Helsinki University of Technology
Laboratory of Industrial Management
Report 2007/3
Espoo 2007

Management of early innovation phases with cost management tools
Benchmarking methods used in business

Frank Bescherer

Helsinki University of Technology
BIT Research Center
Industrial Engineering and Management
Laboratory of Industrial Management
P.O. Box 5500
FI-02015 TKK
Finland

Phone: +358 9 451 2846
Fax: +358 9 451 3665

http://www.tuta.hut.fi
http://www.bit.hut.fi/valuenet/

Edita Oy

Espoo 2007

ISBN 978-951-22-8742-0 (print)
ISBN 978-951-22-8743-7 (online)
ISSN 1459-806X (print)
ISSN 1795-2018 (online)

Contents

Acknowledgements

This research has been completed during a research project titled INCA – INcreased Cost Awareness – at the BIT Research Center of Helsinki University of Technology. I would like to acknowledge funding from the Finnish National Technology Founding Agency (TEKES) who provided the main financial support for this work.

Furthermore, I would especially like to thank Dr. Jouko Karjalainen and Prof. Eero Eloranta for their constructive feedback on this report. In addition, I would like to thank the members of the different companies that have made this work possible through their collaboration, open-mindedness and good discussions.

Executive summary

This report shows how companies handle uncertainties in early innovation phases using cost management tools and gives recommendations regarding the implementation of several practices. Seven international companies' methods were benchmarked and analyzed.

Overview

The report proceeds with an introduction discussing cost management techniques of early innovations. Next, the scope and methodology are described. Then, the challenges of early innovation phases companies are facing are explored. Discussion then considers how these problems can be tackled, before an overview lists all the methods found in the benchmarked companies.

The report next focuses on several, selected tools. For each set of tools, a literature-based introduction is given, after which the methods adopted in the companies is described. Each section includes empirical examples allowing a management overview (these are located in grey boxes embedded in the main text). Finally, a discussion is given on how to arrange the described methods. Additionally, the different roadmapping practices described in the findings are aligned to a coherent method. This method can be seen as a precursor to target costing in early innovation phases, and is referred to as: 'directional costing'.

Summary of findings

There are several challenges that companies are facing in the early innovation stages. One of them is that information is more valuable the earlier it is available, especially before decisions with lock-in effects have to be made. These lock-ins result out of uncertainties that are usually imminent to early innovation phases. A response to these challenges is to proceed more efficiently in the very early stages of innovations. This can be done by dealing with uncertainties in a professional manner. Furthermore, information gathered with the help of good cost management methods can lead to lock-in effects underpinning good development and design, as managerial decision making is made less problematic.

The tools described in this report are not standalone methods, but have to be used as a set of tools, bringing additional information to the mosaic of early innovation. The base is established through high-quality intelligence work which is anchored in good knowledge management practices and the use of expert opinion, e.g. in a cross-disciplinary expert network. Companies are using scenarios in several ways during early innovation stages. Good practices around their use are, for example, to use them to identify different alternatives, to analyze them and to study different drivers for success. Additionally, scorecards can help to make discussions more objective, as they connect values or estimates to a specific situation or development idea under discussion. The created results of scenario analysis and scorecards can be used together with roadmapping in early innovation stages. In an advanced case, trend analysis can be used to understand the dynamic development of the performance and cost of different technologies in the roadmapping work, as a preliminary target costing effort. (This effort is labeled 'directional costing' in this report.) As developments can take several years until market launch, it is important to know how the costs connected to certain technologies will develop over that time. In this instance, a studied company uses the expertise and experience of senior employees to estimate the dynamic cost behavior of technologies over the time. Additionally first cost models are developed already in the front-end of innovation. This cost modeling uses the information gathered during the basic research and later R&D activities. Finally, another interesting set of tools, is the cost capability estimation of new technologies, together with 'perfect waste-free' product cost calculations. In this approach, calculations of the theoretical minimum of costs to fulfill a function are made to evaluate different new, potential production technologies.

As previously discussed, all these methods have to be seen as a set of methods that contributes information towards right decision making during the early phases of innovation. A recommendation when to use different tools is shown in Figure 1.

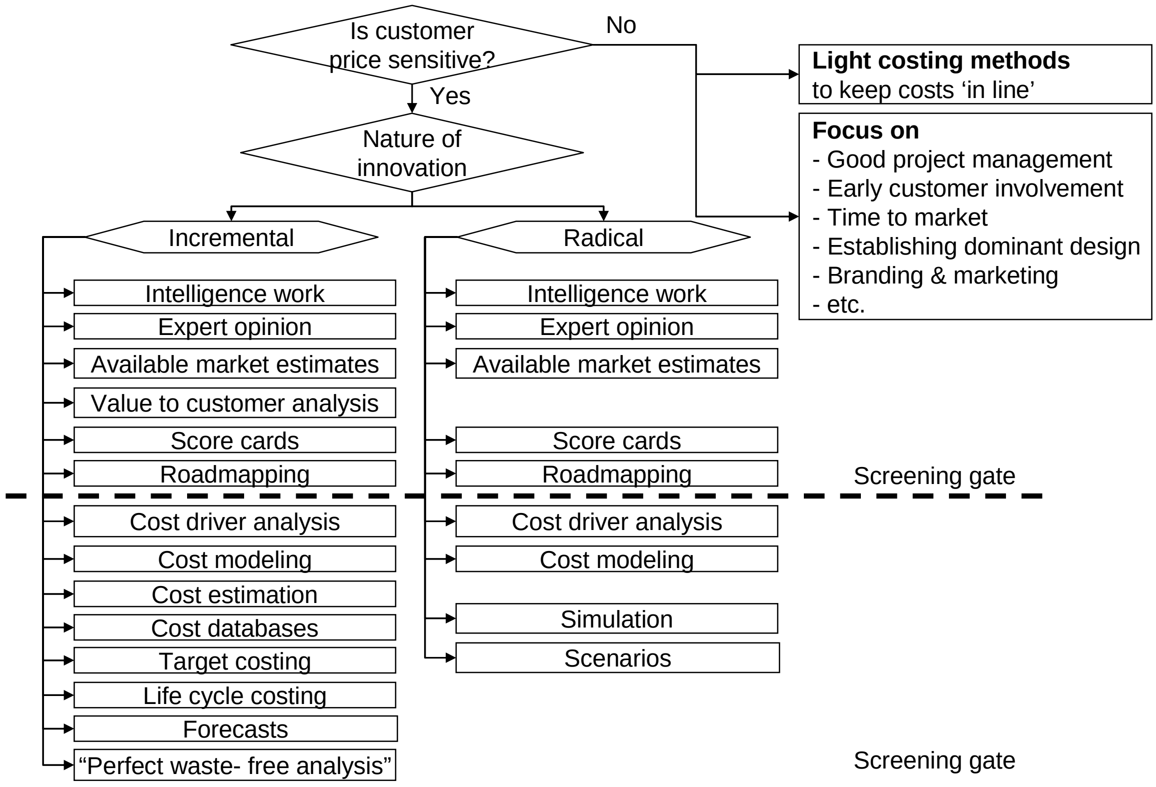

Figure 1: Overview and usage recommendation of different tools

A real life example

A managing director of a corporate research center described one example of a research project he was involved with some 20 years ago. The task was to build a prototype of a 'nowadays' important piece of equipment in telecommunications systems that was just about to get developed. The challenge lay in the fact that the technology was not very developed. This new technology required a new integrated circuit (IC) chip generation that was only nearing development. However, the manufacture of these new generation IC chips, were only as prototypes and the company was not prepared to guarantee the performance of these prototypes. Additionally the testing infrastructure for this new generation of IC chips was not set in place, i.e. only a very limited amount could be tested (laboratory tested) as the standard test could not be used.

The performance of the new generation was 180 MHz, while the standard testers were testing at 1 MHz. The company had to test the chips themselves and a large percentage failed. This made the functioning ICs very expensive per functioning part, but the company was prepared to pay as, the required quantity of chips was very low for the research purpose.

However, suddenly, while the company was installing an initial small-scale prototype, several clients approached the case company, as they also wanted some of these first small- scale prototypes for their own testing and learning with the new technology. The problem, however, was that whilst the amount of ICs to test was multiplied by ten, the costs were now ten times as high. As the interviewed managing director of the research center stated, one could literally see how one was throwing piles of money into the waste bin for every IC that failed the high performance test – several hundreds per month.

On reflection, the managing director of the corporate research center can say that the researchers were overrun by the decisions of marketing to scale-up something that was not meant to be scaled-up in this fashion. The managers of the company did not think that the client wanted to have prototypes so fast. At the same time the researchers did not consider the costs for a market feasible solution over a longer product life cycle. They did not look at the possibility of a cheaper mass manufactured solution, but were just happy that the prototype worked. So, the costs that were investigated were R&D budgets, but the life cycle cost perspective was not analyzed. Nowadays, the interviewed managing director would look at these life cycle costs much earlier…

1 Introduction

In times of saturated markets, the cost aspect becomes more important, as products have to 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.

This report shows how companies handle uncertainties in early innovation phases with cost management tools in real business life and gives a recommendation about how and when which best practices should be implemented.

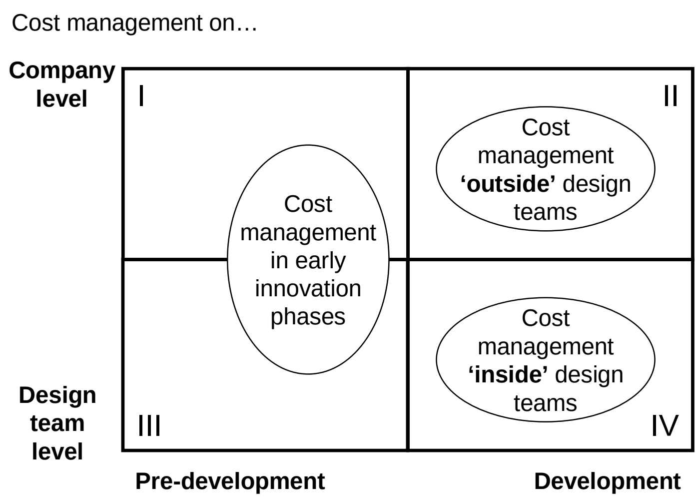

Figure 2: Focal point of this dissertation

However, there is often a clear "tension between focusing on technological innovation, product performance, time-to-market, and designing cost-effective products" (Davila and Wouters, 2004, p. 24) during innovations. So far one 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. Nowadays the frontier of costing research is moved further along the development process to its very beginning – the front-end of innovation. 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. Similar, in the new product development literature, analyses of costs is reduced to feasibility studies, which are usually far away from the preciseness that cost management techniques could offer. The motivation for the research underlying this paper is to find (cost) management practices which could improve management decisions made in the front-end of innovation. For that this benchmarking study was prepared.

Development teams might not want to spend much time on analyzing cost trade-offs in early innovation stages. As argued elsewhere (Bescherer, 2006), tools as guidelines and checklists could bring the cost on the right track, but not hinder creativity or delay the innovation process. Thus research about good and best management accounting practices and methods in early innovation stages is needed to fill the insufficiently explored spot in academic literature and practice.

2 Conceptual framework

In times of saturated and competitive markets, the cost aspect becomes more important, as the product has to be sold at a competitive price in order to be successful on the markets. A good information preparation during these first stages is seen as crucial to the success of new product development projects by the author, as the uncertainty for important decisions about the new development is reduced. This leads ultimately to a mitigation of lock-in effects during the new product development process. The research front of cost management has advanced to the early innovation phases and its challenges.

In the innovation process development teams often do not spend time on analyzing the cost efficiency of a chosen solution (Davila and Wouters, 2004). This can have two reasons. Firstly, the development team might only be interested in solving a problem as fast as possible to move further to the next problem. Or secondly, they do not want to spend so many resources on the analysis, because they do not know if the product will sell in enough volumes, so that they get their development expenses paid back. In both cases it would help if they would have tools that provide the needed information, but are easy to apply.

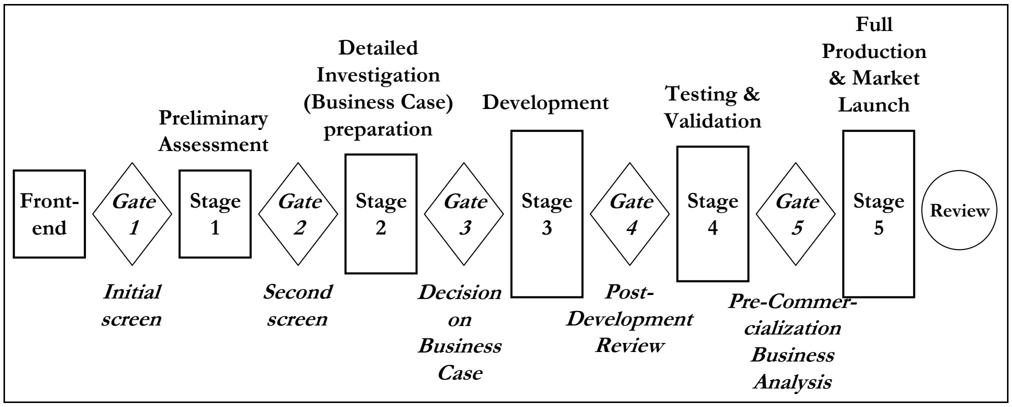

Figure 3: Stage-Gate Model (amended from Cooper, 1990)

This report concentrates on the early stages of the new product development. These are the stages and gates up to gate 3 in the stage-gate model of Cooper (1990). In his model Cooper labels Gate 3 as the 'decision on business case' and describes it as the final gate before the development stage. Cooper and Kleinschmidt (1993) claim that this is the last phase at which a new product development project can be killed before high expenditure incurs.

