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TAMPERE UNIVERSITY OF TECHNOLOGY

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FULLY FUNCTIONAL MOCK-UPS IN CONSTRUCTING VALUE PROPOSITIONS

Master of Science thesis

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Examiner and topic approved by the Faculty Council of the Faculty of Business and Built Environment
on 6th May 2015

ABSTRACT

NAVID KARIMIAN POUR: Fully Functional Mock-ups in Constructing Value Propositions
Tampere University of Technology
Master of Science Thesis, 114 pages
March 2015
Master's Degree Programme in Business and Technology
Major: Managing Technology-Driven Businesses in Global Markets
Examiners: Professor Petri Suomala and Dr. Jouni Lyly-yrjänäinen

Keywords: Customer Value, Product Development, Value Proposition, Cost-Reducing Innovations, Prototyping, Fully Functional Mock-up

Developing products based on customers' needs is one of the key success factors for companies in today's global market. As a result, in recent years, the involvement of customers during the product development process has increased significantly. Companies are trying to gather customer feedback as early as possible in the development process in order to understand customer value. However, reliable customer value can only be gathered once customers have gained experience in using the product. Therefore, companies usually need to wait until the late stages of the product development process after already determining product design and committing most of the costs.

The objective of this thesis is to introduce the concept of a fully functional mock-up, and to explain the role of these mock-ups in assisting companies to construct value propositions for their products in the early stages of product development. In this way, companies can share the whole product concept with the customers very early in the development process and enable them to experience using the product. This allows companies to not only receive customer feedback based on real user experience, but also to analyze customer value before committing most of the costs.

This study shows that fully functional mock-ups were effective communication tools both internally among development team members and externally with customers. Furthermore, they provided the possibility for a real customer experience and offered enough information to build convincing, accurate value propositions in the early stages of the product development process. In addition, fully functional mock-ups enable companies to modify their product design based on customers' real needs, thus preventing or at least diminishing possible financial losses in the future. This study is limited to cost-reducing innovations at a low level of technical complexity.

PREFACE

During my master studies, I realized that I am passionate about research and development. When I discovered that the case company was looking for someone to help them develop a solution to facilitate usage of their products, I became excited. I took the initiative and offered to work for the case company as a product development intern. Fortunately, we reached solid results in only a few months, and they asked me to continue our cooperation as a master thesis worker.

While working in the case company, I learned much about product development. I had the chance to experience and feel all the stages in the development process, its challenges and how to overcome them. Thankfully, I was able to work with a team who taught me a lot and helped me to push the projects forward. I am happy that by the end of my working agreement with the case company, we were successfully able to finish these product development projects. We were able to offer solutions which can benefit the case company financially and at the same time provide better working conditions for the operators.

I would first like to thank Dr. Jouni Lyly-yrjänäinen for his encouragement and guidance throughout the process of writing this thesis and during my whole study period. I would also like to thank Professor Petri Suomala for his valuable comments and insights. Furthermore, I would like to express my sincere gratitude to the management of the case company. Last but not least, I would like to thank my family for their support throughout all the stages of my life.

Tampere, 16.04.2015

Navid Karimian Pour

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LIST OF SYMBOLS AND ABBREVIATIONS

B2B	Business to Business
B2C	Business to Consumer
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
FEM	Finite Element Model
MSHA	Mine Safety and Health Administration
NPD	New Product Development
PDP	Product Development Process
Pictive	Plastic Interfaces for Collaborative Technology Initiative Through Video Exploration
PPP	Phased Project Planning
RP	Rapid Prototyping

1. INTRODUCTION

1.1 Background

In today's business world, successful product development can play a crucial role in the long-term prosperity of companies (Smith & Morrow, 1999). Firms developing attractive products for customers are likely to win (Brown & Eisenhardt, 1995). However, customers consider a product attractive only if the benefits perceived from product usage surpass the sacrifices necessary for acquiring the product (Khalifa, 2004). Quantifying the perceived benefits and sacrifices is challenging and requires in-depth knowledge about customers and their key value drivers. For this purpose, companies have applied customer value assessment methods to help them identify the key value drivers and evaluate customer perceived value (Anderson et al., 2006; Payne & Frow, 2005; cited in Keränen & Jalkala, 2013).

Several decades ago, although customers were exposed to a product, thereby giving them with a chance to experience the product in use, this only occurred in later stages of the product development process (PDP) (Cooper, 1990). At that time, the competition in the market was not as fierce, nor were companies as aware of the importance of customer feedback in all the stages of the PDP. However, since that time, the importance of customers' involvement from the very beginning of the PDP has received increasing attention (Cooper, 2008). For this reason, various PDP models, such as the stage gate model, have emphasized customer involvement from very beginning (Stage-gate international, 2014).

One of the main challenges in gathering reliable customer feedback is that customers perceive the real value of the product mainly after experiencing the product in use (Lanning, 1998; Woodruff, 1997). The use of mock-ups and prototypes has grown significantly as a means to help companies communicate their ideas easier in the development process and to give customers a chance to experience the product in use. On the one hand, in early stages in the development process, mock-ups and prototypes are built to test the core functionalities of the final products, commonly known as low fidelity prototypes. (Preece et al., 2002) On the other hand, during later stages, prototypes are built out of the same materials and components as the final product and offer an equal level of functionality (Yang & el-Haik, 2003). These prototypes are referred to as high fidelity prototypes (Preece et al., 2002).

However, there has been a large gap between prototyping methods. As a result, customers have only been able to experience the real product usage very late in the development process. At this stage, over 80 percent of product life cycle costs have already been committed (Turney, 1991). Hence, even if the company received valuable customer feedback, it would be very costly to apply any modifications to the product (Dowlatshahi, 1992; cited in Asiedu & Gu, 1998).

1.2 Objective

This thesis introduces a new prototyping method, the "fully functional mock-up" to close the gap between low- and high-fidelity prototyping methods (Preece et al., 2002). Fully functional mock-ups share some of the characteristics of both low- and high-fidelity prototypes. They can offer almost the same functionalities as the final product but can be built in the early stages of the product development process using cheap materials, thus allowing customers to fully experience the product and share their feedback with the development team before the majority of the costs have been committed.

Fully functional mock-ups are great tools to build convincing value propositions in the early stages of development process. Due to the nature of fully functional mock-ups, reliable time and cost studies can be performed, the result of which can provide needed input for constructing the value proposition for the product. This gives the company a chance to evaluate the market potential and viability of the idea before making significant investments. Thus, the objective of this paper is…

> *… to introduce the concept of a fully functional mock-up and discuss the role that they play in constructing value proposition for cost-reducing innovations in the early stages of the product development process.*

To address this objective, this thesis reviews the literature concerning customer value, product development and value proposition. Next, a framework is designed to demonstrate the ability of fully functional mock-ups to help in building value propositions very early in the development process. Finally, this framework is tested in a cost-reducing development project in the case company.

1.3 Research Process

The research process was unofficially kicked off in October 2012, when the author started working on a project for a course called "Operative Sales and Sourcing". The project aimed to seek new solutions to cap hose assemblies and was conducted in a hose assembly production facility in Tampere, Finland. Working on this project gave the author an opportunity to learn about the hose assembly process by visiting the production facility various times and talking directly with the managers and operators. The project was concluded in March 2013, and the findings were presented in the "Finnish quality association seminar".

In May 2013, the findings of the capping project were shared with the case company manager. The case company was already supplying hose protection products and was expanding their business to other hose-related accessories. It was assumed that they might be interested in adding plastic caps to their product portfolio. Despite their interest in capping, their priority at that time was in finding a new solution for spiraling hose assemblies. The author expressed interest in this project, and the company agreed to establish a development project for spiraling hose assemblies and finance all the development costs.

During summer 2013, some new ideas were generated and tested until one of these ideas showed very positive results. After sharing the findings with the case company in September 2013, the case company managers decided to develop it further and asked the author to make a prototype of the idea for the Agritechnica exhibition in Hannover, Germany. The exhibition was held in November 2013, and the author with a team from the case company participated in the exhibition to share the idea with customers and gather feedback. Customers were happy with the functionality of the prototype, and the company thus considered this a green light to continue the development. As a result, the case company offered the author a master thesis position in the company to continue development of the spiraling machine as well as work on the sleeve cutting and hose capping projects.

The plan was to push forward all three projects simultaneously, but resources were to be allocated based on company priorities. Parallel with these on-going projects, the literature related to customer value, product development and value proposition were explored to gain the theoretical knowledge needed to support the development process. Figure 1 illustrates the milestones and main activities in the research process.

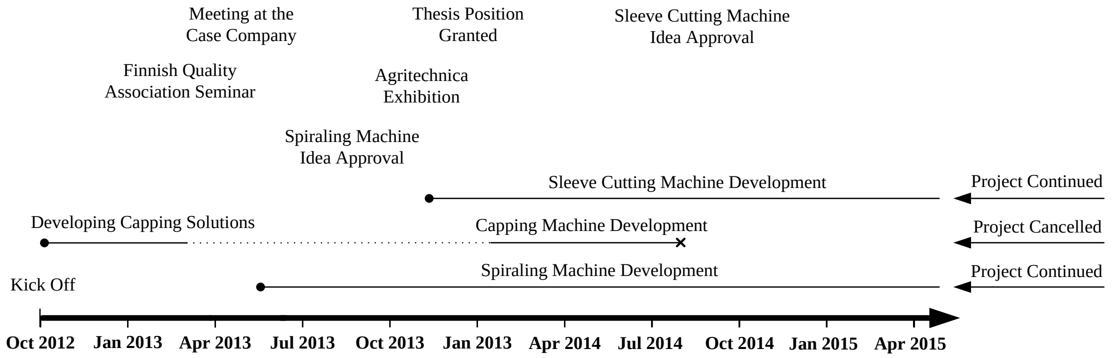

Figure 1. General overview of research process.

Among these three projects, the sleeve cutting machine project was chosen as an example to illustrate the application of the theoretical framework in a real-life situation. Therefore, the sleeve cutting development process is explained in more detail in the following paragraph. Figure 2 highlights the activities related to the sleeve cutting project.

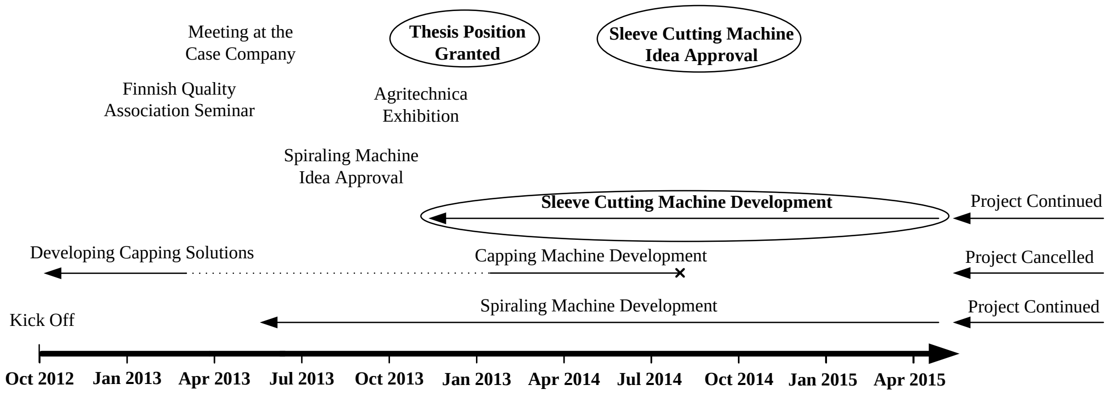

Figure 2. Highlighting sleeve cutting machine project activities.

The first idea for the sleeve cutting project was generated in November 2013. In the following months, more ideas were generated and tested. Finally, in July 2014, the best idea was selected. Thereafter, the selected idea was further developed until the middle of September 2014, when the functionality of the mock-up reached a point that a reliable time and cost study could be implemented. Since the results of the initial time and cost study were satisfactory, the concept was pushed forward (Figure 3).

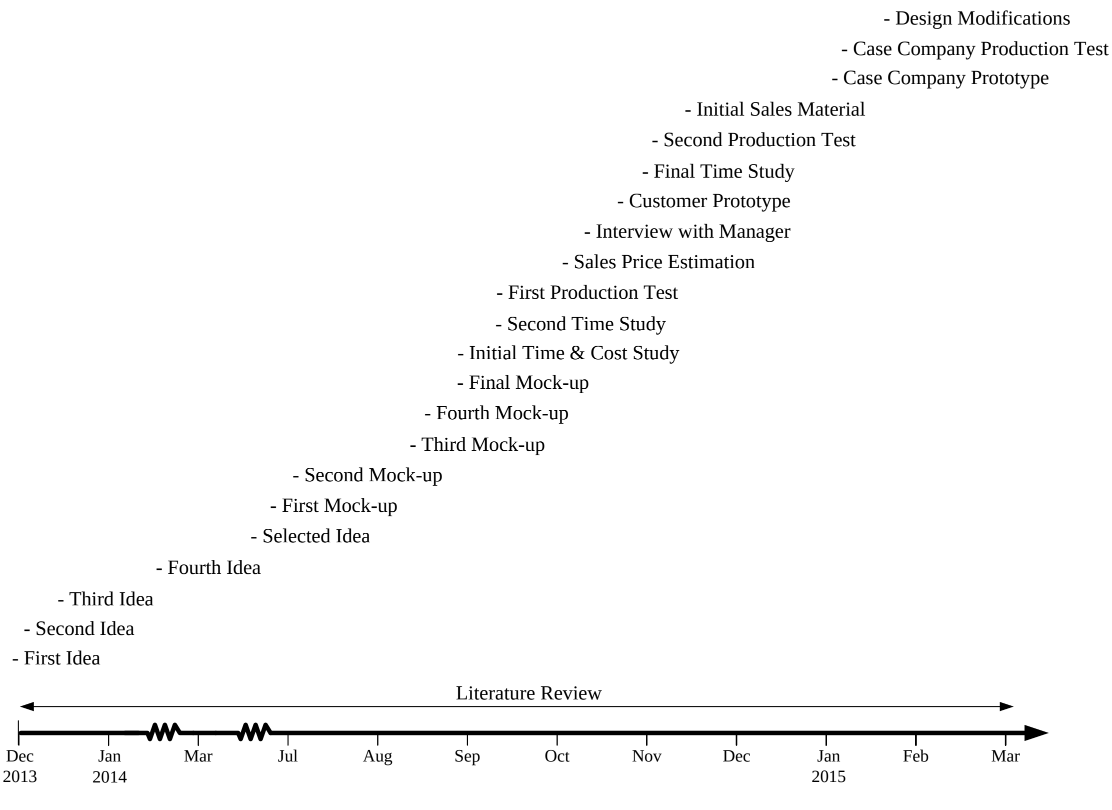

Figure 3. Milestones of sleeve cutting machine project.

In the last week of September 2014, the first production test was conducted. Because the customer was happy with the performance of the sleeve cutting mock-up, the managers of the case company decided to continue the development and financed three more prototypes. The goal was to utilize one of the prototypes in the case company production line. In addition, an agreement was made with two customers to use the two other prototypes for three months in their production lines. Currently, this sleeve cutting machine is in the testing and validation stage of the product development process. Two of the three prototypes are currently being operated for a trial period in production. It is expected that by the end of April 2015, the sleeve cutting machine will be ready for commercialization.

1.4 Data Gathering Methods

Research is a systematic, methodological process of investigation to increase existing knowledge or create new knowledge (Amaratunga et al., 2002). Remenyi et al. (1998) stated that research methodology is a procedural framework within which the research is conducted. Many factors impact on choosing an appropriate research methodology, of which the research topic and the specific research question are the main drivers. From one perspective, research can be theoretical or empirical. Theoretical research investigates only existing theories and hypothesis to answer a research question or create a theoretical framework.

Empirical research consists of gathering and analyzing empirical data and subsequent reporting of findings and conclusions (Minor et al., 1994). Empirical research normally starts with the definition of a research question or problem. Next, the researcher goes through the existing literature and constructs a hypothesis or a theoretical framework. The hypothesis or theoretical framework generated is then tested in a real-life situation. Finally, the researcher reaches conclusions and discusses the viability and limitations of the study. (Simon et al., 1994)

Moody (2002) stated that empirical research methods can be divided into qualitative and quantitative methods. Qualitative methods are more appropriate in the early stages of empirical research, particularly for theory building. On the other hand, quantitative methods are more suitable for theory testing and refinement. However, in practice, no research method is purely quantitative or qualitative. Mostly a combination of quantitative and qualitative methods is used to achieve a particular research objective, referred to as triangulation (Voss et al., 2002). Wohlin et al. (2006) noted that empirical research strategies can be divided into four types: experiment, case study, survey and post-mortem analysis. Among these methods, only experimentation is quantitative, with the rest of these representing a combination of both. Since this thesis is a case study, the characteristics of a case study are explained briefly in the following paragraph.

Case study research is implemented to gain a better understanding about complex phenomena or to explore hidden phenomena. Although case studies can use both qualitative and quantitative data generation methods, qualitative methods are much more common. Gummesson (1993) categorized data gathering methods that can be used in a case study research for management subjects into five groups. Table 1 shows these methods and short descriptions of each.

Table 1. Data gathering methods (Gummesson 1993).

Method	Description
Existing materials	Everything that is conveyed by other media (e.g., books, articles, mass media reports, brochures, films) than humans. Existing materials are often referred to as secondary sources of data
Questionnaire surveys	Questionnaire surveys are used for formalized and standardized interviews
Questionnaire interviews	Questionnaire interviews are the most common method to generate data in case study research. They usefully include open-ended questions, which are asked according to interview flow
Observation	Observation is a method to gather information by observing the subject of the study
Action science	Action science requires the total involvement of the researcher in the process and can contain all other data gathering methods

The goal of this study was to create a theoretical framework for constructing value propositions in the early stages of product development in terms of cost-reducing solutions. The theoretical framework was tested in a real-life product development project. Various data gathering methods were utilized in this study, including existing materials, questionnaire interviews, observation and action science (Figure 4). Initially, information from company catalogues, brochures, company website and other online sources were gathered concerning the company, its operations and future goals. In addition, questionnaire interviews were conducted with some of the case company's personnel to gain more detailed knowledge specifically regarding the reasoning behind investing in these development projects.

Data for the case study were gathered by observation and action science. During the research process, the author visited customers' facilities several times to experience the need for the development project from the customers' perspective and to share with them in the development progress. In addition, the author was involved in all development activities, including the building of mock-ups and prototypes, time and cost studies, as well as demonstrating the ideas to company managers and customers. Involvement of the author in the project provided the opportunity to build the value proposition using the fully functional mock-up and testing it in practice.

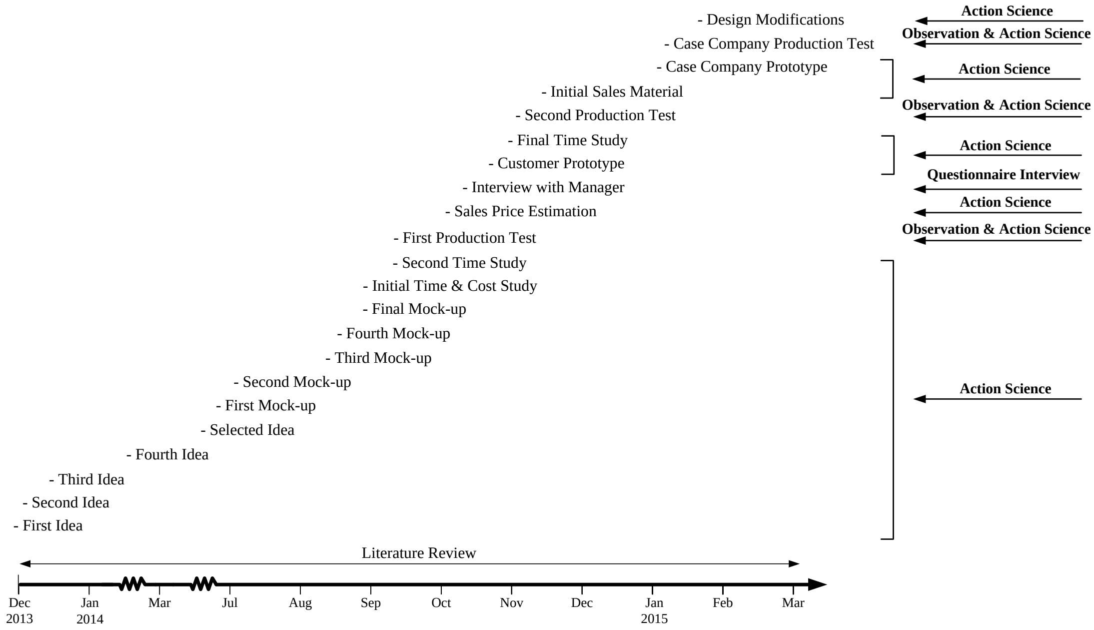

Figure 4. Data gathering methods used in the sleeve cutting machine project.

As shown in the figure above, there are several activities with more than one data gathering method. It can be argued that since action science may include all the other data gathering methods, there is no need to write, for example, both action science and observation for an activity. The only reason for mentioning the data gathering methods in the figure above is to emphasize the role of observation and interviews in gathering data during certain parts of the research process.

1.5 Structure of the Thesis

This thesis is logically divided into eight chapters. The content and objectives of the chapters are as follows:

1. Chapter 1 introduced the background and main objective of the study. It also explained the research process and data gathering methods applied in all the research activities.

2. Chapter 2 discusses the customer value concept in cost-reducing innovations. It extracts main customer value drivers by analyzing several customer value models, creates a new model based on these drivers, and explains the customer value assessment methods.

3. Chapter 3 introduces the product development concept mainly in terms of cost management, describes the evolution of product development process models, and discusses the benefits and role of these models in reducing development process costs.

4. Chapter 4 discusses the value proposition in the context of cost-reducing solutions. Then, it explains how mock-ups can be utilized as a tool to calculate cost savings of future offerings in the early stages of PDP and how this information can be beneficial in calculating the added perceived value of a company's offering.

5. Chapter 5 briefly describes the case company history, financial situation and distribution channels. It also discusses the reasoning behind the company's decision to expand their business, as well as introduces the case company's products, focusing mainly on textile sleeves.

6. Chapter 6 demonstrates the development process of the sleeve cutting machine by explaining the important stages in the development process. In addition, it shows the time & cost study results as well as the application of these results in constructing value proposition.

7. Chapter 7 reviews the research problem and theoretical framework of the thesis. Then, it applies the framework to the case study and analyzes the results. Finally, it states the findings of the research and points out the limitations of this study.

8. Chapter 8 concludes the report.

2. CUSTOMER VALUE OF COST-REDUCING INNOVATIONS

2.1 Definition of Customer Value

In recent years, there has been growing interest in customer value and value-based strategies (Khalifa, 2004). It has been argued by many authors that maximizing delivered customer value is a key factor for business success (Higgins, 1998; Laitamäki & Kordupleski, 1997; Woodruff, 1997; Porter, 1996; Wyner, 1996; Milgrom & Roperts, 1995; cited in DeSarbo et al., 2010). Anderson & Narus (1998) noted that although most customers are well aware of their requirements, this does not necessarily mean that they know the value of fulfilling these requirements for them. This creates a huge opportunity for suppliers to demonstrate the total value of their offerings and to convince customers to focus on total value rather than on only the purchase price. However, only a minority of the firms have the knowledge and capability to assess the total value of their offerings. (Anderson & Narus, 1998) Therefore, it is essential to review the concept of customer value in order to identify the main drivers for customer value creation.

Customer value has been defined by various authors over the past decades. Zeithaml (1988) defined customer value as

> *"… customer's overall assessment of the utility of a product based on perceptions of what is received and what is given".*

Based on this definition, customer value is similar to a trade-off: In order to obtain something from a product, a customer should give something in return. Similar definitions focusing on the trade-off aspect of customer value has been presented by a number of other authors (e.g., Anderson & Narus, 1998; Gale, 1994; Monroe, 1990; Day, 1990). However, customer value has been viewed differently by other authors. Butz & Goodstein (1997) see customer value as

> *"… the emotional bond established between customer and a producer after the customer has used a salient product or service produced by that supplier and found the product to provide an added value."*

This definition views customer value from an emotional and relational point of view. In other words, when a customer perceives added value in the supplier's offering, he tends to establish an emotional bond with the supplier. Therefore, that customer may buy repeatedly or exclusively from that supplier or even recommend that supplier to others.

Another definition for customer value is provided by Woodruff (1997), who views customer value as

> *"…a customer's perceived preference for and evaluation of those product attributes, attribute performances and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations."*

Woodruff's definition of customer value consists of both desired and received value, and emphasizes that value stems from customers' learned perceptions, preferences and evaluations. In addition, it links products with use situations and related consequences experienced by goal-oriented customers.

Khalifa (2004) categorizes definitions of customer value into three groups: value component models, means-ends models and benefit/cost models. Each of these groups focuses more on some aspects of customer value and pay less attention to the other dimensions. At the same time, there is a great overlap among the models in these groups. Each of these groups is described briefly in the following paragraphs.

The first of the well-known value component models is Kano's model of customer perception (Figure 5) which divided the value components into dissatisfiers (expected), satisfiers (desired) and delighters (unanticipated) (Butz & Goodstein, 1997; cited in Khalifa, 2004). Dissatisfiers are features which must be in the product; otherwise, customers will be really disappointed. Satisfiers are characteristics which are expected to be in the product and can create increasing satisfaction by fulfilling customers' needs. Finally, delighters are features that are not expected by the customers because they are coming from the latent needs of the customers. The existence of these features can create huge satisfaction for customers. (Khalifa, 2004)

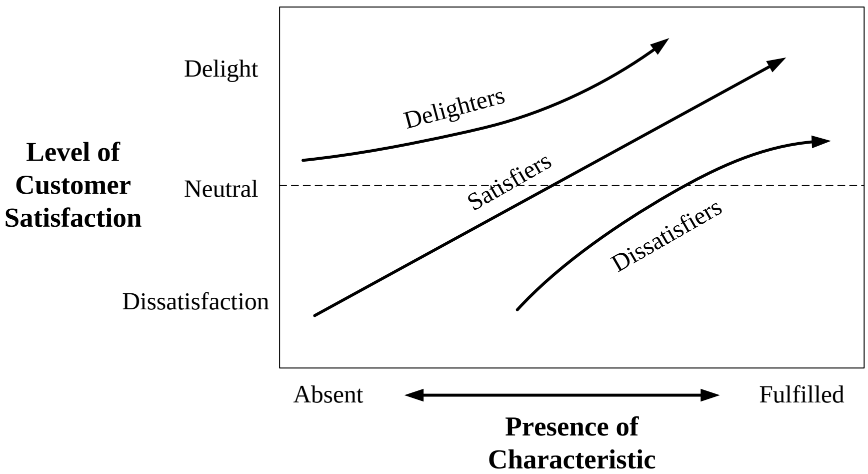

Figure 5. Kano's model of customer perception (Adapted from Khalifa, 2004).

Means-ends models define customer value based on the assumption that customers use products to accomplish some favorable ends. For example, Woodruff (1997) introduced customer value hierarchy (Figure 6) in this context. Starting from the bottom of the hierarchy, customers perceive products as bundles of product attributes and attribute preferences. After purchasing and during usage of a product, customers form preferences for certain attributes, as they facilitate achievement of certain consequent experiences, reflected in value-in-use and possession value. Customers also learn to demand the consequences which help them to achieve their goals.

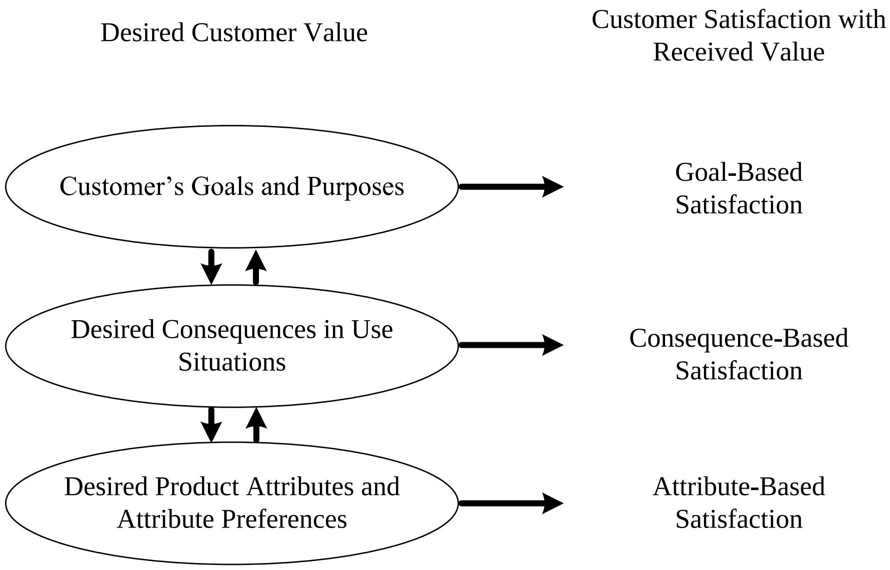

Figure 6. Customer value hierarchy (Adapted from Woodruff, 1997).

Starting from the top of the hierarchy, customers attach importance to consequences based on goals and purposes which, in turn, guide customers when attaching importance to attributes and attribute preferences (Woodruff, 1997). Means-ends models are perfect tools to explain why customers have different weights for benefits in the evaluation process of products or services (Khalifa, 2004).

Finally, benefit/cost models define value as the difference between customers' perception of benefits received and sacrifices made (e.g., Anderson & Narus, 1998; Gale, 1994; Monroe, 1990; Day, 1990; Ziethaml, 1988). Since benefit/cost models are the main focus of this thesis, they are explained in more detail in the following section.

