efforts in pre-development. Overall, the more cost sensitive the final customer is and the more the market competition is based on cost, the more likely it is that a company uses target costing efforts already in pre-development.

6.3 Technological uncertainty and analysis

This section studies whether the tool use for cost analysis in pre-development is guided by the technological uncertainty of the case companies. The classification scheme for technological uncertainty of Shenhar and Dvir (1996) described in 2.1.2.2

is used to classify the different case companies according to their prevailing type of innovation.

6.3.1 Technological uncertainty and tool use

New product developments are connected to environmental uncertainty that is reduced step-by-step before market launch. Yet the different case company’s start from different levels of uncertainty depending on their business.

<table>
<tr><th>A, low-tech</th><th>B, medium-tech</th><th>C, high-tech</th><th>D, super high-tech</th></tr>
<tr><td>No new technology</td><td>Some new technology</td><td>Integrating new, but existing, technologies</td><td>Key technologies do not exist at project’s initiation</td></tr>
<tr><td></td><td>Dali</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Duchamp</td><td></td></tr>
<tr><td></td><td>Kandinsky</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Lichtenstein</td><td></td></tr>
<tr><td></td><td>Miro</td><td></td><td></td></tr>
<tr><td></td><td>Van Gogh</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Warhol</td></tr>
</table>

Figure 101: Case company classification according to technological uncertainty

Different types of innovations are distinguished in the case analysis. Figure 101 shows an overview of the classification of the different case companies according to their technological uncertainty following the scheme of Shenhar and Dvir (1996).

Case Company	Type	Ranking type	Prevailing paradigm	Number tools found	Ranking tools found	Number cost tools found	Ranking cost tools found	Rel. cost tool importance	Ranking rel. tool use
Warhol	C-D	1.	High-tech to super high-tech as some key technologies do not exist in the front end	9	1.	5	1.	56%	4.
Lichtenstein	C	2.	Venturing company that integrates new, but existing technologies for first of its kind uses	6	3.	3	3.	50%	5.
Duchamp	C	2.	Building complex and information intensive new system within state-of-the-art	4	7.	1	7.	25%	7.
Dali	B	4.	Open for new ideas and even radical technologies, but staying in defined applications	7	2.	4	2.	57%	3.
Van Gogh	B	4.	Open for new ideas and technologies, but need to stay in defined markets	5	4.	3	3.	60%	1.
Miro	B	4.	Open for some new technology but trying to stick to the same sales channels / market	5	4.	2	6.	40%	6.
Kandinsky	B	4.	Would like to have new products, but ideas ‘get stuck’ if too radical	5	4.	3	3.	60%	1.

Figure 102: Type of innovation vs. tool use of the case companies

Figure 102 shows a tabulated overview of the different case companies. On the left hand side the case companies are brought into order according to the newness level of the targeted new product developments. Next to that, the prevailing paradigm of the company is given as an illustration of the innovation approach and type. On the right hand side key figures about the analysis during pre-development are given.

When comparing the innovation types (B vs. C and C-D), one can see that there is no strict relationship. Neither with the absolute number of tools found in each case, nor with the amount of cost tools used or the relative cost tool importance in pre-development. However, the next subsection looks one level deeper on tool use level.

6.3.2 Technological uncertainty and uncertainty management tool use

The last subsection has looked at the possible relationship of technological uncertainty with analysis style key figures. However, this section looks specifically at the link of the technological uncertainties of the case companies and their first time use of management of uncertainty tools.

	Technological uncertainty	Uncertainty management
Warhol	C-D	Middle
Duchamp	C	Middle
Lichtenstein	C	Middle
Dali	B	Rear
Kandinsky	B	-
Miro	B	-
Van Gogh	B	-

Figure 103: Technological uncertainty vs. uncertainty management tool use in pre-development

In Figure 103 the classification of technological uncertainty and the first time use of uncertainty management tools are compared. Warhol, Duchamp and Lichtenstein have the highest technological uncertainty and are also all starting to use uncertainty management tools in the middle of pre-development.

It is also interesting that Dali starts using uncertainty management tools in the last pre-development stage before the actual development start. Managers at Dali have stressed their perceived uncertainty towards market assumptions, cost estimates and future sales volumes in the interviews. That could be one reason why they are also using uncertainty management tools before deciding whether an idea should go to development or not. However, Kandinsky worries that the uncertainties connected to future production methods, production volumes and future component prices, is not using uncertainty management tools in pre-development phases.

Overall, one clue of why the pre-development analysis is done the way it is, is the connection between technological uncertainty and the use of management of uncertainty tools. The companies that operate in a business setting with higher technological uncertainty react by using special tools to deal with this uncertainty in the pre-development.

6.4 Tool evolution and specificity

Tool evolution patterns could answer the question why the product cost analysis during pre-development is done the way it is. Tool evolution patterns emerge over the different stages in the pre-development. If they are guided by regularities this could explain analysis styles.

This section focuses on possible tool evolution patterns by looking at the change of the relative use of specific and unspecific tools during pre-development. For this study of tool evolution patterns, both general and cost focused tools are considered. Specific tools analyze information primarily regarding one particular new product development idea, while unspecific tools analyze information for an array of new product development ideas.

6.4.1 Tool evolution connected to the cases

As noted in the within-case analysis, the tool use of Dali shows a pattern from using unspecific tools in the front-end and specific tools more frequently later. To investigate this, the tools used by all case companies are looked at together. Maybe an evolutionary pattern for the future product cost analysis during pre-development phases can be uncovered.

	Front	Middle	Rear	Pattern
Dali	0%	50%	71%	Unspecific to specific
Duchamp	n/a	75%	75%	No trend, highly specific
Kandinsky	25%	25%	40%	Unspecific to specific
Lichtenstein	0%	50%	50%	Unspecific to specific
Miro	67%	60%	60%	***Specific to unspecific***
Van Gogh	33%	40%	40%	Unspecific to specific
Warhol	0%	56%	56%	Unspecific to specific

Figure 104: The specific tool use relative to total tool use during pre-development

The evolution of tool usage during pre-development is shown in Figure 104. A low percentage indicates an unspecific tool use, while a high percentage indicates a specific tool use:

- **Dali** starts the analysis with general business intelligence as a tool and no specific tool use. In the middle of pre-development Dali starts increasing the proportion of specific tools by rating the new ideas with a scorecard (to 1 out of 2). At the rear of pre-development the ratio increases even more (to 5 out of 7) in the last pre-development stage. Thus Dali’s first time tool use evolution is from unspecific tool use in the front end to a relatively specific tool use at the rear end of pre-development.

- **Duchamp's** first time tool use does not show any pattern, as all tools used are used for the first time in the middle of pre-development.
- **Kandinsky's** first use of tools starts with roadmapping, intelligence work and the use of cost databases (which are classified as unspecific), but also first cost estimation (which is classified as specific) in the front-end. This results in a 1 out of 4 used tools to be specific. At the rear of pre-development, Kandinsky starts using target costing efforts, leading to 2 out of 5 being specific. The general pattern of the first time use of tools is from unspecific to specific ones.
- **Lichtenstein** starts its analysis in the front end with intelligence work (unspecific). In the middle of pre-development the tools used get more specific and the half of the used tools are specific (3 out of 6). Thus for Lichtenstein, the overall direction of tool use evolution is from unspecific to specific tool first time use.
- **Miro's** tool use starts in the front end with one tool that is classified as unspecific (roadmapping) and two tools that are classified as specific (scorecard use and value analysis work). That gives a quota of 2 out of 3 being specific, equaling 67% specific tool use in the front end of pre-development. In the middle of pre-development, the analysis is enriched by intelligence work (unspecific) and cost estimation (specific). The quota is lowered to 3 out of 5 being specific (60%). This leads to the fact that the indicator of specific tool use is higher in the front end than in the middle and back end of pre-development. **Thus, at Miro, the overall direction of evolution of the first time use of tools is from specific towards more unspecific tool use.** This is a contradiction to the other cases.
- The first tools that **Van Gogh** is using are intelligence work and roadmapping (unspecific). However, at the same time Van Gogh uses cost modeling and estimation (specific) already in the front end. This results in a quota of 1 out of 3 tools being specific, equaling to 33% specific tool use in the front end. In the middle of pre-development Van Gogh also starts using cost databases (unspecific) and target costing efforts (specific). This results in a share of 2 out of 5 being specific (40%). Thus the pattern points to a first time use that evolves from unspecific to specific.
- **Warhol** starts with roadmapping that is classified as unspecific tool in the front end. However, after the first feasibility screen the analysis starts immediately involving much more tools. Five out of nine are classified as specific in the middle of pre-development. Thus the overall direction of tool use evolution is from unspecific to specific tool first time use.