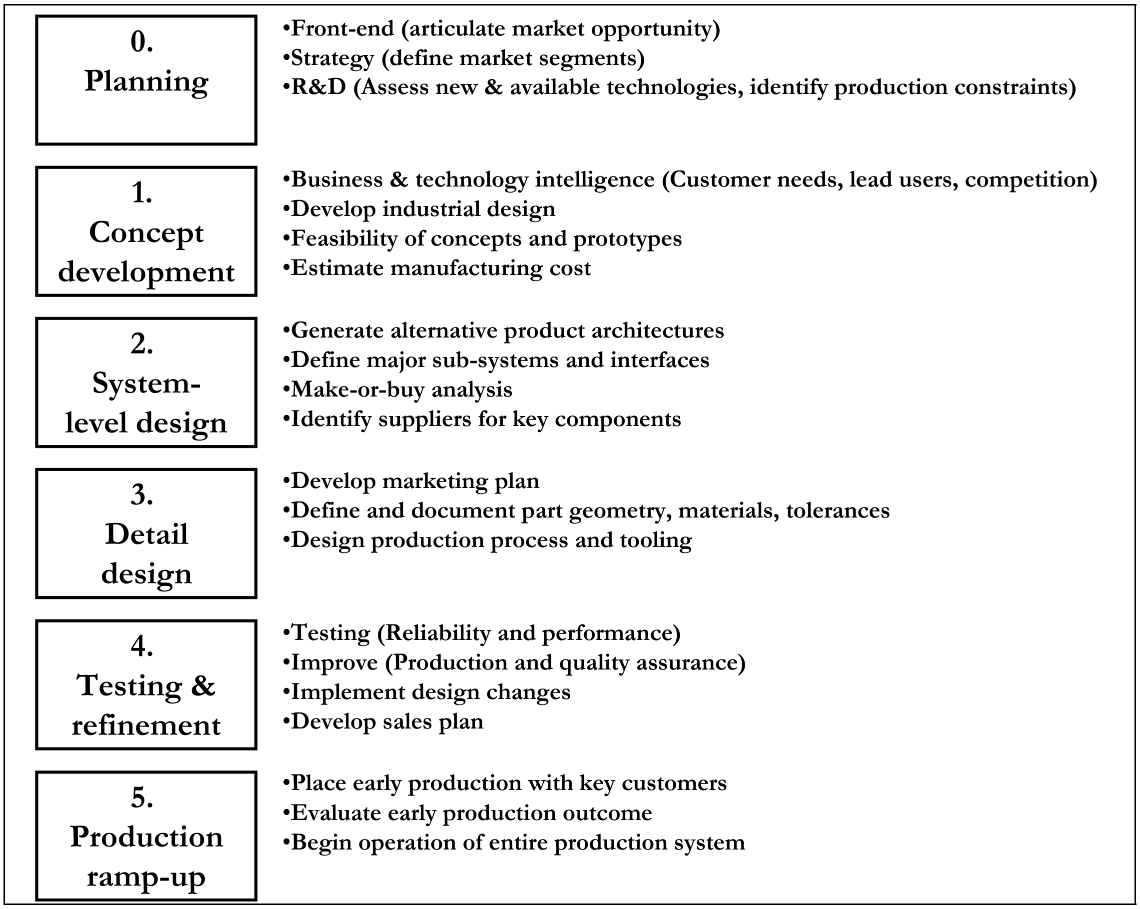

Figure 4: Different phases and main activities of a development process (Ulrich and Eppinger, 2000)

A competing view on the development process is presented by Ulrich and Eppinger (2000). They have segmented the product innovation process into six different phases (see Figure 4).

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. It is the first phase in which Ulrich and Eppinger (2000) describe the use of cost management methods. These methods are used to estimate the manufacturing costs. In a large definition, this phase (together with the planning phase) can be seen as the front-end of innovation.

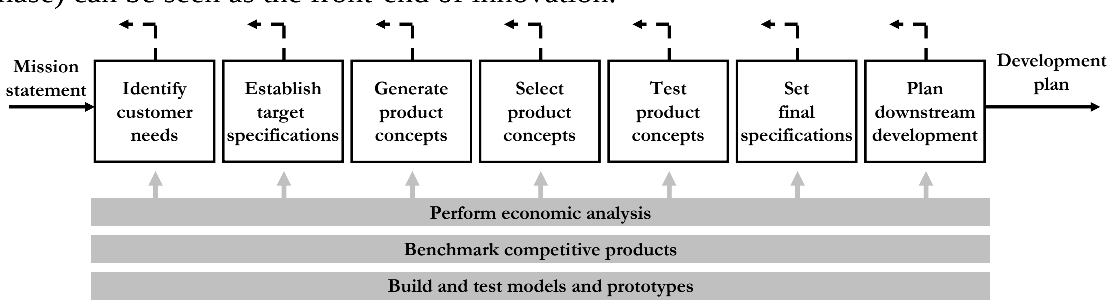

Figure 5: The different sub-tasks of the concept development phase

As this research is focusing on how decision making in early stages of innovations can be supported by cost management, the work focuses on the stages 0 to 2 in the model of Ulrich and Eppinger (2000). They brake the concept development phase further down in several sub-tasks that are done in a sequence and shown in Figure 5. However, in the view of the author, these sub-tasks cannot all be grouped into the concept development phase, but might be located in the earlier or later phases.

Radicalness of innovation

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'. According to these authors radical innovations are innovations that result in discontinuities on macro and micro level of economic systems. Radical innovations are not developed based on a recognized demand, but are breakthroughs that will rather create a demand previously unrecognized by the user. Another term that specifies an innovation type is really new innovations. Garcia and Calantone (2002) define this term as a moderately novel result of an innovation. In their view it is surprising that, even so this type of innovation comprises a large share of innovations, the research on really new innovations is only moderate so far. The third major term that these authors are defining is incremental innovations. They define these as "products that provide new features, benefits, or improvements to the existing technology in the existing market" (Garcia and Calantone, 2002, p. 123).

Another and finer categorization is presented by Wheelwright and Clark (1992). They distinguish four different types of development projects, shown in Figure 6.

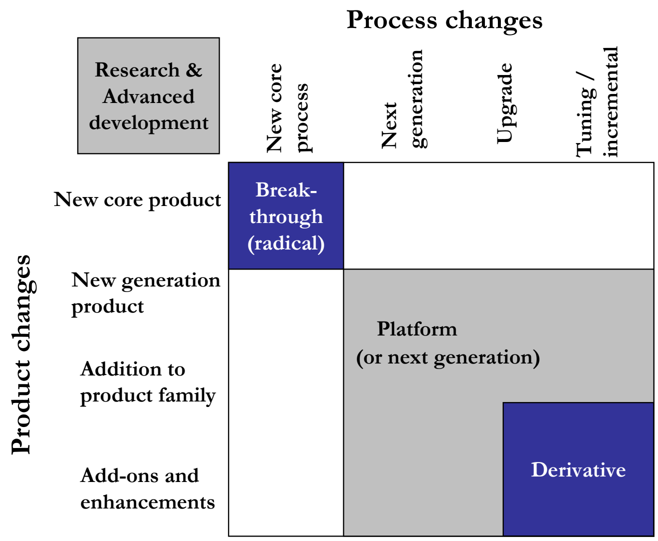

Figure 6: Four types of product / process developments (Wheelwright & Clark)

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 development projects. According to Wheelwright and Clark (1992), these projects are often conducted by a research or advanced development group that is detached from the core development organization. The second type is breakthrough development projects. These projects develop entirely new products and processes (first generation). They are called breakthrough, as they use core concepts and technologies that are completely new to the developing organization. The third type is platform or generational development projects. These concepts are aiming 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. These projects can also be referred as incremental, as they refine and improve selected performance dimensions to better meet the needs of specific market segments. These development projects tend to be significantly narrower in scope and resource requirement than the other development types (Wheelwright and Clark, 1992). Additionally a fifth type could be included according to Wheelwright and Clark (1992) – called alliance or partnered projects. These are projects where the company buys a newly designed product or process from another company.

One challenge in early phases of innovations that goes hand in hand with radicalness, is the technology uncertainty with which companies have to deal with. According to Tatikonda and Stock (2003), the causes of technology uncertainty can be centered on novelty, technology complexity and technology tacitness. Technology novelty itself has two different but related elements, the newness and the degree of technological change. On the contrary, technology complexity has three different elements, the level of internal technological interdependence, the level of external technological interdependence and the scope of the technology. The third class – technology tacitness – is the degree to which a technology is physically embodied, textually or graphically codified and complete, as to be defined and used in its final form. The higher the uncertainty and complexity of a technology in these areas, the more complex innovation around this technology gets.

The innovation process seen as funnel

It has been claimed that it takes about 3000 raw ideas in the initial stage to come up with one commercially successful product. Independent on the analyzed product type there is a general valid pattern for the several screening stages an idea goes through: 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. Trough that the amount it reduced to 300 followed-up ideas. 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 that turn out to be successful. (Stevens and Burley, 1997, p. 16)

Wheelwright and Clark (1992) describe two different time or phase based innovation processes. The first one focuses more on strategic issues and management, while the second focuses on operative issues.

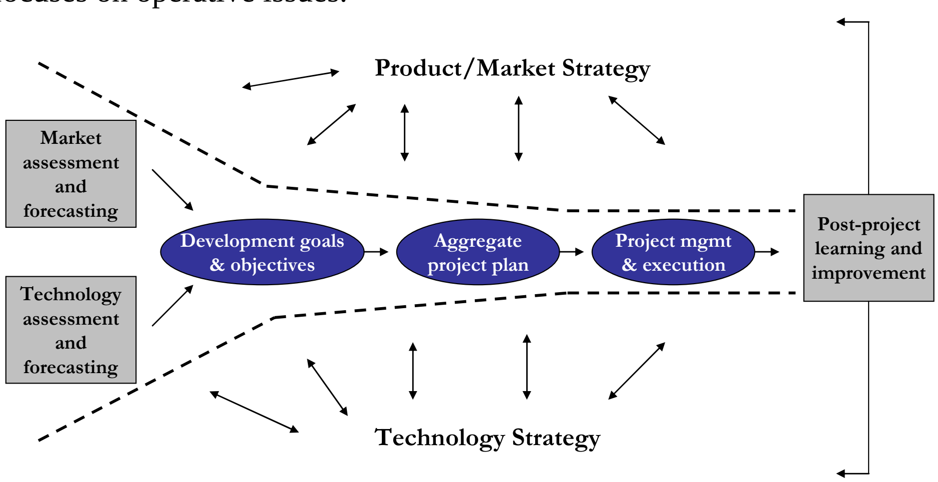

Figure 7: Development strategy framework according to Wheelwright and Clark

The framework presented in Figure 7 plays an important role in focusing development efforts according to Wheelwright and Clark (1992). The goal of this development strategy framework is to create, define and select a set of promising development projects and the capabilities needed to achieve a competitive advantage. Furthermore, the framework helps to effectively and efficiently manage and steer development efforts in the planned business direction.

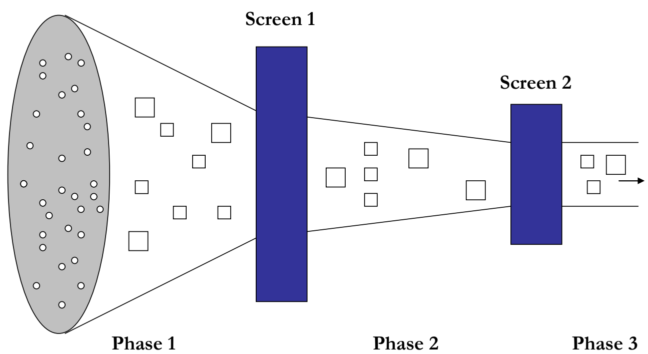

Figure 8: The development funnel model by Wheelwright and Clark

Figure 8 shows the development funnel that is seen as optimal by Wheelwright and Clark (1992). In phase one, the front-end, the new product / process idea generation and the concept development is taking place. In phase two, the proposed project bounds are 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, not to make go/no-go decisions. The reviews of screen one are done in constant 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 / process development options and select the ideas that should be pursuit further in new development projects (Wheelwright and Clark, 1992).

How cost management can contribute to innovation management

When analyzing alternatives in the pre-development state, life cycle costing is one possible method for cost management of these developments. Usually there will be a trade-off between costs occurring at different times of the life span of a product (e.g. higher development costs can save costs during operation). Life cycle costing deals with finding the cost-wise best solution for an investment over the whole life span of a product (Woodward, 1997; Kaplan and Atkinson, 1998; Vasconcellos and Yoshimura, 1999; Jiang et al., 2004). In literature it is claimed that usually a large share of life cycle costs is determined already in the development phase, even so the costs are incurred at a later stage. This effect is called lock-in. E.g. Boothroyd (1988) reports that studies at Ford Motors have shown that even so 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 speak of lock-in effects where 80% of the final product costs are locked through decisions taken in the new product development phase (Blanchard, 1978; Michaels and Wood, 1989). Additionally to life cycle costing, target costing is often used in early stages of new product development. Target costing is a technique 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). A good information preparation during these first stages is crucial to the success of new product development projects. This is as the uncertainty for important decisions about the new development is reduced. This leads ultimately to a mitigation of lock-in effects during the new product development process. In business with high value equipment, it is essential to realize the causes and levels of life cycle costs for the right investment decision. Additionally, companies might need accurate forecasts of costs over a longer time or planning purposes or as they might have to commit to prices for a long time, e.g. six month or a year ahead, with some key customers, e.g. governmental agencies (Carbone, 2004).

Cost management is an important part of innovation processes since the early 1970s, when companies had to focus more on cost control and cost reduction. In the innovation phase model of Ulrich and Eppinger (2000), cost management methods are used already the second phase – concept development – where identification of needs of the target market is situated. In the innovation phase model of Cooper (1990), cost estimations are also part of the second phase – stage 1 – before they are evaluated in the screen of gate 2. What these authors might miss out is that cost estimations as a part of evaluating the attractiveness of a new idea might already play a role in the front-end of innovation. As stated above, the time span spent on the front-end might be very small for some products, but larger for others. Depending on the business type, companies might, or should already use cost management methods in this earliest stage. Thus, as researchers have an objective point of view in the evaluation of concepts of innovation and technology management (Brady et al., 1997), a study about which cost evaluation and assessment should be used to evaluate and rate new technologies is ideally made by a researcher.