2.2 Benefit/Cost Models

Defining customer value from a benefit/cost point of view has been very popular among researchers. Zeithaml (1988) defined value as a customer's overall evaluation of the product's utility based on perceptions of what is received and what is given. This definition shows that customers see value as a trade-off of benefits which they perceive as gained from acquiring a product and the sacrifices they make. Various authors have proposed definitions for customer value similar to that of Zeithaml (e.g., Monroe, 1990; Day, 1990). Although these definitions provide a general understanding of customer value, they have not clearly identified what are these benefits and sacrifices.

Anderson & Narus (1998) stated that value is the monetary worth of technical, economic, service and social benefits gained by a customer in exchange for the price he pays. Lapierre (2000) defined customer value as the difference between benefits and sacrifices perceived by customers. In his paper, he introduced key drivers of customer perceived value based on a literature review and interviews. Figure 7 illustrates the key value drivers introduced by Lapierre.

Scope / Domain	**Product**	**Service**	**Relationship**
Benefit	Alternative Solutions Product Quality Product Customization	Responsiveness Flexibility Reliability Technical Competence	Image Trust Solidarity
Sacrifice	Price		Time/Effort/Energy Conflict

Figure 7. Key drivers of customer value (Adapted from Lapierre, 2000).

Lapierre divides benefit drivers into product, service and relationship related drivers. Product-related benefits include alternative solutions, product quality and product customization. Alternative solutions are related to the range of alternative offers, as well as suppliers' capability and helpfulness in fulfilling the customers' needs and in solving their problems. Product quality denotes the reliability, durability and performance of the product. Product customization refers to the ability of the supplier to offer customized products to customers. The second set of benefit drivers, service-related benefits, represent responsiveness, flexibility, reliability and technical competence. Responsiveness is the supplier's attention to the customers' problems and providing quick answers to those problems. Flexibility is related to the ability of the supplier to handle changes and adjustments in the product when needed. Reliability means accuracy in business operations and keeping promises, while technical competence refers to the creativity and expertise of the supplier in understanding the customers' problems and the ability to offer solutions. Finally, relationship-related benefits include image, trust and solidarity. Image is related to reputation and credibility. Trust is based on the confidence of a customer in the accuracy of information shared by the supplier and fulfillment of its promises. Solidarity refers to the help obtained by a customer from its supplier when problems happen (even if it is beyond the contract terms).

On the other hand, there are sacrifice drivers, which Lapierre divides into product/service and relationship related drivers. Price is identified as the only product/service-related sacrifice, which refers to the amount of money paid by a customer for the product/service. Relationship-related sacrifices include time/effort/energy and conflict. Time/effort/energy refers to, for example, the number of meetings with the supplier or the time spent in training employees to be able to work with a product. Conflict refers to arguments and disagreements that the customer may have with the supplier about how to reach respective goals.

Khalifa (2004) argues that although the customer is willing to spend certain amount of time, money, effort and take certain risks, he expects in exchange to gain benefits that outweigh the total sacrifices. The difference between the total benefits and the total sacrifices is called the net customer value. The customer will purchase the product only if the net customer value is zero or above. In this model, the total customer benefits include utility and psychic value, and total customer sacrifices consist of financial and non-financial costs. Figure 8 shows the model introduced by Khalifa (2004): the value exchange model.

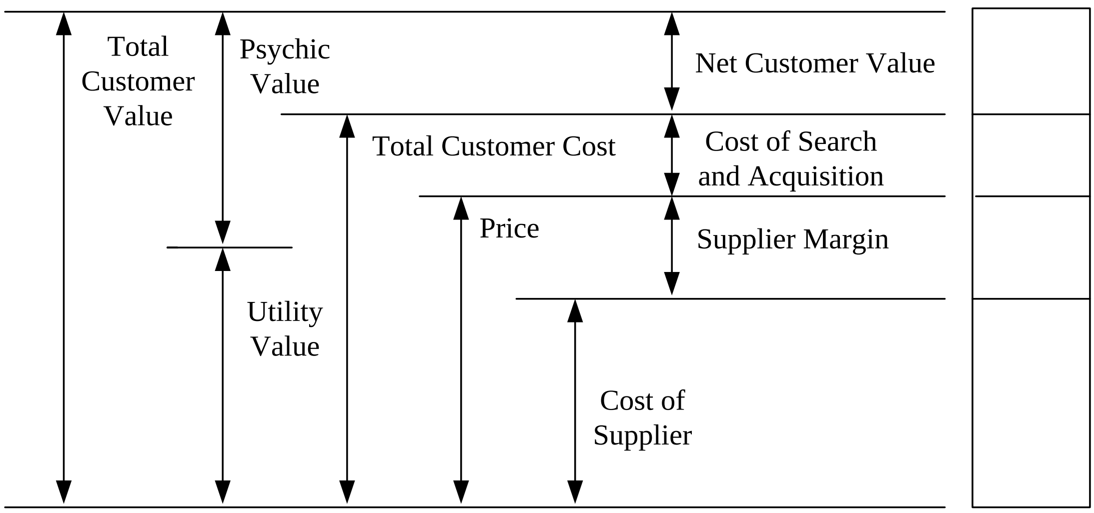

Figure 8. The value exchange model (Adapted from Khalifa 2004).

As shown in the figure, the supplier incurs costs to produce a product or offer a service. The supplier then sets a price, which is related to its profit margin. When the customer wants to buy the product, in addition to the price, he spends a certain amount of money for searching and acquisition. Thus, the customer eventually expects the product to have a value for his company that is higher than what he sacrifices. This difference between the total customer value and the total customer cost is known as net customer value.

Menon et al. (2005) defined customer value as the benefits offered by the seller and the sacrifices customers make to obtain those benefits. The benefits can be divided into core benefits and add-on benefits, whereas sacrifices include purchasing price, acquisition costs and operation costs. Figure 9 demonstrates this definition in more detail.

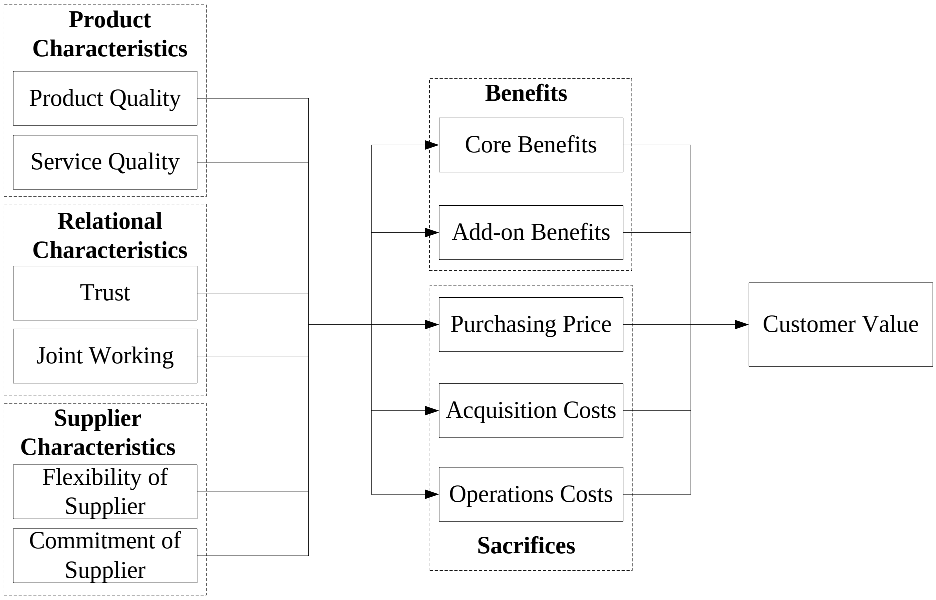

Figure 9. Customer value (Adapted from Menon et al., 2005).

Menon et al. (2005) sees benefits and sacrifices as being influenced by product characteristics, relational characteristics and supplier characteristics. As mentioned previously, this model divides the benefits into core benefits and add-on benefits. Core benefits are said to be a set of minimum attributes required by a customer. These core benefits should be met completely by the supplier because they are essential from the customer's point of view. Add-on benefits are a set of attributes which are not required by customers and can distinguish suppliers from each other. Sacrifices are divided into purchase price, acquisition costs and operation costs. Purchasing price is the amount of money paid by a customer for the product. Acquisition costs consist of expenses and efforts in ordering, delivering, storing, monitoring performance, coordinating and communicating with the supplier. Finally, operation costs refer to expenditures for manufacturing, research and development, internal coordination and downtime.

Smith & Colgate (2007), based on an extensive review of the customer value literature, introduced a framework for customer value creation. In this framework, organizations can create four types of value: functional/instrumental value, experiential/hedonic value, symbolic/expressive value, and cost/sacrifice value. In addition, the framework identified five sources of value: information, products, interactions, environment and ownership. The result of this framework is a 4×5 table which then can be used for various purposes, such as providing a basis for assessing value creation strategies.

Functional/instrumental value is related to the extent that a product has desired characteristics or functions. According to Woodruff (1997), three key aspects of functional value are accurate attribute, appropriate performance and appropriate outcomes (cited in Smith & Colgate, 2007). Experiential/hedonic value refers to the extent the product creates feelings and emotions for the customer. There are four value aspects for experiential value: sensory, emotional, social and epistemic (Sheth et al., 1991; cited in Smith & Colgate, 2007). Symbolic/expressive value is related to the extent that the customer attaches psychological meaning to a product. Self identity, personal meaning, self expression, social meaning and conditional meaning are five value aspects of symbolic value (Holbrook, 2005; Woodall, 2003; Holbrook, 1999; Sheth et al., 1991; cited in Smith & Colgate, 2007). Finally, cost/sacrifice value is concerned with costs involved in transactions. Sacrifice value has four aspects: economic costs, psychological costs, personal investment and risk (Woodall, 2003; Walter et al. 2003; Sweeny, 1999; Grönroos, 1997; cited in Smith & Colgate, 2007). demonstrates the customer value creation framework.

Table 2 demonstrates the customer value creation framework.

Table 2. Customer value creation framework (Adapted from Smith & Colgate, 2007).

	Type of Value			
	Functional	**Experiential**	**Symbolic**	**Sacrifice**
	accurate attribute, appropriate performance and appropriate outcomes	sensory, emotional, social and epistemic	self identity, personal meaning, self expression, social meaning and conditional meaning	economic costs, psychological costs, personal investment and risk
Information	educate and inform customers realize performance	copy and creativity can provide or enhance sensory, emotional, relational and epistemic experiences	can position a product, help customers identify with the product, help them make associations and interpret meaning	helps customers evaluate alternatives, , helps lower prices by greater competition
Products	products directly provide features, functions and characteristics that allow performances	they provide sensory, emotional, relational and epistemic experiences	products enhance consumer self-concepts, provide personal meaning, offer self expression and provide social meaning	product price and augmented product considerations such as operating costs, help to reduce sacrifices
Interactions	sales call frequency and duration, service interactions and interactions with system enhance performance	service attribute such as staff politeness create sensory. Emotional, social and epistemic experiences for customers as do service recovery, customer support	staff and system interactions can make customers feel better and provide personal meaning to customers, privileged interactions support status and prestige. Equity policies can enhance socio-cultural meaning	Interactions with people and systems add to or reduce the economic and psychological cost of a product and increase or reduce the personal investment required to acquire and consume the product
Environment	decorative features of the purchasing or consumption environment such as furniture contribute to functional value by enhancing from product performances	attributes of the purchasing or consumption environment such as music can create sensory, emotional, epistemic experiences for customers	where a product is consumed or purchased can provide personal, social or socio-cultural meaning and can enhance self-worth and expression	contributes of the economic cost of a product, psychological cost, personal investment and personal risk
Ownership	Correct, accurate and timely fulfillment processes provide functional value	fulfilling delivery promises and how a product is delivered can enhance the customer experience	how a product is delivered and by whom can create symbolic value	can be enhanced with payment terms, delivery options, return policies, billing accuracy, etc.

According to Lyly-yrjänäinen et al. (2010), the customer expects to receive economic, functional and psychological benefits from the goods or services they buy. Total customer value is the monetary value of these benefits. However, in order to gain these benefits, the customer needs to pay the price. When a customer buys a product or service, he pays a certain price for it (purchase price): he pays the usage cost, and when the product is disposed, the customer also pays for the disposal. The sum of these costs accounts for the total customer cost. As a result, the customer perceived value of a product or a service is the difference between the total customer value and the total customer cost. (Lyly-yrjänäinen et al., 2010) Figure 10 shows perceived customer value as well as the relationship between the supplier's profit and perceived customer value.

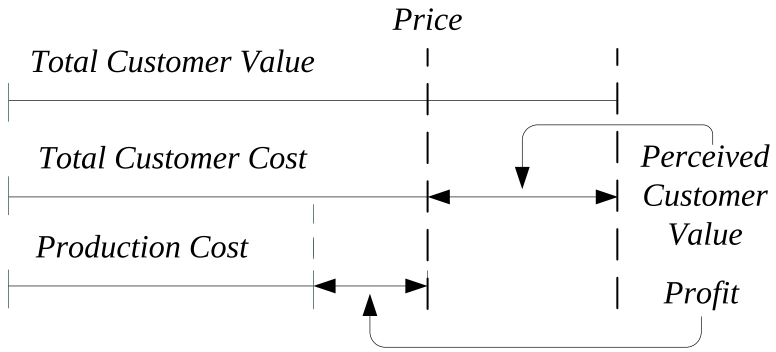

Figure 10. Perceived Customer Value (Adapted from Lyly- yrjänäinen et al. 2010).

The above figure shows that a company should set the price of its products such that it covers all the production costs and also brings certain amount of profit for the company. At the same time, it is important to consider the price level from the customer's perspective. In other words, the customer needs to perceive value when buying a product. Therefore, the product's price should be set in order to ensure that the value from the product perceived by the customer surpasses the sacrifices he makes to acquire it.

This section has discussed the views of the authors regarding customer value. Although all these authors have defined customer value from the benefit/cost point of view, there are differences in how they have identified the key drivers of benefits and sacrifices. Table 3 summarizes these key drivers of benefits and sacrifices.

Table 3. Key drivers of benefits and sacrifices.

Author	Benefits	Sacrifices
Anderson & Narus, 1998	• Technical • Economic • Service • Social	• Price
Lapierre, 2000	• Product related (alternative solutions, customization, quality) • Service related (responsiveness, flexibility, reliability, technical competence) • Relationship related (image, trust, solidarity)	• Time/effort/energy • Price • Conflict
Khalifa, 2004	• Utility value • Psychic value	• Cost of search & Acquisition • Price
Menon et al., 2005	• Core benefits • Adds-on benefits	• Direct purchase price • Acquisition costs (ordering, delivering, storing, monitoring, coordinating, communicating) • Operation costs (R&D, manufacturing, internal coordination, downtime cost)
Smith & Colgate, 2007	• Functional (accurate attribute, appropriate performance, appropriate outcomes) • Experiential (sensory, emotional, social, epistemic) • Symbolic (self identity, personal meaning, self expression, social meaning, conditional meaning)	• Economic • Personal investment • Psychological • Risk
Lyly-yrjänäinen et al., 2010	• Economic • Functional • Psychological	• Price • Usage cost • Disposal cost

By taking a closer look at the table, it can be seen that there are many similarities, although sometimes authors may use different terms for the same concept. For instance, five of the six authors directly mention that price is one of the main sacrifices. Lyly-yrjänäinen et al. (2010), instead of stating price directly, introduced the same concept using the term economic sacrifices. Therefore, a new framework for benefit/cost value drivers can be concluded by combining these ideas. Table 4 illustrates the new framework for the key drivers of customer value.

Table 4. Customer value drivers framework.

		Anderson & Narus, 1998	Lapierre, 2000	Khalifa, 2004	Menon et al., 2005	Smith & Colgate, 2007	Lyly-yrjänäinen et al., 2010
Benefits	Functional	✓	✓	✓	✓	✓	✓
	Economic	✓			✓		✓
	Service	✓	✓		✓		
	Psychological		✓	✓		✓	✓
	Social	✓	✓			✓	
Sacrifices	Purchase price	✓	✓	✓	✓	✓	✓
	Acquisition cost		✓	✓	✓	✓	
	Operation cost				✓	✓	✓
	Disposal cost						✓
	Psychological cost		✓			✓	

This table divides both benefits and sacrifices into five groups. The benefits a customer may obtain by acquiring a product can be divided into functional, economic, service, psychological and social benefits. Functional benefits represent the perceived utility of a product resulting from its features (Sheth et al., 1991; cited in Smith & Colgate, 2007). Economic benefits refer to price and value-in-use advantages gained by a customer. Attributes such as staff behavior, customer support and timeliness form the service benefits. Psychological benefits refer to attributes such as ease of use, simplicity, availability and accessibility of a product. (Smith & Colgate, 2007) Finally, social benefits result from the utility perceived from the product's image and symbolism (Sheth et al., 1991; cited in Smith & Colgate, 2007).

The sacrifices that the customer may need to make can be divided into purchase price, acquisition cost, operation cost, disposal cost and psychological cost. Purchase price is the amount of money charged by the supplier for the product at the time of the transactional exchange. Acquisition costs refer to costs related to activities such as ordering, delivering and storing the product. Operation costs refer to the costs incurred by the customer in the day-to-day operations of its business, such as internal coordination, manufacturing, research and development as well as the costs associated with downtime. (Menon et al., 2005) Disposal costs are related to the expenditures for disposing, i.e. throwing away the product (Lyly-yrjänäinen et al., 2010). Finally, psychological costs "include cognitive difficulty/stress, conflict, search costs, learning costs, psychological switching costs and psychological relationship costs" (Smith & Colgate, 2007).

2.3 Building a Customer Value Model

The previous section introduced a new categorization for customer value drivers. Based on this framework, both the benefits and sacrifices which customers perceive in a product can be divided into five groups. Figure 11 illustrates a simplified version of this framework.

Customer Value	Benefits	- Functional - Economic - Service - Psychological - Social
	Sacrifices	- Purchase Price - Acquisition Cost - Operation Cost - Disposal Cost - Psychological

Figure 11. Framework for categorizing customer value drivers.

Each of the categories mentioned in the table above can be divided into smaller elements. For instance, as stated by Smith & Colgate (2007), functional benefits consist of accurate attribute, appropriate performance and appropriate outcomes. Although the division of each of these categories is helpful in better evaluating benefits and sacrifices, it is not the focus of this thesis. Instead, the framework of customer value proposed by Lyly-yrjänäinen et al. (2010) is chosen for building a customer value model. The main reason for this selection is its simplicity in illustrating the customer value concept. Figure 12 shows the customer value framework introduced by Lyly-yrjänäinen et al. (2010).

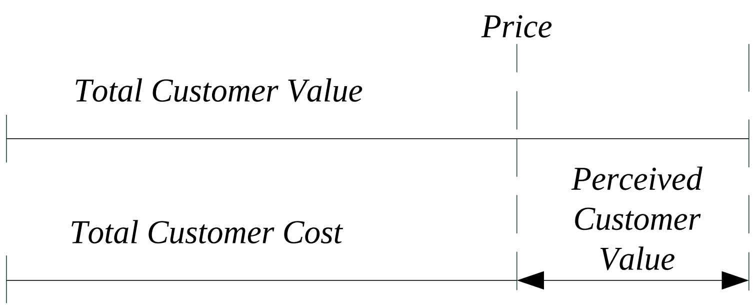

Figure 12. Perceived customer value (Modified from Lyly- yrjänäinen et al., 2010).

According to this model, the total customer value is the sum of all the benefits perceived by the customer, and the total customer cost is the sum of all the sacrifices made by the customer. The difference between the total customer benefits and sacrifices yields the perceived customer value. Customers in most cases will consider purchasing a product when the perceived customer value is positive; that is, the total benefits perceived from a product are higher than the sacrifices made by the customer. (Lyly-yrjänäinen et al., 2010) Applying a new categorization of benefits and sacrifices (Figure 11) to the customer value framework can provide a better understanding of the concept. Figure 13 demonstrates the customer value framework which offers a more detailed categorization of the benefits and sacrifices.

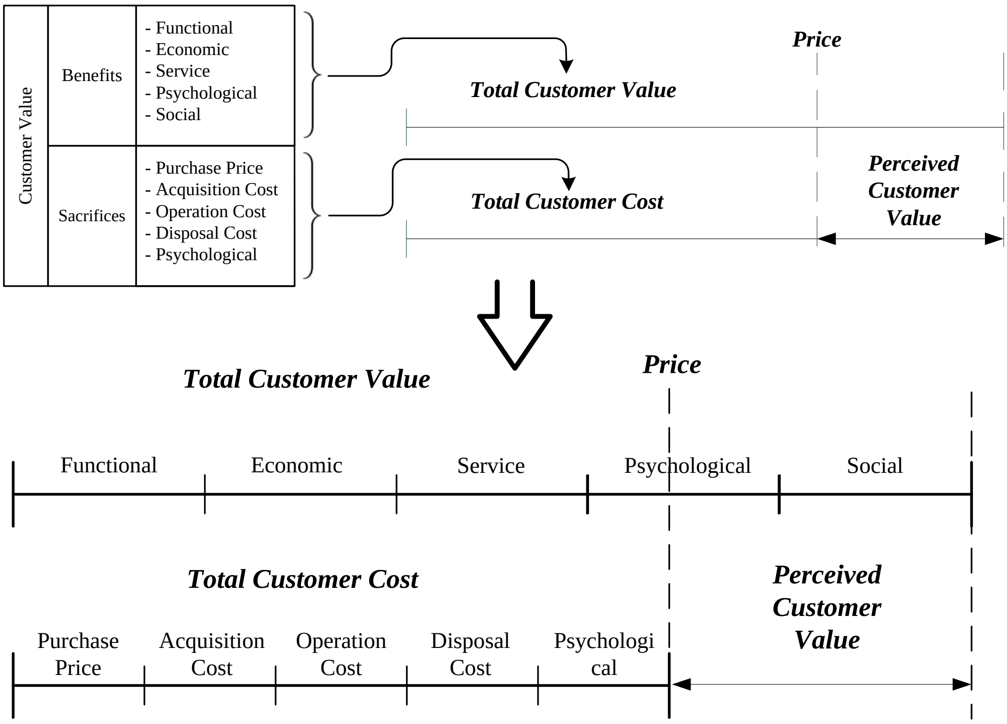

Figure 13. Customer value model.

In the above figure, the total customer value and total customer cost are divided equally among the customer value drivers for the sake of simplicity. However, in a real-life situation, the importance weighting of each of these value drivers from the perspective of customers varies significantly. To demonstrate the difference in the importance weighting of the value drivers, the results of three studies are discussed in the following paragraph.

The first study was done by Ulaga & Chacour (2001) in the food ingredients division of a major chemical multinational. Based on this study, product-related attributes were found to account for 55.8% of the total customer value. The second study was carried out by Parry et al. (2012) in the software industry. This study showed that only 38.6% of the total customer value was associated with product-related attributes. Finally, a study conducted by Busacca et al. (2008) in the air conditioner industry reveals that 75% of the total customer value comes from product-related attributes. Comparing the results of these three studies clearly shows that even after identification of customer value drivers (Figure 11), it is not an easy task to say which of these value drivers has the highest or lowest importance weight, since the importance of value drivers from the customer's perspective is influenced by many factors, including product nature, industry and target market.

2.4 Customer Value Assessment

The previous section showed that total customer value and total customer costs can be divided into value drivers. Furthermore, by investigating the results of a few case studies, it became clear that the importance weighting of these value drivers is dependent on many factors and may vary significantly. This section reviews previous customer value assessment methods to determine how companies measure value drivers and perceived value. Customer value assessment can be defined as quantifying and communicating the value created for customers (Anderson et al., 2006; Payne & Frow, 2005; cited in Keränen & Jalkala, 2013). Differences exist both among customer value assessment methods in B2B and B2C markets as well as between physical products and services (Keränen & Jalkala, 2013). Since the main focus of this thesis is on the customer value of physical products in B2B markets, the methods presented by Anderson et al. (1993) are selected and discussed in this section.

Anderson et al. (1993) stated that there are nine methods which have been broadly used to assess customer value:

- Internal engineering assessment
- Field value-in-use assessment
- Indirect survey questions
- Focus group value assessment
- Direct survey questions
- Conjoint or trade-off analysis
- Benchmarks
- Compositional approach
- Importance ratings

The first three methods draw upon industrial engineering to provide estimates of customer value. Internal engineering assessment estimates the value of a product by implementing laboratory tests in the supplier's firm. This method requires little or no direct customer input and is applied based on the amount of information and knowledge that a firm possesses about the usage of their products in customers' firms and production processes. If insufficient knowledge is available in these areas, internal engineering assessment will not provide useful estimations. Field value-in-use-assessment is based on extracting a comprehensive list of product usage cost elements by conducting interviews in the customer's firm. Values are then assigned to these cost elements to obtain an estimation of overall value in the use of the product. Therefore, this method requires customer firm cooperation and active input based on their experience. In the indirect survey questions method, the respondents are asked what would be the effects of one or more changes in the present product. Combining the answers to these questions with previous information enables the value of each product change to be estimated. This method can assist the firm in determining whether its assumptions regarding the customer usage of the product are correct or not. However, the success of this method, as in the case of the previous method, is dependent on cooperation with the customer firm.

The fourth and fifth methods provide overall estimates of customer value. In the focus group value assessment, potential products or product concepts are shown to the participants, who are then asked about the value of these products or concepts to their firms. According to Calder (1977), this method can provide deep understanding about the customer. However, because of the subjectivity of the technique, concerns have been raised that the results might be changed by any changes in respondents, moderator or setting. (Calder, 1977) Another method is the direct survey questions. In this method, a description of the potential products or product concepts is given to the respondents, who are asked about the value of these products or concepts to their firms. In order to obtain a satisfactory estimation of the value, respondents should be willing to answer direct questions and should also have enough knowledge about the topic. If any of these conditions are not met, the validity of the estimation will be problematic.

The sixth and seventh methods can be grouped as being decompositional in nature. In other words, using these methods makes it possible to break down the respondents' overall perception of the value offering into the elemental value contributed by its component parts. In a conjoint analysis, the respondents are asked to make judgments about the attributes that impact their purchase decisions conjointly, instead of evaluating each attribute individually (Kotri, 2006). This method leads to obtaining elemental values by breaking down the respondent's overall perception. However, the complexity of this method makes it less attractive in some industries. In benchmarks, a description of a product offering is given to the respondents, typically representing the present industry standard that serves as a "benchmark" offering. Then the respondents are asked how much more they are willing to pay for additional features in the products as well as how much less they would pay if some features were omitted from the product. This method also provides elemental values similar to those offered in the conjoint analysis, although it is less particular, which makes this method easy to use and cheaper than conjoint analysis.

The eighth method, the compositional approach, has a procedure opposite to that of the previous group. In this method, the respondents are asked to give the value of selected levels of a set of attributes of their firm which can then be added to obtain an estimation of the overall value of various products. Although this method is easy to use, respondents' unwillingness to reveal accurate information may affect the validity of the method. Finally, importance rating is a method in which the respondents are asked to rate a set of attributes or features of a product according to the importance to their firm. In addition, they should rate supplier firms in terms of their performance, thereby providing a competitor analysis of the value provided by each supplier's product offering. One of the drawbacks of this method is that it does not provide monetary estimation of the perceived worth of the product or its elements.

The percentage usage of each of these customer value assessment methods has been evaluated by Anderson et al. (1993) in different business decision applications. Their evaluation showed that five of these methods are used in new product design, namely internal engineering, field value in use, focus group, direct survey and benchmarks. This thesis uses mock-ups to demonstrate perceived customer value in the product development process. Due to the purpose and limitations of this thesis, only internal engineering assessment and field value in use were chosen as customer value assessment methods for this framework. Moreover, this thesis focuses on cost-reducing innovations. These innovations may affect all total customer cost drivers. However, their impact is more visible and significant on purchase price and operation cost drivers. Therefore, this thesis concentrates only on these two drivers. Figure 14 shows the focus areas of this thesis on customer value model.

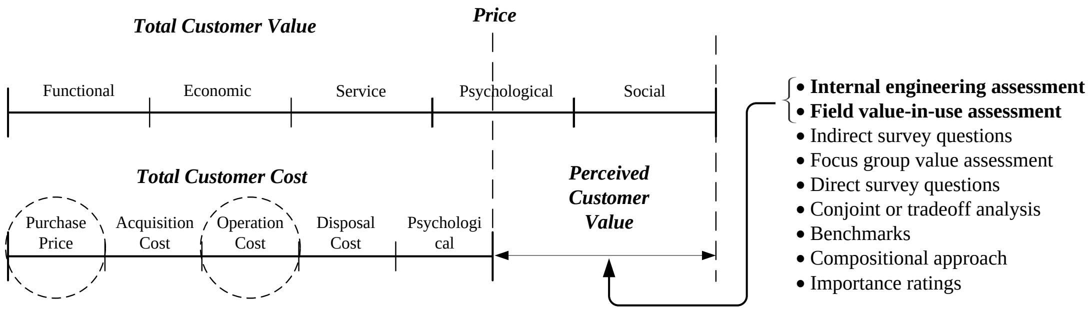

Figure 14. Focus areas of this thesis in customer value.

The customer acquires cost-reducing innovations to improve the production process and consequently diminish operation cost. However, at the same time, these innovations do not come for free. Acquiring these innovations requires a certain amount of investment from the customer, thereby increasing the purchase price. This is basically a trade-off for the customer, spending more on purchase and in return saving costs in operations. As noted by Woodruff (1997), customers need to use the product to experience and evaluate the product attributes, attribute performances and consequences. This is the main way for customers to see if the trade-off is worthwhile for them or not. Hence, after using the product, if a customer perceived that this trade-off brings additional value, it becomes considered a worthy investment (Figure 15).