For Duchamp the pattern cannot be analyzed as all tools are used in one stage for the first time. Out of the other six cases, **all but Miro** show the tendency to start with unspecific tools and then increase the share of specific tools the further one goes in the development phases. However, the case of Miro demonstrates that a strict interpretation of the proposition cannot be supported. So why it is that Miro has a higher specific tool ratio in the front end rather than in later stages?

At Miro, ideas that come out of the front end have to pass an initial test to be assessed further in the first stage. This is done with the help of a scorecard. A manager stated that Miro is facing the challenge that there are risks connected to innovations and new product development ideas. Thus one question to be addressed is who will take these risks and how to evaluate them. To answer this challenge the company has developed a standardized way to deal with estimations – a pre-defined scorecard. This scorecard already rates an idea very specifically. Thus, what sets Miro apart from its other cases is that it uses the scorecard as a rigid framework to rate and select ideas right away.

However, in the case of Miro, the use of their rating scorecard shows a clear pattern from lighter tool use to a more intense one. During the first evaluation in the front end, some qualitative checkpoints are left out. Only one stage later these are then estimated or computed. Thus Miro uses a specific scorecard, but in a light version in the front end idea selection process.

So except this aforementioned case of Miro's scorecard and the case of Duchamp, **the overall tendency of tool use evolution during pre-development phases is generally from unspecific to specific tools down the innovation phases.**

6.4.2 Explaining the outlier

Miro's tool use is pre-dominantly specific in the front-end. Thus Miro has a significantly different approach as the others cases. However, the first check is not very profound in the front end.

There are at least two factors explaining this difference. **Firstly,** Miro has an idea suggestion system approach. For Miro's idea suggestion system approach a fast screening is targeted. Its aim is the selection and reduction to the best ideas from many. Here, a specific tool use is appropriate.

On the contrary, all other cases besides Duchamp have an idea development approach. In the idea development approach some development precedes selection. The selection is eventually not that critical in the front-end, but starts later, in the middle of pre-development. Thus, in order to not waste too many resources, unspecific tools are used at the start. This is also reflected in the tool use.

Eventually all companies want to save resources. Miro does it by a specific screening at first. The other companies do it by starting with more general analysis. In the middle of pre-development Miro uses more tools on the remaining ideas. The other companies (except Warhol and Dali) then do the screening. Yet, Dali and Warhol do it only in the rear end of pre-development.

Secondly, one further reason for the approach taken by Miro is derived from motivational issues. It is seen as very important by the interviewed head of one business unit that employees are not only submitting, but also evaluating their proposed new product development ideas. The employee that suggested an idea might be given some free time to work out the idea further or test it already on a small scale. This employee-rated first gate was described as very light and letting several ideas through to the next evaluation. The employees have to use the scorecard system that provides the final measure in a form of points. There is an openly known minimum of how many points an idea needs to get into the next stage. When asked by the interviewer if this would not lead to the employees polishing the figures up, so that their proposal would reach the minimum needed score, the interviewed manager answered that usually one can see that a new business idea either lies significantly over or under the minimum score. Furthermore, he stated that it is only the first evaluation and a polishing up of figures which would be discovered quickly in the next stage. Also, in this first evaluation stage, the ideas are still seen as company internal proposals. However, in the view of the interviewed manager, **this approach motivates the employees to submit more ideas; even though one idea might not be developed further.**

Overall, there is a tendency of tool use evolution during pre-development phases. Summarizing, one can say that there is a general pattern from unspecific to specific tool use during pre-development. Yet, this logic can be overruled in specific cases as Miro shows. For employee motivation, Miro reverses this approach during idea screening. Yet, the tool use is kept light in order to not waste too much effort on this first specific analysis.

6.5 Tool evolution and tool families

This section looks at the second research question by focusing on the tools and their relation to each other. It looks for more universal connection logics in the tool use that lead to a tool evolution patterns explaining why the product cost analysis during pre-development is done the way it is.

6.5.1 Parallel and sequential tool use prior to target costing efforts

As can be seen in the different case descriptions, most companies start their future product cost analysis during pre-development with some kind of intelligence work. Thus intelligence work is a base tool for the analysis during pre-development phases. The finding that intelligence work is starting to be used early is an indication towards the second research question of ‘why cost information analysis is done the way it is’. Intelligence work can be seen as the base for future product cost analysis during pre-development.

	Intelligence work	Cost modeling and estimation	Cost database use	Target costing efforts
Dali	Front	Rear	Rear	**Rear**
Duchamp	Middle	-	-	**-**
Kandinsky	Front	Front	Front	**Rear**
Lichtenstein	Front	Middle	-	**-**
Miro	Middle	Middle	-	**-**
Van Gogh	Front	Front	Middle	**Middle**
Warhol	Middle	Middle	Middle	**Middle**

Figure 105: Tool use in relation to target costing efforts

However, when analyzing the tool use as it is shown in Figure 105, a further connection of several tools can be seen. Every company deploying target costing efforts in pre-development is using information gathered through intelligence work and gained through cost modeling and estimations. Or stated differently: one can say that **intelligence work and cost modeling always precede target costing efforts in the investigated cases.** This seems logical, as target costing efforts build up on the information of these tools. However, on the contrary not every company using intelligence work and cost estimation is also carrying out target costing efforts.

Yet, there is another tool connection with target costing efforts – the use of cost databases. **Interestingly, all companies using cost databases also use target costing efforts.** The cost information used for the target costing efforts is maintained in cost databases. Cost databases are used by four case companies. In general cost estimation and the codification of costs go hand in hand. This can also be seen by the fact that all companies using cost databases are also doing cost estimation and modeling work in pre-development. This connected tool use is represented in Figure 106.

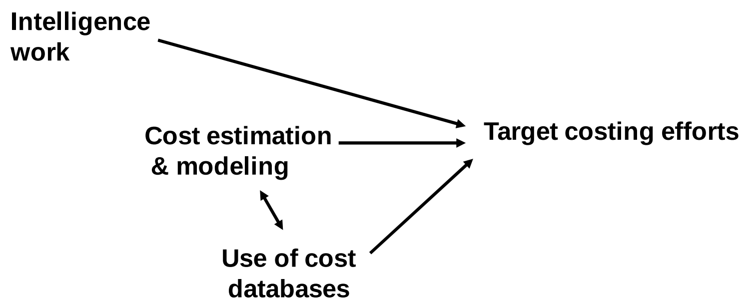

Figure 106: Connection between different tools through parallel and sequential tool use

Figure 106 illustrates that target costing efforts is a central tool with several other tools preceding it. Additionally, a connection between cost estimation and the use of cost databases is found (the cost databases provide figures for the cost estimation). This suggests a connection between the different tool types. Through the cost management use of the tools there is a logical connection between the different tool types. They belong to similar sets of tools, one way or another culminating in target costing efforts. The connection indicates a necessary condition. I.e. there is a clear connection as target costing efforts build on (1) the market information gathered through intelligence work, (2) the information gained through cost modeling and estimations, and (3) cost information stored in some cost database.