Often technology or design choices show a break-even effect, that one technology might be more cost effective at lower volumes, while the other is cheaper for higher ones. This is a static view of the technology choice. However, there is also a dynamic view. Over the time a 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 at a certain time point, they could decrease faster over some years so that the technology gets cheaper in the long run.

In the view of the author cost management together with management of uncertainty tools are likely to reduce the technology uncertainty connected to early innovation phases. This comes from the fact that cost management can reduce the impacts of unknown (novel), complex and tacit technologies through the analysis of these issues with the help of cost management methods.

An overview of the found tools of this study is shown in chapter 6. There are several tools that are not described in the literature review so far. Nevertheless, each tool is introduced with generic descriptions from literature. This is made in order to keep this conceptual framework lighter.

3 Statement of aims, scope and research objectives

The research underlying this report looks at one piece of the mosaic needed for successful innovations. The aim of this report is to demonstrate how cost management is used in early phases of innovations in business so far and how different methods could be combined to have the most effective support to the management of innovations. This study is one part that helps to identify and manage the issues connected to the uncertainty of early innovation stages. The scope of this work is narrowed down through its research approach. In order to find out what could be labeled a 'best practice' a more quantitative analysis should be done. However, it would still be very difficult to claim that a tool would be a best practice, as these tools have to be seen in a set and there are always different conditions attached to a specific situation in which a tool performs best (Lawrence and Lorsch, 1967).

From a scientific point of view the research question which stands on top of this research effort is **how cost management can facilitate the management of innovation**.

However, before looking at the tools companies are using it is examined what kind of challenges companies are facing in the early stages of innovations:

What are the challenges in the early stages of innovations that companies are facing?

This research question is answered in chapter 5.

Another focus on which the research question can be narrowed down is the tools and methods of cost management and their usage in the industry so far to:

What tools related to cost management are used in the industry so far and how are they used?

The first part of this research question is answered in chapter 6 below which presents a list of methods found in the benchmarked companies. The second part of this research question is rejoined with an extensive display of how selected methods are used in real business life by companies.

The report closes with a discussion about how the presented methods could be used and arranged in the most effective way.

4 Methodology

Benchmarking represents the process of comparing and measuring an organization or production process with business leaders anywhere in the world. The aim is to gain information that will help to take action to improve the performance of a company. There are four different levels of benchmarking, depending on whom is used as benchmarking partner. (This study uses the third level.) The cheapest and easiest, and thus first level, is to benchmark several business units / production sites of the own company. However this brings the least new information about other practices and improvement possibilities. The next level would be to benchmark with business units / production sites of competitors. The third level – and **the approach taken in this study** – is to benchmark similar functions with companies working in other fields. This can bring fresh ideas into the industry and offer the benchmarking company a head-start. At the highest abstraction level stands the generic benchmarking. Here different functions with the same basis are compared to find out improvement possibilities. An example is the benchmarking of the ground service of an airline with a formula one pit stop (Baum et al., 2004).

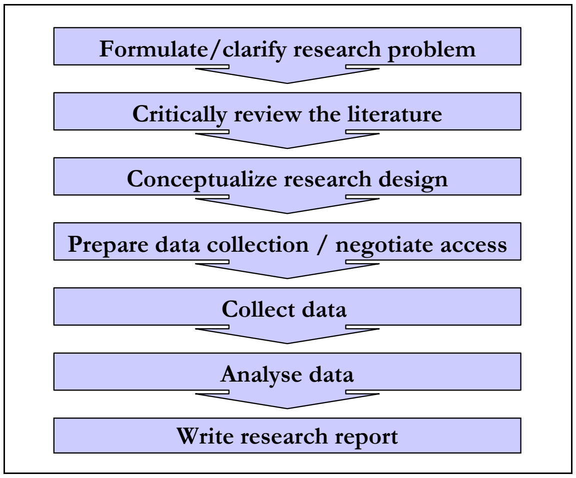

Figure 9: Generic steps of a research project (amended from Kumar, 1996 & Saunders et al., 2000)

Figure 9 shows how the research project was built up. The first step was to formulate and clarify the research problem. That was done in several discussion rounds with academic and industrial colleagues. After that the literature was reviewed, focusing on literature from the fields of cost management and innovation management. In the third step the research approach was conceptualized as a qualitative benchmarking study. The preparation of the data collection and the negotiation of access were done by the researcher contacting different companies and presenting the research proposal. Once a company agreed to join the benchmarking study, interviews with key employees were set up. At least two representatives of one company were interviewed. Usually, managers were interviewed independently and the interviews were recorded and transcribed. The interview length typically stretched from one to one and a half hours per session. The information collected was processed in a conceptually clustered matrix (Robson, 2002) and the written findings were fed back to the interviewed managers for a check of confidentiality, confirmation and comments.

To keep the confidentiality the different case companies were assigned names of artists (Dali, Duchamp, Kandinsky, Lichtenstein, Miro, Van Gogh, Warhol). The analyzed case companies come from various industries, from telecommunications to chemicals. Similar is the size distribution with a range from medium sized to very large companies.

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, like for example for vote analysis. The aim of random sampling is to be demographically representative. On the contrary, theoretical sampling tries to look for specific characteristics. 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 not preferable.

The sample selection aimed to cover several central aspects. The first and maybe most important was that the company should be engaged in innovation activities. The second aspect was to get some extremes in the size of the companies under study. Two studied companies can be classified as medium sized companies (turnover between 10 and 100 Mio Euro), while two other companies can be classified as very large companies (turnover over a billion Euro). No small companies were included in the study, as the innovation activity and the amount and effort of cost management made in the early innovation phases was estimated as being rather low, and the companies would not have met the first criteria. The third aspect 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 tried to get a diversified industry sample, i.e. companies operating in different industries. The industries of the case companies range from the chemicals to the telecommunication industry. However, some pre-selected companies could not be motivated to join the study.

5 Challenges in early innovation phases

This chapter demonstrates the challenges that companies and their managers are facing in the early phases of innovation. First, a literature- based overview introduces the topic. Subsequently, the different difficulties that the case companies are experiencing are illustrated, before the final section summarizes and draws conclusions.

According to Zhang and Doll (2001) development teams have to manage the uncertainty connected to the demand, technology and competition in order to develop new products successfully. According to Koen et al. (2001) there are clear differences between the front-end and the development process itself. For example the work in the front-end 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 also the date of commercialization of results is vaguer in the front-end than in later phases.

The following sections show different challenges reported by interviewed managers from their work life.

5.1 Information and its value

In their article about what the fuzziness in the front-end of innovation contains, Zhang and Doll (2001) state that for a robust product conception and definition, information and feedback from many sources in and outside of the developing company is needed. This information typically consists of data that comes from engineering, R&D, marketing and manufacturing. Kim and Wilemon (2002) claim that 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.

Importance of specific knowledge in research and production stages

One early innovation challenge is that the cost analysis is done by a mix of employees of new technology purchasing and R&D as the managing director of a corporate research center of Warhol explained. There are **difficulties resulting from different approaches** which lead to the situation that R&D personnel and new technology purchasing employees do prefer different suppliers. The R&D staff is mostly interested in **suppliers with a high degree of experience and knowledge** in a new technology, while employees from purchasing want to involve suppliers to which the company has **steady relationships** with, however these might not be as knowledgeable and experienced with the new technology so far. Thus there are examples where new developments start with the suppliers of which the researchers do know that they posses knowledge in the new technology under development, even so this supplier is not capable to produce in high volumes. Volumes are not seen as critical by the researchers, as long as their chosen suppliers are able to deliver the volumes required for the start-up. If that happens the company might be transferring the production after ramp-up to another supplier. In this situation the new technology purchasing employees are evaluating the situation and might plan to transfer the new technology to a company with mass manufacturing capability for the high volume production of the new product.

Similar an interviewed senior new technology purchasing manager describes that there can be a conflict between developers and the purchasing department about which supplier would be the best. Developers might find some performance criteria so important that they insist on a supplier that would not be preferred by the purchasing department. These issues are then discussed and the performance in terms of cost per benefit is evaluated.

As the interviewed chief design engineer of company Warhol explains it is important that information, including cost information, is **available during the development time**. Information that comes on time to be used in development and design decisions is more valuable than after the lock-ins in design have happened.

The information gathering and processing has to be efficient

The **resources available for the first screen are limited**. Furthermore, the matter is more complicated through issues of available time of the employees that could do the evaluation and that they are located at different company sites. Thus even so the director in charge of the employee suggestion process would like to evaluate ideas in a group session; it is not seen as feasible because of time resources and location distance. Generally, the efforts of evaluation have to be taken into consideration as the amount of ideas evaluated is so high (around 40-50 per month). Thus the director in charge of the employee suggestion process is trying to make this evaluation as effective as possible to save time:

> *"For example if you have 40 ideas a month, and I'm working 50 % of the time [on the new development ideas], then it would mean ten days; ten working days on 40 ideas, and I have other duties […], because I have to maintain the […process], I have to inform other people, I have to put the [special development focus] themes there, I have to look for new themes, I have to work, speak with management, so in practice I have only a few days in a month to look at the ideas, so I have to do the first evaluation very quickly. […On] some I spent two minutes; [for] some I have to think what to do and I put that aside and then I come back, trying to figure out what to do with that."*

5.2 Lock-in

As already mentioned above, it is claimed in literature that most lock-ins happen during innovation. E.g. even so only about 5% of total cost of a car is spent on the design activity itself, it determines about 70% of the total product cost (Boothroyd, 1988). Similar, 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).

Lock-in effects through technology selection

Warhol is aware of the fact that it experiences lock-in effects. Once the technology selection is done it is expensive to change them. The technologies and the cost structure determined by them are locked then. Thus the relevant cost information has to be uncovered and made available earlier so that an optimal technology selection can be made.

Furthermore the **situation is worsened by lock-in effects through software developments** according to the interviewed chief design engineer. In his opinion these lock-ins are **very difficult to avoid** and they come mostly through software needed for the main products of Warhol. Writing the software is a major investment and it shows a trade-off. On the one hand, re-writing parts of the software would increase the development cost of a product. On the other hand, a hardware independent software development is more difficult and through that more expensive than a software written directly to the hardware. The decision about this choice was described as significant and consequential.

5.3 Uncertainty and risk

The early phases of innovation give one of the greatest opportunities to improve the overall innovation effectiveness as ideas can be turned into high-quality proposals and designs. However, the flip side of the coin is that uncertainties are higher during these early stages. According to Schneider and Miccolis (1998) risk is very important to senior managers these days. They see the job of senior management as business risk managers. Business is often a trade-off between some kind of risk and a connected possible return. "In a sense, the uncertainty and possibility of harm is the price we pay for a reward." (Schneider and Miccolis, 1998, p. 10) Shareholder value is created when the return exceeds the cost of 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).

Uncertainty about cost evolvement might hinder the pursuit of new ideas

When asked what the most problematic issues are in the front-end the interviewed chief design engineer working in company 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."*

So the estimation of the cost situation of a new development can be a critical issue in decision making.

Iterative and discontinuous processes

Even so the development funnel is often showed as a streamlined one way development, reality is different. As also stated in the work of Wheelwright and Clark (1992) the new idea development reality is that the **process is iterative and can be discontinuous** as the statement of the director in charge of the employee suggestion process of company Duchamp shows:

> *"I have been drawing this kind of pictures [of a staged development funnel] also earlier, where […] you make what decision. […] The problem with this is always that […] the process is not […smooth and step by step], it goes, bumps back and then maybe it dies for a certain period, but then pops up again and then comes back. […] One idea, in a way, could go around here somehow, and then maybe finally it comes out as a product, but you never know."*

Early stage costing in theory and challenges in real life

Warhol is operating in a **constantly changing business setting** and the **cost information gets outdated fast**. Because of that all cost information is concentrated in the databases of one corporate function. However, **new technologies have often no 'price tag' attached to them** so far. They are so novel that no market price has been established so far as the chief design engineer explains:

"Especially in the case with technologies not on the shelf; there's 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. "

Similar the managing director of a corporate research center sees the challenges of the fuzziness of new technology developments connected to the fact that there is **no standardization** so far in the new technology area.

Uncertainties of future costs of processes

There is large uncertainty connected to innovations due to existing processes that might not be able to handle a higher workload resulting from new developments. These can have a serious impact on the **cost structure of the new development idea** as the example stated by the director in charge of the concept development of company Duchamp shows:

"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's 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."

Different technology optima depending on volumes

Depending on the novelty of an innovation, uncertainty and design changes might hinder cost optimization. For new generation developments, where products have to be developed that are new to the company, the company may face a technology selection out of different technologies that show **different cost optima depending on volumes**. The first generation of a newly developed idea may not be cost-optimized, because the **specifications might still be changing** and the design might be adapted. The result is that the optimal choice is not the technology with the lowest possible unit costs, but one technology that offers also **flexibility**, as the interviewed chief design engineer of Warhol explains.

Similar, Company Kandinsky experiences **high uncertainties in respect to the finally 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 of 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.

Challenge of fast pace developments

One challenge in the front-end of innovation is that employees might be rushing in the beginning without doing enough pre-work to research and evaluate a new development idea and its requirements. **Management wants things to get started**; maybe too early, as one interviewed senior new technology purchasing manager working at Warhol points out:

"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."

5.4 Organizational issues

According to Kim and Wilemon (2002) many ideas are turned down in the front-end. Thus to avoid disappointments and frustration a positive and motivational frame of mind, rewards, acknowledge and support play a big role. Another recommendation of the authors is to appoint a knowledgeable individual (or team) as leader in the front-end.

Getting enough attention by the senior management can be problematic

As the interviewed director in charge of the employee suggestion process of company Duchamp declares, **getting the higher management interested in new ideas might be a problem** as there are many business issues and new ideas competing on the attention of the management.