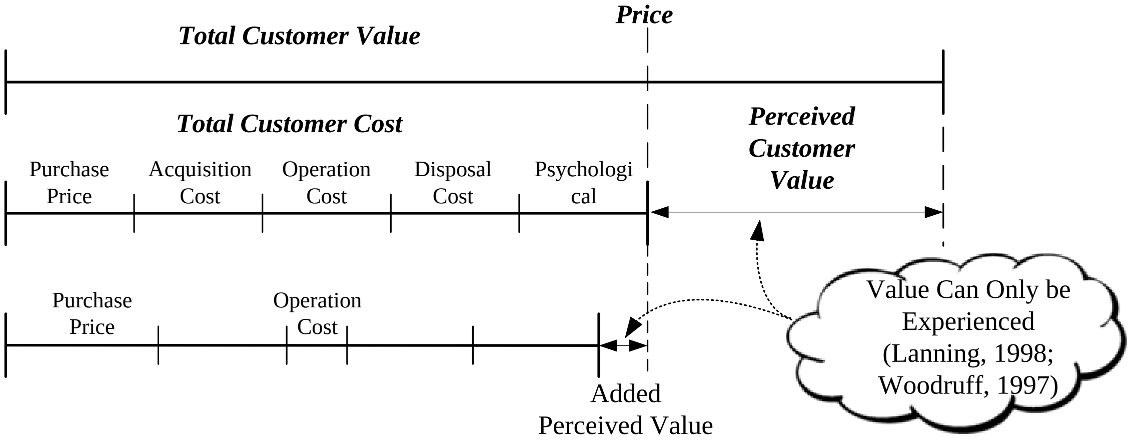

Figure 15. Impacts of trade off between purchase price and operation cost on perceived customer value.

For companies providing cost-reducing innovations, it is important to know whether their product can create added perceived value for the customers or not. In other words, they need to calculate it as soon as possible in order to evaluate the viability of their offerings before committing a significant amount of resources. The following chapter discusses how mock-ups can be utilized to gain enough information for calculating added perceived value.

3. THE PRODUCT DEVELOPMENT PROCESS AND MOCKUPS

3.1 Product Development

Today, companies compete in a global, dynamic environment. Firms utilize new organizational approaches, new business strategies, new business processes and new enabling technologies for improving their product development processes. (Phillips et al., 1999) Successful product development can play a large role in the long-term viability of organizations (Smith & Morrow, 1999). Firms developing exciting products that people are willing to buy are likely to win. Therefore, product development is considered to be an important source of competitive advantage. (Brown & Eisenhardt, 1995; Cooper & Kleinschmidt, 1991)

Product development can be defined as the process in which a product is conceived, designed and launched in the market. This process also includes the feedback received from production and product use (Ulrich & Eppinger 1995; cited in Formoso et al., 2002). However, it should be noted that product development is not only about creating new products, it is also an important learning process for the company (Lyly-yrjänäinen et al., 2010). Although product development mostly consists of product design and process design activities, it also involves other activities, such as financial and economic evaluation, legal design approval, and customer surveys (Formoso et al., 2002).

One of the key factors which companies need to take into account in product development is cost management because it significantly impacts the competitive advantage of the company. Turney (1991) argued that there is an enomous opportunity for cost reduction during the design process. For instance, in Ford Motors 60 to 80 percent of a product's life cycle costs are already locked in after completion of the design phase. This figure rises to 90 - 95 percent when design of the production process is completed. Figure 16 shows the critical role of design in product life cycle costs.

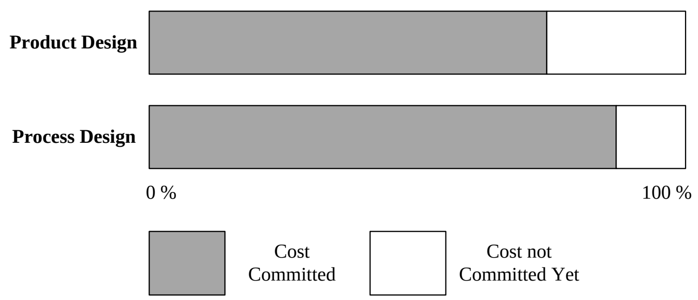

Figure 16. Role of design in product life cycle costs (Adapted from Turney, 1991).

Dowlatshahi (1992) uses the findings of several studies concerning the impacts of product design on product costs to emphasize the importance of the design and development stage in the product final cost. In the first study, Huthwaite (1988) argued that although product design is responsible for only 5 percent of product cost, it can determine 75 percent or more of the manufacturing cost and 80 percent of the product's quality performance. Another study from Nevins & Whitney (1989) pointed out that 70 percent of the life-cycle cost of the product (i.e., cost of materials, manufacturing, use, repair and disposal) are determined at the design stage. Thus, the results of these studies show that 70 to 85 percent of the total product costs are determined in the design stage, suggesting that the majority of cost reduction activities should be carried out in the early stages of the development (Dowlatshahi, 1992; cited in Asiedu & Gu, 1998).

Belay (2009) also mentioned that 80 percent of the cost is usually determined before finishing the design phase of a product. This number increases to 95 percent by the time that the product goes into production. He continues that, in terms of the Toyota philosophy, the cost of the product is mostly determined at the planning and design stage, and when the full scale production begins, the effects of cost improvement activities become insignificant. It should be considered that improvements at the planning and design stages can be ten times more effective than those occurring at the manufacturing stage. Figure 17 illustrates the cumulative percentage of incurred and committed cost in each phase of the product life.

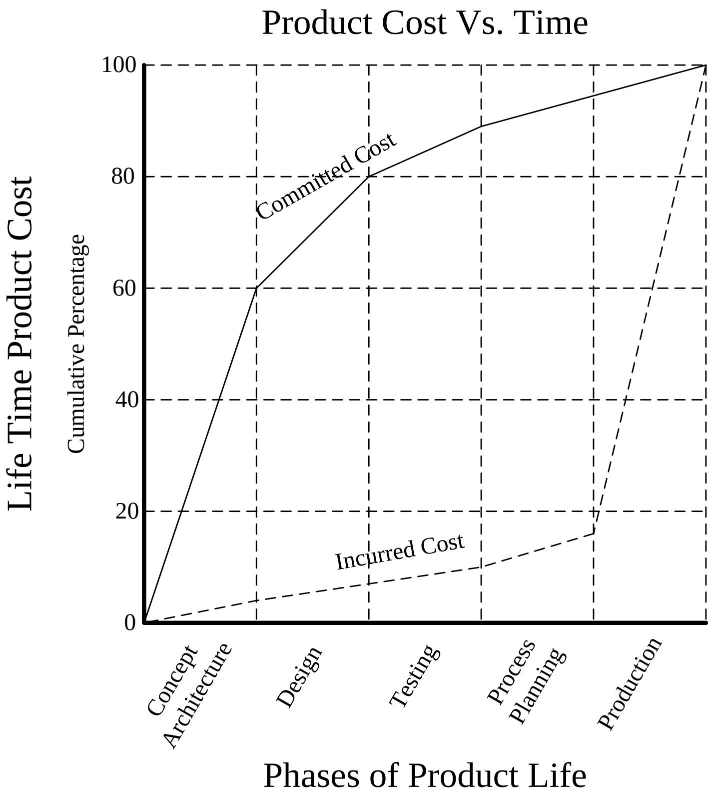

Figure 17. Committed and incurred cost in product life phases (Belay, 2009).

As mentioned in this section, around 80 percent of the costs are already determined in the early stages of product design and development. Therefore, it is essential for companies to focus their cost management efforts on these stages.

3.2 Product Development Process Models

The first generation scheme for product development was developed by NASA in the 1960s. NASA's phased project planning (PPP) was developed to help NASA work with its contractors and suppliers on space projects. PPP broke the development down into phases, with the end of each phase containing review points. Projects could only continue to the next phase if certain prerequisites had been met at the review point. The main purpose of designing this process was to ensure that all the activities would be completed within the project time frame. However, the performance of PPP has some weaknesses. Although the system reduced technical risks and ensured completion of tasks, time was spent on the review phases of the project, focusing mainly on the technical aspects and the risks of development rather than the business side. (Cooper, 1994)

Cooper (1983) stated that based on the lessons learned from new product research, changes should be made in the development processes. First, the development process should be sufficiently detailed in order for managers to use it as a guide for their actions. Second, the development process should be strongly market oriented. Third, the development process should enhance internal communication among the key groups. Finally, due to the high failure rates of new products, there should be evaluation points in the development process to recognize dead-end projects and eliminate them throughout the process. Figure 18 illustrates the PDP model introduced by Cooper.

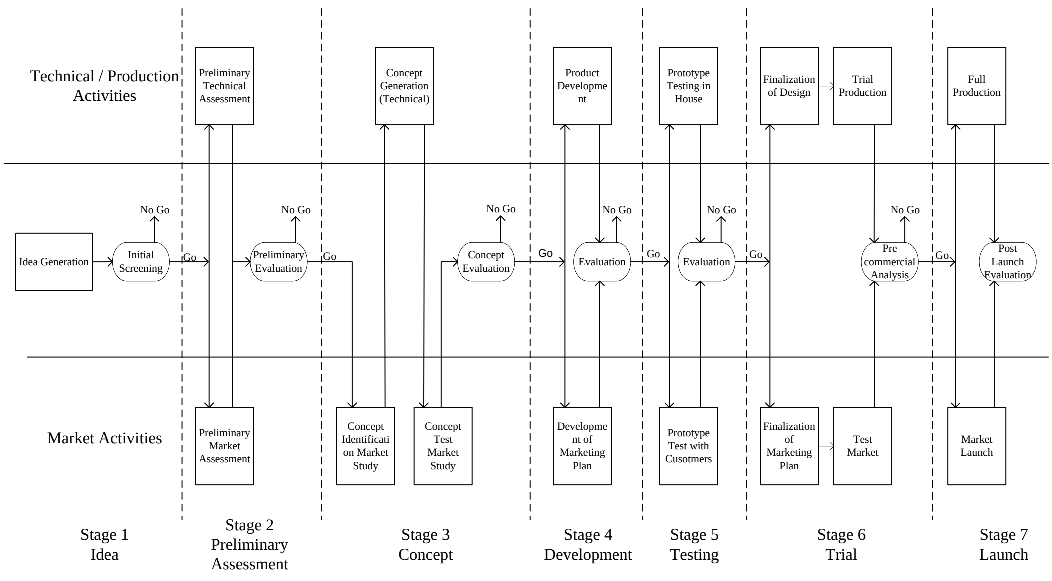

Figure 18. Flow diagram of seven-stage new product process model (Adapted from Cooper, 1983).

This model illustrated the idea of having a systematic approach to manage PDP proceeding from idea generation point to post launch evaluation. In his research, Cooper further introduced a simplified version of the above flow diagram as a stage-gate system, as illustrated below in Figure 19.

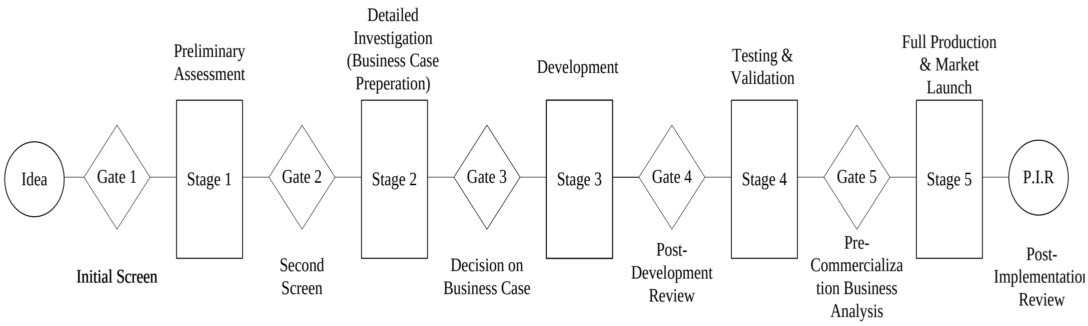

Figure 19. Stage-gate system (Adapted from Cooper, 1990).

A stage-gate system is a conceptual, operational model to move a product from idea to launch effectively and efficiently. The stage-gate system divides the innovation process into various stages. At each stage, certain activities should be done; after each stage, there is a gate to control and evaluate the work of that stage. The stage-gate system uses certain criteria for this evaluation, and based on the result of this evaluation, one of four possible decisions (i.e., Go/Kill/Hold/Recycle) can be made. Based on the company or the division utilizing the stage-gate system, the number of stages may vary from three to seven, though usually each stage is more expensive than the previous one. (Cooper, 1990)

The first step in the stage-gate system is the generating of ideas. There is a need for a great number of ideas which are then matched with market demand. The first gate consists of an initial screening in which ideas are selected based on whether they are worthy of committing resources for further development. The main criteria for idea selection at this point can be strategic alignment, project feasibility, market attractiveness, competitive advantage and conformity with company policies. (Cooper, 1999) The first stage comprises a preliminary assessment which involves gathering information and evaluating the attractiveness and feasibility of the project. It consists of a quick market study identifying the market size and possible market segments. (Cooper, 1983)

The second gate is rather similar to Gate 1. In this gate, the project is re-evaluated but this time with the help of information gathered in the first stage. Sometimes, additional criteria, such as simple financial assessment, are utilized in this gate. (Cooper, 1999) The second stage includes a detailed investigation or preparation of a business case. In this stage, characteristics of the product, target customer and positioning strategies should be defined before spending more resources on the project. Some of the key activities in this stage include value in use assessment, competitive analysis, concept testing as well as detailed technical and financial analysis. (Cooper, 1999; Cooper, 1983)

The third gate involves making a decision on the business case. This is the last stage before actual development and heavy investments begin. Therefore, decision making in this stage is usually done by the management team. (Cooper, 1999) Development is the third stage of the stage-gate system. A prototype or a sample of the product is usually the outcome of this stage, with companies also focusing on internal testing of the product. Simultaneously, a marketing plan should be finished, and supporting elements of marketing, such as advertising, distribution and service, are decided. (Cooper, 1999; Cooper, 1983)

The fourth gate consists of a post-development review. The main goal of this assessment is to ensure the compatibility of the developed product with the original definition of the product decided at Gate 3. Furthermore, accurate financial analysis is done based on the new data acquired. (Cooper, 1999) After the post-development review, the testing stage begins. In this stage, tests are implemented to confirm the commercial viability of the project. For this purpose, in-house testing is done to ensure that there are no technical flaws in the product. In addition, samples or prototypes can be sent to customers to evaluate the attractiveness of the product and identify possible defects or areas for improvement. (Cooper, 1999; Cooper, 1983)

The fifth gate comprises a pre-commercialization business analysis. It is the point when managers show that they are 100 percent aligned with the project and, if not, it is the last point to cancel the project. (Cooper, 1999) The last stage of the stage-gate is full production and market launch, during which the company starts up commercial production of the product and implements its marketing plan completely. This stage is followed by a post-implementation review held by the company to monitor the performance of the product in the market in terms of factors such as market share, sales value and production costs. In case something is not going according to plan, the company then needs to take corrective actions. (Cooper, 1999; Cooper, 1983)

Implementation of the stage-gate process brings many advantages to the company. It improves teamwork among the members, reduces rework, identifies defects and problems earlier, as well as leads to a faster, more successful development process (Cooper & Kleinschmidt, 1991). However, this system suffers from several major drawbacks. First, projects should wait at each gate until all the activities of the previous stage have been completed. Second, stages should be completed in the specified order, and no overlapping between stages is possible. Third, the process is too bureaucratic, leading to difficulties in adapting to evolving market demands. Finally, the stage-gate system is like a waterfall, when one stage passes, it is expensive to go back. (Unger & Eppinger, 2011; Cooper, 1994)

One of the solutions to overcome some of these drawbacks in the stage-gate process is to apply a spiral development instead of a linear development (Cooper & Edgett, 2008). The concept of spiral development allows project teams to rapidly finalize product designs through a series of iterative build, test, feedback and revise loops. This approach makes it possible to apply customer feedback and opinions continuously to the development process, thereby increasing the success rate of the development project. Spiral development also provides an option to deliver mock-ups to the customer in stage 2 of development rather than stage 3 (Cooper, 2008) Figure 20 illustrates the idea of utilizing spiral development in the stage-gate system.

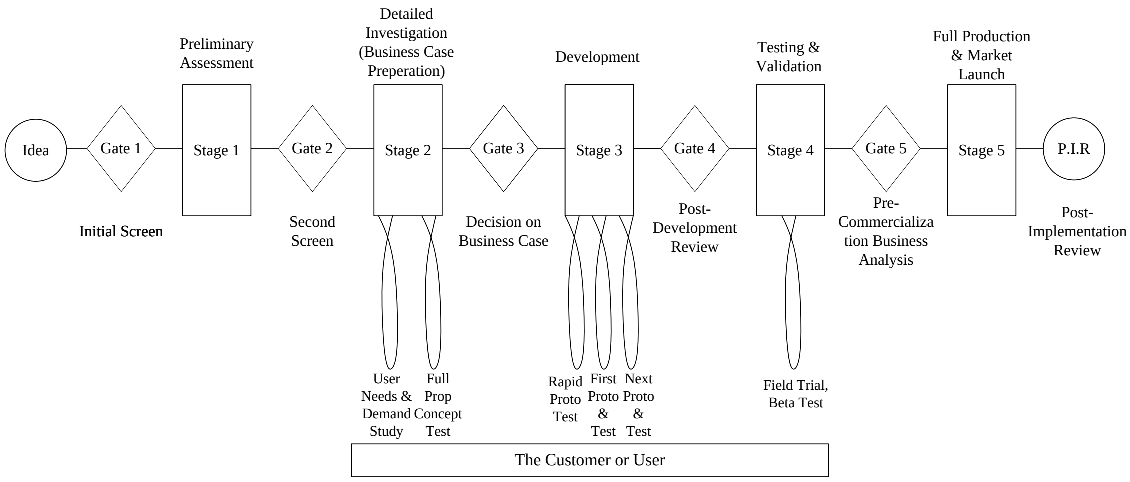

Figure 20. Utilizing spiral development in stage-gate system (Adapted from Cooper, 2008).

The first loop (spiral) reflects the voice of the customer in that the members of the project team visit a customer to identify unmet needs and problems. In the second loop, the project team offers a solution to the customer. This solution can be represented in the form of a simple mock-up, a sketch or computer design. In this way, the company can provide an idea to the customer about the product and how it will work. Feedback from the customer is received and required changes are made to the product definition. In the development stage of the product development, utilizing iterative loops simply involves building step-by-step more advanced versions of the product and continuously applying customer feedback until reaching a desired level of development. Finally, the last loop refers to an iterative field trial of the product, in which the product is sent to several customers to obtain more accurate feedback concerning the market attractiveness of the product. (Cooper, 2008)

Unger & Eppinger (2009), based on the spiral development concept, introduced a new PDP called the spiral PDP. This model, in addition to having spiral iterations in each stage of product development, allows repetition of some or all stages of PDP based on the nature of the development project. One of the main characteristics of spiral PDP is the high level of flexibility which makes it attractive, especially in the software industry. Figure 21 illustrates the spiral PDP introduced by Unger & Eppinger.

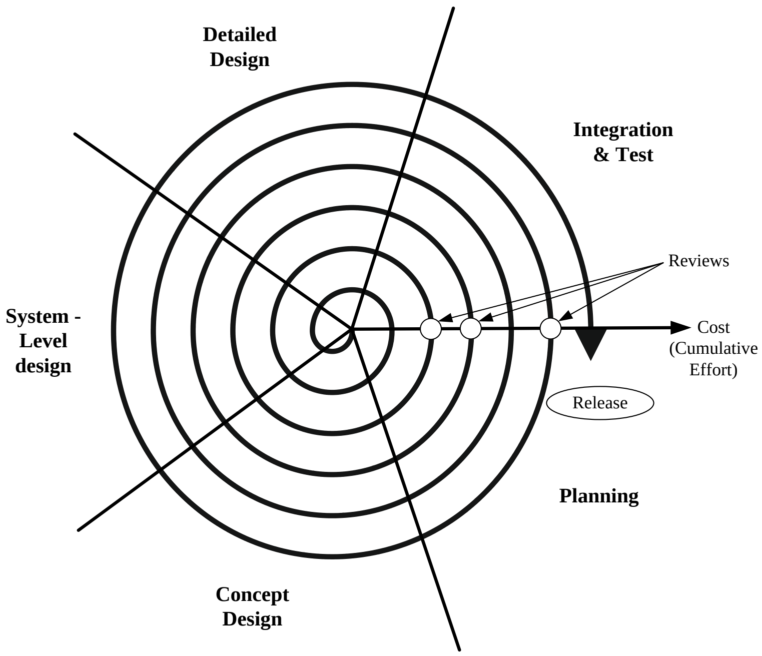

Figure 21. The spiral PDP (Adapted from Unger & Eppinger, 2009).

As can be seen in Figure 21, the spiral PDP provides an option to go through the stages over and over again. By going through many stages with the expectations of returning to them later, the spiral PDP allows the project team to gain a brief glimpse into the future of the project. This glimpse gives the project team information about different stages, which is useful in order to reduce overall risk of the project. Despite the advantages that spiral PDP brings to a company, it also has some disadvantages. Firstly, implementation of spiral PDP is more sophisticated and requires constant attention from the management team. Moreover, the high degree of flexibility may cause some delays when developing complex subsystems. (Unger & Eppinger, 2009)

This section has presented a general overview of the history of PDP models and discussed the stage-gate system and the spiral process as two of the most popular PDP models. These two processes can form two ends of a spectrum for PDPs, with other PDPs being positioned somewhere between these two models. Therefore, companies need to analyze their needs and select or customize a PDP according to their requirements. Since the main focus of this thesis is on the new product development (NPD) of physical products, applying the spiral PDP is not suitable. However, as Cooper states, some of the characteristics of the spiral PDP can be used within the stage-gate model to accelerate certain stages. (Stage-gate international, 2014) Figure 22 illustrates application of spiral PDP characteristics within the stage-gate model.

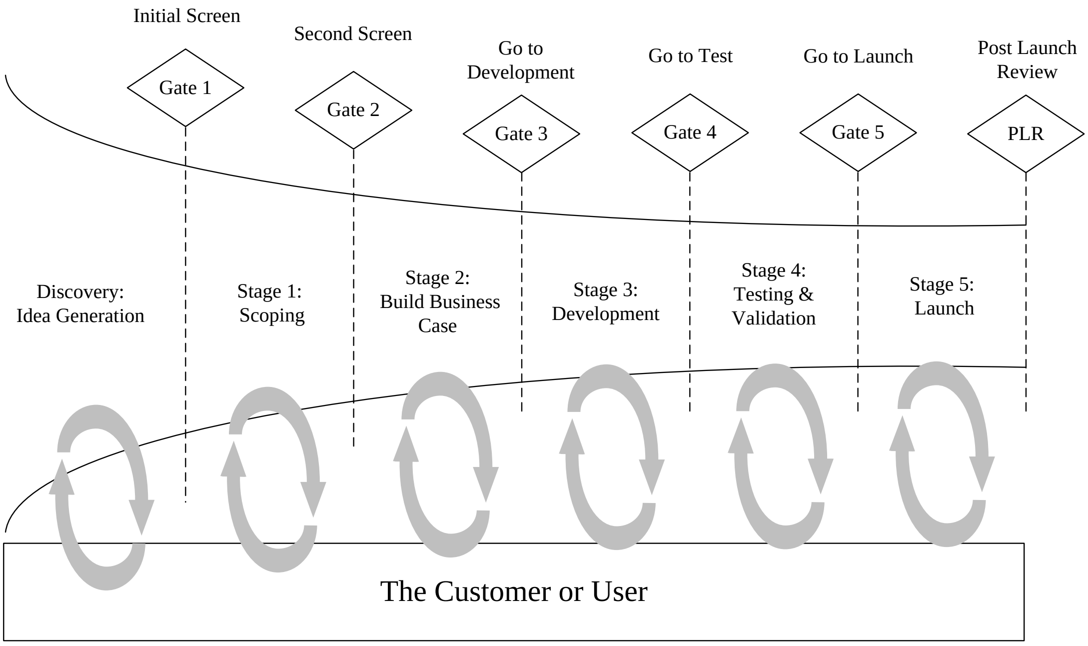

Figure 22. Applying spiral PDP characteristics within stage-gate model (Stage-gate International, 2014).

The above figure presents a more comprehensive version of Figure 20 and expands involvement of the customer or user to the very beginning of the development process. Therefore, this model is more adaptive and responsive to fluid market conditions and changing market requirements. At the same time, this model keeps the advantages of stage-gate models, such as better management and control over the whole project. As a result, this model has been selected as the most appropriate PDP for the purpose of this thesis.

3.3 Prototyping

Utilization of various models has been considered significantly important in the PDP for a long time (Brandt, 2007). Hatmann & Klemmer (2006) mentioned that prototyping is the core activity in innovation, collaboration and creativity in design. Zorriassantine et al. (2003) believed that successful entrance of new products in a competitive global market is dependent on the efficient and extensive application of prototypes (see Liu et al., 2013). Therefore, it is important to define mock-up and prototype and then introduce some of the prototype categorizations mentioned in the literature.

Mock-up has been defined as “a scale or full sized model that is used for demonstrating and evaluating the functionality of a design” (Limbuddha-augsorn & Sahachaisaree, 2010). Based on a study by Brandt (2007), using mock-ups in a new PDP brings various advantages. First, mock-ups evoke different aspects. Even a simple mock-up clarifies many benefits and drawbacks of a product concept. Furthermore, mock-ups are useful for facilitating interactions. Especially tangible mock-ups can help all project stakeholders to get a visual and tactile feeling about the concept and reduce uncertainties and misunderstandings among members.

Preece et al. (2002) defined a prototype as "a limited representation of a design that allows users to interact with it and to explore its suitability". A prototype can be, for example, a scale model of a building, a video simulation of a task or a three-dimensional cardboard model of a workstation. Prototypes are useful tools to communicate ideas among team members and between development team and other stakeholders. They also help in testing current solutions and generating new ideas. Finally, building prototypes of all the alternatives makes it easier to select the best idea to be pushed forward.

Prototyping impacts product cost, quality and time significantly. When building a prototype, it is important to have a purpose. Gathering initial user requirements, showing proof of concept to senior management, validating system specifications, quality assurance and increasing constructive user participation can be some of the reasons behind prototyping. In addition, it is recommended to use cheap, readily available materials and parts for building prototypes. In this way, future changes and maintenance would be much easier and less expensive. These considerations reduce the cost of the development process while maintaining the quality of work. (Liou, 2007)

Prototypes can be categorized into physical and analytical forms. A physical prototype is an object or combination of objects made out of materials to show one or more aspects of a product concept (Anderl et al., 2007). Physical prototypes can provide visual and tactile evaluation of aspects which are important particularly during interactions with customers (Campbell et al., 2007; cited in Liu et al., 2013). Analytical prototypes represent a product in a mathematical or computational form (Yang & El-Haik, 2003; Wang, 2002). In addition, paper prototyping can be considered to be one of the methods of analytical prototyping (Liou, 2007). Both physical and analytical prototypes have their own advantages and disadvantages. For instance, physical prototypes are better in fine tuning and detecting unanticipated phenomena. On the other hand, analytical prototypes are more flexible and easier to modify. (Liou, 2007) It should be taken into account that physical and analytical prototyping should not compete with each other; they can bring more advantages to the PDP if they are applied simultaneously in the process. (Liu et al., 2013)

Most commonly used physical prototypes are experimental, alpha, beta and preproduction prototypes. Experimental prototypes are those which are designed to evaluate a well-defined subset of functions of a product. Alpha prototypes are utilized to check the functional validity of the product. In these prototypes, almost all the functions of the actual product are included and they contain the same components as the final product. However, the production process for making these prototypes differs from that of the actual product. Beta prototypes are used to analyze factors, such as reliability requirement validations, usage requirement validation and product specification validation.

They have the same components as the actual product, which are made by the same production processes. The only difference is that these prototypes are not made at the intended mass production facility. Finally, preproduction prototypes are the first batch of products manufactured by a mass production facility. They are utilized to evaluate mass production capabilities and debug the process if needed. (Yang & El-Haik, 2003)

Analytical prototyping uses paper, mathematical or computer models (virtual models) to demonstrate and evaluate the product idea without spending money to build a physical prototype. Many aspects of the product can be analyzed using this type of prototyping. For instance, an FEM (finite element model) can be used to evaluate various parameters of a mechanical part, including force stress and deformation. (Yang & El-Haik, 2003) Among the various methods for analytical prototyping, virtual and paper prototyping have been discussed more frequently in the literature during the past years. Virtual prototyping integrates technologies, such as computer-aided manufacturing (CAM), computer-aided engineering (CAE) and computer-aided design (CAD), into a single visual environment for observation, evaluation and analysis of a product model. Virtual prototyping increases the flexibility of the prototyping process because modification of virtual models is easier and cheaper compared to physical models. In addition, it enables cost-efficient data integration and a concurrent engineering approach. (Liou, 2007)

Paper prototyping refers to the making of a paper mock-up of an object or interface to demonstrate its look, feel and functionality. These prototypes are cheap and fast to build as well as very easy to modify. Therefore, they are a helpful tool at the early stages of development to ensure that the designs are compatible with customer requirements. Sketching, storyboarding, pictive interfaces and Wizard of Oz are some of the main paper prototyping methods. (Liou, 2007) Sketching involves a simple demonstration of the idea on a piece of paper or on a board. Story boarding consists of a series of sketches showing how the prototype functions or demonstrating how the user performs a task using the device. (Preece et al., 2002) Pictive (plastic interfaces for collaborative technology initiatives through video exploration) interfaces provide a paper mock-up, which allows users to take part in the development process by giving them an idea of how the system will look and perform after it is finished. Finally, Wizard of OZ is a system for testing non-existing systems. “In this system the human (wizard) simulates system responses and interactions with the user via a simulated software interface”. (Liou, 2007) Figure 23 demonstrates categorization of prototyping based on prototyping methods.