This necessary condition is an indication towards the second research question of ‘why cost information analysis is done the way it is’. The ‘rule’ is that if target costing efforts are found to be used in the future product cost analysis during pre-development, also intelligence work, cost estimations and information storage in cost databases are likely to be used at that time or earlier. This comes from the nature of target costing.

6.5.2 Combining technology, cost and market information

A further parallel tool use is found in company **Warhol** (see 4.7.7). Roadmapping plays a significant role in the very early phases of the innovation process. As the time to market at Warhol is usually several years, the information available at the beginning of a new product development effort is very vague. However, managers at Warhol are compiling the information and updating it as soon as more certain information is found through internal or external research.

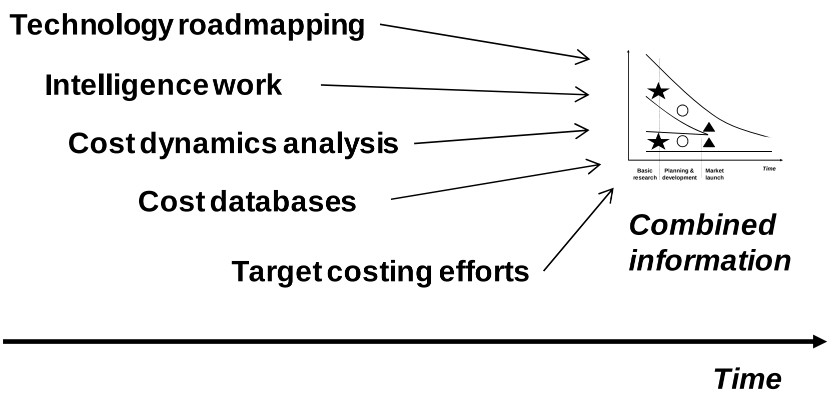

Figure 107: Combining the gathered information

This gathered information is then combined, as shown in Figure 107. Firstly, Warhol is doing extensive technology roadmapping in pre-development to manage their technology portfolio. Secondly, Warhol is carrying out forecasting, trend analysis and cost dynamics analysis through cost capability estimations for promising technologies and they collect information from different sources and concentrate it into internal reports. Thirdly, target costing efforts, market trends and volume estimates are brought together for further analysis of the new product development idea. Furthermore, the results of cost dynamics analysis and cost databases are also used.

6.5.3 Tool attributes and cost analysis

Regarding tool evolution and tool families, two patterns guide the tool use throughout the cost analysis during pre-development.

Firstly, target costing efforts are central and building on several other tools preceding it. These tools are intelligence work, cost modeling and estimation, and cost databases. The connection is a necessary condition. Target costing efforts cannot start earlier than these preceding tools.

Secondly, Warhol uses directional costing as a further parallel tool use. Directional costing is the combination of target costing efforts, market and volume estimates, technology roadmapping and cost dynamics analysis through cost capability estimations for a deeper analysis of the new product development idea in pre-development.

7 Discussion of results, literature and constructs

The preceding chapters have identified and describe how new product development ideas are analyzed with cost information gathered in the pre-development of the case companies. According to Eisenhardt (1989) the next step towards theorizing after the within and cross-case analysis is to shape propositions using the insights of the analysis findings. She points out that it is important to get a ‘sharpening of constructs’ with a refining of the construct definition. Thus, while the last chapters have focused on the within and cross-case analysis and turned up several findings, this chapter will merge these findings to constructs and compare them with the body of knowledge (BoK).

According to the methodology of Eisenhardt (1989) the found data should be compared with possible theoretical ideas. In that phase emerging impressions and relationships of the within- and the cross-case analysis are compared systematically in an iterative process to assess how well or poorly these impressions and relationships fit with case data.

Besides this ‘constant comparison between data and constructs’, the construct definition is also checked against the existing literature. This check of literature statements exposes similarities, but maybe also contradictions. In the cases that contradictions are found, it has to be analyzed why these contradictions are existent (Eisenhardt, 1989). Thus, the function of this section is also to establish the link between previous literature and the findings of the within and cross-case analysis done in the last two chapters.

Following that, this chapter presents the results of this research and deals with the results of the preceding analysis regarding the research questions. In the next step the validity of the research and its limitations are discussed, before a conclusion is drawn.

7.1 First time tool use for cost analysis in pre-development

This section contributes to the answer of the first, descriptive research question of how product cost analysis is done during pre-development.

7.1.1 Finding summary

The findings of this work are overviews on (1) what kind of tools, (2) how many tools and (3) how these tools are used. This is shown on the one hand in a company setting for each company (chapter 4), but also in an aggregated view in the cross-case analysis (section 6.1).

The within-case and the cross-case analyses show the cost information analysis processes of the case companies during pre-development. It is e.g. shown that all but one case company use cost estimation and modeling in pre-development.

This work also studies the first time use of the different analysis tools. Through the aggregated cross-case analysis general patters can be uncovered. Concluding one can say that there are some tools that are starting to be used by many companies in the front end. E.g. all case companies start using intelligence work either in the front end or in the middle of pre-development, indicating that intelligence work is commonly used in early stages of innovation. Yet, there are other tools that are mostly used later for the first time (e.g. cost estimation and modeling). On top of that some tools are used less frequently, but always at the same point of time during pre-development phases. E.g. dynamic analysis of costs during pre-development is only performed by two out of seven companies, but both companies start using it in the middle of pre-development.

One finding of this analysis is an overview, at which point in time the different case companies are using which kind of tools for the first time in their future product cost analysis during pre-development. This can be seen in the different case descriptions in the within-company analysis in Figure 91 on page 203 in section 5.10 and in section 6.1. This finding contributes to the answer of the descriptive, first research question of how the cost information analysis is done. Additionally, the analyzed first time use offers an indication towards the second research question. It partly answers why the cost information analysis is done the way it is, as some tools are generally used earlier and some are generally used later for the first time.

The average tool use during pre-development is overall approximately six out of nine tools per company. Looking at the cost tools only, the average cost tool use during pre-development is three cost tools out of five per company.

Three companies are starting to use cost tools in the front end. Three companies are starting to use cost tools in the middle of pre-development. And one company starts using cost tools in the rear of pre-development. Yet, the biggest step in first time cost tool use is in the middle of pre-development. Four companies increase their cost tool use most significantly then.

Cost modeling and estimation is the most popular tool for product cost analysis during pre-development, as six out of seven case companies use it in pre-development. Two companies start this tool already in the front end. Furthermore, three companies start its use in the middle and one company in the rear of pre-development.

The second most often used tool for product cost analysis during pre-development is value analysis work, followed by the use of cost databases in pre-development. Both tools are started in some cases to be used in the front end.

On the contrary, target costing efforts and cost dynamics analysis are only started in the middle of pre-development.

7.1.2 Enfolding pre-development process literature

Overall the trend of growing cost importance in innovations over generations according Rothwell (1994) has also translated in the use of product cost analysis in pre-development. The found tool use is generally in line with the literature review of Ernst (2002). Yet, the work of Ernst (2002), Cooper and Kleinschmidt (1986) and Cooper (1988) focus on general analysis and this study focuses more on cost analysis.

Cooper (1990) describes Gate 1 as a 'gentle screen' where the newly proposed idea is checked against a few key criteria such as strategic alignment, project feasibility, magnitude of the opportunity, differential advantage, synergy with the firm's core business and resources, and market attractiveness. The information gathered for these parameters can all be validated by using intelligence work. Thus one would expect that all companies use intelligence work before the first screen in gate 1. However, as Figure 91 on page 203 shows, only four of the seven case companies use intelligence work in the front end. The other three companies start using intelligence work only in the middle of pre-development. Two of these three companies (Warhol and Miro) use roadmapping instead as a first tool. I.e. there the strategic planning aspect is higher valued as a direct evaluation.