New development ideas might be challenging to communicate

As some new development ideas might be far away from existing products, even not so radical **new development ideas might be difficult to communicate**. This can be seen on the fact that company Duchamp saw the need to generate business and product scenarios for internal and external communication. These can also be used for customer pilot trials. The idea is to have a better ability to experience a new development idea and to be able to do experimental studies with lead users.

5.5 *Summary and conclusion*

Generally, innovations are seen as risky by managers, due to the fact that many innovation activities do not lead to a successful new product or service. Furthermore, the success could come only with a time delay. Furthermore, the information gathering and processing has to be efficient in early stages as many new ideas are evaluated and the time for their evaluation is limited. There are many uncertainties connected to innovations. One reported uncertainty is the ambiguity about future cost evolvement of new technologies. Managers perceive the innovation process is iterative and discontinuous, but at the same time the managers want to see first results fast. **The first option leading to more successful innovation might be to spend more time in the start to investigate a new development idea. The second one would be to proceed more efficiently in the very early stages of innovations! Thus, the question is how the process can be made more efficient.**

Additionally the environment around a company is constantly evolving. Through this constantly changing business setting, cost information can get outdated fast. Furthermore, the cost implication of new technologies, as base for new developments, is often uncertain and so is the cost structure of the resulting new development idea. Additionally, specifications might still be changing in early phases of innovations, so that the cost estimations are difficult in the early stages. As stated above, there is an additional uncertainty about future cost evolvement connected to innovations. So the estimation of the cost situation of a new development can be a critical issue in decision making. That means that tools that would allow the reduction of this uncertainty would be valuable in these situations and might clear out doubt and hesitation. There are also technological uncertainties connected to new developments as uncertainties in respect to the finally chosen production method is present, resulting in an uncertainty of future product costs. Additionally, often no standardization has taken place so far, thus technology selection gets difficult. Additionally to the technological risk, there are also market risks connected to demand and competition that can affect the cost structure of new developments. Different technologies can show different cost optima depending on demand volumes. **As there is an uncertainty of future costs connected to early innovation phases, that issue could (and should?) be handled by cost management. Thus it is important to deal with uncertainties in a professional manner. Many challenges that are connected to this uncertainty should be seen as manageable risks connected to chances, as the tools provided by management of uncertainty together with information gathered through cost management can lead to mitigation of risks.**

As also stated in literature, companies are facing lock-in situations during the development of a new idea. This is natural, as decisions have to be taken from concept creation over development to the preparation of the market launch. In some cases it is possible to modify or revise decisions taken earlier if they turn out to be not optimal. However, as stated above, the software coding during development restricts the possibilities of iteration, as reprogramming would mean additional expenses. Through that flexibility obtains a certain value in early phases of innovations. Furthermore, it is important that information, including cost information, is available during the development time. **Information that comes on time to be used in development and design decisions is more valuable than after the lock-ins in design have happened. Thus, similar as stated above, information gathered with the help of good cost management methods can lead to a turn of lock-in effects into good developments and designs, as managerial decision making is made less problematic.**

Moreover, employees of different functional areas in one company might have different views on matters during early innovation phases depending on which aspects they stress according to their background and experience. Also, it is seen as important, but difficult to motivate employees and communicate ideas in the early stages. **Cost management methods could help to make decisions more objective through the use of information and better estimates rather than mere intuition. Through that employee frustration can be lessened and communication could be more clear-cut.**

The remainder of this report deals with handling the challenges of uncertainty at the front-end of innovation. It is argued that analyzing, evaluating and managing the earliest phases of innovation in a well organized way can lessen or even avoid the impact of the challenges described above.

6 Overview of the found tools

This chapter shows an overview of early innovation management tools that were identified and analyzed in the seven benchmarked companies. The tools highlighted in bold are described in more detail with different cases in the next chapter.

Human expertise based tools

- **Business and technology intelligence**
- **Expert opinion/statement/judgment**
- Idea database, Idea submission competition
- Rule of thumb cost estimations in the FE

Qualitative, routine tools

- Available market estimations
- **Cost capability estimations**
- Risk evaluation
- **Roadmapping**
    - **Technology roadmapping**
    - **Cost roadmapping**
    - **Target profit/cost roadmapping**
    - **Other roadmapping**
- **Scorecards**
- **Qualitative analysis**
- Supplier pre-screening
- Value to customer analysis
- **Volume forecasts /scenarios in the FE / what-if scenarios/ scenario thinking**

Costing and financial calculations based methods and tools

- **Cost capability estimations**
- Cost driver analysis
- **Cost modeling and estimations**
- **Cost tables and databases**
- Financial risk analysis
- NPV, ROI etc. calculations in early stages
- **Perfect waste-free or technical cost calculations**
- Simulation
- **Target costing**
- Three point estimates
- Total cost of ownership / LCC

The found tools were classified into three different types of categories. The first category is called human expertise based tools. The tools classified in that category draw mostly on insight and creativity of employees. The second category is called qualitative, routine tools, to express that they are mostly based on organizational routines that have a qualitative aspect. More quantitative based tools are assigned to the third group: Costing and financial calculations based methods and tools. The different tools can also be rearranged into another classification depending on the data they process (see Figure 10).

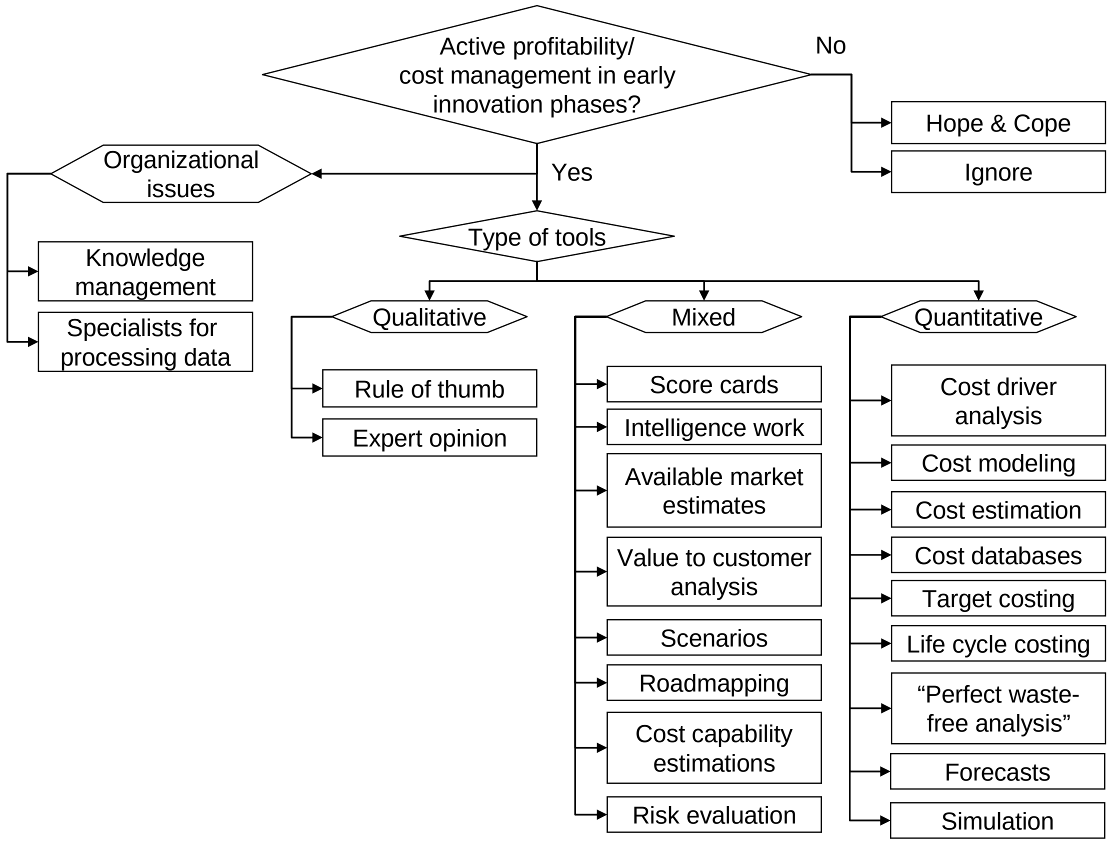

Figure 10: A logical classification of the found tools

The overview of the different found tools in Figure 10, starts with the decision whether cost management as a mean to reach profitable innovations is actively done or not. If a company is actively managing costs in the early phases of innovation, it can choose between a set of qualitative, quantitative and mixed tools. Additionally two organizational issues that are contributing to a successful management of costs in early innovation phases were identified. These were knowledge management methods and the use of specialists in companies to process the data gained with the tools. From these found tools, some important ones are described in the next chapter.

7 Description of found tools

This chapter describes selected tools that companies and managers are using in observed business life during the early phases of innovation. The chapter commences with statements chosen from relevant literature to focus the scope and establish the boundary of the topic. The main section illustrates the tools and the setting in which they are used, demonstrates the contingencies of the approaches, before the tools are discussed in detail.

The model shown in Figure 8 of the literature review chapter (page 9) has developed out of the two extreme funnel approaches found in reality by Wheelwright and Clark (1992) (shown in Figure 11).

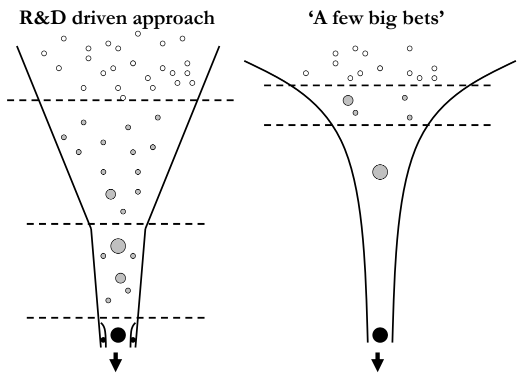

Figure 11: Two extreme models of the development funnel found in industry

These two extreme models are on the one hand what Wheelwright and Clark (1992) call a grass roots or bubble up approach and on the other hand a top town model that bets on a single project. According to Wheelwright and Clark (1992) the first one is found in R&D driven companies, while the second is found in small, entrepreneurial start-ups. They are in favour of a balanced approach between the both shown in Figure 11. However, the models show that there are many different ideas proposed and then screened on different phases.

Similar like Wheelwright and Clark (1992), also Kim and Wilemon (2002) suggest that it is very important to put up the right screening methods – not too soft and not too ridged. The first will lead to too little 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. Additionally different variations of an idea should be considered. These should then compete until the best product concept crystallizes.

Koen et al. (2001) describe the idea genesis as evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The first screen according to Koen et al. (2001) is the idea selection. Its purpose is to choose if or not to pursue an idea by analyzing its potential business value. In the view of these authors it goes hand in hand with the concept and technology development. During this part of the front-end of innovation the business case is developed based on estimates of the total available market, customer needs, investment requirements, competition analysis and project uncertainty.

7.1 Business and technology intelligence with expert opinion

All studied companies are using some kind of intelligence work in the front-end of innovation. This comes often together with the use of experts to judge new development ideas and aspects connected to them. The information gathered is usually stored inside the organization, sometimes more, sometimes less tacit. One has to bear in mind that a very large amount of ideas is evaluated in the front-end of innovation. In order to be efficient the first evaluation has to be fast, but also reliable in screening to separate the good and feasible ideas from other ones.

> Best practice encompassing the use of intelligence work, are centered on sound knowledge- management practices. In these cases, the information is stored in the intranet, available to employees, and regularly updated. However, we did not observe any use of expert systems dedicated to early innovation phases. However, the use of expert opinion comes close to expert systems. The best practice found for involvement with experts, was in the regular use of a cross-disciplinary expert network.

Business intelligence

Duchamp is using business and technology intelligence from earliest innovation phases on. However, the use changes from situation to situation and is dependent on the persons analyzing new development ideas. Similar the information is not fully centralized, but might be located at several places in the organization. However, one big resource is the intranet where reports and business evaluations are stored.

New information from business intelligence leads to updates in the estimations of the early stages as the interviewed director in charge of the concept development explains:

> *"In a way in each phase you have to update that, that it represents your latest view, […] with the information that is available and with assumptions [… about] 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."*

Tear down analysis

Dali uses teardown analysis of competitive products in order to follow the development of competitor's products, find improvement possibilities and try to evaluate the cost structure of the competition. This information can also be used in the front-end. If a new technology / product should fulfill the same function as the product of the competition, the cost estimates can be benchmarked with the cost information of the solution of the competition.

Intelligence work and expert networks

The interviewed head of one business unit explained that Miro is using business intelligence and human expertise based tools in early stages of innovation. He stated that it depends on the business segment and research unit, how much these tools are used. 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. The company involves a manager that is experienced in the targeted business area of the innovation. Similar technology experts are involved in research projects. This is done in order to allow expertise to flow directly into the innovations or research projects, so that some problems during later stages can be avoided. Additionally the company has a network of experienced experts that evaluate new ideas. For example in the business unit of the interviewed manager there is a R&D network in which all new ideas are discussed. The expertise of this network is used to check whether an idea has a potential or not. Furthermore, Miro employs a R&D coordinator who collects all ideas and structures them in a project portfolio. With the help of this portfolio the company can evaluate the different new idea projects as a whole and compare them.

7.2 *Volume forecasts and scenarios in the FE*

HP has developed a forecasting tool that uses three levels of uncertainty as a base for their cost estimations (Carbone, 2004). 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. In this case the suppliers are not granted any risk premium to their product.

One tool used for forecasting and connected to expert opinion (see section 7.1 above) is the so called Delphi method. 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 later the Delphi method was brought into the scientific research world. Nowadays it is used in all kind of scientific fields like forecasting (Gerstenfeld, 1971; Martino, 1980), however, even so the practices found were similar to the Delphi method, it was never named like this in the analyzed companies.

A potential further development could be a tool that is named backcasting. Opposed to forecasting, backcasting begins with the wanted goals or targets. While forecasting is based on extrapolating one or several paths into the future, backcasting turns this approach around and starts with the wanted situation and tries to find paths that lead to the current situation. Therefore backcasting can be used to show discrepancies between the current planning and the needed one, to achieve the wanted goals and targets (Geurs and Wee, 2000). However, no backcasting practices were found in any case company.