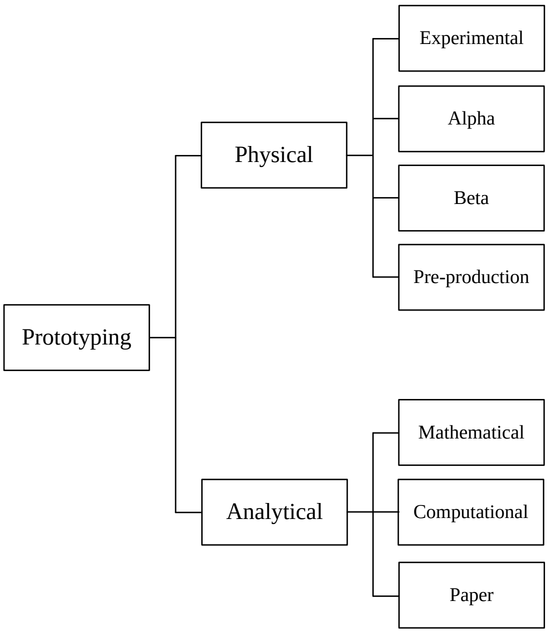

Figure 23. Prototyping Categorization (Adapted from Yang & El-Haik, 2003).

In recent years, there has been a growing trend towards utilizing rapid prototyping in the development process (Yan & Gu, 1996). Rapid prototyping (RP) basically integrates virtual and physical prototyping methods in order to rapidly create a physical prototype from a virtual design of the product. This provides designers with the freedom to produce physical models of their drawings more frequently, thus allowing them to check the assembly and the function of the design. (Pham & Gault, 1998) This also makes it is easier for designers to detect problems and improve the design (Liou, 2007). It has been claimed that RP can reduce new product cost by up to 70% and time to market by 90% (Waterman & Dickens, 1994; cited in Pham & Gault, 1998). RP methods can be divided broadly into two groups: material addition and material removal. Material addition methods make a work piece by adding material, while material removal methods make a work piece by removing material (Pham & Gault, 1998; Kruth, 1991) Explanation of each of these methods remains outside the focus of this thesis, though detailed explanations has been provided by Kruth (1991), Schaaf (2000) and Pham & Gault (1998). Therefore, this section continues by discussing other approaches to prototyping categorization.

From a different perspective, prototypes can be categorized into focused and comprehensive prototypes. Focused prototypes demonstrate only a part or a subset of a product function, whereas comprehensive prototypes represent most or sometimes all product functions and attributes. (Yang & El-Haik, 2003) For instance, companies may use styrofoam to show the appearance of the final product. Hence, a prototype that is only made for showing attributes of the product partially would be considered to be a focused prototype. In contrast, making a prototype of a full vehicle to test various aspects and functions would be considered a comprehensive prototype. Based on these two prototyping categorization perspectives, a positioning map can be made to compare the characteristics of each of the prototyping methods (Figure 24).

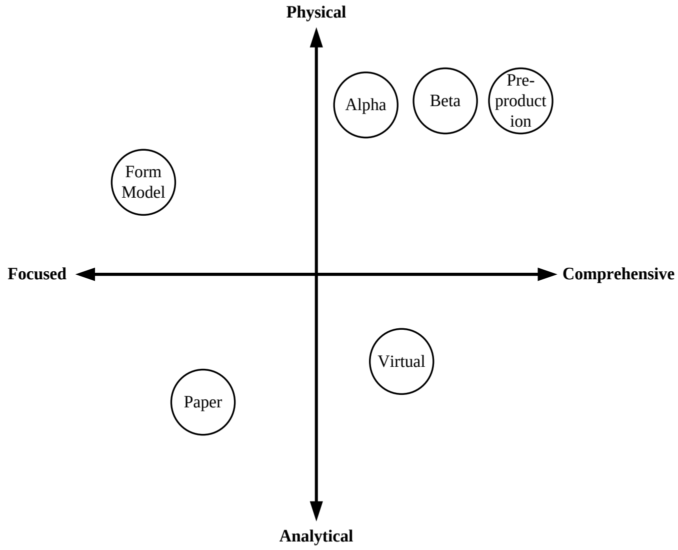

Figure 24. Prototyping methods positioning map (Modified from Liou, 2007; Yang & El-Haik, 2003).

The above figure shows that among the physical prototypes, the form model is the most focused one. Form models are usually made to show the appearance of the prototype and can be made from various materials, including plastic and styrofoam. On the other hand, pre-production prototypes are the most comprehensive prototypes as they share the same features and functions as the final product. In terms of analytical prototypes, the paper prototype is the more focused and is usually used to emphasize certain functions. However, virtual prototypes are designed to demonstrate various functions and attributes of the product.

Another approach for categorizing prototypes is based on fidelity. Fidelity is the degree to which a prototype demonstrates the final product (Liou, 2007). A low-fidelity prototype is a simple, cheap and quick model of a product, which does not necessarily need to be similar to the actual product. These prototypes can be modified easily and quickly, which is a really important factor especially in the first stages of the development process. Low-fidelity prototypes are not meant to be kept and integrated into the final product. The main purpose of these is to show and test one or several aspects of the final product. Paper prototypes and mock-ups are two examples of low-fidelity prototypes. High-fidelity prototypes on the other hand, are usually made of materials similar to those of the final product. Indeed, the prototype is almost identical to the actual product in both performance and appearance. Table 5 provides a comparison between low- and high-fidelity prototypes.

Table 5. Comparison between low and high fidelity prototypes (Modified from Rudd et al., 1996; cited in Preece et al., 2002)

TYPE	ADVANTAGES	DISADVANTAGES
Low fidelity prototype	• Low development cost • Evaluate multiple design concepts • Useful communication device • Useful for identifying market requirements • Proof of concept	• Limited error checking • Facilitator driven • Limited utility after requirements established • Limited usefulness for usability tests
High fidelity prototype	• Complete functionality • Fully interactive • Use for exploration and test • Look and feel of final product • Marketing and sales tool	• Inefficient for proof of concept design • Not effective for requirements gathering

The above table shows that both low- and high-fidelity prototypes have their own advantages and disadvantages. As explained previously and as shown in Table 5, low-fidelity prototypes are cheap, simple and fast to build as well as easily modifiable. Therefore, in the early stages of product development when many ideas need to be evaluated and compared, low-fidelity prototypes can provide cost-effective, efficient tools for communicating ideas and for concept approval. On the other hand, high-fidelity prototypes are needed to see the functionality of the product as a whole. In addition, these prototypes are those which can be sent to the customers for further testing or used by the company as marketing tools. As a result, high-fidelity prototypes are needed at the final stages of development when the company needs to gain more detailed feedback regarding the product.

3.4 Fully Functional Mock-ups

As discussed in the previous section, prototypes can be categorized into physical and analytical prototypes. In categorization of prototypes presented by Yang & El-Haik (2003), a large gap exists between experimental and alpha prototypes. Sometimes, in the development process, it is possible to test the whole functionality of the product without building the prototype from the same components as the final product. For instance, the body of the prototype can be built of wood or other cheap materials, yet it can give almost the same functionality of the final product. As a result, it has been recommended that another group be added: the fully functional mock-up. A fully functional mock-up can show the functionality of the final product but is made of materials different from those of the final product (Figure 25).

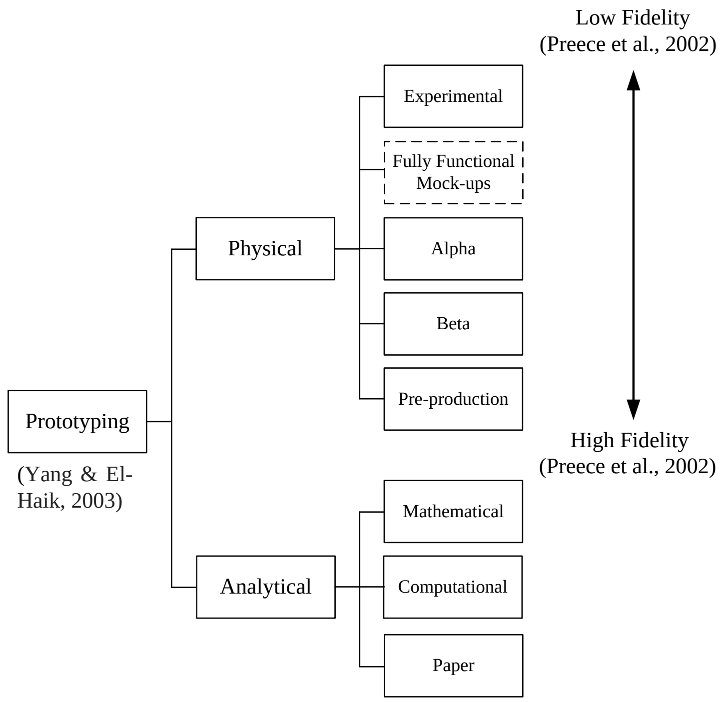

Figure 25. Positioning of fully functional mock-ups.

From the fidelity perspective, fully functional mock-ups have some characteristics of both low-fidelity and high-fidelity prototypes. On the one hand, they are easy, fast and cheap to build and can be easily modified. On the other hand, they have almost all the functionalities of the final product, thus making them viable tools for various testing purposes, including time and cost study, initial customer tests and performance evaluation. Table 6 highlights the advantages and disadvantages of fully functional mock-ups.

Table 6. Advantages and disadvantages of fully functional mock-up.

TYPE	ADVANTAGES	DISADVANTAGES
Low fidelity prototype	• Low development cost • Evaluate multiple design concepts • Useful communication device • Useful for identifying market requirement • Proof of concept	• Limited error checking • Facilitator driven • Limited utility after requirements established • Limited usefulness for usability tests
High fidelity prototype	• Complete functionality • Fully interactive • Use for exploration and test • Look and feel of final product • Marketing and sales tool	• Inefficient for proof of concept design • Not effective for requirements gathering

Finally, fully functional mock-ups can be categorized as comprehensive prototypes. Although all or some of the materials and components used in these mock-ups are different from the final product, they are able to show almost all functions of the final product.

It was discussed that in the early stages of product development, the degree of uncertainty about ideas is high. Therefore, companies would like to evaluate all the alternatives in a fast and cheap way. Thus, using low-fidelity prototypes, such as paper prototypes and experiential prototypes, is common. These prototypes are usually built to test core functions of the product. Later on in the development, once core functions have been tested, it is time to build fully functional mock-ups to evaluate the whole functionality. If the result were satisfactory, it would then be logical for the company to allocate more resources to build more advanced models, such as alpha, beta and pre-production prototypes. In this way, almost all the functions of the final product could be evaluated, and the prototype could even be used as a marketing tool for the company. Figure 26 illustrates utilization of prototypes in different stages of the development process. Based on the figure below, proceeding further and further into the development process results in a need for more comprehensive prototypes to test and evaluate performance and functionality.

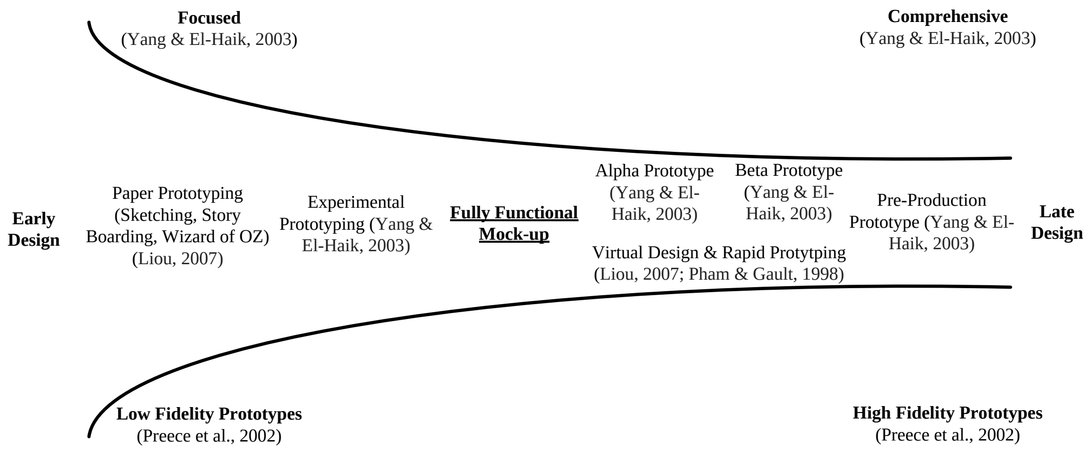

Figure 26. Utilization of prototypes in development process.

There are many arguments in the product development literature regarding prototyping in the early stages of product development. Thomke (2003) believes that companies underestimate the cost savings of early testing and evaluation. The earlier the design changes are made to the product concept, the less costly they are (Sauer et al., 2006). The findings of these studies show that problem solving in late stages of the development process cost 100 times more than in the early stages (Thomke, 2003). As a result, it is suggested that building mock-ups and prototypes start from the very beginning of PDP (Figure 27).

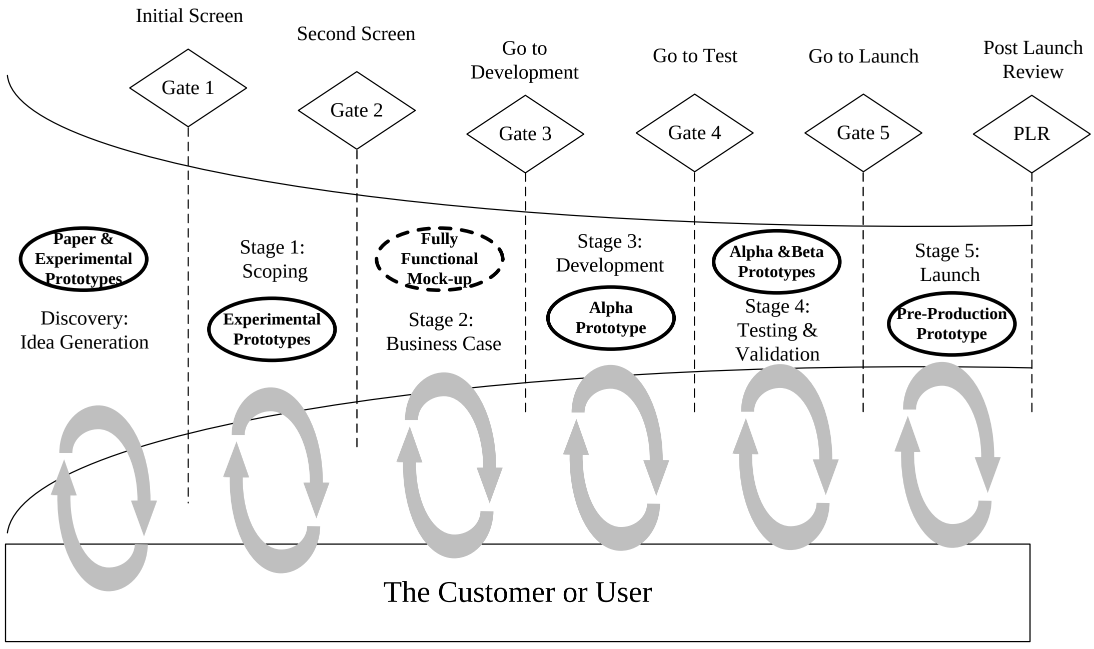

Figure 27. Utilization of mock-up and prototype in stage-gate model.

As shown in Figure 27, using paper prototypes, such as sketches, as well as experimental prototypes would be helpful to communicate the idea among the team members during the idea generation phase of the development process. In the first stage, since there are still many ideas worth testing, experimental prototypes would provide viable options to test the core functionalities of the ideas. In the second stage, the ideas need to be tested thoroughly because the company should select only one or several of these ideas after this stage. Hence, building a fully functional mock-up can provide the company with an opportunity to see the whole functionality of the product without investing significantly. In the third stage of the PDP, since the development decision has already been made, it is time to make the first prototype incorporating most of the functions of the final product. From this stage, prototypes can be sent to customers for field tests or as a promotional tool for the company. In addition, further development of the prototype focuses on fine tuning the product design and evaluating mass production capabilities as well as debugging the system if necessary.

Based on the discussion in Section 3.1, 80 percent of the product life cycle costs are already locked in by the time the design process of the product is finished (Belay, 2009; Turney, 1991). In the PDP model, decisions on the design of the product are made at the end of Stage 2. Therefore, at this point approximately 80 percent of the product life cycle costs will have also been committed (Belay, 2009; Turney, 1991) (Figure 28).

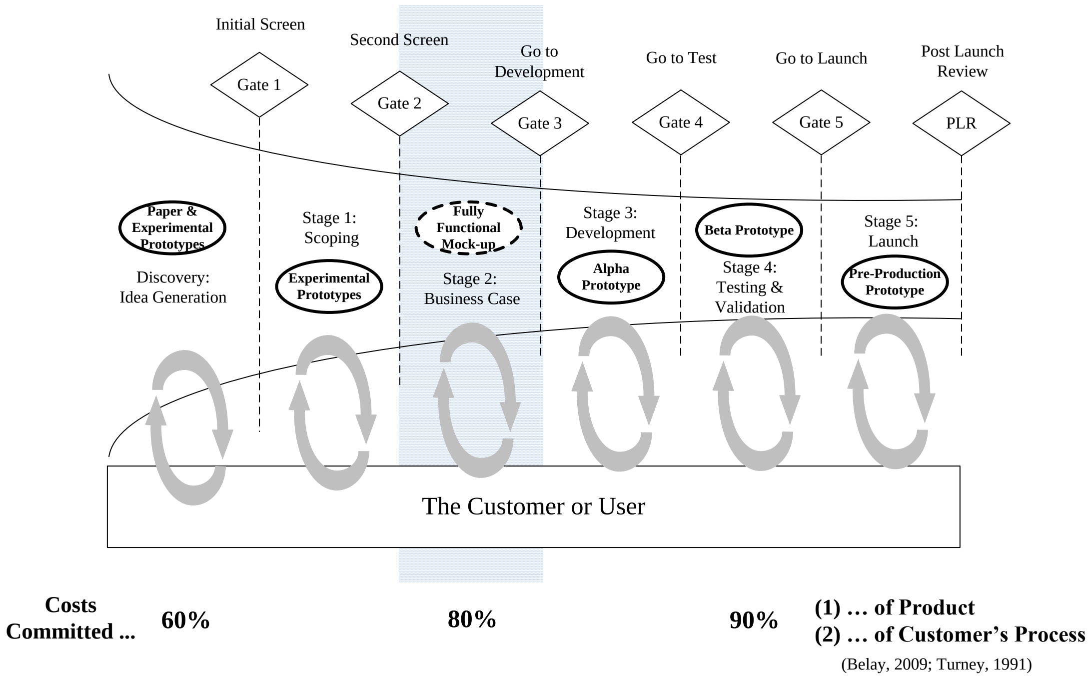

Figure 28. Product life cycle cost identification.

As discussed in this section, fully functional mock-ups provide great tools to be utilized in the second stage of PDP. Fully functional mock-ups are comprehensive enough for helping management team to implement accurate technical and financial analysis to select ideas that will move forward to the development process. Furthermore, fully functional mock-ups can demonstrate the final product design which accounts for more than 80% of product life cycle costs. Hence, it can be argued that fully functional mock-ups can be a key tool to prevent or diminish the possibility of incorrect decision making by management before committing the majority of development costs. The following chapter investigates how these fully functional mock-ups can be utilized as a tool for evaluating value proposition at early stages of PDP.

4. VERIFYING VALUE PROPOSITION WITH MOCK-UPS

4.1 Value Proposition When Reducing Customer's Cost

Demonstrating the value of a product or service has a significant importance in business transactions, with value proposition providing a methodology that can be utilized for this purpose. (Camlek, 2010) Customer value proposition has become one of the most commonly used terms in the business markets in recent years (Frow & Payne, 2011; Carter & Ejara, 2008; Anderson et al., 2006). Value proposition is defined as (Webster, 1994; cited in Rintamäki et al., 2007) ...

> "… *the verbal statement that matches up the firms distinctive competencies with the needs and preferences of a carefully defined set of potential customers. It's a communication device that links the people in an organization with its customers, concentrating employee efforts and customer expectations on things that the company does best in a system for delivering superior value. The value proposition creates a shared understanding needed to form a long-term relationship that meets the goals of both company and its customers*".

Based on this definition, a value proposition is a communication tool for vivid core competences and unique characteristics of a company and its offerings to well-defined customer segments. Value proposition needs to increase benefits or decrease the sacrifices perceived by the customer and should be superior to the competitors' offerings. (Rintamäki et al., 2007) Furthermore, a value proposition should be specific, precise and measurable (Barnes et al., 2009; Anderson et al., 2006; Lanning, 2000). Value proposition should be constructed from the customers' perspective (Lindi & sa Liva, 2011; Barnes et al., 2009; Rintamäki et al., 2007) and take the operation model (i.e., operational excellence, customer intimacy focused and product leadership) of a target company into account (Camlek, 2010). Finally, a value proposition should be sustainable (Lindi & sa Liva, 2011; Anderson et al., 2006) and lead the company to a competitive advantage (Rintamäki et al., 2007).

The origin of value proposition can be traced back to a project held by McKinsey & Co in the 1980s. At that time, only a brief mention was made concerning this concept. (Bower & Garda, 1985; cited in Ballantyne et al., 2011). Subsequently, Lanning & Michaels (1988) defined value proposition as a statement of benefits offered to a customer and the price that the customer should pay for it. They introduced a framework called the value delivery system that included three steps: choose the value, provide the value and communicate the value to present the idea. (see Ballantyne et al., 2011) Figure 29 demonstrates the value delivery system framework.

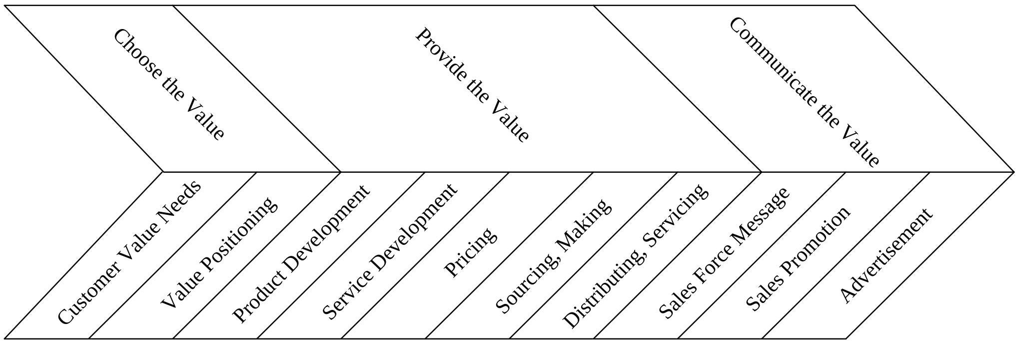

Figure 29. Value delivery system (Adapted from Lanning & Michaels 1988; cited in Ballantyne et al., 2011).

According to the value delivery framework, the first step is creating a clear and specific statement of value proposition by analyzing the market place and identifying customer needs. The second step would involve providing value to the selected customers through activities such as product development, service development and pricing, depending on the customer needs and market structure. Finally, it is essential that the company, in addition to proving the value, is able to communicate it. This means that the company, by doing activities such as sales promotion, advertisement and sales force messages, makes sure customers understand and appreciate the full value of the company's offerings. (Lanning, 2000)

Barnes et al. (2009) introduce a value proposition builder, an iterative process model to construct value proposition. They claim that this model is not just a theoretical framework; it has been applied to many real-life client situations successfully. Figure 30 illustrates the value proposition builder.

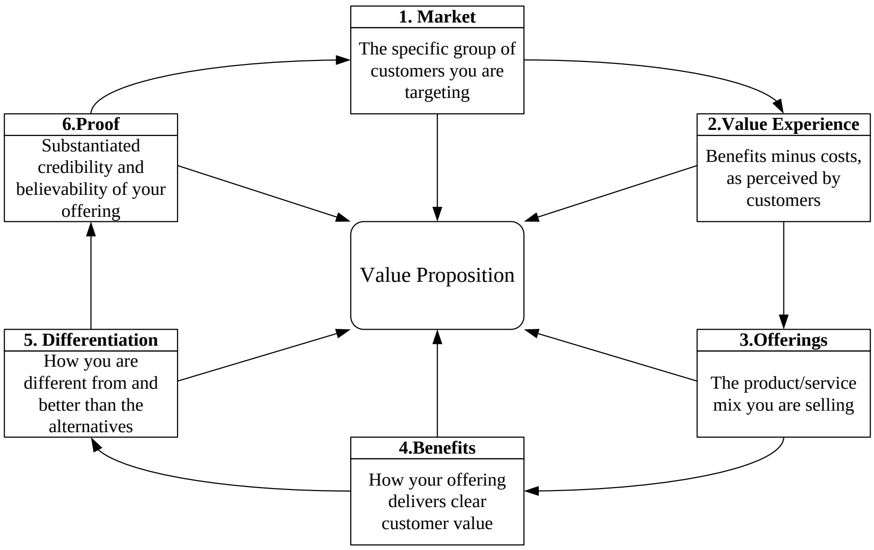

Figure 30. Value proposition builder (Adapted from Barnes et al., 2009).

Based on this model, the first step in building a value proposition is analyzing the market to identify a segment or segments from which the company is capable of offering value profitably. The second step consists of identifying what customers consider to be valuable. Face-to-face interviews, focus groups and online surveys are only some of the methods that can be used for extracting customers' real needs. The third step categorizes the company's existing offerings and defines an offering mix capable of leveraging proven value experience. If necessary, development of the new offerings should be considered in this step. The fourth step involves calculating the value of the company's offerings, i.e. extracting the benefits and costs of each offering from the customers' perspective. In the fifth step, competitors and alternative offerings in the marketplace are investigated and then a value proposition is built which is superior to that of the competitors. The final step aims to demonstrate the value of the offering by providing a solid proof. Case studies, value calculator and customer testimonials are some of the techniques which company can use to gain customers' trust. (Barnes et al., 2009)

Anderson et al. (2006) classified the ways suppliers construct value proposition into three types: all benefits, favorable points of difference and resonating focus. The all benefits value proposition requires that managers just list all the benefits that their offerings provide for the customers, and they do not consider any specific customers and market needs. As a result, it may lead to drawbacks, including claiming benefits which are not considered beneficial by customers and an inability to show differential aspects of the offering in comparison with the competitors' offerings.

The favorable points of difference value proposition means that companies study alternative solutions and list all the differential elements their offering has in comparison to the alternative solutions. Then, without investigating the customers' real needs and requirements, the company emphasizes the differential element that seems more valuable. However, the main pitfall of this approach is that companies' assumptions may not be aligned with what the customers see to be valuable in the product. Therefore, the company may spend its resources to promote features of its offering which are not the most valuable ones in the eyes of the customers. (Anderson et al., 2014; Anderson et al., 2006)

Resonating focus is the last type of value proposition which should be the gold standard. It differs from the previous types of value proposition in two main respects. First, based on this approach, more points of difference is not considered good. Basically, an offering may have several points of difference, though the resonating focus proposition only emphasizes one or two elements as providing the greatest value to the customers. Second, the resonating focus proposition may also mention points of parity between the offering and alternative solutions because existence of those elements are essential for the customers to even consider buying the company's offering. Despite the effectiveness of the resonating focus value propositions, constructing them is not easy and requires deep understanding of customers and competitors. (Anderson et al., 2006) An example of Finn-power crimping machines is explained in the following paragraphs to clarify the resonating focus value proposition concept (Lyly-yrjänäinen et al., 2010).

The company making Finn-Power crimping machine is the global market leader. These crimping machines are utilized for producing hose assemblies needed in different kinds of machines powered by hydraulic equipment. Since Finn-power crimpers are mostly used in B2B markets, they need to provide customer value in order to be considered as a profitable investment for the customers. Finn-power has constructed value proposition of its crimpers based on the resonating focus concept by focusing only on productivity improvement. Finn-power shows productivity enhancement of its crimpers in monetary terms by a simple example (Figure 31).

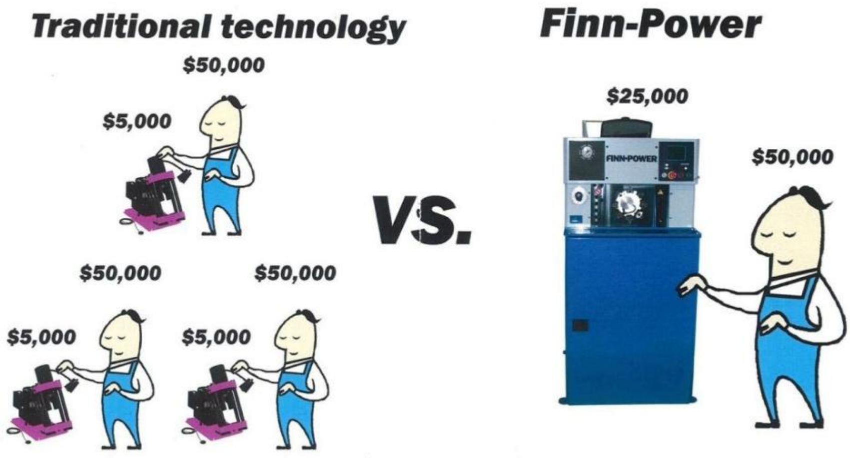

Figure 31. Finn-Power value proposition for crimpers (Adapted from Lyly-yrjänäinen et al., 2010).