According to Cooper (1990) several rather inexpensive research activities are carried out before gate 1 in order to find out the potential of the idea, its total available market, and its likely market acceptance. In the case companies, most tools can be categorized as rather inexpensive activities as the information used is usually non-specific to a development and gathered anyway.

Another interesting finding is the financial and cost focus some case companies show right from the start. According to Cooper (1990) financial and cost criteria are not part of this first screen. Nevertheless, two of the seven case companies (Kandinsky and Van Gogh) already carry out cost estimations before the first screen (see Figure 91 on page 203).

The second screen in gate 2 is very similar to the one of gate 1 according to Cooper (1990). According to Cooper's (1990) experience, the idea is re-evaluated with the help of the additional information gained since its last check. Additionally, new evaluation criteria around marketing and financial issues are also used. In line with the finding that some case companies show a financial and cost focus right from the start, the financial focus is also increased in all case companies. Some case companies (Van Gogh and Warhol) already start target costing efforts in the middle of pre-development.

Overall, the case companies show a pattern to more cost analysis work before the first two gates than reported two decades ago by Cooper (1990).

In their time sequenced classification, Ulrich and Eppinger (2000) state that the idea creation in the front end (= stage 0. Planning) is supported by strategic reflections and R&D activities. According to Ulrich and Eppinger (2000) business and technology intelligence are typically starting to be used in the first stage after the front end. In contrast, the case studies show that intelligence work is used by four case companies right away from the front end on. This indicates that intelligence work is started earlier (nowadays) than stated by Ulrich and Eppinger (2000). However, the other three case companies start using intelligence work in the first stage after the front end (stage 1) as stated by Ulrich and Eppinger (2000).

Ulrich and Eppinger (2000) state that the first time that costs are estimated is usually in the middle of pre-development (in their model, stage 1, the first stage after the front end). The case studies show that two companies start it in the front end; three start it in the middle and one in the rear of pre-development. Thus there is a range when the companies start using cost estimation with the mean being in middle of pre-development as Ulrich and Eppinger (2000) state it.

In total one can say that the first time tool use found in the case companies is similar to the one stated by Ulrich and Eppinger (2000), but slightly shifted towards the front end.

According to Kotler and Armstrong (2008) the innovation process starts with an idea generation stage that is immediately followed by a screening stage. The purpose is to reduce the number of ideas significantly and to drop poor ideas as soon as possible. The checked parameters include manufacturing costs and rate of return (Kotler and Armstrong, 2008). Such an early check of future costs and financial return was not found in the studied case companies.

According to Schmitt-Grohe (1972) a two gate approach of idea screening should be used. The first gate is a coarse screen of new product development ideas to eliminate ineffective new product development ideas as soon as possible. The second gate is an economical analysis that should select the most promising ones from the remaining new product development ideas. This approach mirrors the found screening of Miro very well. Also the general tendency that specific cost focused tools are starting to be used predominantly in the middle of pre-development (see Figure 91 on page 203) is in line with the statement of Schmitt-Grohe (1972).

7.2 Organizational contingencies and tool use approaches

Regarding the second research question of ‘why cost information analysis is done the way it is’, it is interesting to analyze whether organizational contingencies are governing the cost analysis during pre-development.

7.2.1 Findings regarding company characteristics

In section 6.1 the analysis approach of the different case companies is compared to the different characteristics of the case companies. The finding is that the style of the different case companies is not significantly interrelated with the analyzed company characteristics like (1) the turnover, (2) the size, (3) profitability, (4) ratio of R&D spending per turnover, or whether the case company (5) operates in a business-to-business (B2B) or a business-to-consumer (B2C) environment. Furthermore, (6) whether a company is market or technology driven (the innovation style) does not correlate with the found patterns of cost analysis during pre-development. Thus the research question ‘why cost information analysis is done the way it is’ cannot be answered by looking at these company characteristics, as these company characteristics are not applicable contingency factors. For the (7) P/E ratio some correlation could be found but statements should be limited as only four data points are available.

7.2.2 Findings regarding other organizational contingencies

However, there are contingency factors for the cost analysis during pre-development that indicate ‘why cost information analysis is done the way it is’. Figure 97 on page 210 and Figure 99 on page 212, show that all companies using an **institutional search and development** approach have a higher relative cost tool importance and use more cost analysis tools in pre-development than companies using an idea suggestion program based idea initiative. Both companies with the **idea suggestion style** (Miro and Duchamp) have the lowest cost tool use. Yet, these two companies are also in the service business, while the goods focused companies do show a significantly higher relative cost tool importance percentage.

The innovation funnel style impacts the number of cost tools used for the cost information analysis process in pre-development (see Figure 97 on page 210). The **few big bets** approach is driven by choosing a single development project quite early during innovation and taking it all the way to a successful market introduction. This approach will lead to a more intense use of different tools right from the start of an innovation project. The other approach is driven by the notion of **survival of the fittest** of concurring innovation projects. This approach will lead to a slower step up of first time tool use during pre-development. Furthermore, companies with a survival of the fittest innovation funnel type tend to have a balanced relative cost tool importance. Also, companies with a survival of the fittest innovation funnel type use on average more tools in the cost analysis during pre-development.

Also, the more **cost sensitive** a company’s customers are, the higher the relative cost tool importance will be and the more likely it is to find target cost efforts during pre-development (see Figure 100 on page 215). If a company is using an approach of target prices segments, it is likely to use target costing efforts for analysis in the pre-development. On the contrary, companies that are not establishing price targets in the pre-development cannot use target costing efforts for the cost analysis during pre-development.

7.2.3 Findings regarding technological uncertainty

There are three major observations that can be combined regarding technological uncertainty and cost analysis during pre-development. The first observation is the finding that organizational contingencies do not govern the first time use of uncertainty management tools (see section 6.2). The other two observations are found in Figure 103 on page 218, where the classification of technological uncertainty and the first time use of uncertainty management tools are compared. The second observation is that all companies with the highest technological uncertainty are also all starting to use uncertainty management tools in the middle of pre-development. The third observation is that two companies that have a lower objective uncertainty, but still worry uncertainties subjectively show two different approaches. One of them uses uncertainty management tools, while the other does not. From these two observations one can deduct that it is the objective technological uncertainty (as defined by Shenhar and Dvir, 1996), rather than a subjective uncertainty, that guides the use of uncertainty management tools in pre-development.

7.2.4 Enfolding literature

Some of the studied **organizational contingencies** are also reflected by other authors in articles and books. However, comparable literature regarding the organizational contingencies and first time tool use is found only fragmented.

Schmitt-Grohe (1972) states on a more general basis that companies operating in markets with a low innovation activity are likely to also have a lower analysis activity during pre-development due to data needs and complexity. Yet, this is not supported by the finding that the ratio of **R&D spending per turnover** is not significantly interrelated with the found first time tool use. However, Schmitt-Grohe (1972) mentions the amount of new products per year in this context and not explicitly the R&D spending per turnover.

The literature dealing with screening approaches of new product development ideas like Schmitt-Grohe (1972), De Brentani and Droege (1988), Bösch (2008) do not distinguish the above mentioned **idea initiative**. Thus, it is not directly stated that companies using an **institutional search and development approach** have a higher relative cost tool importance and use more cost analysis tools in pre-development than companies using an **idea suggestion program** based idea initiative. Yet, Hauschildt and Salomo (2007) state on the case of Bayer that the institutional search and development approach looks ahead to discover trends in advance. This is done to ramp up research and development already before the eminent market introduction is needed. Yet, this approach also implies that more analysis is done in pre-development and thus also explains that more cost analysis tools are used in pre-development with this approach.