> Scenarios are used in several ways in the benchmarked companies. They are used to evaluate business directions, to facilitate discussions during innovation phases and as a part of the communication of new development ideas. Companies using scenarios in early innovation phases find that their use facilitates new developments and allows focusing on decision-making.
>
> Scenarios can be used to discuss different development options and their impact e.g. on costs. The best practices around their use are to identify different alternatives, to analyze them and to study different prior drivers for success. Costs are one target that has to be balanced with others in order to find the optimal solution. The use of a particular approach to let experts think through a limited amount of different scenarios (similar to the Delphi method) is likely to be beneficial for managing early innovation phases, as it brings new insights, and can be classified as a relatively low-effort method with significant benefits.

Scenarios

Duchamp uses scenarios in several ways. First they are evaluating business directions through several scenarios and secondly they use it to facilitate discussions during innovation phases. They use it as a part of the communication of new development ideas. Through that the company finds that new developments and their judgments are facilitated.

> *"When you think about R&D […], you can there have different views on where the world is heading and even though you choose one way that that is how we believe*

it's going and that's where we mainly direct our activities, it is still good to have alternatives in order to be prepared if something unexpected happens. But then, when we go deeper in certain areas, one thing where people use scenarios is actually to make it easier to have[a] dialogue with people, […that] are not so much working with R&D; they are working with the current business. So it is easier to discuss and understand the scope, and then come back to the ideas you had."

Analysis of different alternatives through what-if scenarios

Managers at Warhol are also using what-if scenarios to discuss different development options and their impact e.g. on costs. This is done in order to find out what possible results of different alternatives could be and what it would mean for the targets of the new development. 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. The interviewed senior new technology purchasing manager sees cross-disciplinary discussions as one key for effective developments, i.e. developments that fulfill all set target parameters, and for finding the cost optimal solution. He stresses the importance of a cross-functional team approach with good communication of information. In this cross-functional team some employees will be very cost aware, while others are purely concentrating on the technological functionality. Together these employees are then thinking through a limited amount of different scenarios. In several rounds the scenarios are evaluated and the best approach is selected:

> *"It needs a good interchange of information. […] I strongly believe that this kind of cross-functional team approach is the only way to really implement this approach. So […the employees in charge of purchasing] need to have been very cost aware before a discussion with the very technically aware people. And they need to be discussing quite closely a number of different scenarios, that they would need go several what if –rounds to figure out what's the best approach. So what if we structure […some important product module] in this way; what does the cost look like. Or what kind of devices could we use, what could the mix be like. And what if we do it this other way, how would that work. So you have to do quite a lot of this probing around to find out what could be the optimal approach to get along. And that can't be done by one function or another function. The […new technology purchasing] function cannot do it, because they do not have sufficient architecture or technical awareness of how the thing will get put together. The technical or architecture people don't have access to the cost information at a sufficient detailed level to model it. So it's a cooperative endeavor in practice between the different […functions]. And it involves a lot of different scenarios, you just got to model several different approaches until you find one that suits your business case."*

7.3 Contrasting qualitative analysis and scorecards

Scorecards are commonly used in business today. They can foster objective discussions as they connect values or estimates to a specific situation under discussion. Generally, one can say that scorecards assemble different qualitative and quantitative metrics in a summary form. This summary is then scored and the final score is evaluated.

The best practice found was when using a scorecard directly for the evaluation of new development ideas. A scorecard can give a fast and effective overview of the attractiveness of the new proposal. As previously discussed, scorecards tend to be industry specific. However, there are several points that will be similar for most industries. These are associated with the strategic alignment and the attractiveness per risk of the new proposal. In the company in which this best practice was found, employees suggesting ideas are performing the rating themselves. Through that process, a fast feedback will reach employees. Furthermore, the employees see that the importance of innovations is acknowledged and at the same time discover themselves if an idea has a greater potential or not. Through that process, frustrations can be mitigated in the case where an idea is not developed further.

The method itself can be seen as very adaptable and suitable to very early phases of innovation. Furthermore, the effort/benefit ratio is very favorable and company internal knowledge can be coded and transferred through scorecards. However, the method has limitations and be seen as part of a bigger set of tools for improving the accuracy and management of early innovation. It is important that the scoring dimensions are well described and understood by all employees working with the scorecard.

Scorecards and qualitative analysis with a quantitative background

In the Miro, the evaluation of new product ideas is centered on a score card that evaluates the attractiveness of the proposed idea to the company. The major categories of this score card are:

1. Strategic fit
2. Advantage of new technology/concept
3. Market attractiveness
4. Synergies
5. Technical feasibility
6. Potential financial return

Even so the gate 1 was described as very light, the first cost estimates are already made at that point. Generally one can say that the score card assembles different qualitative and quantitative figures in a summary. This summary is then scored and the final score is evaluated.

Potential pay-off check lists

Duchamp is primarily interested in whether a new development idea has the potential to pay off and then secondly about whether it is technologically possible. Managers in research are carrying out commercial feasibility evaluation already during research phases, in some cases even before checking the technological feasibility.

In the first screen, ideas coming from research are screened with several templates. Even so the evaluation tools of the first screen are flexible at Duchamp, the director in charge of the concept development points out several points that are checked when ideas are transferred from technology research into product development:

> *"So each phase […a new development idea is] entering has one or several templates […] which you have to fill […]. So the proposal has to be done according to a certain template; and those templates force you to at least […] describe the basic elements that are important and of course the business potential […], the revenue and of course some kind of understanding […about whether] it is also profitable enough. Then, links to existing plans and roadmaps. That is a little bit difficult to explain in one way, but you may have a small case here, but it could be very important part of a bigger concept, then it is good for that small idea, or if that type of thing is already somehow included in plans of other products, then it maybe not so good […]. Well, in a way it is good, but it does not mean that we go ahead with that, so it will be included in other activities. […] And then, I would say two kinds of feasibility things are important here. First is of course if it is technological feasible to do and we know how to go ahead, but on the other hand, do we have competencies enough, and right type of competencies. […] The more challenges we see, the more time it takes here, and it may not be so easy to go ahead with things that […do not] fit very well into existing ways to work, plans, and so on."*

Projects that could lead to new developments are steered by project management methods. These are if the goals and targets of a project are met and whether milestones and time schedule are kept.

About the economic and technical feasibility in the first screen in development stages of Duchamp the director in charge of the concept development continues:

> *"You have to have both technical and commercial feasibility documents here [at the first stage in the development process]. […] Especially now, when I would say most of the basic cost-cutting has been done, the focus is now on growth, […] you are looking for new revenues, but on the other hand, because of the market, so far mainly all […competing companies] have same type of basic […products and services], then of course one basic criteria is whether it helps you to differentiate against the competitors. So there may not be direct revenues, but there could be indirect [ones], by the help of […] increased customer loyalty […] or they support, or could be a platform for other services."*

However, he also points out that the selection is restricted by available resources, dictating which new development idea can be pursued:

> *"Even though it shouldn't be so, it's quite often in practice a matter of different bottlenecks and prioritization of resources."*

If ideas are coming from employee suggestions the screening is done by one of eight employees working part time within the employee suggestion panel. The role of this group is to collect different ideas and do a first screen of the ideas. The first check in this screen is whether a suggested idea has already been evaluated earlier. If it is a new idea, the team makes rough estimates about the total available market (TAM) of the idea, the technological feasibility and the potential value to the customer. If a new development idea looks promising, the employee suggestion panel recommends it to the top management teams of the different business units for further evaluation.

Risk scorecard

Scorecards are also used as a risk management tool. As the interviewed chief design engineer clarifies, Warhol is evaluating risks in a scorecard approach. This scorecard contains different items and is custom-made for each project from a general 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. This risk evaluation is done repeatedly as a project management tool starting in stage 2.

Similar, Dali is using a scheme for evaluating risks of new technologies and their development. The director for New Concept Development and IPR explained a qualitative approach to evaluation of new technologies and new product ideas. The company is using a scorecard to guide them to critical issues that have to be checked for new technologies and products. This is a template that is continuously filled and it includes a scoring of different parameters. The information is gathered through a questionnaire. The purpose of this scorecard is to identify risks. A light version of this risk assessment is made before a project passes gate 2. After that, in stage 2 the risk study is made in depth. Three risk categories are distinguished:

- Technical risks
- Operational risks and capability of handling the new technology
- Market risks

These different risk categories itself contain a quantity of different risks that apply to the case companies business and which are checked. The risks are scored on a scale from 1-5. Later, the total risk is then presented graphically to the board, with the help of stacked columns and bubble diagrams. In the bubble diagram the coordinate axes are on the one hand risk and on the other hand the potential return. Additionally the needed investment is indicated through the bubble size of the new technology / product proposals.

The benefit described was that this risk evaluation tree leads to identify possible risks that would otherwise be overlooked or not handled explicitly. The company is aware that the scoring is based on guesses which might not reflect reality very precisely and through that has a limited worth. However, in total the tool is seen as a valuable tool.

7.4 *Roadmapping*

There are needs for roadmapping on different levels of organizations. One of these needs originates in the linking of strategy and operational issues. 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 many production parameters have to be taken into account, decisions made on intuition and past experience may yield not as good results as if roadmapping is used as a management technique for this purpose (Tan and Platts, 2004).

In the view of the researcher, one dominant way of presenting and analyzing information in early innovation phases is roadmapping. Even so there might not be an explicit roadmapping done in companies, often the business and technology strategy is broken down to the different business and research units and communicates this to the employees. Some companies include cost data in their roadmapping routine in early stages of innovation, as the cost of different alternative technologies plays an important role in the technology selection process of new developments.

Extensive technology roadmapping during early stages of innovation can be seen as one of the best practices identified to manage different kinds of portfolios. This is completed in the industry for planning purposes, to identify areas to be further elaborated on and where development has to be accelerated. Of the studied companies, the most exceptional one is carrying out trend analysis to understand the dynamic development of the performance and cost of different technologies for its roadmapping. In the best-organized setting, the information is collected from different sources and concentrated into internal reports that are shared throughout the company. In the situation where further development of an important technology is uncertain, research projects are initiated to explore new technological possibilities. The best practices around roadmapping include a regular update of information as soon as certain information is found through internal or external research. In best practices, a company would already use roadmapping as a preliminary target -costing in very early phases of innovation for their planning purposes. 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. In this case the expertise and experience of senior employees is used to estimate the dynamic cost behavior of technologies over the time. The gained insight is regularly updated. The cost development over time is compared to a feasible market price, a paradigm known from target costing, to estimate the feasibility and the development over time. In the case that the cost estimate over time and the feasible market price are too far apart, a development is stopped. However, if both estimates are different, but the company evaluates the market launch as possible, research efforts are conducted to bring the technology costs down to a feasible level.

Technology roadmapping

Warhol is doing extensive technology roadmapping in early innovation stages 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. 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."*

Roadmapping and trend analysis

Warhol uses a multitude of sources for their roadmapping. One source is technology intelligence. It can originate from external or internal sources. The company is carrying out forecasting and trend analysis for interesting technologies. 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 […the case company 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 the development department]."*

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.*

Roadmapping of target cost connected with expert knowledge

Warhol is using the approach of target cost already in very early phases of their planning. It can be described as cost roadmapping based on expert knowledge. 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. Employees are using qualitative estimates when analyzing the cost capability of new technologies. These qualitative cost capability estimates are seen as a preliminary target costing effort. Warhol often faces technology choices about which technology to integrate in a product under development. As these developments might take several years until production ramp-up, it is important to know how the costs connected to certain technologies will develop over that time. The expertise and experience of senior employees is used to estimate the dynamic cost behavior of technologies over the time.

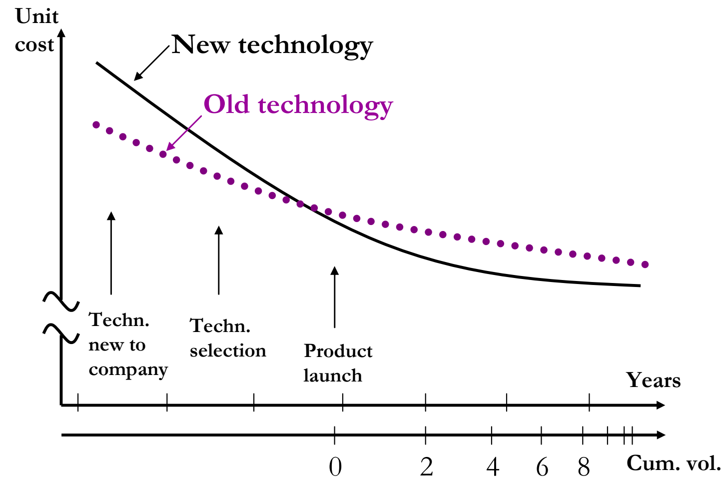

Figure 12: Technology choice on the example of dynamic unit costs

E.g. a situation similar to the one shown in Figure 12 would be possible. In that case there are two competing technologies that could be integrated into the new development. In that case the managers of Warhol would try to estimate the cost potential of both technologies for several years ahead through expert judgment. In the case that the costs of both new technologies under discussion are estimated to be too high to fit into the target cost for that product part, the company has to find another solution. Thus the company is performing a target costing process that includes figures that are blurry in the beginning, but are to be refined during the R&D process as a senior new technology purchasing managers 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."*

7.5 Cost modeling, estimations and calculations in early stages

In literature it is seen as important to have accurate product cost estimations already at the concept design stage to support decision making (Ong, 1993). As stated above, cost estimations are part of early innovation phases and important for the evaluation in early screening (Cooper, 1990). There has been some standardization work been done for the estimation of life cycle cost (IEC 60300-3-3:2004) that can be used for cost estimation and modeling. This standard distinguishes between three different cost estimation principles. 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. 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 straightforward and brief technique. 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, e.g. person hours are transformed to costs.