Based on this example, producing a certain amount of hose assemblies by traditional technology requires three small crimpers (5000 USD each) and three operators (50000 annual salary). Finn-power argues that replacing these three small machines with a better crimper will reduce operation costs of the company. Although the customer needs to invest more on purchasing the machine (25000 USD in comparison to 15000 USD), labor costs decrease significantly (from 150000 USD to 50000 USD per year). Therefore, Finn-power can reduce the operation costs of the customer 90000 USD in the first year. Focusing on only these two points in the value proposition would be more than enough to show the value of the crimper to the customers and to distinguish it from its competitors.

This example clearly shows that building a value proposition based on one or two important aspects can lead to a very convincing tool for promoting and selling the product. By looking back to the customer value models discussed in Chapter 2, Finn-power basically focused on total customer cost drivers in a particular operation cost to build its value proposition (Figure 32).

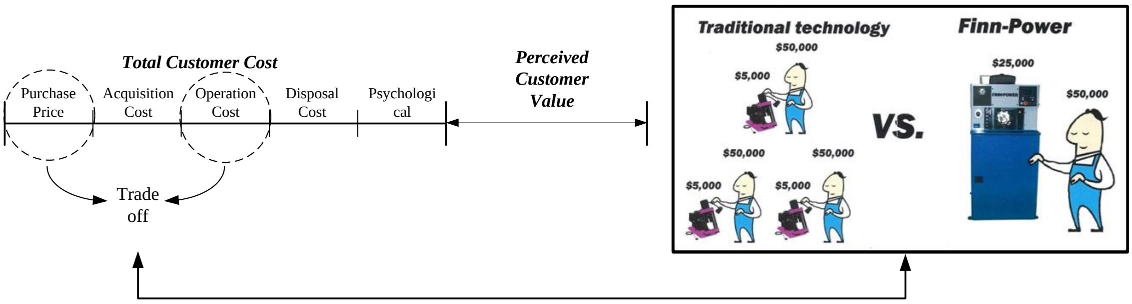

Figure 32. Cost drivers involved in building Finn-Power value proposition.

For building a value proposition, it is not always necessary to know all the details about total customer costs and total customer value drivers. As long as the company can find one or two aspects which are very important in the eyes of the customers, a convincing value proposition can be built based on those aspects. Finn-power realized that reducing operation costs would be an important aspect from the customers' perspective, and it built a value proposition based on that perception. This thesis is mainly concerned with decreasing customers' operation costs by providing cost-reducing solutions and building value proposition based on these cost reductions. Hence, in the following section, it is first necessary to understand how to analyze the process impacts of such cost-reducing solutions.

4.2 Process Modeling

A process can be defined as any activity or group of activities which take inputs, add value to it and provide it to internal or external customers (Harrington, 1991). A business process consists of five elements (Davenpor, 1993; Hammer & Champy, 1993; cited in Lin et al., 2002):

- A business process has its own customers
- A business process is composed of activities
- These activities are aimed at creating value for customer
- Activities are operated by actors which may be humans or machines
- A business process often involves several organizational units

A manufacturing process represents one type of business process which consists of a set of mechanical or chemical steps to create a product. Generally, a production process involves utilization of raw materials, man power and machinery (Business dictionary, 2014). Manufacturing processes can be illustrated by a process model, which is basically a visual illustration of what happens in the process (Rolland, 1993). Process models offer a systematic way of demonstrating the structure of a company's production process (Busby & Williams, 1993). Figure 33 shows a simple manufacturing process.

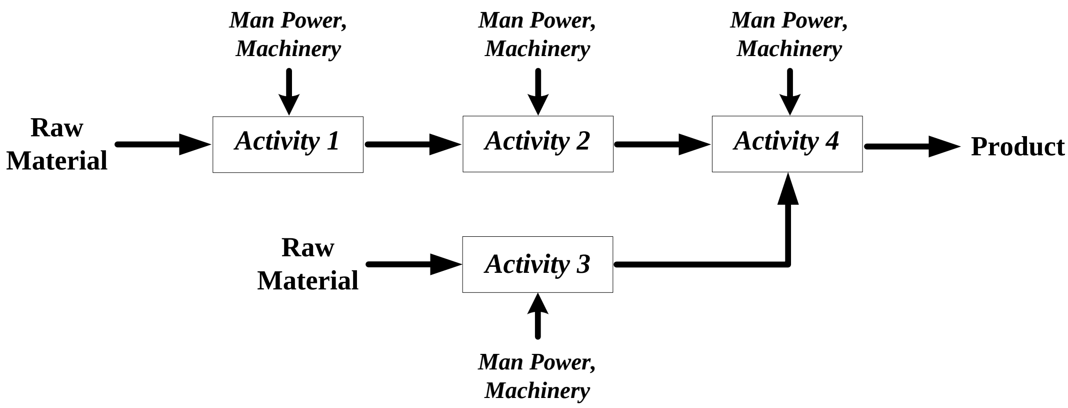

Figure 33. Example of a manufacturing process model.

According to Hansen & Guan (2007), one way to calculate product cost is to use cost objects. A cost object is any item such as product, project or activity for which costs are measured and assigned. Costs can be directly or indirectly associated with cost objects. Direct costs are those which can be traced easily and accurately to a cost object. On the other hand, indirect costs are those which cannot be traced easily to cost objects. The ability to assign a cost directly to a cost object in an economically feasible way through a causal relationship is known as traceability. Tracing costs to cost objects can be accomplished in two ways: direct tracing or driver tracing.

Hansen & Guan (2007) stated that direct tracing involves the process of identifying and assigning costs which are specifically or physically associated with a cost object. This process is usually done by physical observation. For instance, in the process of making a pair of blue jeans, material usage and the amount of time an operator is spending on sewing the pieces together is physically observable and can be directly traced to a pair of jeans. Driver tracing is applied when it is not physically possible to see the amount of resources a cost object consumes. Therefore, it is necessary to use identifying factors, called drivers, which can be observed physically and which measure resource consumption of cost objects. For instance, if in the company producing blue jeans the manager wants to know how much electricity is used by a sewing machine, it is not possible to physically observe the consumption of electricity for the sewing machine. Hence, a driver such as machine hour can instead be used to assign the cost of electricity to the sewing activity. (Hansen & Guan, 2007) This thesis is concerned with calculating the cost of physical products when activity is defined as a cost object and direct tracing is possible. Thus, the discussion will continues based on this assumption.

Costs can be divided into two functional categories: manufacturing and nonmanufacturing costs. Manufacturing costs can be divided further into direct material, direct labor and overhead. Direct materials are related to the material consumption of each activity. Direct labor refers to the time spent by labor to do an activity which usually can be traced directly. Finally, overhead is related to all manufacturing costs apart from direct materials and direct labor. Nonmanufacturing costs refer to marketing and administrative costs. For the purpose of this thesis, nonmanufacturing costs are also considered as overhead. Figure 34 provides an example of product cost structure. (Hansen & Guan, 2007)

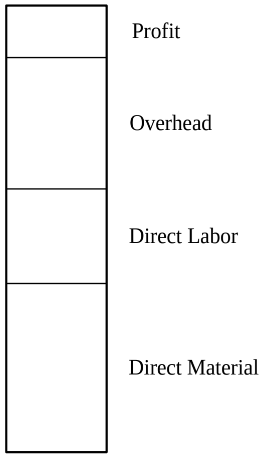

Figure 34. Product cost structure example.

An imaginary manufacturing process can be used to explain how the costing of a manufacturing process works. Product A is a simple product which is made through a process that consists of three activities (Figure 35).

Figure 35. Product A manufacturing process model.

All of these activities are done by an operator, and there is no need of a complex manufacturing process for this product. Therefore, the direct costs of this product include raw material and labor costs, both of which can be traced directly. Raw material cost equals to the amount of money paid by the company for acquiring the raw material shown in the bill of materials. Calculating direct labor cost is a bit more complicated. In order to determine what the direct labor cost for a product is, production process time needs to be analyzed with a time study.

Zandin (2001) stated that a time study is used to determine time standards for tasks such as planning, costing and scheduling. Time study evaluates the required time needed for performing a certain task by a qualified operator at a normal performance level. Various techniques have been used for time study, including predetermined time system, historical data, work sampling and stopwatch time study. Among these methods, stopwatch time study is a common method to determine the process time. (Zandin, 2001)

In stopwatch time study, it is necessary to first select an operator who is cooperative, efficient and has an acceptable task performance level. Then, the time study process should be explained and possible instructions should be shared with the operator. If needed, the work performed by the operator is divided into smaller operations, each of which is timed separately. Finally, the process should be timed and recorded. Usually, the process is timed several times to reach a more accurate result. (Zandin, 2001) Figure 36 shows the result of a stopwatch time study on the manufacturing process of Product A.

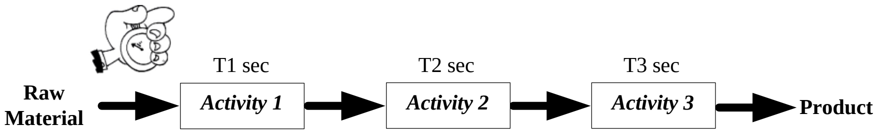

Figure 36. Result of time study on product A.

To calculate the direct labor cost, the time of each activity needs to be multiplied by the cost of the operator per second. This is illustrated in Figure 37.

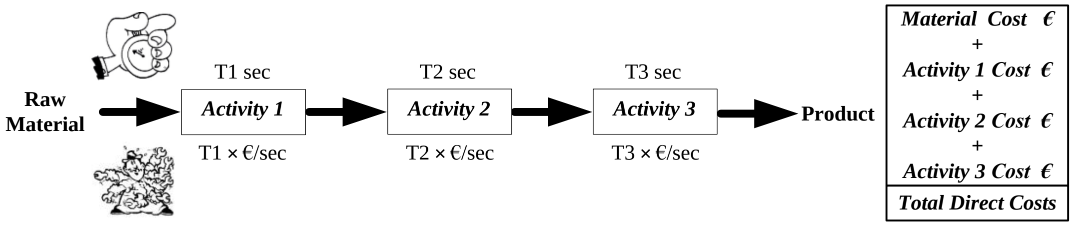

Figure 37. Calculating Product A activity costs.

After completing product costing calculations, the company realizes that Activity 3 is consuming too many resources. In order to solve this problem, company decides to replace Activity 2 and Activity 3 with Activity 4 by acquiring a process machine (a cost-reducing offering) (Figure 38).

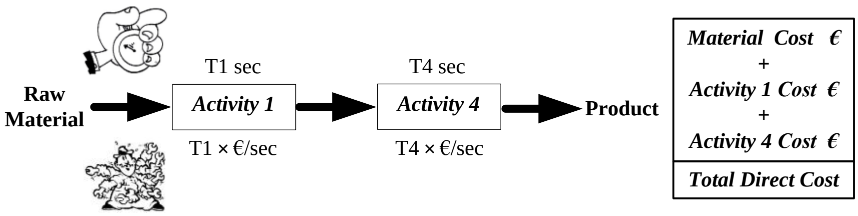

Figure 38. Developing manufacturing process of Product A.

This change in the production process has no impact on the material cost or Activity 1 cost. However, since Activity 4 requires less time than was needed for Activity 2 and Activity 3 together, the total direct labor cost is decreased (Figure 39).

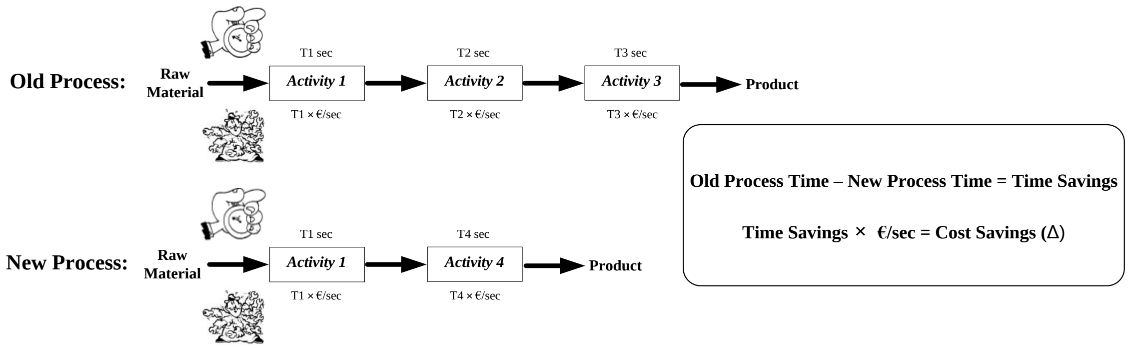

Figure 39. Calculating cost savings of cost-reducing offering.

This simple example shows the basis for calculating the direct costs of a production process. More importantly, it raises an important point regarding the calculation of the time and cost savings in process development. This example shows that in some cases, when a process is under development, it is possible to calculate how much a new process can save the company without access to detailed financial data of the company. The only thing needed is the time savings of the new process, which leads to cost savings. This cost savings basically can tell how much more value (Δ) the new process can provide to the company. This simple way of calculating added value (Δ) may be utilized as a tool for communicating value, which is discussed in more detail in the following section.

4.3 Analyzing Perceived Value of Cost-Reducing Offering

Chapter 2 explained the customer value concept. It was mentioned that the total customer value and total customer costs are formed based on customer value drivers. Further, the importance of these value drivers is not the same but depends on many factors, such as industry and customer characteristics. Then, it was shown that evaluating customer perceived value can be accomplished by utilizing customer value assessment methods, of which only internal engineering assessment and field value-in-use assessment were chosen. Moreover, it was mentioned that the focus of this thesis is on cost-reducing innovations. Hence, only purchase price and operation cost value drivers were chosen for further discussion.

At the end of the chapter, it was stated that acquiring cost-reducing innovation is similar to a trade-off between the purchase price and the operation cost for the customer. This trade-off shows how much more value (or less value) acquiring cost-reducing innovation brings for customers. In Section 4.2, an example was given to demonstrate the cost savings (Δ) when an old process is improved by acquiring a cost-reducing innovation. Now, it is time to look further ahead and to explain how a company can benefit from Δ in order to build a convincing value proposition.

The supplier of the process machine realizes that the manufacturing company is struggling in producing Product A and is therefore looking for a solution to speed up their production process. The supplier wants to convince the manufacturing company that their process machine can bring value. The supplier knows the current process time of the manufacturing company and is able to calculate the new process time by internal engineering assessment. This data basically helps the supplier to calculate cost savings (Δ) as demonstrated in Figure 39. But how this Δ can help the supplier to build a value proposition?

Based on this Δ, the supplier can make a comparison between the total customer costs of the old process and the new process. The supplier can argue that by using their process machine, it is possible to make Product A at lower cost. In other words, utilizing the process machine can decrease the operation cost of the manufacturing company. However, the manufacturing company, in order to gain benefit from using this process machine, needs to invest a certain amount of money for acquiring the machine. Hence, investing in improving the old process represents a trade-off for the manufacturing company. The supplier needs to build a value proposition in such a way that it clearly shows that the benefits coming from the process machine surpass the investments for buying the machine. The supplier can do this calculation by doing a payback period analysis.

The payback period is a method for evaluating capital investments. The goal of the payback period is to determine the minimum time it will take to recover the initial investment. (Needles et al., 2013) The payback period method follows a simple formula:

$$\text{Payback Period} = \frac{\text{Cost of Investment}}{\text{Annual net cash inflows}}$$

In this example, the cost of the investment equals to the cost of acquiring the process machine. Annual net cash inflows can also be calculated by multiplying Δ by the number of Product A produced per year by the manufacturing company.

However, for building value proposition, it is also necessary to calculate unit level depreciation of the machine. There are various ways to calculate depreciation. The simplest method is using straight line depreciation to calculate depreciation of the machine. Then, depreciation should be divided by annual production volume to calculate unit level depreciation.

$$\text{Depreciation} = \frac{\text{Assets Purchase Price} - \text{Salvage Value}}{\text{Asset's Life}}$$

$$\text{Unit Level Depreciation} = \frac{\text{Depreciation}}{\text{Annual Production Volume}}$$

Since the new process utilizes the process machine, depreciation of the machine should be added to the total customer costs. Except for the operation cost, the value of other cost drivers can be considered to be the same for both the old and new processes. These simple calculations can provide the supplier with enough information to calculate the added perceived value of its offering. Figure 40 illustrates the process of calculating added perceived value for cost-reducing offerings.

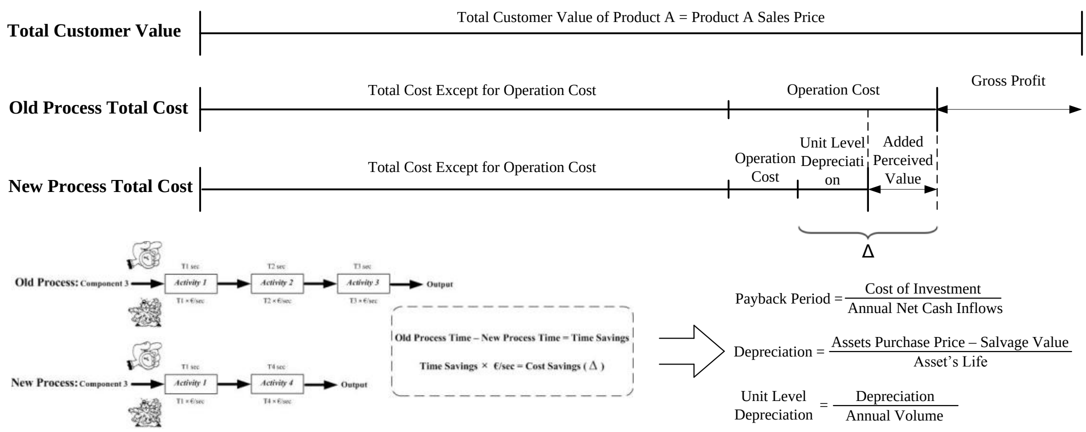

Figure 40. Process of calculating added perceived value for cost-reducing offerings.

To sum up this example, the first step for the supplier to build a value proposition is a time study of the customer's processes. Time study for the old process can be done in the manufacturing company facility, and the new process can be done by internal engineering assessment. The outcome of this time study gives the supplier Δ, which can further be used for calculating the payback period. Since the outcome of the process (which is Product A) for both the old and the new process are the same, it can be assumed that only operation costs will change significantly and other cost drivers remain the same. Hence, by including depreciation into the total cost of the new process, it is possible to make a comparison between the old and the new process and calculate the added customer perceived value of the supplier's process machine.

The purpose of this example was to show how a company can build and communicate its value proposition without knowing all aspects and drivers involved in the customer value. Hence, this example shows how a company can build a resonating-focus value proposition. The idea of this example is similar to what Finnpower did for communicating the value of their crimpers to the customers. However, this example analyzes the savings at the unit level. It can be argued that building a value proposition is not only possible by doing detailed customer value assessment but also, in many situations, by communicating the fact that an offering of a company can increase perceived value by a certain amount can be more than enough to build a convincing value proposition.

In this example, it was assumed that the supplier first developed the process machine and then carried out a time and cost study on it to calculate the cost savings of the new process in comparison to the old one. In a real life situation, developing a new product is time consuming and costly. Thus, if a company realizes that the product they just developed cannot save any cost or is not attractive from the customers' perspective, this could lead to significant losses for the company. As a result, it is recommended that the cost study and the constructing of the value proposition be done in the early stages of product development before a significant amount of time and money are spent on the development.

4.4 Role of Mock-ups in Constructing Value Proposition

Chapter 3 discussed product development concept and explained that, in order to succeed in product development, it is necessary to use a product development process model, such as the stage gate model, to coordinate activities and increase efficiency. It was also pointed out that, during PDP, communication with the customer is important because it is the customers who will use the product. Hence, paying attention to their opinions is crucial. Later, the chapter explained that in current product development models, building mock-ups and prototypes starts at the earliest in the second stage of development. However, it was argued that it is better to start building models of the product from the idea generation stage. Building models as early as possible in the development process brings several benefits, including customer involvement and better understanding of the idea among the team members.

Another important aspect of building mock-ups and prototypes as early as possible in the product development process is to give customers a chance to experience the product in use. In the past, it has been common for companies to build a product and then let customers try the product only at late stages of PDP. Nowadays, in some industries, it is becoming increasingly common to involve the customer in the development process in order to shift the customer experience away from the end of PDP to the early stages. For instance, in the mobile phone industry, some companies are making models of their future cell phones only to gain user feedback regarding the design and appearance of the phone. Building a fully functional mock-up is a very cheap and convenient solution for companies to create a reliable customer experience of the final product idea in the early stages of product development. Figure 41 illustrates the idea of shifting customer experience to earlier stages of PDP.

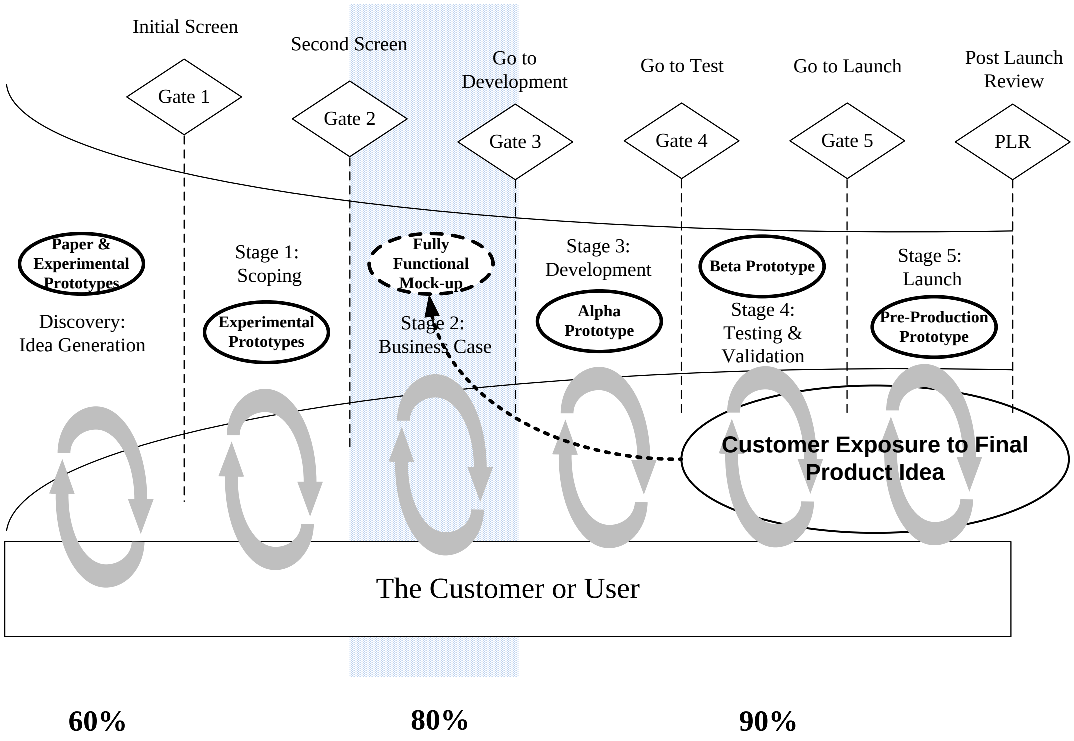

Figure 41. Shifting customer experience to earlier stages of PDP.

Based on this model, fully functional mock-ups in the second stage of PDP are fast and cost effective for testing alternative solutions but, at the same time, comprehensive enough to determine the majority of the product life cycle costs. Hence, the supplier can use these mock-ups for implementing technical and financial analysis at a desirable level in order to determine whether the future product can offer the needed performance level.

The previous chapter explained that if companies want to wait until the end of the development process to build value proposition, in the case of failure, it can cost them a significant amount of money and time. Why not start building the value proposition of a future product as early as possible in the development process by utilizing mock-ups and prototypes? Although the value proposition may not be accurate at the beginning of PDP, as early as the second stage of development, fully functional mock-ups can be comprehensive enough to show the majority of the performance of the future product. Hence, building the value proposition based on those mock-ups is relatively close to building value proposition based on a final product. Figure 42 gives an illustration of the accuracy of building value proposition at different stages of product development.

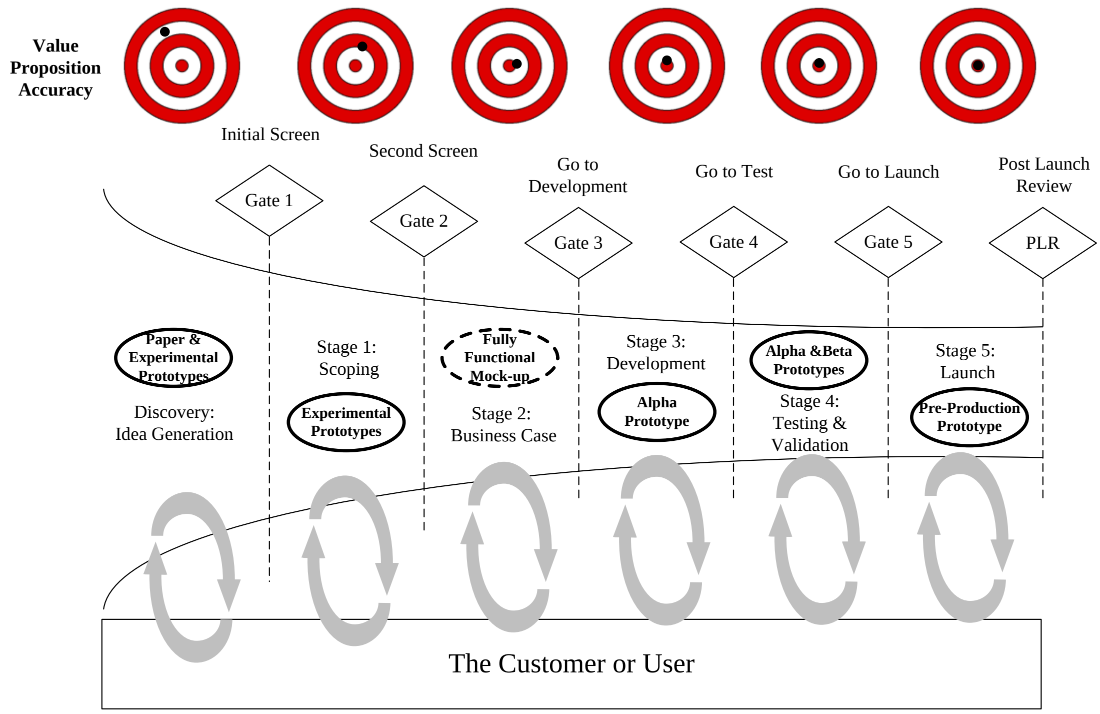

Figure 42. Value proposition accuracy in different stages of PDP.

Looking again at the example in the previous section, it is better for the supplier to start building models of its process machine idea at the beginning of the development process. Then, by the second stage of the product development, there is a mock-up which is comprehensive enough to be used for time and cost analysis, thus enabling comparison of the results with the old process. This analysis can thereafter be used as a tool to make an acceptable value proposition before spending resources in the development process. In this way, the supplier has a chance to communicate the value of its future offering with the manufacturing company and receive some customer feedback based on real use experience. Also, the supplier still has an opportunity to make improvements to the design if needed. Figure 43 illustrates utilization of a fully functional mock-up in building value proposition.

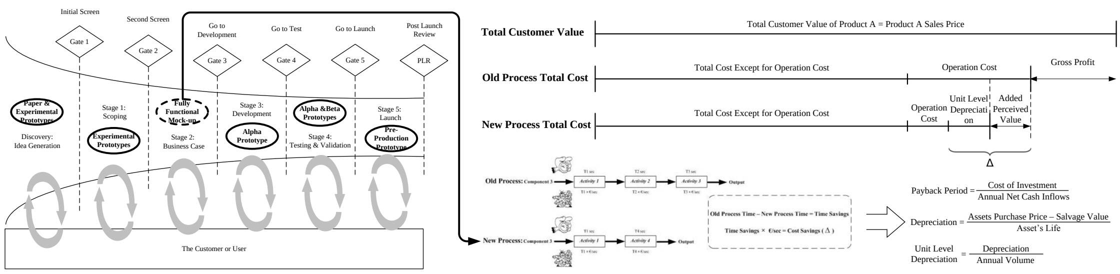

Figure 43. Application of fully functional mock-up in building value proposition.

To sum up, this chapter argues that building a value proposition is essential for communicating value to customers. In practice, using value proposition models for building value proposition is not always possible due to challenges in gathering information from customers. However, for cost-reducing innovations, value proposition can be built based on cost savings (Δ) of current products/processes and potential products/processes. Further on, it was discussed that it is not even necessary to wait until the end of PDP to calculate Δ. Fully functional mock-ups can be utilized to calculate Δ in very early stages of PDP.

The idea of building value proposition with mock-ups in early stages of PDP will now be applied in a case company. The underlying research process and results of this case study are discussed in detail in the following chapters.

5. THE CASE COMPANY

5.1 The Case Company

This case study was conducted in one of the subsidiaries of a company which manufactures industrial accessories for a wide range of firms throughout the world. This company from now on will be referred to as the parent company. The parent company was established in 1948 in Tampere, Finland. At the beginning the parent company offerred mainly textile products to its customers. However, due to various acquisitions over the last decades, the product offering of the parent company has increased significantly. In addition, the company has established various facilities, including production lines and sales offices, in other countries. Figure 44 shows a simplified version of the parent company's organizational structure.