The **few big bets funnel** builds on a single development project and rather makes adjustments than kills the new development idea. A company using this kind of funnel will consider quite a broad range of ideas in the start. However, they rapidly screen and merge them into a single project aimed at meeting specific market needs (Wheelwright and Clark, 1992). Furthermore they state that even at the outset market potential and financial expectations are the primary criteria for the project selection in this type of funnel approach. The other development funnel is driven by the notion of **survival of the fittest** and has many ideas in the funnel (‘in petto’), out of which the most promising are selected quite late during innovation. There the key approach is to identify the most promising new development ideas (Wheelwright and Clark, 1992). The screening is arranged accordingly: Companies using the few big bets funnel type create a multitude of ideas that are then sharply reduced to a few in the first screen. In contrast, companies using the survival of the fittest funnel type keep many ideas running parallel to each other and then select at later stages the most promising ones (Wheelwright and Clark, 1992). The findings indicate that the survival of the fittest innovation funnel type goes hand in hand with a balanced relative cost tool importance and use on average more tools in the cost analysis during pre-development. These points are reflected by Wheelwright and Clark (1992). They state that the survival of the fittest innovation funnel is characterized by a selection process based on broader peer review and formal authorization. They also state that the few big bets innovation funnel is characterized rather by senior management selection based on informal processes and gut feeling (Wheelwright and Clark, 1992). Thus these findings are in line with literature. Yet, this also means that when a company is trying to migrate from one funnel type to the other, the future product cost analysis during pre-development phases will also change accordingly.

Cooper and Slagmulder (1997) deal with the **cost sensitivity of customers** and its connection to target costing, however, not precisely with target costing efforts in pre-development. Instead they look at the use of target costing during development phases. The target costing process is internalizing market needs and cost pressure to new product development (Cooper and Slagmulder, 1997). According to Cooper and Slagmulder (1997) companies are operating in so-called survival zones that are determined by the minimum feasible and the maximum allowable price of new product developments. From this price the allowable future costs for new product developments can be derived. Further dimensions of the survival zone are quality and functionality. Cooper and Slagmulder (1997) state that generally target costing is particularly valuable for companies that compete in environments with narrow margins and price levels that change location rapidly but are relatively predictable. The findings in this thesis are in line with this statement. The companies that used target costing efforts in pre-development could predict price levels, while a company that could not do it, did not use target costing efforts. Furthermore, three of the four companies using target costing efforts in pre-development are in situations where the customer has considerable power.

Survey results from Dekker and Smidt (2003) somehow contradict the findings of Cooper and Slagmulder (1997) about the contingency of predictable environments. Dekker and Smidt (2003) found that (1) a perceived intensive competition and (2) an unpredictable environment lead to a use of target costing. Regarding (1) the findings of this research, they are in line with the study of Dekker and Smidt (2003). For (2) this research found that technological uncertainty is not relevant for the use of target costing efforts during pre-development. If using this technological uncertainty as a proxy for an unpredictable environment, the findings somehow contradict Dekker and Smidt (2003). Yet, the technological uncertainty of Shenhar and Dvir (1996) is not identical to the notion of an unpredictable environment of Dekker and Smidt (2003). This could also explain the contradiction in the findings of Cooper and Slagmulder (1997) and Dekker and Smidt (2003).

Hibbets et al. (2003) found that product differentiators in situations of high company rivalry in their industry are likely to use target costing in development. The findings of this research are not directly comparable as the focus lies on pre-development. However, the findings add a notion to the results of Hibbets et al. (2003). This research found that the use of target prices segments increases the likelihood of using target costing efforts in pre-development.

It is found that the technological uncertainty is guiding the use of uncertainty management tools in pre-development. Yet, Ax et al. (2008) articulate that it is not the objective subjectivity, but the perceived uncertainty that drives the efforts of managers. However, that is not the case in these findings; the studied cases move along the objective technological uncertainty defined by Shenhar and Dvir (1996). The higher the objective technological uncertainty the more likely it is that uncertainty management tools are used with the cost analysis during pre-development.

7.3 Tool evolution in pre-development

The second research question of 'why cost information analysis is done the way it is' is also guided by an inherent nature of the tools used for the cost analysis during pre-development. Several patterns guide the first time tool use throughout the cost analysis during pre-development.

7.3.1 Finding summary on tool evolution and specificity

There is a general pattern from unspecific to specific first time cost tool use during pre-development. It is based on the overview of all but one case shown in the different subsections of the cases in chapter 4 and the detailed cross-case analysis in section 6.4 that both illustrate this overall pattern. However, this pattern can be overruled if a company values other aspects more as the outlier shows. Still in this case, the tool use is kept light in order to not waste too much effort on a first specific analysis.

The implication is that if a tool is classified as specific, it is likely to be used later for the first time in the cost analysis during pre-development, while an unspecific tool is likely to be found to be used for the first time earlier in the cost analysis during pre-development.

7.3.2 Enfolding literature on tool evolution and specificity

The characteristics of the tools used for the first time in the analysis change as the new product development idea proceeds in the innovation process. The first time use migrates from unspecific tool use towards more specific tools. This was not found in literature in this detail, but it is in line with general statements in the innovation literature that companies arrange their tools with a rising evaluation effort (Wheelwright and Clark, 1992; Hauschildt and Salomo, 2007). The findings follow the statement of these authors that the effort spent on analyzing one idea goes constantly up the further the idea proceeds. The goal of innovation management is to create, define and select a set of promising development projects that lead to new products with a competitive advantage and that advance the company in the planned business direction (Wheelwright and Clark, 1992). Yet, innovation management has to be designed efficiently and has to justify its expenses (Hauschildt and Salomo, 2007). This means that the knowledge gained with the unspecific tools has reached its limits at some point and that the companies are prepared to spend more effort on analyzing the new product development ideas in detail with different tools to 'define and select a set of promising development projects' (in the words of Wheelwright and Clark, 1992). Also Bösch (2008) recommends using screening with increasing depths, where the detailing of investigation per category increases for each gate.

7.3.3 Finding summary on tool evolution and tool families

There are families of tools that have interconnections, dependencies and preceding tools that are necessary before another tool can be used. E.g. target costing efforts are central and build upon several other tools preceding it. These tools are intelligence work, cost modeling and estimation, and cost databases. The connection is a necessary condition. Target costing efforts cannot start earlier than these preceding tools.

As Figure 105 on page 223 and the analysis in subsection 6.5.1 show, intelligence work and cost estimation always precede target costing efforts in the investigated cases. Additionally, cost databases are always used with target costing effort. This is inevitable through the connection of target costing with these tools: First, target costing builds upon the information gained through intelligence work and this explains why intelligence work has to lead target costing efforts. Second, cost estimations are a crucial part of target costing and explains why cost estimations are starting to be used earlier or with target costing. Third, cost databases are used to store cost information and as this cost information storage is essential during carrying out target costing efforts this explains the connection of these two tools.

This means that different tools are interconnected. They build on each other by using the results of one tool as the input of the other tool. The rule is that if interconnections and dependencies exist for tools generally, they will also exist during the cost information analysis process in the pre-development. In the example of the use of target costing during pre-development phases, one can see a ‘target costing family’. Target costing efforts build on the results of other tools as input. However, the other tools can also stand alone. The overview of Figure 105 in 6.5.1 also shows that target costing is not routinely done when a company uses intelligence work and cost estimation. Thus target costing is a culmination of different other tools and lies on a path that necessitates other tools, but this path can be left earlier when target costing is not done in pre-development phases.