One possible further development to what was found in the benchmarked companies is extreme order-of-magnitude cost estimating. This technique is defined as a quick method of determining an approximate probable cost of a project without the benefit of detailed scope definition (Simpson, 2000). However, the effort/benefit ratio might be differently from case to case of the extent of the new development idea to be assessed.

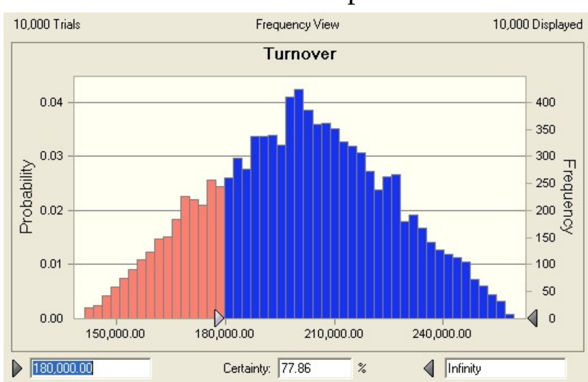

Figure 13: Monte Carlo simulation

Furthermore, as cost figures are vague in the early stages of innovation, three point estimates can be used to investigate a spectrum of outcomes. These define usually a minimum, most likely and maximum value to uncertain parameters. Afterwards a Monte Carlo simulation is run that gives a distribution as outcome, rather than an absolute number (see Figure 13).

Out of the several cost estimation possibilities the benchmarked companies are often using parametric cost estimations in early phases of radical innovations. In the case of incremental innovations the full set of different cost estimation possibilities is used. In particular, especially the engineering cost estimation method is can be used well if the bill of materials of a new development idea is similar to the one of an existing product.

One of the benchmarked companies is formulating its first cost models already in the front-end of innovation. This cost modeling uses the information gathered during the basic research and later R&D activities. As also seen in other benchmarked companies, the cost modeling is either fully or at least partly done by specialists, not by project managers or design engineers. Through this early modeling the benefits and disadvantages of different design solutions can be quantified in very early innovation phases. Of course this is still seen as a preliminary attempt to put a figure on an idea that has moving specifications. But, in the best practice, values figures are constantly updated as soon as there is more certain information available. The company conducting having the earliest cost modeling regards the effort as a cost scenario modeling, mapping out possible cost settings and developments. Cost modeling in early stages could further enriched by including also other costs from a total cost of ownership perspective, e.g. logistic costs. If the new development idea is not extremely radical, this kind of information should be easily available inside an organization. Whether early cost modeling is worth the effort, might depend highly on the targeted market. As seen in one benchmarked company, the answer whether calculations are made or not depends on whether the targeted customers are sensitive to prices or not.

Rule of thumb and first guesstimates

Managers at Van Gogh compute the first financial estimations already in the evaluation for the first gate. A product manager prepares a one page overview of the proposed idea for the first screening meeting. Already in that stage, he is estimating potential sales deducted from market data. Furthermore he will discuss project cost estimates with the R&D department. With the help of that information, the product manager can evaluate the potential of a new idea and compute expected gross margins and return on investment (ROI) figures. These figures are then presented to the steering group in the evaluation meeting through MS-Excel generated charts. The company has a set of several financial targets that new product proposals have to fulfill.

Later the company is using more accurate profitability calculations. Together with the costing calculations the product manager is also computing first profitability calculations to estimate the potential profitability of the new product idea. As stated above the case company Van Gogh computes the first financial estimations already in the evaluation for the first gate. During the further work this estimations are refined and calculations are repeated. Due to the more accurate information that results from the costing efforts, the profitability calculations will also be more precise.

Cost modeling in early innovation phases

Whenever possible managers at Warhol try to quantify the benefits and disadvantages of different design solutions as accurately as possible, says the interviewed chief design engineer. The earliest and through that still vague costing effort of the company is cost modeling. The company performs cost modeling in the front-end of innovation. This cost modeling uses the information gathered during the basic research and later R&D activities. According to the interviewed senior new technology purchasing manager the cost modeling in the front-end depends on the time available for a project.

Development engineers have to understand different parameters for the technology selection process. The first parameter is what kind of alternative technologies are available, the second one is the performance levels that can be achieved and the third is the cost structure connected to a certain technology. In the early phases of innovations, the cost modeling is seen as a preparation work to make the right basic technology choices. As the interviewed chief design engineer explains there is some basic cost modeling that happens before the technology selection. Due to the uncertainties attached to it, it might be more of a cost scenario modeling, mapping out possible cost settings and developments. This 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 the technology selection is made.

Cost calculations in incremental vs. radical innovations

Kandinsky uses 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. However, estimating the future price of components is difficult as the senior technology manager states. Furthermore, fluctuations in exchange rates complicate a long time planning. However, for radical innovations, the cost modeling of new technologies is made when the need for it is seen. In this case mostly parametric cost estimations are made. In one studied case, preliminary cost calculations are made on ad-hoc basis when the gathered information was sufficient to allow first, rough calculations. The gained new knowledge was sent then out per email to group of other employees that could be interested or concerned by the issue.

Van Gogh uses parametric and analogous cost relationships for the early cost estimations of its new product ideas that are not radically new. The new product idea is compared with similar products already in production. If a similar product is identified, the bill of material and its component prices are used in the calculations. Once the costs for the materials are estimated, the production time and its connected costs are evaluated. Similar like using the bill of material of old products, the manufacturing steps needed for the production of the new product idea are derived from the production records of similar products. The actual cost data is retrieved from the cost database that is connected to the company's ERP system. On top of these costs, the company classifies other costs that are to be kept in mind, e.g. costs for software programming and licensing. With the help of these calculations the first cost estimation per unit is derived and then used to derive a target price and for further decision making. The cost analysis is done more all-embracing when the new product idea has moved up through several gates and the company has to decide the product manufacturing location.

Cost calculations and investment appraisal

In the first gate Miro does not do a life cycle cost analysis, but is just evaluating how much R&D expenses are about to occur in the near future (budget cost instead of life cycle cost view).

According to the interviewed head of one business unit of Miro the first cost calculations are made in stage 2. However, rough estimations are already made before that point. He described the cost calculations 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. The company evaluates in quite early stages what is the role of the new development idea in the customer's costs is. If the targeted customers of the new development are very price sensitive, costs play an important role from the beginning of the R&D work.

Cost driver analysis

Kandinsky uses cost driver analysis to investigate the cost structure and actual costs of their products and purchased components. This has revealed some counterintuitive pieces of cost information. Starting from that the company redefined cost drivers that were more accurate. This 'realizing' of what the actual cost drivers are radiated also into their early innovation analysis. Thus it is important that costing and cost estimations are done correctly already in early stages of innovations.

Cost estimations for new product ideas based on activity based costing

From a costing point of view the case company Van Gogh is using a set of several methods to derive cost estimations for new product ideas. First it uses cost information records from old projects. Furthermore the company is using figures of its ERP system for cost estimates. Together with that the company is defining a recommended retail price, an approach that resembles the basic structure of target costing.

According to the Controller for R&D and Production the cost modeling of the company is based on ERP system records of old products for the costs of raw materials. The company is using an inbuilt cost estimator of its ERP system. In the past the case company Van Gogh used to have an absorbtion costing system, where fixed costs were allocated in different percentages on the products of the company. However, the company changed the system and is using activity based costing since four years. This led to surprising results for some products. After the change in the cost accounting approach, it was discovered that some products were not as profitable as thought.

Triple point estimates and Monte-Carlo simulations

Another tool Dali is using is based on Monte-Carlo simulations in new technology and product developments. The managers using this technology acknowledge that the information handled contains mostly out of estimates and that these show a certain kind of variation. In order to make the assumptions behind best guesses more reliable, managers use triple estimates. They estimate the most likely, the worst and best case to run the simulation. The company sees the benefits, but also the limitations of early simulations based on the Monte-Carlo method. They used it to evaluate new product portfolios, but are hesitant to use it for the profitability calculations of a specific new technology.

7.6 Cost capability estimations and target costing

As already stated in the introduction, target costing is a technique 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). 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).

One principal idea of target costing is that costs are an input to the product development process and used during it. In this case the costs are not a mere result, but a development criterion. The target costs are derived by estimating an aim selling price of a new product, according to what customers are willing to pay, and by subtracting the desired profit margin from it. 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, 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.

In the literature about target costing, the computation of the perfect waste-free cost level is used to enhance the target costing process by showing the theoretical limit as a goal to stretch at. According to Cooper and Slagmulder (1997) the perfect waste-free level is the cost level that is reached when no non-value-added activities are performed and all value-adding activities are performed as efficiently as possible. They also define a second waste-free cost level – the unavoidable waste-free cost. They define this second term as the most aggressive short-term cost reduction goal possible for a product. According to Cooper and Slagmulder, the first waste-free cost level is the ultimate long-term goal of a lean enterprise and is linked to the zero-defects objective in quality management. The second waste-free level is a nearer future cost target.

Generally, the benchmarked companies see target costs as an important factor that has to be evaluated relative to the potential market price for an innovation. All benchmarked companies are using some method of target costing approach; some starting earlier, some starting later during innovation. The best practices around target costing in early innovation phases are loosely following the interaction between target costs, strategy, the chosen business model and potential production technologies. One company also 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.

The benchmarked companies are using qualitative estimates to evaluate the cost capability estimation of new technologies. For these early phases of innovation, the cost capability of a new technology is playing a significant role in the dynamic view of target costing. As the cost capability estimation is a rather difficult task, it should be done by experts in this field. This restricts the earliest possible use if there are numerous new development ideas to be evaluated. However, if a thorough pre-screening is done, these experts can analyze a large fraction of the new proposals. On the other hand, cost capability estimates are less interesting and important once the design of a new development idea is locked, as any specification changes would mean that parts have to be redesigned; leading to higher costs and/or that the development delays. Thus, the cost capability estimation has to be made in the early stages and during the time that different design choices have to be evaluated.

Another interesting aspect was the identified 'perfect waste-free' product cost calculation of one benchmarked company. In this approach, calculations regarding the theoretical minimum costs to fulfill a function are made to evaluate different new, potential production technologies before any equipment is purchased and installed. One further interesting practice found, and that can be set into the target costing family, is a cost / functionality trade-off analysis. One best practice found is the analysis of 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.

As already mentioned before, these methods can be seen as rather laborious and heavy. If a company is operating in a very volatile environment, it might be too difficult to set up target prices and different approaches might yield a better cost management result.

Cost capability estimations based on qualitative estimates; volume forecasts

Miro uses several qualitative methods in stage 2 to get more information about an idea and to evaluate its potential. As the interviewed head of one business unit explained, in stage 2 of a new development project the innovation teams of the different business units are using qualitative methods to evaluate uncertain issues. One of these methods is cost capability estimation, based on qualitative estimates. This is done by a couple of employees analyzing and evaluating the value of a new idea to the potential customers. This is mainly done by the marketing side. This analysis and evaluation also includes volume forecasts.

It is interesting to note that technical oriented employees are not doing cost estimations if they are not forced to do them and if they do not get any support for that. That is why

Miro is involving business experts in new development teams. It is very complicated for technical oriented employees to estimate the business potential because of uncertainties connected to volumes, costs and markets as the interviewed head of one business unit explained:

> *"…because in practice […technical oriented employees] don't make any cost calculations without somebody really pushing them to do that, and they probably [do] not always have the ability to do the cost calculations in our […] industry. Because it's 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 […] the value of the product to the customers."*

The involved business experts have a good understanding about the cost structure of present products that contributes to the need that there are no hidden costs that are discovered in later stages of a new idea development. Furthermore, these experts have an understanding of what is the value of the product to the customers.

Cost capability estimation

The managing director of a corporate research center of Warhol illustrated how cost capability estimations can be critical, but also that it is only a facet in the analysis done in the front-end of innovation. The idea under investigation was partly related to telecommunications and would have bought an additional feature to one of the main products of Warhol. The idea that came from the research center was proposed internally to a different business unit in charge of marketing. The managers in this business unit were generally interested, but of course wanted to know immediately how much it would cost. However, the research center made first a technical feasibility study, before analyzing the potential cost further. After some work in the research center, the technical feasibility to integrate the feature was confirmed. The technology was already available and employed in a comparable way in products of another industry. So finally the potential implementation costs of the proposed idea were analyzed. The result of the cost analysis was that at an appropriate acceptance by the market, the costs for the new feature were in a high but still acceptable range. Thus the managers of the company analyzed if there is already an existing customer base that would appreciate the new feature and be prepared to pay for it.

The cost capability estimations are done mostly in the early stages of innovations in Warhol. As interviewed chief design engineer states, cost capability estimates are done during development. Once the production is ramped up the design is locked and the company is not interested in them anymore, as a change would mean that a part has to be redesigned or that the development would be delayed. Thus the cost capability estimation has to be made in early stages and during the time that different design choices have to be evaluated.

Cost estimations in a 'perfect waste-free' approach

At Kandinsky a similar approach was found. The senior manager for new technology development has developed a product cost calculation that could be labeled 'perfect waste-free'. He has made calculations about the theoretical minimum of costs to fulfill a function. The difference is that in literature the perfect waste-free cost level is used to evaluate the efficiency of the installed production equipment and process. However, he is using it to evaluate different new, potential production technologies before any equipment is purchased and installed.

When used in the front-end, another difference is that sometimes he has also not taken investment costs into the calculation since realization may be done via partnering (split of investment over several companies) or other such arrangements in order to reduce the investment. In this case the analysis is more of a marginal costing investigation. He described the analysis as a ‘technocratic approach’. This should make obvious that only unit level cost are taken into account, mostly raw material and direct labor. This is made to find the gross profit margin as a bottom line. Sometimes there are calculations that show such a high gross profit margin that it is easy for the company to decide to proceed, so it can pass gate 1 and they don’t want to spend more resources on evaluating.