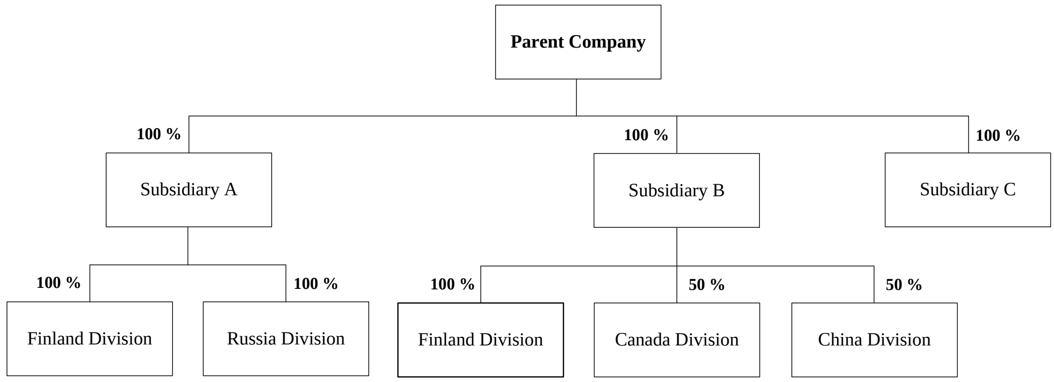

Figure 44. Parent company organizational structure.

The parent company's headquarters and the majority of the production lines are still located in Tampere, Finland. However, the parent company has three subsidiaries, of which Subsidiary A and Subsidiary B have completely or partially owned sales facilities and production lines in other countries. Net sales of the parent company was reported to be around 12 million Euros in 2013, with more than half of this coming from the subsidiaries. Table 7 shows a financial information summary for the parent company over the past four years.

Table 7. Financial summary of the parent company (Finder.fi).

	12/2010	12/2011	12/2012	12/2013
Company Turnover (1000 EUR)	3 787	5 597	5 213	5 822
Turnover Change %	180.6	47.8	-6.9	11.7
Result of the Financial Period (1000 EUR)	-10	73	368	254
Operating Profit %	-1.8	0.6	0.2	-0.6
Company Personnel Headcount	24	44	45	48

The empirical research for this thesis was implemented in the Finland division of Subsidiary B, which will henceforth be referred to as the case company (Figure 45). The remainder of this section describes the case company in more detail.

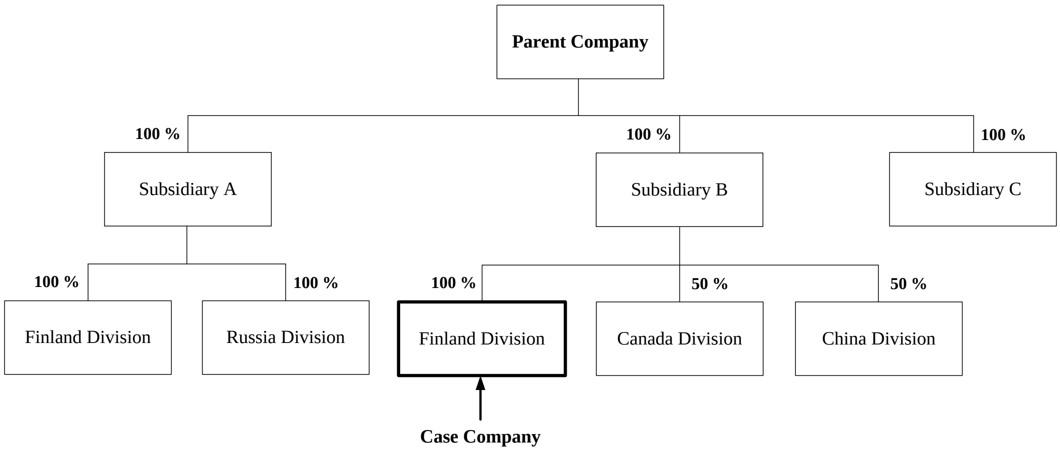

Figure 45. Case company in the organizational structure of the parent company.

The case company was founded in 1997 by an entrepreneur. In 2004, the former CEO of the parent company saw the potential of the business and acquired the business. The case company specializes in producing high-quality spirals and textile products mainly for hose protection purposes. The case company's production lines and sales office are also located in Tampere, Finland. The case company employs 11 personnel under its name, but that only includes employees who work in the production lines and warehouse. All administrative tasks are conducted by personnel working under the name of the parent company.

Although the recession has had a significant negative effect on the operation and financial situation for the majority of companies in Europe, the case company has continued to expand its business during the past years. Table 8 shows the financial summary of the case company over the past four years. During an interview with the case company manager, he confirmed that recent changes in the European economy have not significantly affected the case company's business, and the case company has been able to maintain steady growth even in this recession:

> *"The recession has created major problems for many companies in Europe. Even other subsidiaries of the parent company have slightly suffered from the recession. However, we are pleased that we have been able to maintain steady growth despite the recession."*

Table 8. Financial summary of the case company (Finder.fi).

	12/2010	12/2011	12/2012	12/2013
Company Turnover (1000 EUR)	978	2 344	2 769	3 213
Turnover Change %	-	19.8	18.1	16.1
Result of the Financial Period (1000 EUR)	-1	2	2	4
Operating Profit %	4.4	4.8	5.4	4.9
Company Personnel Headcount	5	10	10	11

Based on the above table, the case company has shown steady growth in revenue. However, this has not been supported by the case company profit. The case company manager agreed that there is a contradiction in these figures:

> *"Financial summary of the company is a bit misleading. It basically shows that the case company is unprofitable. The main reason is that we transfer majority of the profit to the parent company. Thus, part of the profit shown in the financial summary of the parent company belongs to us (the case company)."*

When the case company was acquired by the parent company, the majority of the customers were located in Finland and Sweden. After acquisition, the parent company invested in increasing the production capacity of the case company and started to look for new opportunities in foreign markets. Simultaneously, various regulations, such as ISO 3457 and the MSHA (mine safety and health administration) standard, have forced companies such as earth moving machinery manufacturers to use hose protection products (e.g., plastic spirals and textile sleeves). For instance, ISO 3457 stipulates that "hoses containing fluid at pressures exceeding 5000 Kpa or temperatures about 60°C which are located within 1 meter of the operator in the normal operating position and whose direct spray in case of failure can reach the operator shall be guarded". As a result, machine manufacturers are increasingly using more of these safety products.

Because increasing demand for plastic spirals and textile sleeves created a huge opportunity for the case company, they had to expand their distribution channels to cover customers' needs all over the world. The next step was establishing a production and distribution facility in Canada and a warehouse and sales office in China. The parent company managers decided that the Canadian division would cover all the demand for the North American market and the China division would be responsible for distribution in the East Asian market. Customer demands in the rest of the world would then be met by the case company:

"*We are selling our products mainly to hydraulic retailers, machine manufacturers and hose assembly manufacturers. We have around 300 active customers all over the world. In some countries such as Spain and Indonesia, we have agreements with local hydraulic distributors that we only sell our products through their channels. However, this is not the case for all the countries."*

Figure 46 shows a simple demonstration of the case company's distribution network.

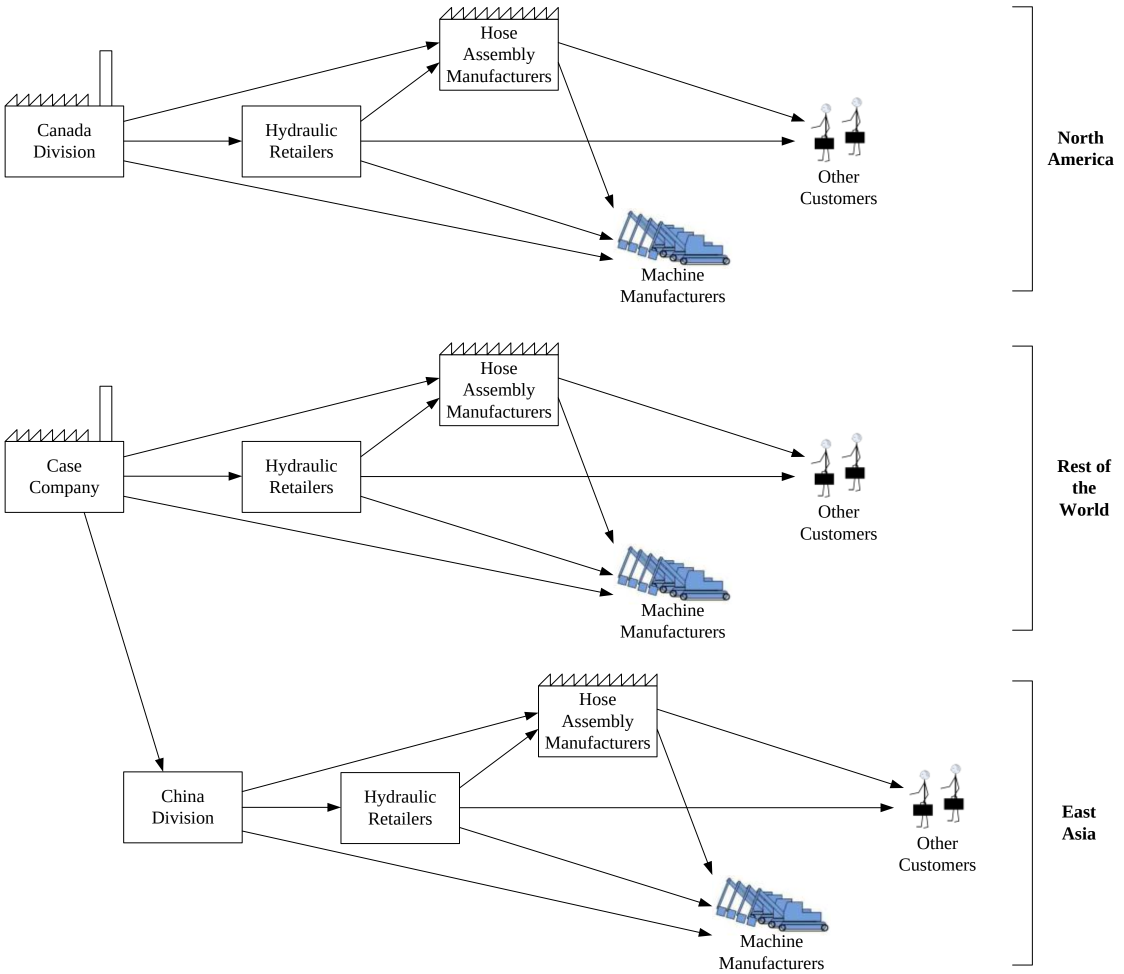

Figure 46. The case company distribution network.

At the moment, the case company manager is satisfied with the distribution network, though this may not be the case in the future:

> *"Currently we do not have any certain plans for developing our distribution network. However, if the market in Europe grows significantly, we may consider establishing a warehouse in a country in the center of Europe to reduce transportation costs and lead time."*

This section briefly discussed the history and financial situation of the parent company and the case company. In addition, this section explained that production capacity and distribution channels of the case company have grown due to an increase in market demands. The following section discusses the product portfolio of the case company.

5.2 Hose Assembly and Hose Protection Products

The case company produces and distributes hose protectors and hose binding products for various purposes. The case company's customers are mainly hydraulic retailers, machine manufacturers and hose assembly manufacturers. Therefore, to understand the case company product usage better, it is necessary to begin by explaining hydraulic hose assembly and its manufacturing process. Hydraulic hose assembly is one of the vital components in hydraulic machines, which enables transmission of force within a machine. A hydraulic hose assembly consists of three major components: hose, ferrule and insert. Figure 47 illustrates a hose assembly and its main components.

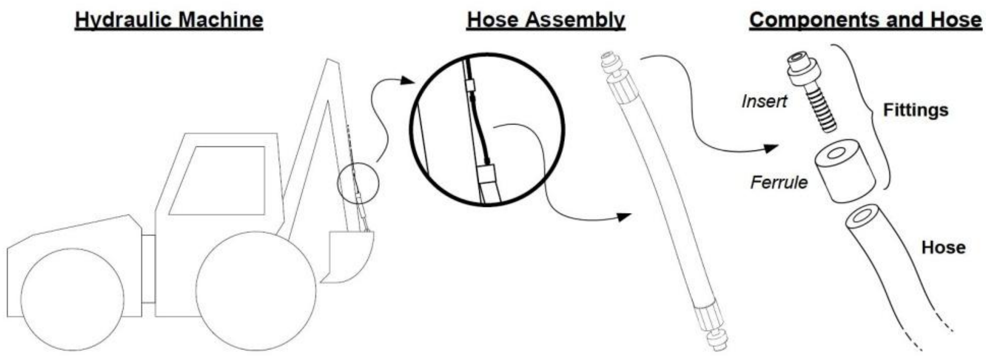

Figure 47. Hose assembly and its components.

The manufacturing process of a hose assembly is simple. First, the desired length of hose is cut. Then, the ferrules and inserts are attached to the hose ends, and the ferrules are squeezed radially to tightly attach the hose and fittings. Finally, the hose ends are sealed with plastic caps or other methods to protect the hose from contamination. Figure 48 shows the hose assembly manufacturing process.

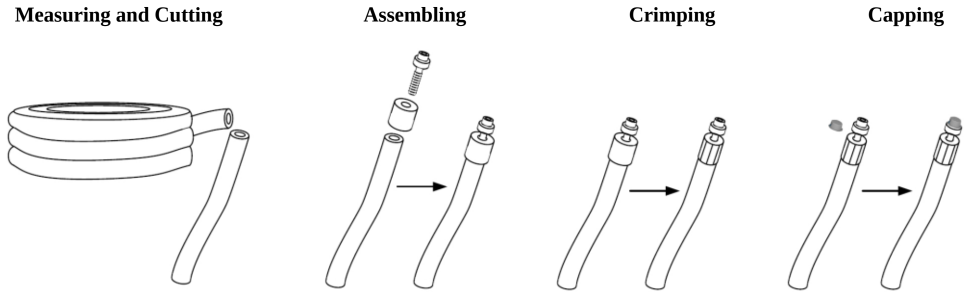

Figure 48. Hose assembly manufacturing process.

The case company’s products can be categorized into five groups: plastic spiral, textile sleeve, safe wrap, safe strip and binding strap. Figure 49 shows examples of these products.

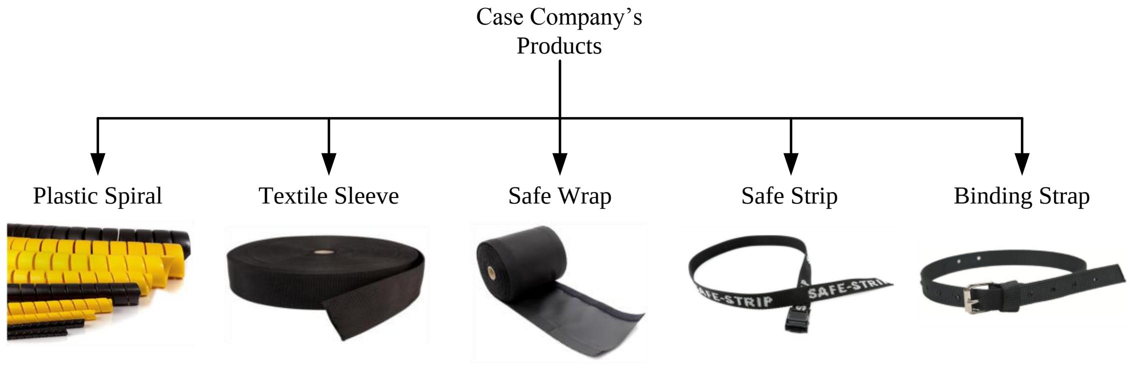

Figure 49. The case company products.

The majority of the case company's production consists of plastic spirals. Plastic spirals are high-quality, low-cost solutions for protecting hoses and cables. The case company produces various types of plastic spirals, including safe spiral, safe spiral mine, flex spiral and binding spirals. Customers can choose the spiral type most suitable for their working environment. For instance, the safe spiral mine is designed for environments that demand flame resistance, a characteristic needed in mining machinery and mining appliances. Figure 50 shows hydraulic hose assemblies with plastic spiral.

Figure 50. Hydraulic hose assemblies with plastic spiral.

Hose protection sleeves are textile products made of materials such as polyester and polypropylene. The main purpose for using hose protection sleeves is to protect the hoses from external threats while at the same time protecting the operators from possible hose failures. The safety sleeves are mainly used for protecting hydraulic hose assemblies, although they also can be used for other purposes, such as protecting cables. Textile sleeves account for the second highest production volume in the case company. Figure 51 shows hydraulic hose assemblies with protection sleeves.

Figure 51. Hydraulic hose assemblies with protection sleeve.

Safe-Wrap is a textile sleeve with Velcro fasteners, making it very fast and easy to mount on hoses. This makes Safe-Wrap a cost effective solution for hose protection and hose bundling. Figure 52 shows hydraulic hose assemblies with Safe-Wrap.

Figure 52. Hydraulic hose assemblies with Safe-Wrap.

Safe-Strip is utilized for strapping multi-hose bundles and can be used over and over again. There are three different types of Safe-Strips: Safe-Strip standard, Safe-strip with a mounting eyelet and Safe-Strip with a buckle. Figure 53 illustrates bundling multiple hose assemblies with Safe-Strip.

Figure 53. Bundling multiple hose assemblies with Safe-Strip.

The binding Strap can be used for various purposes, including bundling hydraulic hoses or electric cables (Figure 54). Binding Straps are made of very durable woven polyester and have adjustment holes.

Figure 54. Binding strap for bundling hose assemblies.

This section explained the case company products. However, due to the importance of textile sleeve for the purpose of this thesis, the characteristics and specifications of this product are explained in more detail in the following section.

5.3 Hose Protection Sleeves

As discussed in the previous section, one of the main products of the case company is the textile sleeve. Two types of textile sleeves are produced in the case company: safe sleeve and safe sleeve MSHA. Safe sleeve is a textile sleeve made of polypropylene which meets the requirements of EN 12999 and ISO 3457 standards. This product is very durable and endures acids and alkalis well. The recommended temperature range for this product is -40°c to +80°c. The safe sleeve MSHA is made of polyester, which in addition to EN 12999 and ISO 3457 standards, is accepted by MSHA. Most of the characteristics of safe sleeve and safe sleeve MSHA are the same. However, safe sleeve MSHA can tolerate a greater range of temperature (-40°c to +120°c). The case company sells sleeves in 50 meter rolls or pre-cut sleeves based on customer needs. Table 9 shows the range of sleeves for both safe sleeve and safe sleeve MSHA.

Table 9. The case company textile sleeve sizes.

Safe sleeve MSHA product code	Safe Sleeve product code	Inner diameter (mm)	Flat (mm)
MSHA-RD17M	SL-RDX 17	17	30
MSHA-RD23M	SL-RDX 23	23	40
MSHA-RD27M	SL-RDX 27	27	45
MSHA-RD30M	SL-RDX 30	30	50
MSHA-RD36M	SL-RDX 36	36	60
MSHA-RD39M	SL-RDX 39	39	65
MSHA-RD46M	SL-RDX 46	46	75
MSHA-RD55M	SL-RDX 55	55	90
MSHA-RD62M	SL-RDX 62	62	100
MSHA-RD79M	SL-RDX 79	79	125
MSHA-RD109M	SL-RDX 109	109	175
MSHA-RD125M	SL-RDX 125	125	200

The above table shows that there are two key dimensions for identifying sleeves: inner diameter and width of a sleeve when it is flat. These dimensions are illustrated in the following figure.

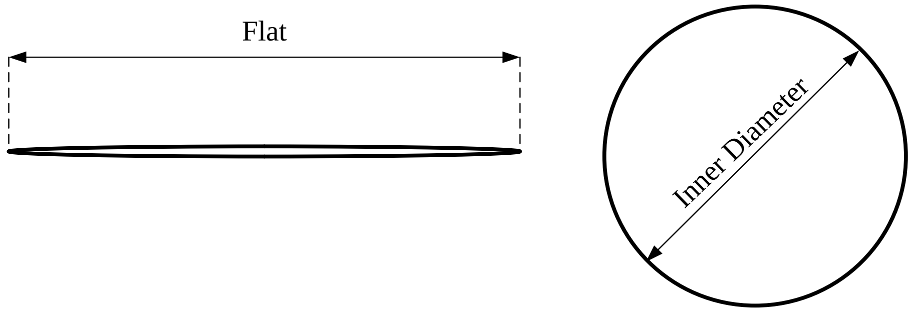

Figure 55. Key dimensions for identifying sleeves.

There is a significant variation in the demand for different sleeve sizes. One of the case company sales managers did some calculations on the monthly sales reports. Based on this calculation, she realized that the demand for the narrow sleeves is much higher than that for the wide sleeves:

> *"There is a demand for all range of sleeves and this demand changes slightly every month. However, on average more than 80% of monthly sales belong to sleeves with less than 46 mm inner diameter."*

The majority of the customers buy sleeves in rolls. Therefore, they need to cut sleeve pieces based on the length of the hose assemblies later in the production/assembly line. Sleeve pieces can then be fixed onto the hose assemblies using various methods, including crimping aluminum rings. Figure 56 shows the basic principle for covering a hose assembly with a sleeve and fixing it with aluminum rings on the top of the ferrules.

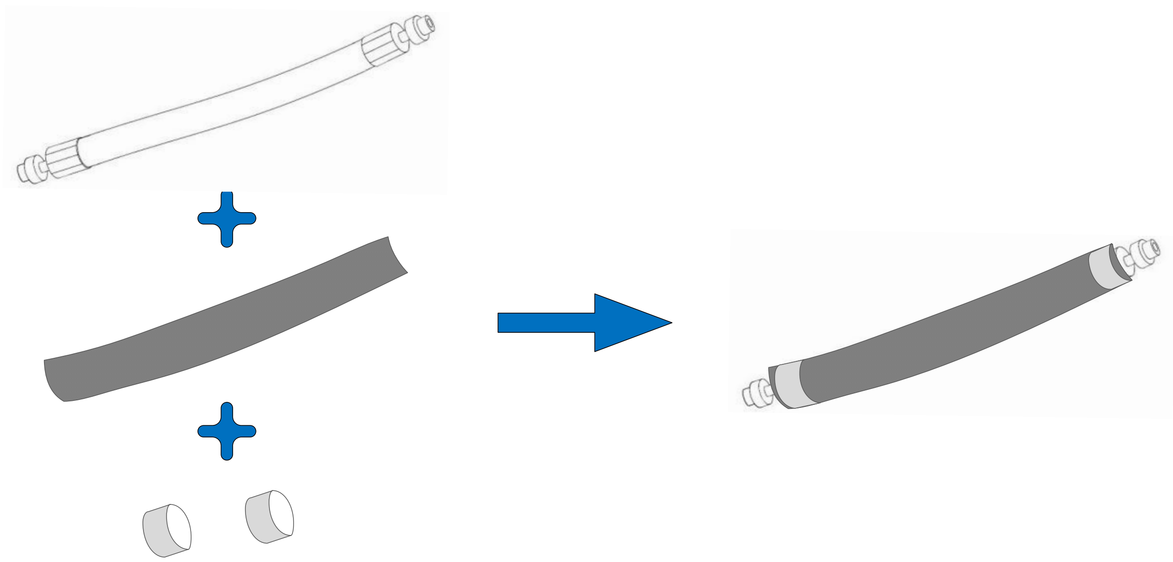

Figure 56. Process of covering hydraulic hose with textile sleeve.

The simplest way to prepare a sleeve piece is by measuring and cutting the sleeve with manual or automated methods. For instance, one of the customers also uses a manual hose-cutting machine for making sleeve pieces. Figure 57 shows cutting sleeves with smooth rotating blade of this machine.

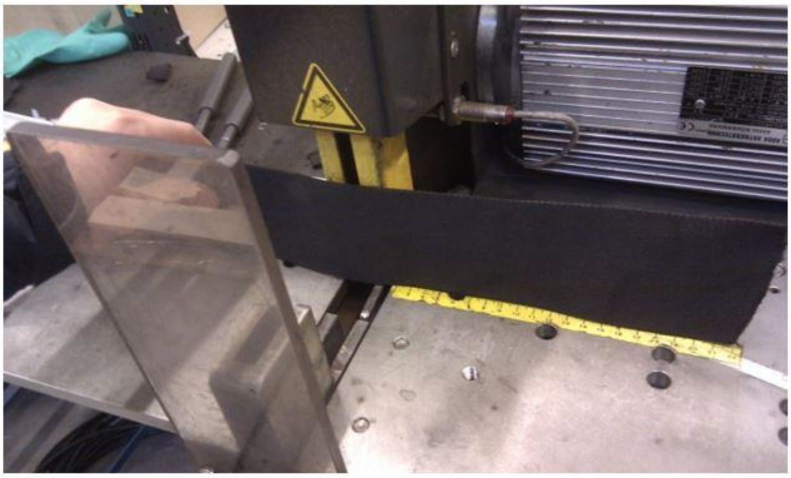

Figure 57. Preparing sleeve pieces with manual hose cutting machine.

However, the sleeve is a textile product which makes the cutting process challenging. Textile products are flexible woven materials made of a network of natural or artificial fibers. When the textile is cut, the fibers on the cutting point become loosened and tend to come out, resulting in textile frays in the area close to the cutting edge (Figure 58).

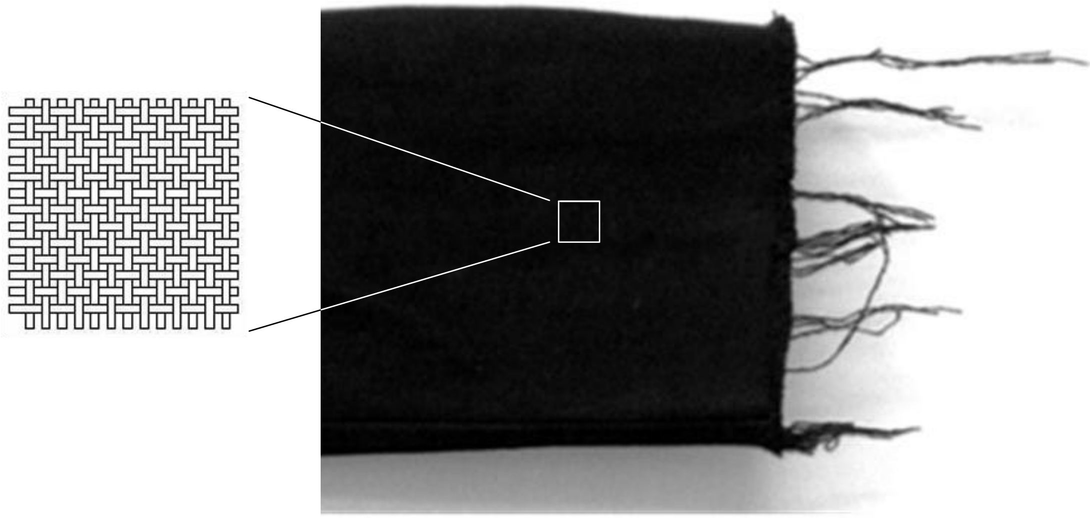

Figure 58. Textile frays after cut.

If the textile sleeve frays after cutting, these loose threads prevent the hose assembly from travelling smoothly into the sleeve. As a result, inserting the hose assembly into sleeve may become more difficult (Figure 59).

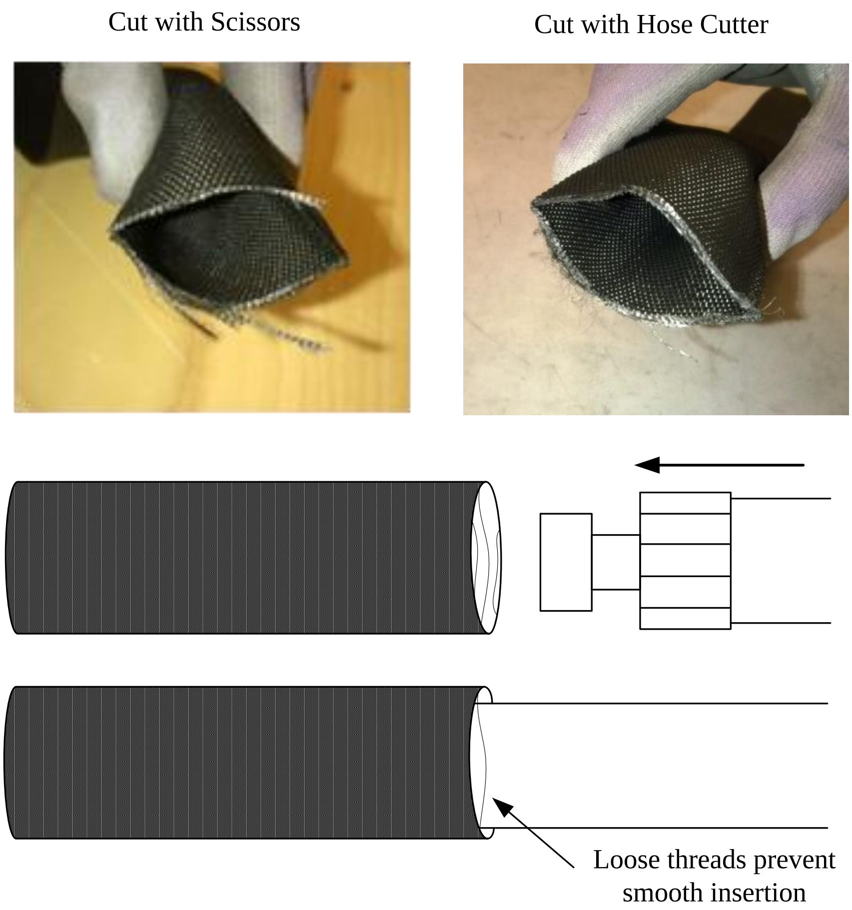

Figure 59. Textile sleeve cut quality without burning edges.

One common solution to prevent the textile from fraying is to burn the edges during or after the cut. Therefore, many companies are forced to have an additional step in preparing sleeve pieces which is melting the edges or finishing. Thus, the sleeve cutting process consists of three steps: measurement, cut and finishing (Figure 60).