7.3.4 Enfolding literature on tool evolution and tool families

The finding of how target costing efforts are used and that they are usually preceded by the use of intelligence work, cost estimation and cost databases is in line with the target costing literature. Yet it was not stated for pre-development so far. Target costing literature (e.g. Cooper and Slagmulder, 1997; Kaplan and Atkinson, 1998; Kaplan and Cooper, 1998; Ewert and Ernst, 1999; Ellram, 2006) notices the importance of cost estimation in the cost breakdowns to investigate the estimated costs against the allowable cost level. Furthermore, the current state of the art survey of Tani et al. (1994) showed that 88,1% of the surveyed companies also use cost databases together with target costing.

The statement that there are families of tools, with interconnections and dependencies in the future product cost analysis during pre-development has also not been stated clearly in the innovation management literature so far. Even though Wheelwright and Clark (1992) describe different sets of tools and activities that have interconnections and dependencies, these tools and activities lack the focus on costs. Furthermore, these authors do not draw attention to the fact of the interconnections and dependencies. Similar Ulrich and Eppinger (2000) do not explicitly point out interconnections and dependencies between tools and methods in their description of actions in the pre-development phases.

7.4 Directional costing in pre-development

The findings of tool evolution and tool families show that there are interconnections and dependencies between tools in the product cost analysis during pre-development. This section deals with directional costing that also incorporates these traits of tool evolution and tool family groups.

7.4.1 Finding summary on directional costing

Directional costing is a future cost analysis and tracking procedure performed before the start of specific new product development procedures, aiming to map costs and functionalities that are the base for later target costing (see subsections 4.7.7 and 6.5.2). Directional costing uses estimates from cost roadmaps and experience curve effects over the time. It analyses what unit production costs can be achieved with a certain technology in the future.

Information available on the beginning of a new product development effort is often very vague and blurry. Yet, directional costing compiles this kind of information in pre-development based on technology roadmapping, forecasting, trend analysis, and cost dynamics analysis through cost capability estimations, target costing efforts, market trends, and volume estimates.

7.4.2 Comparing directional costing to the body of knowledge

Directional costing incorporates several traits of future novel development roadmapping. Wheelwright and Clark (1992) present roadmapping of relative performance and Groenveld (1997) and Grossman (2004) report roadmapping in different companies. Groenveld (1997) states that roadmapping is a process that helps integrating future technology developments with the business needs of new product development. Directional costing is doing this as well. Also the time horizon reported by Groenveld (1997) and the one of directional costing found in the case analysis are similar. Groenveld (1997) states that for products with short product life cycles these are often not more than three-to-four years, but can extend up to ten years for other more generic product categories. Similarly, directional costing is used for planning ahead in a range of three and more years (before market launch) as it is carried out before the actual development start.

What is different is the cost focus that directional costing has. Even though Groenveld (1997) points out that roadmaps require a good understanding of markets and future functionality, the roadmapping he reports of (made at Philips) focuses on technical issues and not costs. Also the roadmapping reported by Grossman (2004) (made at General Motors) looks mostly at technology and project management controls, but also at marketing and purchasing. He reports that the costs of projects are mapped against the budgeted resources. However, the expected costs of new product developments are not roadmapped and it misses the target costing idea that the cost have to fall below a certain limit to become economically feasible.

Directional costing incorporates several traits of cost roadmapping. Albright and Kappel (2003) have reported a roadmapping approach that they labeled 'forward cost model'. This forward cost model shows cost developments over time. These approaches are also used to analyze the cost evolution of new technologies. The forward cost model does so by using an experience curve trend that it extends into the future. Similar to the case of Warhol, this practice is embedded in a multitude of different other roadmaps that show how a quantity of parameters develop over time.

What is different is the innovation focus that directional costing has. However, these concepts are different to directional costing, as the 'forward cost model' of Albright and Kappel (2003) is not used for innovation evaluation, but as a general roadmapping tool and it is missing the target costing idea that the costs have to fall below a certain limit to make innovations economically feasible.

Directional costing incorporates several traits of product-platform planning. Davila and Wouters (2004) have reported a roadmapping approach that is used in product-platform planning. Product-platform planning is an approach that incorporates future cost saving possibilities into design decisions, by allowing components, processes, and knowledge to be shared across a set of products. Similar to this study, Davila and Wouters (2004) found this approach in a company they studied.

What is different is the scope that directional costing has and the time when both tools are used. Even though the reported product-platform planning also incorporates roadmapping, the decision making is focused on whether to modularize parts of the development to simplify and streamline future developments (Davila and Wouters, 2004). Contrary to this, directional costing looks at the cost level of new technologies and their feasibility in the market - independent whether these new technologies are used singularly or as product-platform. Furthermore, directional costing is done strictly before development start and thus usually precedes platform planning. However, both tools complement each other. The information gained in directional costing can be used in product-platform planning in later stages of the innovation process.

Directional costing also incorporates several traits of target costing. It incorporates the analysis of estimated future product costs of new product development once these are in the market (in contrast to the budget costs of a development project) (Tani et al., 1994, Cooper and Slagmulder, 1997, Kaplan and Atkinson, 1998, Ellram 2006). Furthermore, it assists in analyzing the trade-off between (target) cost and functionality in respect to the market demands. That companies develop target costing methods on their own is known in literature. Dekker and Smidt (2003) found that Dutch companies had independently developed practices that resemble target costing, through the pressures of the competitive and volatile environment they are operating in. Most of the analyzed companies claimed to use target-costing-like methods, but used different names for them. Similar findings are stated by Boer and Ettlie (1999) for U.S. companies.

What is new is the earliness at which directional costing is used. In the literature review, target costing is defined as a set of activities during the planning cycle, aiming to reach a cost target through activities that assist the planning, development and detailed design of new products. Target costing is used for choosing product and process designs that will result in a product that can be produced at a cost that will allow an acceptable level of profit, given the product's estimated market price, selling volume, and target functionality. Even though Tani et al. (1994) report a connection to long-range planning, the classical approach to target costing is to begin using it during the planning cycle when a specific development is kicked-off (Cooper and Slagmulder, 1997; Kaplan and Atkinson, 1998). The difference to target costing is that directional costing starts earlier, almost during basic research and before specific new product developments are started. Through that earliness the figures used for directional costing are fuzzy and less clear than in traditional target costing. It is a forerunner to traditional target costing in a stage when the costs are still too high to start a development program. However, directional costing helps to keep a potential development on the radar screen until the cost of a technology come down to a level that is near to reach the allowable costs of the market. At this point in time development activities are ramped up, so that the new product development is ready once the actual cost of a new product development and the allowable costs meet each other.

Davila and Wouters (2004) state **four large limitations of target costing** when there are no clearly established price points, the understanding of new technologies is limited and when product costs are essential to profitability. (1) In these cases a focus merely on costs distracts from revenue drivers. Furthermore, (2) target costing is too time consuming if time-to-market and technology are essential to profitable new product developments. Additionally, (3) target costing requires formal procedures that are too bureaucratic and linear and are thus not used during new product developments; and last but not least (4) target costing is too detailed and may not reflect future processes for product development decisions in fast moving environments.

However, these statements show to be misleading to some extend when contrasted to the case study of Warhol. Warhol is operating in a high technology setting and regularly carries out developments without clearly established price points and a limited understanding of new technologies to be applied. It should thus be objected to the limitations stated by Davila and Wouters (2004). However, as shown in subsection 4.7.1 Warhol starts target costing efforts already in the first stage after the front-end.

One reason could be that **directional costing responds to two of these limitations**: As for the limitation that (2) target costing is too time consuming, the analysis with directional costing provides information in advance that can then easily be summoned up during the development process. Some part of traditional target costing is moved ahead of the detailed development and **thus is not extending the time to market.** Additionally, directional costing can be used to **map future processes** and thus answers to the stated limitation that (4) target costing may not reflect these future processes.