Target price estimates

Company Duchamp is doing target price estimates in early innovation stages. Real target costing that starts with a target price might be too difficult to set up, as the company is a price taker on a market that experiences high price fluctuations and the prices for their products and services are moving as the interviewed director in charge of the concept development states:

> *“You must have some kind of estimation how much customers would be willing to pay for something, and then how big amount of customers we could get and other possible alternatives, but on the other hand, with existing products, there are all the time price changes depending on the market situation, so you never know for sure how much customers actually will pay for a product after some years.”*

Value to customer analysis as a base for target cost thinking

Duchamp is doing customer value analysis in very early phases of innovations. 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.”*

This customer value analysis can be seen as the first step towards some kind of target costing effort, as he explains further:

> *“If we see that okay, this brings value and it’s something for the need of the customer, but it’s very difficult to implement, so we then have to consider if we make it and what are the cost […connected to] that technology. Then we have to look the, how much business we would get there, does it make […] sense to make that difficult thing to happen.”*

Merging cost capability estimations and target costing

Target costing is done already at early stages of innovations in Warhol. As one senior new technology purchasing managers explains there is an interaction between target costs, strategy and the chosen business model that is more dynamic in the early phases of innovation than in later stages. The cost capability of a new technology is playing a big role in the dynamic view of target costing. Through learning and similar cost reducing effects the cost of a product and its parts is decreasing.

In the research phase, the first rough estimates are 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 as the interviewed chief design engineer describes:

> *The research project […went down to] the component level, so they […] analyzed the main components, […] their existing or current […and through that] known component prices, and also […made some] gap analysis […about] areas we should improve and know. […] That analysis is bringing some knowledge […about the level of] cost of the component. So in this case it has been quite precise. Of course […] not going into very details, but [a] kind of rough analysis of the requirements. […] That has been the outcome of the research project, and now the research results have been brought into the business unit, so that it was […transferred from stage 1 to the] preparation phase [of stage 2], and there we try to make [the] next step of the preciseness of the performance analysis. […] So, as deep and as precise as possible, […] depending on the knowledge of the people as well."*
>
> As already stated above, Warhol is using target costing from very early stages on in their innovation process. Usually, Warhol knows the acceptable market price for a new development idea at early stages already through their market intelligence and/or market strategy. The target costing process is very similar to what is described in literature. The company starts with the acceptable market price and calculates toward the allowable costs of the different product modules. At the same time the company knows the prices for many standard components and can through that calculate and estimate the cost for the different product modules. As reality has it, the estimated costs are usually higher than the allowable target costs. The next consideration in this case is whether or not cost could be saved by reducing the functionality or the cost per functionality ratio of the new development proposal. If this still does not yield a feasible development option, the idea is put on hold and might be evaluated at a later time, when technology has progressed.

Classical target costing

In Van Gogh there is a distinction in R&D developments depending on the end-customer price level for the product under development. The design and technological configuration are targeted to several target markets. In that sense the case company uses target costing in a very early stage. Similar to the Walkman case of Sony (Cooper and Slagmulder, 1997) the company has target prices that it does not want too exceed. The development and design of new products have to be made like that that the costs of a product plus its targeted profit margin, stay below these targets.

7.7 *Cost tables and databases*

Cost tables can be defined as databases of detailed cost information based on a range of cost drivers or manufacturing variables (Yoshikawa et al., 1990). According to Yoshikawa et al. (1990) they 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.

The earliest reference about cost tables found by the author originates from Joseph B. Hubbard (1921) where he describes the use of cost tables for projecting cost through forecasting cost estimations. At this early point of time the cost table is used for labor cost estimation and variation analysis in a construction company. 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 on the focus shifted towards the functions or parts of products (Yoshikawa et al., 1990).

The distinctiveness of cost tables against normal databases with cost information is their planned approach, 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, answer cost implications of different designs (design cost tables), and find cost reduction potentials of products in the production phase (manufacturing cost tables) help to make decisions about (dis-)continuation of product lines. Thus they have a good potential to be used in early innovation phases.

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 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 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). Similar results are found in some benchmarking case companies.

As stated above in the section dealing with cost estimation, the engineering cost estimation method can be used if the bill of materials of a new development idea is similar to the one of an existing product. In this case, cost databases are rather easy to maintain, as past cost records of running products can be used. Thus, the best practice is to use information available in the company's internal ERP system.

Cost tables can be used in very early innovation phases for incremental new developments. In this case the best practice is to start early with a set of several generic requests for quotes that are linked to several cost drivers. The information gained can be very important in early decision making in the concept development. Also in later stages of the innovation process, cost databases can be useful, but their potential for cost reductions of designs is decreasing the more lock-in decisions are taken.

Quotations database

In Kandinsky, some cost considerations in the front-end are based on a quotations database. The information of this database has been assembled by the senior manager for new technology development through quotations over a time span of five years. Out of the information of this quotations database, ad-hoc cost calculations are made, e.g. to determine the best material choice for a product. The information gathered in this quotations database is also used for roadmapping purposes through trend extrapolation.

Costing templates

Two different types of costing templates where found in the case company Dali. One type is ad-hoc developed costing templates developed by single managers specifically for a new technology development that they had to administer. The second type is a specifically set-up cost table that is linked to the company internal ERP system.

Ad-hoc developed costing templates

For one of the studied cases, two interviewed managers had developed costing calculations individually. Both were based on MS-Excel and contained several work sheets. Both were adapted to the information need at the specific time situation of development. I.e. the earlier of both had more an overview function and tried to incorporate all possible costs. The second, which was done by a manager with production responsibility focused mostly on production cost. While the first one handled points like currency exchange rates, investments and different value adding production steps, the second one concentrated in more detail on the different production steps.

Cost tables and databases with information of similar operations

One interesting method found at Dali is the use of cost tables and databases in early stages of innovation. The function of the model that the studied case company is using goes beyond the function of a classical cost table. This cost table is a connection of classical cost table (i.e. database of tabulated costs) with an investment appraisal calculation program. It is electronically linked to a database of continuously updated ERP-system based (cost) information (e.g. hourly cost or cycle times of different kind of tasks). This electronic cost table has several levels of cost information stored. 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. On product level machinery investment costs are processed. Furthermore, more general information that is needed for the cost calculations is also maintained regularly (e.g. currency exchange rates).

Cost tables based on a virtual quotations database

Warhol developed a method based on the concept of cost tables for new product development projects. This method was found to shorten time-to-market in innovation projects, keep fair component prices even so design changes occur and increase the use of cost information throughout the innovation process. It is based on a virtual auction system. It is called 'virtual' because it is sometimes carried out, without a direct product development project for it, but rather to scout new technological possibilities on the supply 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. The database is constantly updated by requesting virtual quotes in an auction technique from several suppliers. 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. The method is carried out constantly in roughly half-year steps from the purchasing department by sending out questionnaires and requesting technical quotes. The most important benefits are faster time-to-market in NPD projects, reduction of an unsymmetrical information situation, availability of detailed cost information for feasibility studies and during product design and the reduction of uncertainty. Difficulties can arising in the case that the suppliers are unwilling to share information.

Company Kandinsky also has an information system for component and material costs. This is a system of different cost tables which the employees can access through intranet. In this cost table price information about purchased materials and components is stored. All quotations and price data the company has about its purchased parts are feed into the cost table for further use in purchasing and design. Furthermore different preferred components are marked and recommended to be used. Through that labeling of 'preferred components to be used', the usage of these components should be encouraged so that a lower number of item types have to be purchased. The purchasing of parts can then use economies of scale in regard to their handling and lot sizes as also in regard to the purchasing power of the organization. Parts can be chosen in a drop-down menu style according to general function, specification and technical details. Once a part is selected the cost table shows the actual purchasing price.

Use of cost databases connected to the ERP system

Van Gogh has a culture of open cost information access. The controller of R&D and production can easily use historical information on prices of purchased items of several years. He can compute historical trends of component costs and see all changes in prices that happened in the past. This information he can then pass further in an aggregated way to evaluate cost issues in innovations.

Furthermore, Van Gogh uses cost tables that are built on top of information stored in their ERP system. Like that the company uses always the latest cost information in its cost estimations and calculations for the evaluation of new product ideas. According to the controller for R&D and production the cost information has to be processed and aggregated before it can be used in the feasibility studies of new product.

8 Discussion, limitations and a recommendation for business use

This section concludes the previously discussed results of the benchmarking study. It discusses the limitations of the findings, but also gives recommendations built on our findings.

Limitations

Generally, one can say that the best practices of the cost management methods centered on early innovation phases are split over several different benchmarked companies. Not one company excels in all categories. . Equally, it should be kept in mind that practices are often ‘sticky’ to key persons or department approaches. That means that not all early cost management methods will have been discovered in a company, but that the interviewed managers will have focused on methods that they are personally aware of and familiar with. Another limitation is the kind of industry analyzed. If costs do not play a significant role (e.g. in a high value brand strategy) cost management will equally not be important. Nevertheless, if competitive prices of new developments are important in order to be successful in the markets, the discussed methods are of high importance.

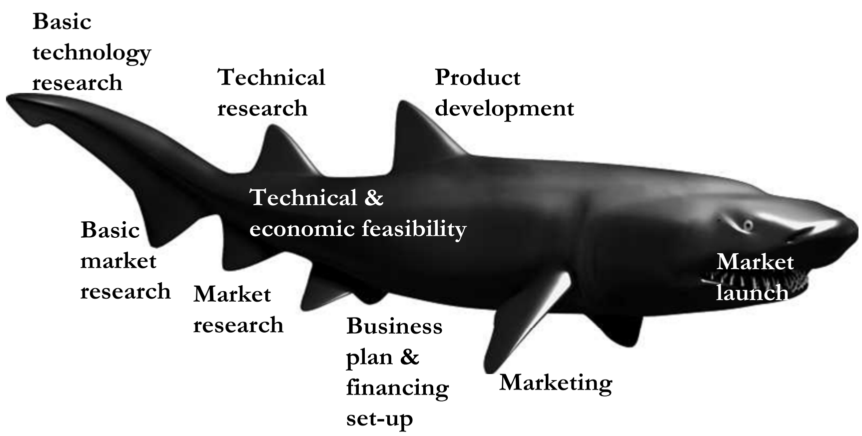

Figure 14: Seeing innovation in a shark structure

It is my view that the *big picture* of the early innovation could metaphorically be described with a picture of a shark. The tail would be longer on the top, in this case representing the technological R&D. However, innovations can also come from market impulses, the lower part of the caudal fin in Figure 14 would be shorter. This comes from the fact that the time to market would generally be shorter for market driven developments, as most likely known and proven technologies would be used to fulfill the market need. The further fins of the shark represent the different inputs to the innovation process, leading to the market launch of an idea in the end.

Lineage of tools

The lineage of the different tools can be seen in different levels. It leads from (cost) data capture, presentation and processing, and finally to decision-making preparation in the early innovation phases. First, information centered on the idea and situational factors around it has to be captured. This is done by data gathering with the help of intelligence work and research. These facts can be enriched by statements of experts. Scorecards will make sure that all the main points are considered for an innovation. Furthermore, they also assist internal knowledge management during early innovation phases.

The connection between future technologies and future product costs are one important aspect in technology management during the early innovation phases. This information can be enriched by trend extrapolation in cost development roadmaps and will be stored in cost databases. These give the basis for costing efforts conducted during early innovation phases. These costing efforts will incorporate a large amount of different methods, out of which cost modeling and estimation are stressed in this report. The roadmapping work is then transferred into directional costing as a preliminary target costing effort. During the use of directional costing, the cost development roadmaps and scenarios map the value and cost of a new development idea over time and into a future development and measures (and so influence the costs of the proposal can be considered). Once a new innovation idea enters the development phase, the directional costing effort is transformed into regular target costing.

It is our view that cost management can this way effectively assist innovations in early phases and significantly contribute to the success of a new development.

A recommendation for light and beneficial tools

It is our view that the previously described challenges show that **good knowledge management practices** are very important to perform efficiently cost management in the early phases of innovation. The **codification** of methods, as well as identifying decision criteria, is very important for organizational learning in a field that is still under-developed. Arguably, it is advantageous to include the involvement of experts in early phases of innovations, e.g. through the regular use of a **cross-disciplinary expert network**. These can work hand in hand with project managers and development engineers to optimize the decision making in the early stages. Moreover, the use of **scenarios** is very helpful. Through the generation of alternative ideas, it helps decision-making and communication in the early phases of innovation. In this early phase, **cost estimates** and **scenarios** can play a significant role.

The next tool that can be recommended is use of a **scorecard system**. It would help decision making and organizational learning, as all the important **check points** for a business could be incorporated. One astute practice identified is the use of a **scorecard** directly **in the employee suggestion system**. In this case, the employees are performing the evaluation of new development ideas themselves with the guided help of the scorecard. Generally, the method itself can be seen as very light and suitable to early phases of innovation.

The first described cost models are already found in the front-end of innovation of benchmarked companies. **Parametric cost estimations** dominate other approaches **for radical** innovation. However, when historical information can be reused, what happens mostly in **incremental innovations, the engineering cost estimation** method appears to dominate.

Another set of tools that is very beneficial in the early innovation phase, as it is rather light but powerful, is **roadmapping**. All kinds of trends can be roadmapped and brought together to be analyzed. One special roadmapping advance would be directional costing.