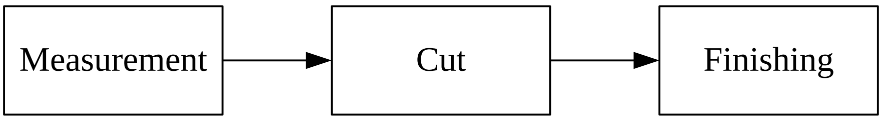

Figure 60. Sleeve cutting process.

There are several approaches to carry out this process. The most basic approach is to first use a measuring tape for measuring the sleeve. Then the sleeve can be cut with scissors and the sleeve edges burned with a butane torch or a heat gun (Figure 61).

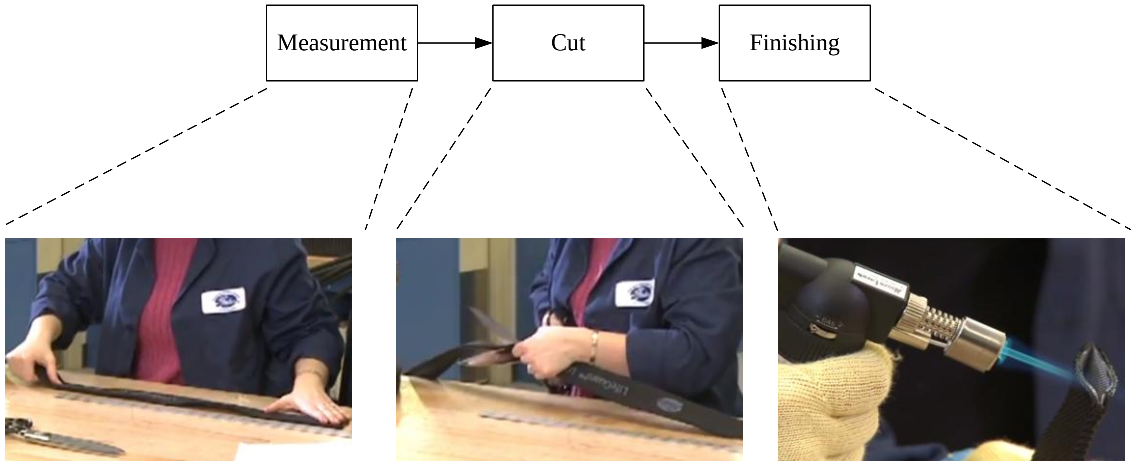

Figure 61. Sleeve cutting process with scissors and butane torch.

Another approach which the case company is currently using to prepare pre-cut sleeves for its customers is an automated machine to measure and cut the sleeves. Then, an operator burns the edges by pressing the sleeve edges to a hot metal plate. (Figure 62)

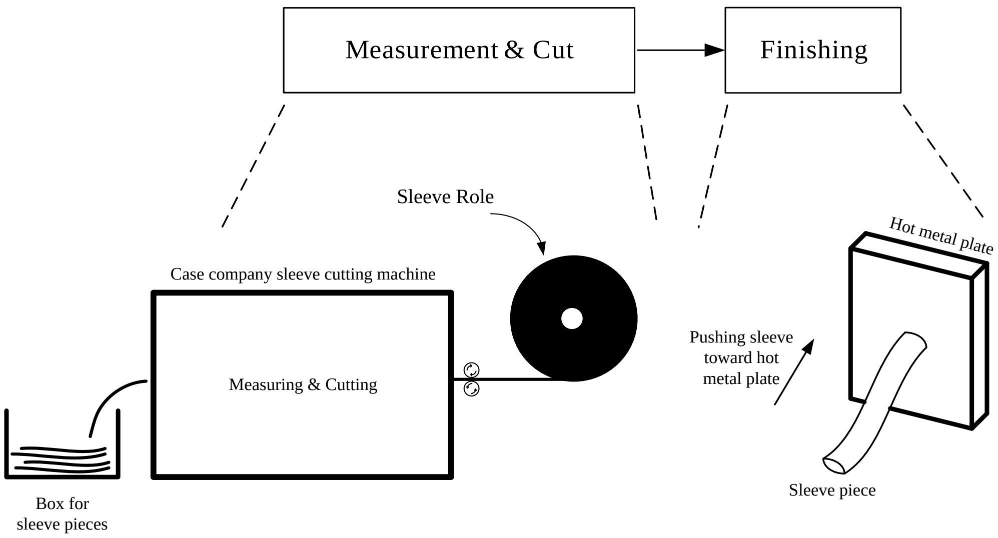

Figure 62. The case company current sleeve cutting process.

These solutions provide acceptable cut quality. However, these processes are time consuming and therefore, developing a new solution for this process is needed.

5.4 From a Material Supplier to a Solution Provider

Although the case company has shown significant growth, there has always been this mindset among managers that they need to constantly improve their product quality and services to retain their competitive position in the market place. Sales managers during their visits and discussions with customers realized that customers are happy with the quality of the products. However, their concern has been the installation time in particular with spirals and sleeves. Most of the customers have had to utilize these products manually which is time consuming and irritating for the operators. The case company manager was convinced that they should offer something to their customers:

> *"We started looking for solutions to facilitate usage of our products in 2005. At that time once a while customers were asking if there is any solution available or not. Thus we developed a simple tool to facilitate mounting of spiral on hose assemblies. Unfortunately, customers were not happy with the idea and we were out of options for a long period of time. In 2008 we were able to find a tool for our purpose. It was not a commercialized product so we needed to acquire permission to sell the tool under our name."*

Figure 63 shows the tool which the case company offers to the customers for mounting spiral on hose assemblies.

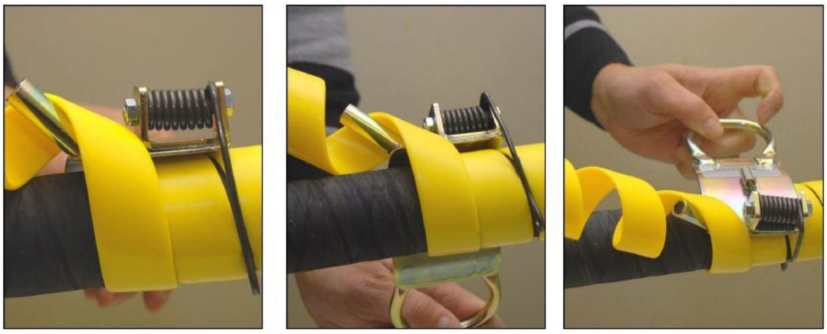

Figure 63. The case company tool for mounting spiral.

The case company manager continued:

> *"It was around 2010 when a large machine manufacturer asked us to prepare 10000 pieces of textile sleeves for them. We made few sample with our textile cutting machine and delivered it to them. Customer did not approve the quality of our cut and asked us to burn sleeve edges after cutting. We realized that it is not cost efficient for us to do this process manually so we declined the order. This example and some other comments we received from our customers forced us to start thinking about a solution for cutting textile sleeves with better cut quality".*

During the past few years, customers have been asking whether the case company could offer them a better tool or machine for mounting the plastic spiral and cutting the textile sleeves. Hence, managers realized that developing a new solution for these needs should be a high priority for the company:

> *"It is very important for us to have a close relationship with our customers and providing solutions to facilitate the usage of our products is a step in the right direction. In addition, offering these solutions may open up new opportunities for us. We may be able to sell more products to current customers or even find new*

> *customers in the market. Finally, if everything goes well, we may be able to gain a profit out of these solutions which is always nice."*

Thus, based on the manager's statements, it can be concluded that the case company is moving from being only a material provider to a solution provider. They want to get involved with their customers' operations and to help them in finding solutions for their problems. In addition, the case company is looking for new opportunities to expand their product portfolio. They want to supply the majority of hose protection products needed by their customers. Figure 64 illustrates the steps that the case company is taking to expand its business.

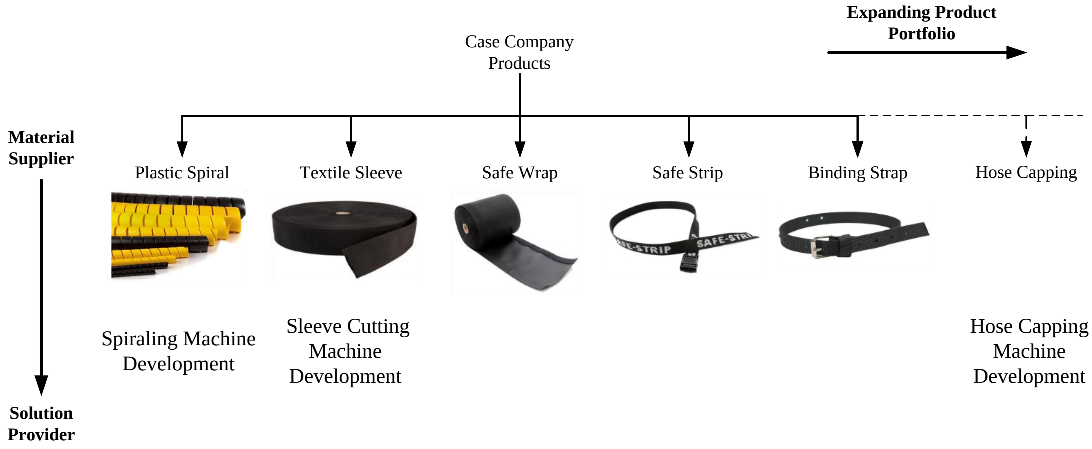

Figure 64. The case company business growth plan.

Becoming a solution provider can offer various benefits to the case company. First, they will be the first company in the industry to provide a reliable solution which would improve the competitive position of the company in the market place. Second, they can show to their customers that their relationship with them is not just a simple buy-sell transaction, but a long term business relationship which can benefit both parties. This will increase customer loyalty and will have a positive impact on the company's annual sales. Third, new customers may become interested in working with the case company instead of their current suppliers because the case company will have proved that they have an understanding of their customers' operations and have the capability to help them solve their problems. Finally, facilitating product usage may simply lead to an increase in demand.

To move toward this goal, the case company defined three development projects: spiraling machine, sleeve cutting machine and hose capping machine. The author of this thesis was involved in all these development projects. Among these projects, the sleeve cutting machine was chosen to be discussed in more detail. The main reason for this selection was that the development process of the sleeve cutting machine involved less complexity than the other two projects, making it a good example for the demonstration and testing of the theoretical framework.

6. SLEEVE CUTTING MACHINE

6.1 Idea Generation

The first step in developing the sleeve cutting machine was to generate ideas. This process started in November 2013 and continued until July 2014 when finally one of the ideas was selected for further development. Figure 65 shows the idea generation stage of the sleeve cutting machine on the project timeline.

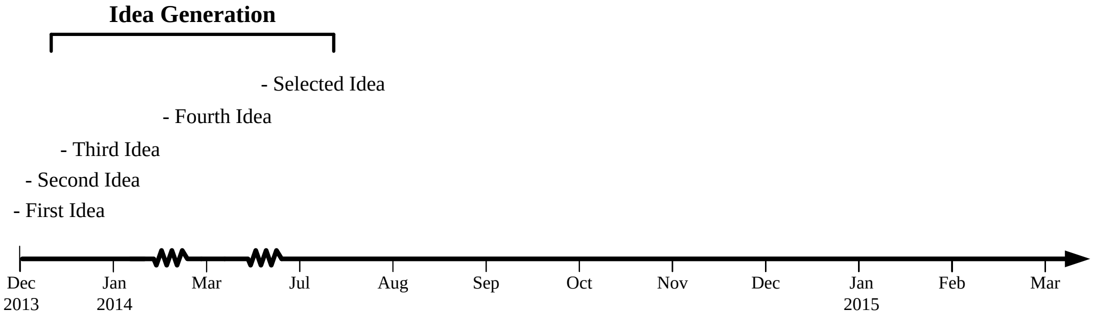

Figure 65. Idea generation stage in the sleeve cutting machine project.

After observing efficiency and performance of the current sleeve cutting methods, it was realized that, if the cutting and finishing steps were combined in one step, it could have a significant impact on the process time (Figure 66).

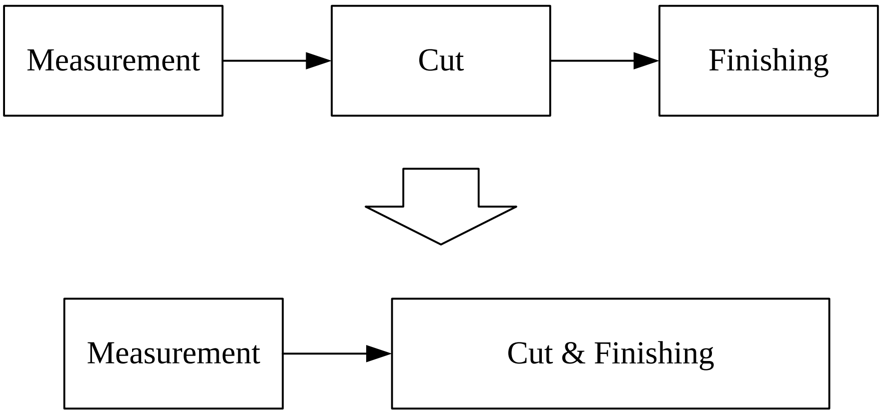

Figure 66. Combining cutting and finishing steps in sleeve cutting process.

The first idea which came to mind was to cut the sleeve with a hot knife. It was assumed that by setting the hot knife temperature to a certain level, it might be possible to cut and finish the edges simultaneously without melting the two sides of the sleeve together. In addition, this cutting method would not be limited by the length of the sleeve (Figure 67).

Figure 67. Cutting sleeve by hot knife.

The quality of the finished sleeve was acceptable. However, the idea had a major drawback. Due to the limitation in the temperature level, it took a long time to cut a good quality piece of sleeve. To reduce the cutting time, it was suggested that the hot knife be replaced with a circular saw and an induction heating mechanism be used to heat the saw blade. In addition, a thermostat could be used to monitor temperature of the saw blade and keep it at a desirable level all the time to prevent the sleeve edges from melting together. Figure 68 illustrates the idea of using a circular saw with inductive heating to cut sleeve pieces.

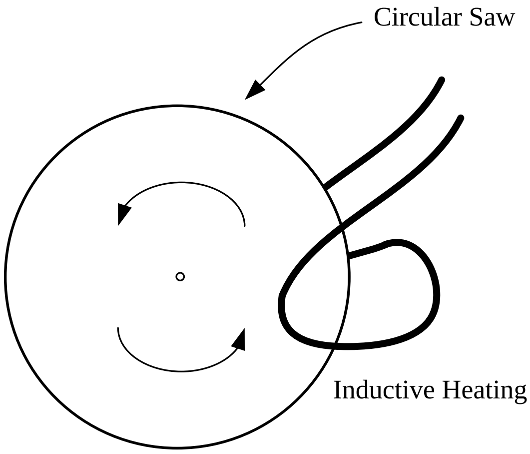

Figure 68. Circular saw with inductive heating to cut sleeve pieces.

A mock-up was built by connecting the round blade of a pizza slicer to a hand drill and a heat gun was utilized to heat the blade (Figure 69). Although the performance of this mock-up did not reach the point for performing proper tests, it provided enough information to conclude that cutting sleeves at a low temperature will not lead to a fast and high quality cut. Moreover, using a circular saw and inductive heating led to unnecessary complications in the development process, thereby increasing the price of the final product. Hence, it became clear that it is not possible to cut the sleeve and melt the edges in a reasonable time without opening up the sleeve.

Figure 69. Circular saw with inductive heating mock-up.

To solve this issue, a vacuum mechanism was used to open up the sleeve sides before cutting. Once the sleeve sides were open, it was possible to increase the knife temperature and cut the sleeve faster without melting the sleeve sides together. Figure 70 shows use of the vacuum mechanism for opening sleeve sides. The picture on the left shows the opening of two sleeve sides with two vacuum cleaner suction pipes, while the picture on the right demonstrates the first wooden mock-up of the idea.

Figure 70. Vacuum mechanism utilization for opening sleeve sides.

The results of the initial tests were promising. The idea had the potential to provide good quality and at the same time improve the process time. Thus, a more advanced mock-up of this idea was built of wood, plastic pipe and four vacuum cleaners. The main purpose of this mock-up was to test how the idea works in the continuous sleeve cutting process (Figure 71).

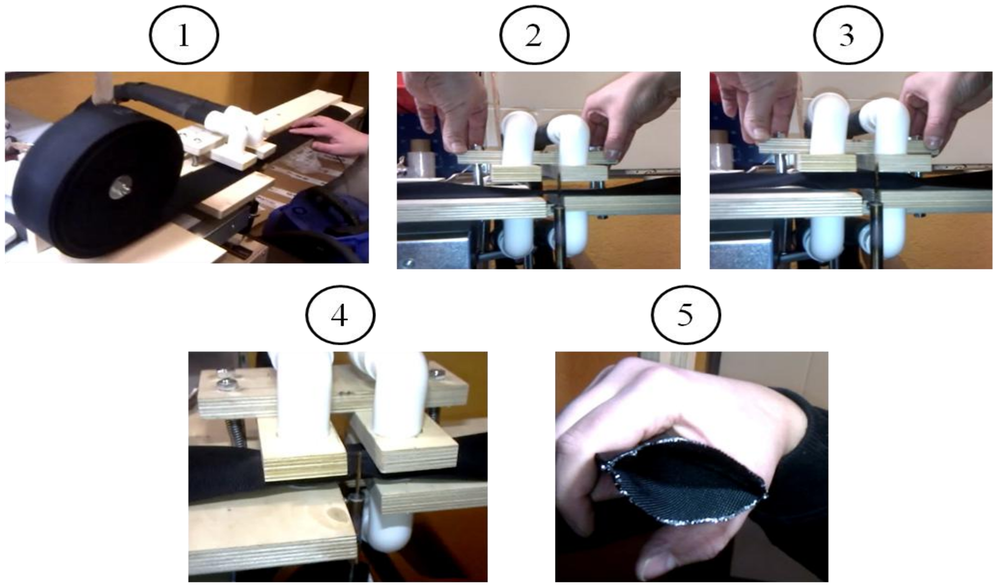

Figure 71. Continues sleeve cutting with vacuum mechanism first version.

The first step involved feeding the sleeve into the machine while at the same time measuring the length. In the second step, the top suction pipes are pressed down until they touch the sleeve surface. The third step consists of slowly releasing the top suction pipes. The suction system was designed to create a small gap between the two sides of the sleeve. Finally, the sleeve was cut with the hot knife and the suction system was turned off to release the sleeve. Picture 5 shows the quality of the finished cut produced with this mock-up.

The previous mock-up demonstrated the core functionality of the idea. However, to reach a better conclusion in terms of the performance of the idea, a new version was made of wood and assembled on an aluminum profile structure. The new mock-up was designed to work with different sleeve sizes and had a more stable holder for the suction system. In addition, the hot knife was replaced with a more powerful model which could improve both the quality and speed of the process. (Figure 72)

Figure 72. Continues sleeve cutting with vacuum mechanism second version.

When the solution was tested with the new mock-up, it was noted that the suction system opened up the sleeve mostly from the center and the sides of the sleeve remained very close to each other. Therefore, when the hot knife starts cutting, the two sides of the sleeve melt and attach to each other at the corners, thus making it difficult to insert thereafter the hose assembly inside the sleeve. (Figure 73)

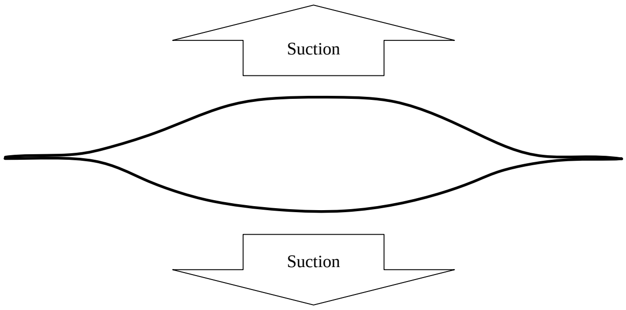

Figure 73. Main problem with vacuum mechanism.

Therefore, the next improvement was to open the two sides of the sleeve from various suction points instead of only one in the middle. For this purpose some pneumatic suction cups were acquired to replace the previous suction system. (Figure 74)

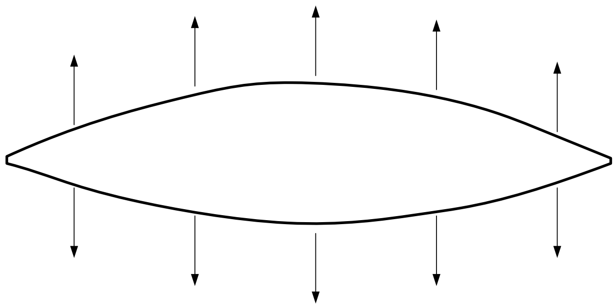

Figure 74. Vacuum mechanism with several suction points.

Unfortunately, the pneumatic suction cups were mainly designed for solid surfaces. Hence, they were not a suitable alternative for use with textile products. (Figure 75)

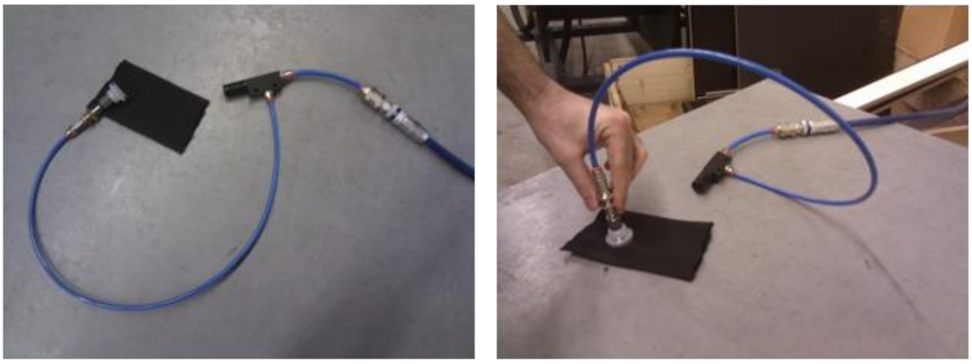

Figure 75. Vacuum mechanism with several suction cups test.

Despite the progress made, the project was put on hold for a while until an interesting discovery took place. During a visit to the production facility of one of the customers, it was noted that the majority of sleeves are used to protect short hose assemblies. Immediately after this observation, some of the customers were asked about the maximum length of the sleeves they cut. The responses of customers were interesting. One of the Finnish customers mentioned:

> *"Most of our customers buy sleeves in rolls. However, there are few customers who require pre-cut sleeve pieces which are less than one meter long with less than 50mm inner diameter."*

A customer from Italy responded:

> *"High volume orders for pre-cut sleeve pieces belong to narrow sleeves which are maximum 2 meter long."*

When these findings were shared with the case company managers, they also confirmed that the orders they had received during the past years for pre-cut sleeves had been mainly for narrow and short sleeves. The statements of the customers and the previous pre-cut sleeve orders of the case company provided valuable input for the development process; as long as the case company develops a machine that efficiently cuts sleeve pieces up to 2 meters in length, the majority of the customers' needs would be covered. Shortly after these findings, a new idea was generated. For short sleeves, it is possible to separate the two sides of the sleeve by inserting something like a metal rod inside the sleeve and then cut the sleeve close to the end of the metal rod. The idea was tested immediately with a piece of metal profile and the hot knife acquired for the previous mock-up (Figure 76).

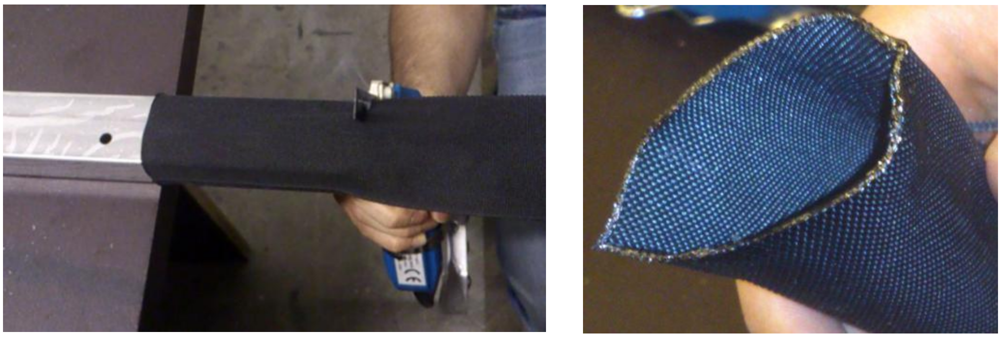

Figure 76. Separating sleeve sides by inserting a metal profile.

This test showed that positioning the blade close to the end of the metal profile can result to a clean cut. A few samples of sleeves were sent to the customers and they approved the quality of the cut. Therefore, this idea was selected for further development.

6.2 Developing & Testing the Selected Idea

The second step in developing the sleeve cutting machine involved developing and testing the selected idea. This process started in July 2014 and continued until mid-September 2014. During this period, various versions of the selected idea were built and tested in order to reduce uncertainties regarding the functionality of the idea as much as possible. Figure 77 shows the development and testing stage of the sleeve cutting machine on the project timeline.

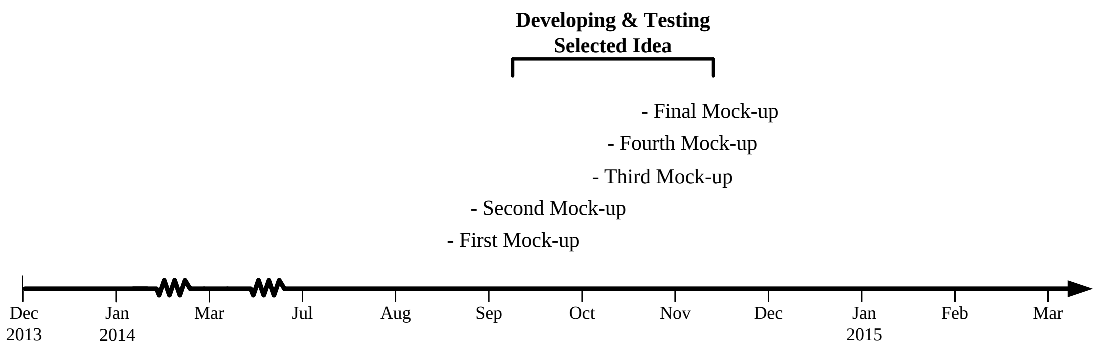

Figure 77. Development stage of the sleeve cutting machine project.

In the next phase of the development, the metal profile was replaced with two aluminum rods. One of these rods was connected to a pneumatic cylinder which made it possible to expand the gap between the two aluminum rods to completely open the sleeve. With this change, it was faster and easier to feed the sleeve into the machine, making the whole process faster without reducing the quality of the cut (Figure 78).

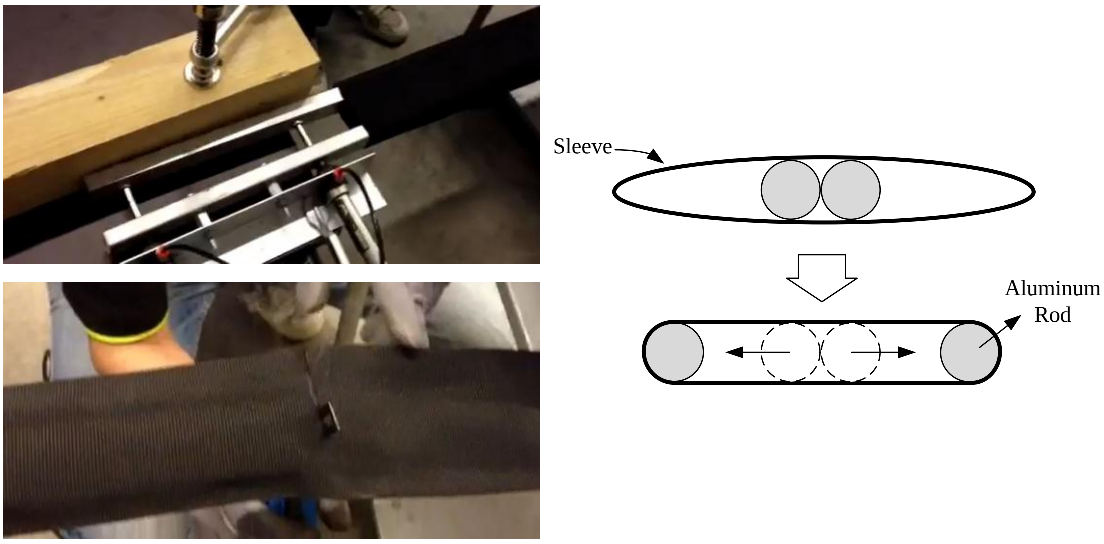

Figure 78. Using two aluminum rods to open up the sleeve sides.

After cutting a few sleeves with this mock-up, it was decided to build a new version with more features and longer aluminum tubes. For this purpose, the hot knife was attached to a pneumatic cylinder for controlling the hot knife movement (Figure 79).

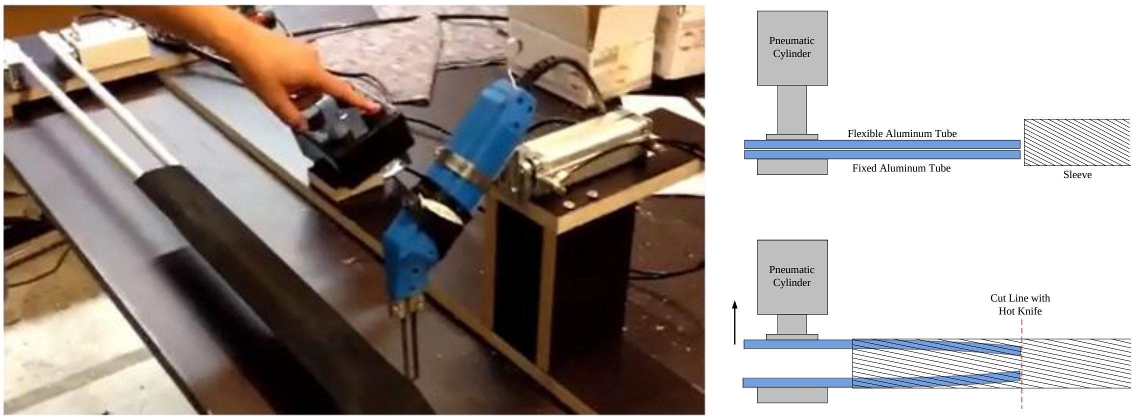

Figure 79. The hot knife connected to the pneumatic system.