Summarizing, one can say that directional costing is based on several other approaches like roadmapping and target costing. However, the combination to a specific tool for the future product cost analysis during pre-development is novel to literature. None of the tools found in literature incorporates all three characteristics of directional costing at once. These characteristics are (1) the analysis of future developments for novel technologies, (2) a future product cost focus, and (3) its use in pre-development. Furthermore, directional costing can be an answer to two limits of target costing. It can be kept low on time consumption and thus does not extend the time to market. Also, it uses and provides information about future processes, another limit of target costing according to Davila and Wouters (2004).

7.5 Sharpening of construct and synthesis

The preceding chapters show that product cost analysis during pre-development is based on several regularities through contingencies. These regularities shape the actual cost analysis first time tool use during pre-development and answer the second research question of why the product cost analysis during pre-development is done the way it is. Also, along the approach of managerial choice, these regularities are not a must, written in stone. Managers can choose to not follow these regularities; however, at a penalty in form of cost, inefficiency or new knowledge deficit. In that case, this penalty can be seen as a trade-off for another, desired effect.

The regularities are:

- There is a general pattern from unspecific to specific first time cost tool use during pre-development.
- The innovation funnel type impacts the cost analysis process in pre-development. A few big bets approach will lead to an intense start, but use less tools overall than a survival of the fittest approach. The latter will lead to a slower step up of first time tool use during pre-development, but is likely to have a balanced relative cost tool importance and above-average tool use during pre-development.
- Idea initiative and service intensity affect the cost analysis during pre-development. Companies developing goods and using an institutional search and development approach have a higher relative cost tool importance and use more cost analysis tools in pre-development than companies using an idea suggestion program based idea initiative in the service business.
- Intelligence work is a base for the cost analysis during pre-development as it is commonly and early used in pre-development.
- Relative cost tool importance will be higher and target costing efforts are more likely to be found during pre-development if customers are cost sensitive and price targets can be established for the market.
- Yet, if a company cannot establish price targets in the pre-development, target costing efforts will not be used in the cost analysis during pre-development.
- The higher the objective technological uncertainty the more likely it is that uncertainty management tools are used with the cost analysis during pre-development.

7.6 Contribution table as overview of findings

This research looks at the circumstances of development preparation of cost-competitive products and focuses especially on the future product cost analysis during pre-development phases. Using the research methodology explained in chapter 3, a seven case company study is used to derive the above mentioned research results. In order to investigate how new product development ideas are analyzed with cost information gathered in these early innovation phases, the main research questions of this study are:

RQ I: How is product cost analysis done during pre-development?

RQ II: Why is the product cost analysis during pre-development done the way it is?

Overview of finding	RQ I	RQ II	Addressed in literature so far
Tool overview and managerial use	X		to some extent
First time use of tools in pre-development	X		to a small extent
Company characteristics and cost tool use		X	to a small extent
Different funnels - different approaches on analysis		X	to a small extent
Idea initiative affecting tool use		X	to a small extent
Cost sensitivity and target price affecting cost tool use		X	to a small extent
Tool use from unspecific to specific		X	to a small extent
Parallel and sequential tool use	X	X	to some extent
Directional costing	X		not so far

Figure 108: Summarizing contribution table and classification of findings

Figure 108 gives an overview of the different findings of this research. Behind each finding a cross specifies which research question is mainly addressed by which finding. The last row of Figure 108 states the degree that the literature has explicitly addressed the finding so far.

7.7 Theoretical contributions and managerial implications

One contribution to the body of knowledge is the detailed description of tools used for future product cost analysis during pre-development phases, answering the first research question and thus about 'how the analysis is done'. This is done for seven case companies and provides insights and inspiration to interested **managers** that want to build up, structure or enlarge their future product cost analysis during pre-development. Applying versions of tools that are easier to handle could shorten the analysis time and increase the utility during pre-development. Using further, not so far known tools could help managers to avoid pitfalls during the innovation process. Also from a **theoretical point** of view, the tool overview and description of the managerial use is interesting. It shows a qualitative impression of what kind of tools are used nowadays in companies for the future product cost analysis during pre-development. Furthermore, it shows also the limits where companies see the marginal use of tools against the efforts that they have to spend.

Another finding answering the first descriptive research question is the presentation of when tools are used for the first time during pre-development. The different case descriptions in chapter 4 show at which point in time how many companies are using which tool for the first time during pre-development. This gives **managers** a benchmarking possibility for their company and directions for the new design of the future product cost analysis during pre-development. The **theoretical implication** is two-folded. Firstly, it shows when which kinds of tools are used in companies nowadays. Secondly, it shows for specific tools that they are used already in pre-development phases. E.g. target costing efforts, classified as specific, are shown to be used already from the middle of pre-development on and thus this finding contributes to the body of knowledge.

A further contribution of this work is the presentation of directional costing. In the case of directional costing the **theoretical contribution** and the **managerial** use are similar; a novel arrangement of known tools that fits the needs and framework of future product cost analysis during pre-development. Managers can use that tool to understand the dynamic development of the performance and cost of different technologies faster than the competition not using directional costing. It provides managers the possibility to be aware of future development possibilities several years before a development process (with target costing) is started.

Yet, the second research question asking ‘why the analysis is done the way it is’, is answered in the **theorizing** part of this work that is located in the chapters 6 and 7 and culminates in the section 7.5. Several regularities answering this research question were found. Thus, according to this research, the future product cost analysis during pre-development phases is typically arranged according to certain regularities.

From a **theoretic point** of view this is in line with the innovation management research, but was so far not studied under the aspect of first time tool use for the future product cost analysis during pre-development phases. The **managerial implication** is that the approach on innovation of a company has to be taken into consideration when designing the process for future product cost analysis during pre-development. Furthermore, a change in this approach on innovation will also lead to the need to change the tool use for this cost information analysis.

All in all, this work presents several situations that the case companies and managers are facing in real business life in the pre-development. It integrates these with organizational issues and provides seven major findings that contain, on the one hand, theoretical propositions and on the other hand have managerial implications.

7.8 Evaluation of the research and limitations

The validity of these findings will be discussed in this section. Validity issues have already been touched upon when discussing different methodological possibilities in chapter 3. The following subsections emphasize three major quality criteria of this research, the reliability, the validity and the generalizability of the findings.

7.8.1 Reliability

The value of research stands and falls with the validity of findings. However, for a finding to be valid it has to be measured first of all by a reliable measure. “Unless a measure is reliable, it cannot be valid” (Robson, 2002, p. 101). Reliability is the consistency or stability of a measure and a key question is that if the research were to be repeated, would the same result be obtained? (Robson, 2002, p. 93).

Unreliability might have several basic causes in this research. One source of unreliability in this research might be **observer error** and **observer bias**. In order to avoid this, the case study approach of this work followed the approach of Eisenhardt (1989) to let relationships emerge and then test these emerging constructs with the evidence in each case. Furthermore, a case study database was maintained, following the recommendation of Yin (1989). Furthermore, the research was carried out by using a conceptually clustered matrix (Robson, 2002) which focuses the analysis on different aspects next to each other and not case-by-case.

Another possible source of unreliability in this research is the other participants of this research. The interviewees can be wrong in their statements (participant error) and/or interviewees can also be biased (participant bias). To avoid **participant error** in this study of future product cost analysis during pre-development phases, the procedures were asked for each case company from several employees individually. Furthermore, if possible, written statements, corporate charts and presentations were asked for, as well as the company pre-development procedures as a basis for the further interviews and discussions. This research followed the recommendation of Eisenhardt (1989) to be opportunistic and to use all material that is available, i.e. not to restrict the data gathering on specific types of information. This increases the likelihood of discovering participant error. In contrast, a **participant bias** might be incorporated in the findings. The strength of qualitative research is to incorporate some kind of intuition, beliefs and values to yield findings that quantitative research would probably not uncover. However, this openness to these ‘soft factors’ makes qualitative research potentially subject to participant bias. In this research the participant bias was handled by working with several people and discussing issues repeatedly. Also, the participants did not have any motivation to distort their answers. Discretion was guaranteed by researcher and senior faculty staff, none-disclosure agreements were signed before starting data collection and the (masked) data used for this research was subjected to company internal checks before being released for the research.