Merging cost capability estimations and target costing to directional costing

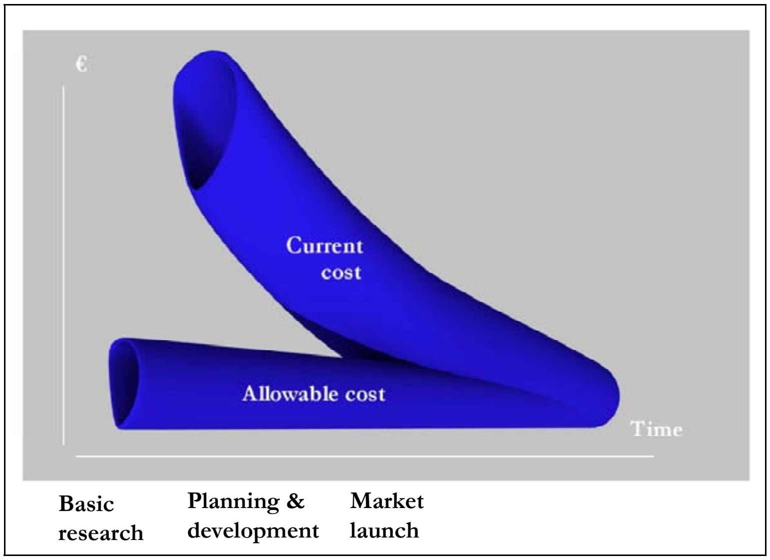

Figure 15: Directional costing

As stated above, one dominant way of presenting and analyzing information in early innovation phases is roadmapping. Especially in technically radical innovations, the operative roadmapping efforts would look similar to the previously depicted shark. The technological roadmapping would be the earliest, followed by market, and cost roadmapping. In the case where developments might take several years until production ramp-up, it is important to estimate how the costs connected to certain technologies will develop over time. Out of the above findings, in the benchmarked companies one could assemble a method that would use the philosophy of target costing, but could be used much earlier, i.e. in the front-end of innovation. This approach that can be labeled 'directional costing', as it takes estimates and vague figures from cost roadmaps and combines them over a time axis. The difference from directional costing to target costing is the preliminary nature of the estimates used for decision making. The upper variable, known as the current cost, can be analyzed and estimated through the analysis of the cost capability of a technology. Allowable cost as a variable is found through market allowable price estimations and market research.

Depending on the magnitude of which these both variables are apart, a company should focus on different tasks. As it is important at the start to bring the costs of a technology down. Moreover, research should be aimed at lowering the costs of the required technologies. Once the feasibility of the new idea can be seen through directional costing, planning and development efforts should be ramped up, so that the new development can be launched as soon as current cost and allowable cost start overlapping.

Cost databases as foundation

Another tool that can be very valuable is cost databases. These can help screening out not only feasible new developmental ideas, but in particular help in decision making in early innovation phases. For incremental new developments, cost databases can be used in very early innovation phases, i.e. the front-end of innovation.

Tools as a set

However, none of the described tools is a 'Holy Grail' in itself that would guarantee a new development success or a superior screening. Only together and with the use of other methods (not described here), can an optimal support of innovation activity by cost management be achieved. Thus, it will be a set of tools that should be incorporated.

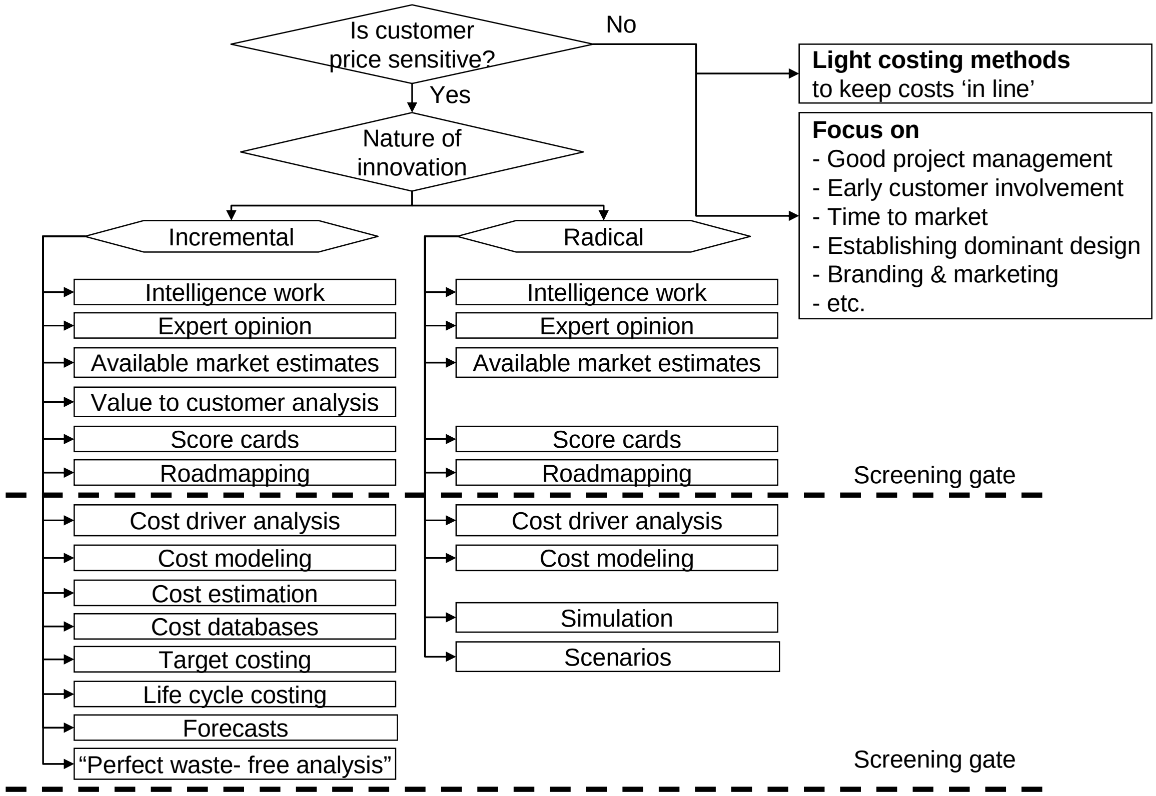

Figure 16: A flow chart to choosing an optimal mix of tools

A more detailed overview of which tools can be recommended to be used in special business cases is shown in Figure 16 (Screening gates according to the above mentioned model of Cooper). The flow chart shows how different tools should be selected. First, managers have to ask themselves if the targeted customer is price sensitive. If this is the case, then the nature of the innovation has to be taken into account. Incremental innovations will have less uncertainty around costs connected to them as compared to radical innovations. This is because incremental innovations can use the cost information of the existing offering of a company. The tool recommendation is split over the first two stages of a general innovation process as shown in Figure 3. At the front-end of innovation a company should at least have business and technology intelligence, together with scorecards and/or expert opinion. Furthermore, roadmapping can be seen as beneficial in this stage. Later a directional costing effort can be ramped-up, that would lead to target costing in the development stage, by freezing the specifications gradually. At the mid-stage, cost databases would be very helpful for correct decision making. However, their installation can be difficult, so it has to be seen from case to case whether it is beneficial to use them or not.

The final selection has, of course, to be done taking the specific boundary conditions of the innovation into consideration. We are confident that these tools and their right application will lead to a company managing its cost better than the competition. This will lead to a sustainable competitive advantage in this special field that contributes to the overall capability of a company to deliver innovation successfully to the market. Meanwhile, there are numerous pitfalls in other areas of the innovation process that a company has to be cognizant of.

References

Baum, H.-G., Coenenberg, A. G., Günter, T., 2004. Strategisches Controlling. Schäffer Poeschel, Stuttgart, 3rd ed.

Bescherer, F., 2006. Cost awareness in early stages of innovation: The need for efficient management accounting tools and methods. 5th Conference on new directions in management accounting: Innovations in practice and research. December, 14-16, 2006, Brussels, Belgium.

Blanchard, B.S., 1978. Design and Manager to Life-Cycle Cost, Portland, OR, M/A Press.

Boer, G., Ettlie, J., 1999. Target costing can boost your bottom line. Strategic Finance, July 1999, Vol. 81, Iss. 1, pp. 49-53.

Boothroyd, G., 1988. Estimate Costs at an Early Stage. American Machinist, Vol. 132, No. 8, Aug 1988, pp. 54 - 57.

Butscher, S. A., Laker, M., 2000. Market-Driven Product Development. Marketing Management, Summer 2000, Vol. 9 Issue 2, pp. 48-53.

Carbone, J., 2004. Medal of excellence: Hewlett-Packard wins for the 2nd time. Purchasing. September 2, 2004. Vol. 133, Iss. 15, pp. 34-48.

Chow, C.W., Haddad, K,M, Williamson, J.E., 1997. Applying the Balanced Score Card to Small Companies. Management Accounting, Aug. 1997, Vol. 79, Iss. 2, pp. 21-27.

Cooper, R. G., 1990. Stage-Gate Systems: A New Tool for Managing New Products. Business Horizons, May/June 1990, Vol. 33, Iss. 3, pp. 44-54.

Cooper, R. G., Kleinschmidt, E. J., 1993. Screening new products for potential winners. Long Range Planning, Dec 1993, Vol. 26, Iss. 6, pp. 74-81.

Cooper, R., Slagmulder R., 1997. Target costing and value engineering. Productivity Press, Portland, Oregon.

Dalkey, N., Helmer, O., 1963. An Experimental Application of the Delphi Method for the Use of Experts. Management Science, Vol. 9, Iss. 3, pp. 458-467.

Davila, A., Wouters, M., 2004. Designing Cost-Competitive Technology Products through Cost Management. Accounting Horizons. Mar 2004. Vol.18, Iss. 1, pp. 13-26.

Dekker, H. and P. Smidt, 2003. A survey of the adoption and use of target costing in Dutch firms. International Journal of Production Economics, Vol. 84, Iss.3, pp. 293-305.

Eisenhardt, K., 1989. Building theories from case study research. Academy of Management Review, Vol. 14, Iss. 4, pp. 532-550.

Ewert, R., Ernst, C., 1999. Target costing, co-ordination and strategic cost management. European Accounting Review, May 99, Vol. 8 Iss. 1, pp. 23-49.

Fogelholm, J., Bescherer, F., 2006. Productivity and performance improvement in paper mills: Procedural framework of actual implementations. Performance Improvement, Vol. 45, Iss. 10, pp. 15-20.

Garcia, R., Calantone, R, 2002. A critical look at technological innovation typology and innovativeness terminology: A literature review. The Journal of Product Innovation Management. Mar 2002, Vol.19, Iss. 2; pp. 110- 132.

Gerstenfeld, A., 1971. Technological Forecasting. The Journal of Business, Vol 44, Iss. 1, pp. 10-18.

Geurs, K., Wee, B. V., 2000. Backcasting as a Tool to Develop a Sustainable Transport Scenario Assuming Emission Reductions of 80-90%. Innovation: The European Journal of Social Sciences, Mar 2000, Vol. 13, Iss. 1, pp. 47-62.

Helms, M. M., Ettkin, L. P., Baxter, J. T., Gordon, M. W., 2005. Managerial implications of target costing. Competitiveness Review, Vol. 15, Iss. 1. pp. 49-56.

Iansiti, M., 1998. Technology integration: making critical choices in a dynamic world. Harvard Business School Press.

IEC 60300-3-3:2004. Dependability management - Part 3-3: Application guide – Life-cycle costing. International Electrotechnical Commission (IEC), Switzerland.

Jiang, R., Zhang, W.J., Ji, P., 2004. Selecting the best alternative based on life-cycle cost distributions of alternatives. International Journal of Production Economics, May 2004, Vol. 89 Iss. 1, pp. 69-76.

Kaplan, R. S., Atkinson, A. A., 1998. Advanced Management Accounting. Prentice Hall International Inc., Upper Saddle River, New Jersey, 3rd ed.

Kaplan, S. R. and Norton, D. 1992. The Balanced Scorecard-Measures that Drive Performance. Harvard Business Review. Jan/Feb 1992, Vol. 70, Iss. 1, pp. 71-79.

Kim, J., Wilemon, D., 2002. Focusing the fuzzy front–end in new product development. R & D Management, Sep2002, Vol. 32, Iss. 4, pp. 269-279.

Koen et al., 2001. Providing clarity and a common language to the 'fuzzy front end'. Research Technology Management, Vol. 44, Iss. 2, pp.46-55.

Kumar, R., 1996. Research Methodology – a step-by-step guide for beginners. SAGE Publications, London, Thousand Oaks, New Delhi.

Lawrence, P., Lorsch, J., 1967. Organization and environment: Managing differentiation and integration. Harvard Business School, Boston.

Martino, J. P., 1980. Technological Forecasting – an Overview. Management Science, Vol. 26, Iss.1, pp. 28-33.

Michaels, J.E., Wood, W. P., 1989. Design to Cost, New York, John Wiley & Sons.

Ong, N. S., 1993. Activity-based cost tables to support wire harness design. International Journal of Production Economics, May1993, Vol. 29, Iss. 3, pp. 271-289.

Robson, C., 2002. Real world research. Blackwell Publishing, Malden, 2nd ed.

Saunders, M., Lewis, P., Thronhill, A., 2000. Research Methods for Business Students. Pearson Education Ltd, Harlow.

Schneider, R., Miccolis, J., 1998. Enterprise risk management. Strategy & Leadership, Mar/Apr 1998, Vol. 26, Iss. 2, pp. 10-14.

Simpson, T. E., 2000. Extreme order-of-magnitude estimating. AACE International Transactions. pp. ES14A, 4 pgs.

Stevens, G. A., Burley, J., 1997. 3,000 raw ideas = 1 commercial success! Research Technology Management, Vol. 40, Iss. 3, pp.16-28.

Tan, K.H., Platts, K., 2004. Operationalising strategy: Mapping manufacturing variables. International Journal of Production Economics, Vol. 89, Iss. 3, pp. 379-393.

Vasconcellos J., Yoshimura, M., 1999. Life cycle cost model for acquisition of automated systems. International Journal of Production Research, June 1999, Vol. 37 Iss. 9, pp. 2059-2077.

Wheelwright, S. C., Clark, K. B., 1992. Revolutionizing Product Development. Free Press, New York.

Woodward, D. G., 1997. Life cycle costing – theory, information acquisition and application. International Journal of Project Management, Dec 1997,Vol. 15, Iss. 6, pp. 335-344.

Yoshikawa, T., Innes, J., Mitchell, F., 1990. Cost Tables: A Foundation of Japanese Cost Management. Journal of Cost Management, Vol.4, No. 3, Fall 1990, pp. 30-36.

Zhang, Q., Doll, W. J. 2001. The fuzzy front end and success of new product development: A causal model. European Journal of Innovation Management, Vol.4, Iss. 2, pp. 95-112.