7.8.2 Validity

Not only has the research to be carried out in a reliable way, but the findings that research yields also have to be valid. “Validity is concerned with whether the findings are ‘really’ about what they appear to be about” (Robson, 2002, p. 93). Yin (1989) distinguishes three types of validity: The first one is construct validity, the second one internal validity and the third one external validity.

Construct validity is about whether the measures used in the study achieve a correct measurement for the issue under study (Yin, 1989; Robson, 2002). E.g. it can be delicate to judge whether a tool is unspecific or specific, as a company can use an unspecific tool for a very specific analysis. However, there is a clear general inclination for each of the different tools and the impression that the cases gave were quite clear.

According to Yin (1989) construct validity is an often criticized point in case-study research. This work follows the recommendation of Yin (1989) and Eisenhardt (1989) to use multiple sources of evidence to enhance the construct validity. Furthermore, Yin (1989) recommends maintaining chains of evidence in the case study reports. This thesis displays chains of evidence by following the methodological steps given by Eisenhardt (1989) also in the way the research is reported (from how the field is entered, the analysis is conducted up to reaching the conclusions and enfolding literature).

Internal validity is about whether the causal relationships presented in a study are sound (Yin, 1989; Robson, 2002). Generally in research, a pointed out relationship might well be only a spurious correlation or may be a misinterpretation of the impact of some other variable (Yin, 1989; Eisenhardt, 1989). This is irrelevant to the descriptive part of this work, but very important to the theorizing findings. In order to also ensure internal validity, several patterns have been followed in this work. First and foremost, the methodology used in this research provides a sound base for the internal validity of findings. When Eisenhardt developed the case study research methodology that is used in this work, she incorporated recommendations of Yin on how to increase the internal validity of findings (Eisenhardt, 1989). Additionally, this work followed Yin’s (1989) recommendation to use explanation building, i.e. to build a causal explanation about the case study data analyzed. Furthermore, pattern-matching was carried out with all findings presented in this study. The pattern matching logic compares an empirically based pattern with a predicted one to strengthen its internal validity (Yin, 1989). This was done with every finding, by comparing it to similar findings stated in literature, an internal testing procedure built into the followed research methodology of Eisenhardt (1989).

External validity stands for the fact that the findings of a study can be generalized beyond the immediate case study (Yin, 1989; Robson, 2002) and is dealt with in a separate subsection.

7.8.3 Generalizability

Generalizability or external validity refers to the extent to which the findings of case study research are more generally applicable beyond the specifics of the setting studied (Yin, 1989; Robson, 2002). According to Yin (1989), generalizability or external validity is often criticized for case studies, especially for single case studies. For this reason, a multiple case study approach was chosen. Also, the research methodology presented by Eisenhardt (1989) ties the research closely to existing literature and that "enhances the internal validity, generalizability, and theoretical level of theory building from case study research" (Eisenhardt, 1989, p. 545).

As already mentioned above, the research underlying this study is about tools that might be unfamiliar to managers. Also the sophistication of use will be different in different companies. Therefore the validity of the results of a less deep qualitative research (e.g. a survey) would be doubtful from a reliability point of view. This study used the strength of the case study research approach and brought up issues that quantitative research would have hardly been able to identify. In the words of Yin (1989), this case study research approach brought up findings from analytical generalization, rather than statistical generalization (as quantitative research would yield).

Yet, there are also points that may reduce the generalizability of this research. Caution should be exercised in generalizing the results to industries with patterns very different than the ones of the case companies. As many of the studied companies are operating in the telecommunications or electronics industry, there might be a bias in the findings towards these kinds of industries. The case companies were not selected randomly, but according to Eisenhardt (1984) guided by the requirements stated in 3.4.2.1. However, no case company was dropped because it did not fit other findings, thus there is no reason to suspect that the sample is biased though selective fact preference.

Furthermore, the scope of this thesis is deliberately restricted to the area of pre-development. Many presented tools are or could also be used in later phases of the product life cycle. Also, some findings valid in the pre-development could be not valid in these later phases anymore. Thus, in addition to the research made, the use of the found tools in later phases of the product life cycle could also have been studied. However, this would go beyond the capacity of this thesis.

7.9 Conclusion and possibilities of further research

This study set out to identify, classify and describe how new product development ideas are analyzed with cost information gathered in pre-development. The focus of this research is the circumstances of development preparation of cost-competitive products through future product cost analysis during pre-development phases. This work contributes to the answers in several directions of research requested by other academics: Foster and Young (1997) call for finding relatively unexplored areas in management accounting. Deszca et al. (1999) call for research on how companies can assess technologies and new product development ideas for breakthrough innovations in an efficient way. Shields and Young (1994) call for research on how R&D

professionals make decisions that affect product life-cycle and target costs. And last but not least Dekker and Smidt (2003) call for the study of the actual processes and methods of cost management during innovations by firms.

To discover general patterns, this thesis uses a seven-company case study with a contingency theory approach that looks at the different conditions attached to a specific situation in which some cost management tools are used by some companies while others do not so. Besides the descriptive part, this research takes the contingency approach that there is not only one right way to arrange the analysis of cost information during pre-development phases. It rather depends on several characteristics of the specific company and environment in which it is operating in. This research provides contingent variables of the new product development idea nature, organizational characteristics, and innovation approach which are important to understand why new product development ideas are analyzed with cost information gathered in pre-development as they are. The case studies and its reflection show that product cost analysis during pre-development has to follow several regularities to fit contingencies of the company and situation of the innovation.

This thesis shows that industry sees a need for future product cost analysis during pre-development, as most companies are using different tools for it. It shows how cost information is collected and processed in business and provides descriptions for their use and indicates the arrangement parameters of the analysis of new product development ideas with cost information in pre-development. Through that, it contributes to both business research and also the improvement of industry practices.

Furthermore, this thesis identifies regularities as contingency factors for the product cost analysis during pre-development. These sketch the framework that the studied case companies are operating in. Yet, this research uses only a one time snap-shot. It would be interesting to also study the development of the product cost analysis during pre-development over the time in a longitudinal study. This would add a further interesting dimension by analyzing how the product cost analysis during pre-development alters, as companies and their competitive environment change. Similar as in the model of Khurana and Rosenthal (1997), companies could move in three categories over time according to their product cost analysis during pre-development based on the aforementioned regularities. The first category (awareness) would contain tools that are seen as a basis for the cost analysis during pre-development. The second category (islands of capabilities) would progress towards cost modeling and estimation during pre-development. Yet, if a company is developing its cost analysis during pre-development even further it can advance to the third category (integrated capability) and use directional costing.

Directional costing has only been found to be used in one case company . Even though it is novel to academic literature; it could be used by other companies. It would be interesting to identify these companies and study their use of directional costing. Also, the actual application of directional costing in business could be researched further to acquire a deeper understanding of its use, benefits and limitations.

This thesis looks deliberately on the narrow spot of product cost analysis during pre-development. However, this research also shows that many approaches used in business utilize target prices and look for profit estimates. For this analysis, product cost is only one side of the coin. It would surely also be very interesting to study the marketing point of view of the analysis during pre-development. This would allow not only looking at the future cost, but also at the future sales. Together this would make it possible to obtain the full picture of the business potential of new product development ideas in pre-development.

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