Although the quality of the cut with this mock-up was acceptable, there was still room for improvement. The main problem of using two aluminum tubes for opening the sleeve was that the aluminum tubes did not have enough strength to remain straight and thus bent. Therefore, the sleeve was not completely stretched near the cutting point. To solve this problem, the aluminum tubes were replaced with two aluminum profiles (Figure 80).

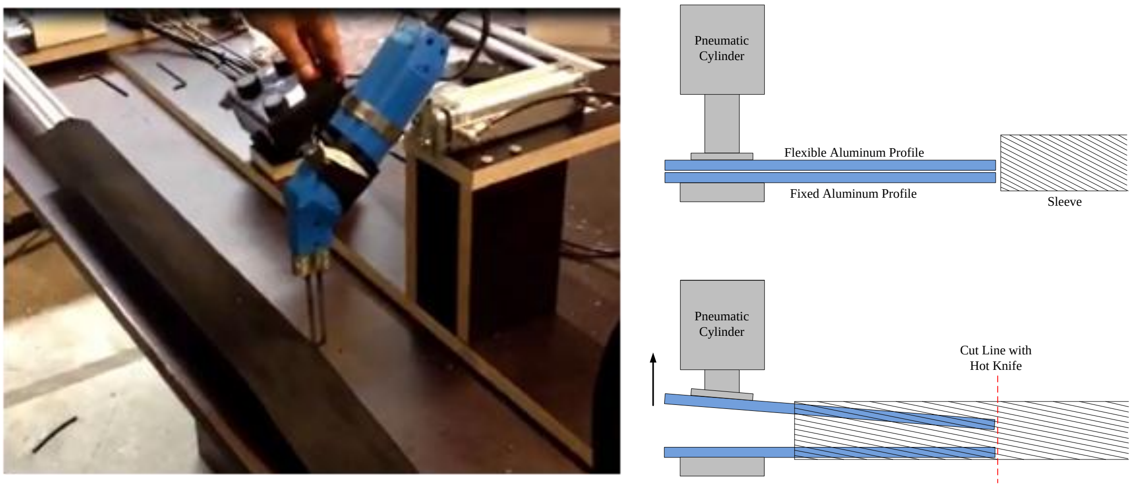

Figure 80. Replacing aluminum tubes with aluminum profiles.

Since the aluminum profiles had a higher strength than the aluminum tubes, they did not bend. However, problem with using aluminum profiles was that they transferred the pressure to the cylinder's pistons. As a result, the cylinder pistons could not open evenly, causing a slope in the aluminum profile and preventing the sleeve from stretching completely near the cutting point. In order to ensure that the cylinder's pistons would open evenly, a back stop was designed (Figure 81).

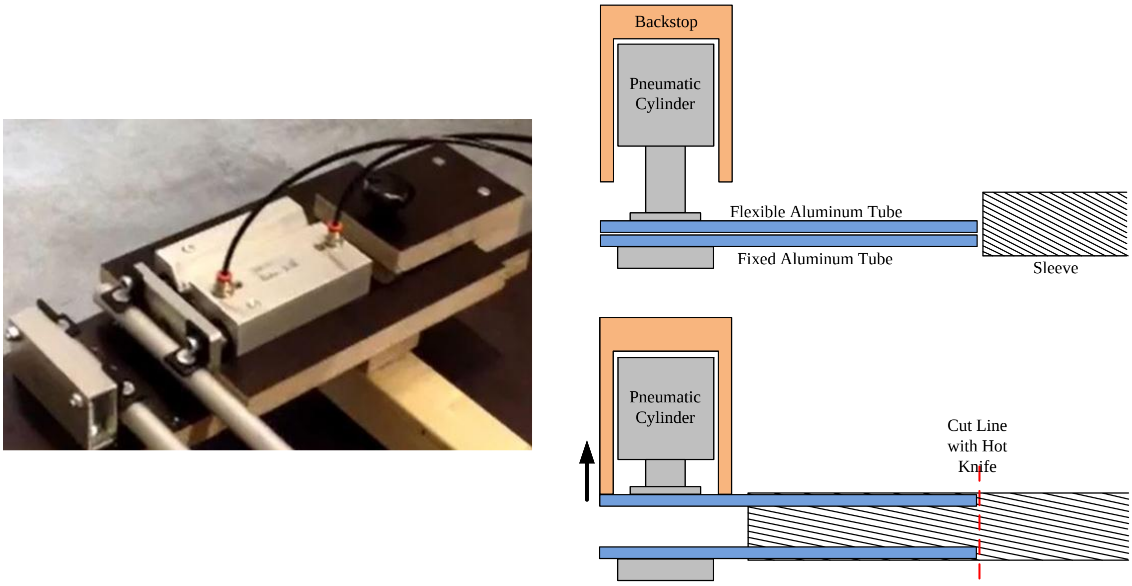

Figure 81. Backstop for controlling cylinder's pistons movement.

The backstop initially provided promising results when it was assembled on the sleeve cutting machine mock-up. Therefore, it was decided to build another mock-up suitable for cutting sleeves up to 2 meters long. In the new mock-up, aluminum profiles were 1 meter longer than the previous ones. Despite having the backstop, the aluminum profiles were simply too long and did not have enough strength to remain straight all the way. Thus, the aluminum profiles bent in a manner similar to the aluminum tubes (Figure 82).

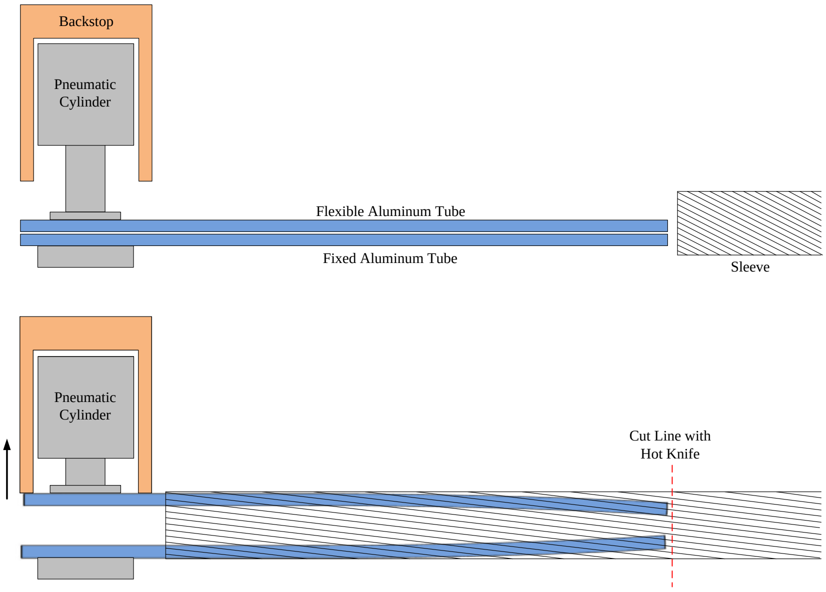

Figure 82. Problems with using the long aluminum profiles.

Since both the aluminum profile and aluminum tube ultimately bent in the sleeve cutting process, it was decided to continue the development with aluminum tubes. The sleeve cutting process with the mock-up shown in Figure 79 was slow. To speed up the process, a few features were added to the mock-up. The hot knife was replaced with a more powerful model. In addition, a holder was designed for the sleeve roll and pneumatic switches were replaced with a foot pedal. Hence, the operator was able to control the sleeve better in the cutting process (Figure 83).

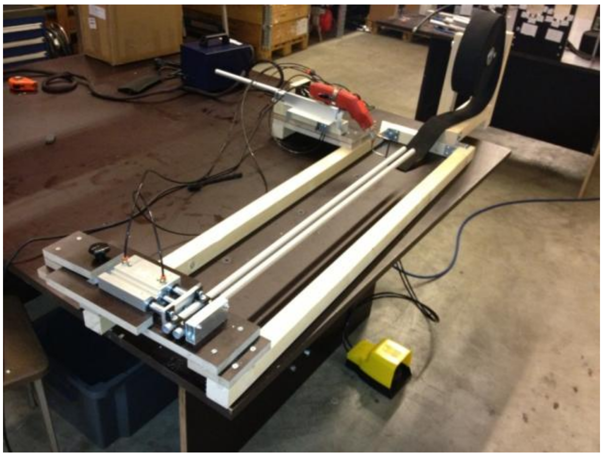

Figure 83. Assembling foot pedal and sleeve roll holder to the mock-up.

Another back stop was added to the cylinder controlling the hot knife, allowing the operator to adjust the backstop to control the movement of the hot knife (Figure 84).

Figure 84. Backstop for controlling cylinder stroke.

Finally, a measuring system was added to enable the operator to easily set the machine and then cut a batch of sleeves with the same length more efficiently (Figure 85).

Figure 85. Designing a sleeve measuring system for the mock-up.

During the testing process, it was realized that it may not be essential to stretch the sleeve completely before cutting. In fact, as long as the two sides of the sleeve are separated, the quality of the cut is acceptable. In addition, based on the monthly sales volumes (as it was discussed in Section 5.3), the majority of the sales were based on narrow sleeves. Thus, a decision was made to design a machine which can work for up to 75 mm flat sleeves. The results of the tests confirmed that an aluminum tube with a 16-mm outer diameter can open all the sleeves up to 75-mm flat wide enough to attain a clean cut (Figure 86).

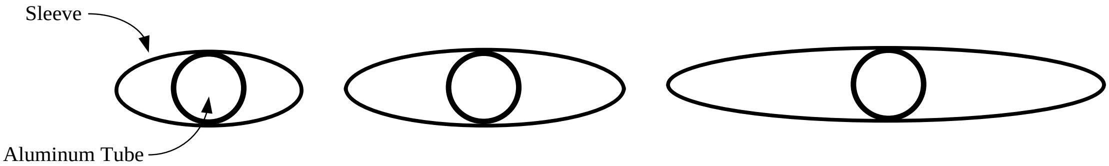

Figure 86. One size aluminum tube for all narrow sleeves.

Initially, the idea was tested with sleeves shorter than 1 meter. After receiving successful results from the initial tests, it was decided to make the next version for up to 2-meter-long sleeves (Figure 87).

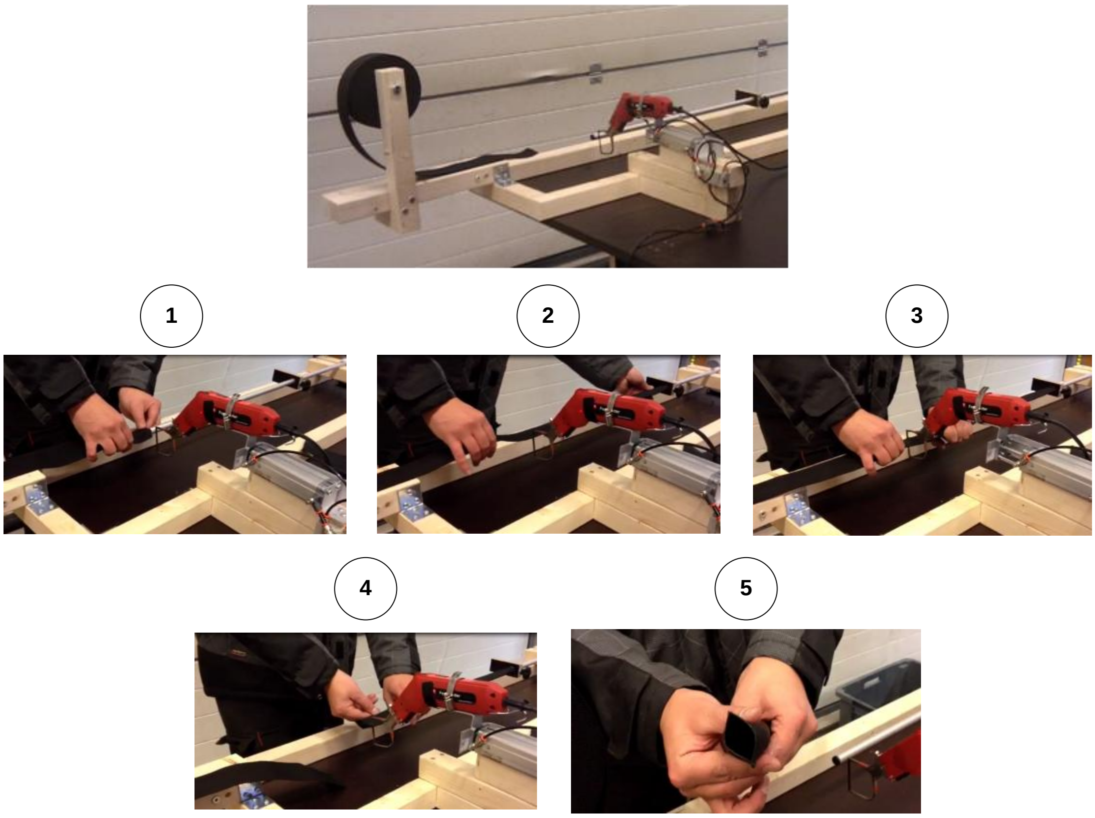

Figure 87. Sleeve cutting mock-up for cutting two meter sleeves second version.

Before starting the process, it is necessary to adjust the back stop to speed up the cutting process. The first step would be to slide the sleeve into the aluminum rod (picture 2). By pressing the foot pedal, the blade starts to move and cuts the sleeve (picture 3). There is a limit switch for the blade and, when triggered at the end of the cut, the blade automatically returns to its initial position. Finally, the sleeve should be pulled from the aluminum rod (picture 4). The last picture shows the quality of the cut with this mock-up. This mock-up could provide all the functionalities of the final machine. However, this mock-up was not suitable for continuous production, since the blade needed to cool down and be cleaned on average after 10 sleeves.

6.3 Building the Value Proposition

The third step in the sleeve cutting machine project was to build the value proposition. This process started in the mid-September 2014 and continued until the end of October 2014. During this period, a time and cost study was implemented to generate the needed inputs for building the value proposition. Figure 88 shows that stage of the sleeve cutting machine project on the project timeline.

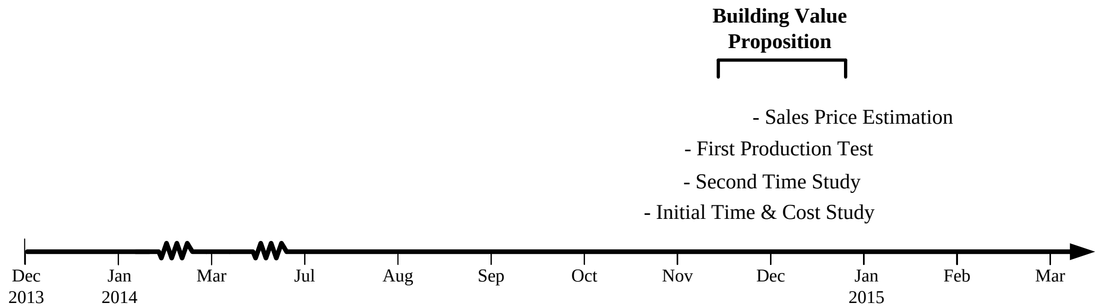

Figure 88. Value proposition construction stage of sleeve cutting machine project.

As discussed earlier in this chapter, the quality of the cut and process time are the two most important aspects which should be taken into account in the sleeve cutting process. As previously mentioned, two methods are currently used by companies to make sleeve pieces. The first method was to measure and cut the sleeve manually and then burn the edges with a tool such as a butane torch (Figure 61). The second method was to use an automated measuring and cutting machine and then finish the sleeve edges manually with a hot metal plate (Figure 62). In addition, a new solution was developed to facilitate the sleeve cutting process by combining the cutting and finishing steps (Figure 87). All these solutions can provide acceptable cut quality. Therefore, the only way to select the best solution is through process time.

The process time needed for each of the above mentioned methods was calculated differently. Since there was no possibility to access any of the customers who are doing the sleeve cutting process manually, two people from the development team were selected to act as operators. Each of the operators was asked to cut five 60-cm sleeve pieces, and the whole process time was recorded with a stopwatch. Later on, the process time for each operator was divided by 5 to calculate the time required for cutting and melting one sleeve. Finally, the process time for manual sleeve cutting was obtained by calculating the average process time of both operators (Table 10).

Table 10. Manual sleeve cutting time study.

	Operator 1	Operator 2
Overall Sleeve Cutting Time	183 sec	202 sec
Time per One Sleeve Cut	36.6 sec	40.4 sec
Average Manual Sleeve Cutting Process Time	38.5 sec	

The second sleeve cutting method is the one used by the case company. Based on the statement of the case company manager, 100 sleeves can be cut in 1 hour, the process time for cutting one sleeve is 36 seconds (Figure 89).

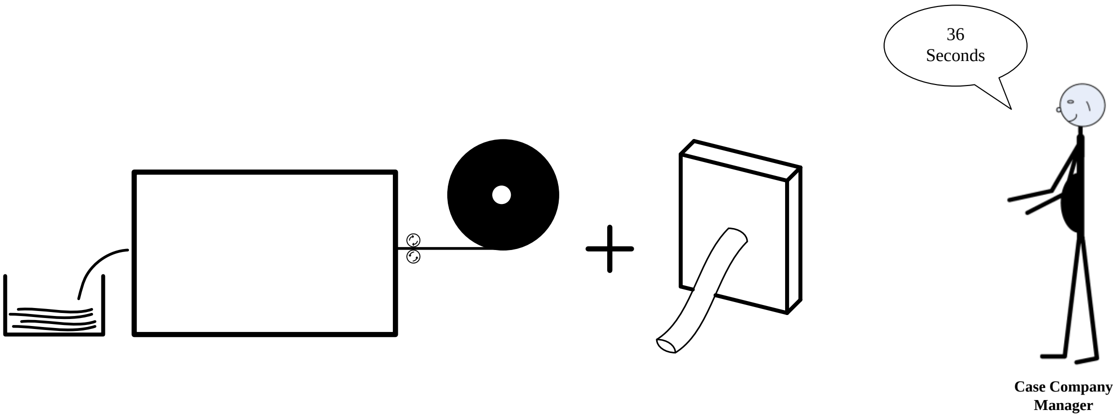

Figure 89. Case company sleeve cutting machine time study results.

The initial time study for the new solution was conducted by utilizing a demo video which was made for the case company managers. In this video, one of the development team members was running the latest mock-up to cut four sleeve pieces continuously in order to show the potential of the idea to case company managers. Based on this video, the process time for cutting four 60-cm sleeves was 43 seconds, indicating 10.75 seconds on average per sleeve (Figure 90).

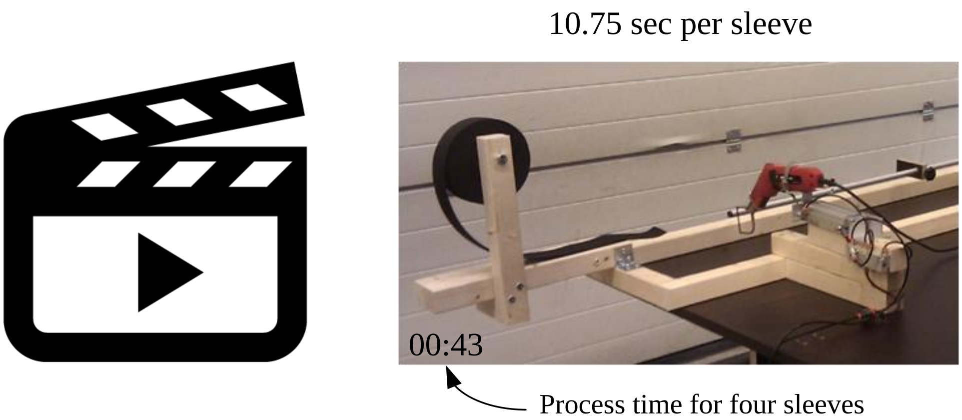

Figure 90. Sleeve cutting machine time study results.

Figure 91 compares the results for the time study of these three sleeve cutting methods. The results showed that the new sleeve cutting method can significantly reduce the process time.

	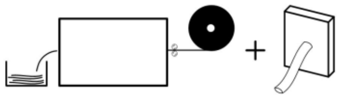	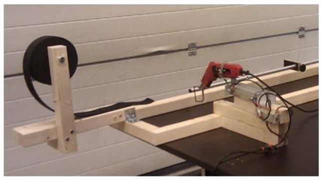
38.5 sec	**36 Sec**	**10.75 Sec**

Figure 91. Comparison between different sleeve cutting methods.

This finding was shared with the case company managers and with one of the customers. The customer became interested in testing the functionality of this idea further and provided an opportunity for the development team to use the sleeve cutting mock-up in their production. They requested that a batch containing 80 pieces of 60 cm sleeves be prepared for one of their customers (Due to limitations in continuous use of the sleeve cutting mock-up, the test batch was made in batches of 10).The second time study was done at this stage. The first three batches were made by three members of the development project who had experience in operating the sleeve cutting mock-up, and the process time for each batch was recorded. The results of this time study are presented in the table below.

Table 11. Sleeve cutting mock-up time study results.

	Operator 1	**Operator 2**	**Operator 3**
Overall Sleeve Cutting Time for batch of 10	103 sec	110 sec	98 sec
Time per One Sleeve Cut	10.3 sec	11.0 sec	9.8 sec
Average Manual Sleeve Cutting Process Time	10.36 sec		

After completing the time study, the customer's production manager and one of the operators were asked to join the test. The operator was trained to work with the machine, and he was asked to continue preparing the test batch. When the test batch was ready, the production manager and the operator were asked to give their feedback. The production manager approved the concept and the operator was happy with the performance of the machine. Figure 92 shows the first production test of the sleeve cutting mock-up.

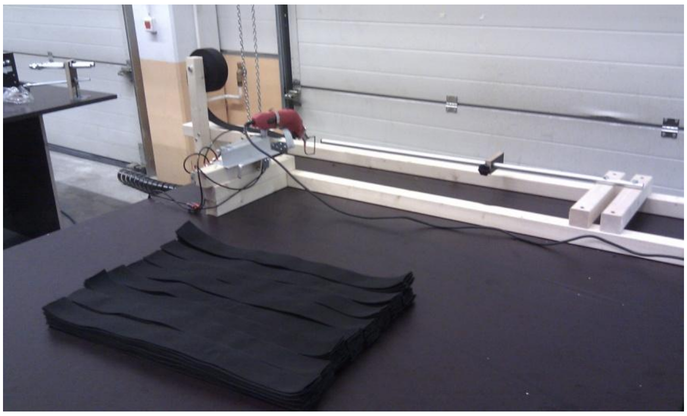

Figure 92. Sleeve cutting machine production test.

Approval of the customer represented a very important milestone in the development of the sleeve cutting machine. Hence, it was the time to calculate the approximate sales price of the machine. In order to calculate the sales price, the first step would be to estimate the cost of making the machine. Based on the final wooden mock-up, it was very easy to calculate the price for the aluminum frame, since the wooden mock-up was made from wooden pieces with the same dimension as the aluminum profiles. Thus, by measuring the length of the wooden parts, it was possible to calculate approximately how much aluminum profile would be needed to build the frame (Figure 93).

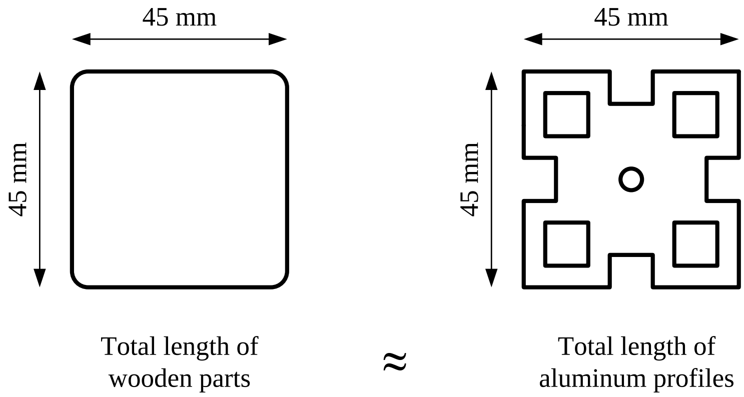

Figure 93. Wooden frame vs. aluminum frame

In addition, the pneumatic system and the hot knife for the final product would be almost the same as the one which was built for the wooden mock-up. The only challenging part was estimating the cost of a few attachment parts which was acquired through discussion with a local supplier. Table 12 shows the cost estimation of the main components of the sleeve cutting machine and the sales price calculated from the information gathered by building the fully functional wooden mock-up.

Table 12. Sleeve cutting fully functional mock-up bill of material.

Components	Price
Hot knife	[redacted]
Pneumatic System	[redacted]
Aluminum Frame	[redacted]
Others	[redacted]
Total Cost	[redacted]
Gross Profit	[redacted]
Sales Price	3 000 €

Based on this estimation, the case company, in order to cover its expenses and possibly gain some profit, needs to sell the machine at around 3000 €. However, sales price should not be only about setting a price in a way that it is profitable for the supplier. Customers also need to see the profitability of this investment. Therefore, after evaluating the approximate sales price, it was time to calculate the payback period for customers.

If customers are using the fastest solution (which is automated cut and manual finishing), the new sleeve cutting method saves 25 seconds per sleeve. The average cost of an operator in Finland is 30€ per hour. Thus, savings per sleeve cutting would be 0.208€ as shown below.

Cost of operator per second: 30 € / 3600 = 0.0083 €

*Savings per sleeve cutting: 0.0083 * 25 = 0.208 €*

This calculation indicates that cutting one sleeve with the new sleeve cutting machine can save 0.208 € for the company, yet this cost saving is not coming for free. The customer needs to spend 3000 € to acquire the sleeve cutting machine. Assuming that the sleeve cutting machine is working for 5 years and it does not have any salvage value, the depreciation of the machine would be as follows.

Depreciation: 3000 € / 5 = 600 €

The payback period for the machine is directly related to the number of sleeves cut by the customer. Assuming a customer cuts 20000 sleeves annually would yield a payback period for the machine as follows.

Cost Savings: 20000 0.208 € = 4160 €*

Payback period: 3000€ / 4160 € ≈ 0.72 year

If customers cut 20000 sleeves per year, the sleeve cutting machine would pay for itself in 0.72 years. Of course, the annual sleeve cutting volume of companies may vary significantly. Hence, it would be logical to have a simple system to demonstrate the payback period for different sleeve cutting volumes. The following section first explains the process of building an alpha prototype of the sleeve cutting machine and then continues the value proposition discussion by illustrating a simple tool to cover the payback period calculations for different volumes.

6.4 Alpha Prototype and Value Proposition

The last step in the sleeve cutting machine project consisted of testing and validation. This process started at the end of October 2014 and continued until the end of February 2015. In this period, due to a request by the case company managers, an alpha prototype of the sleeve cutting machine was designed, built and shipped to customers for long-term testing purposes. Figure 94 shows the testing and validation stage of the sleeve cutting machine on the project timeline.

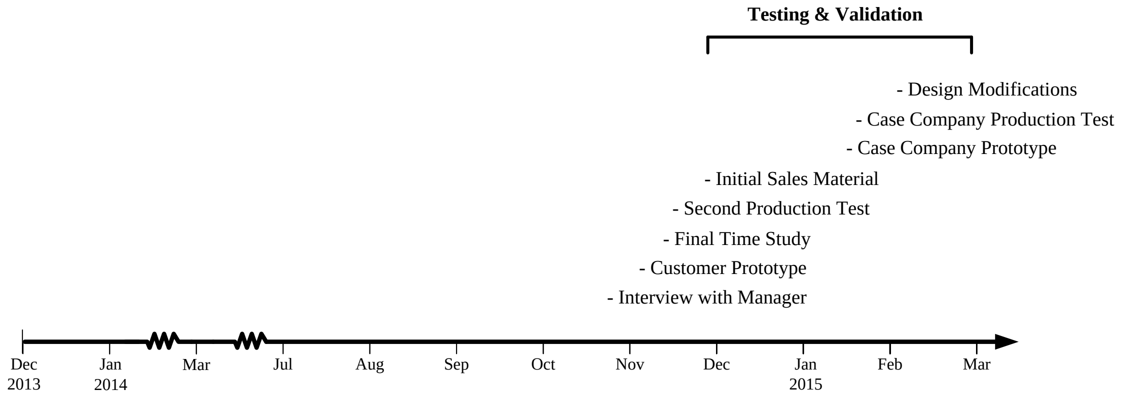

Figure 94. Testing and validation stage of sleeve cutting machine project.

Section 6.1 showed that customers mainly cut sleeve rolls to pieces less than 2 meters in length. In addition, high volume sleeve usage are associated with narrow sleeves (less than 75 mm in diameter). As a result, a decision was made to build three machines which would be suitable for cutting up to 75-mm (flat) sleeves at a maximum length of 2 meters.

A 3D model of the sleeve cutting machine was designed, and then parts were ordered for building one machine. The 3D model was utilized to create the bill of materials for one sleeve cutting machine (Figure 95).

Figure 95. Sleeve cutting machine 3D design.

Later on, the machine was sent to one of the selected customers for production tests. The customer was asked to give initial feedback after the first run of the machine. Since the customer was completely happy with the design and performance of the machine, parts for the two remaining machines were ordered. Figure 96 illustrates the sleeve cutting machine.

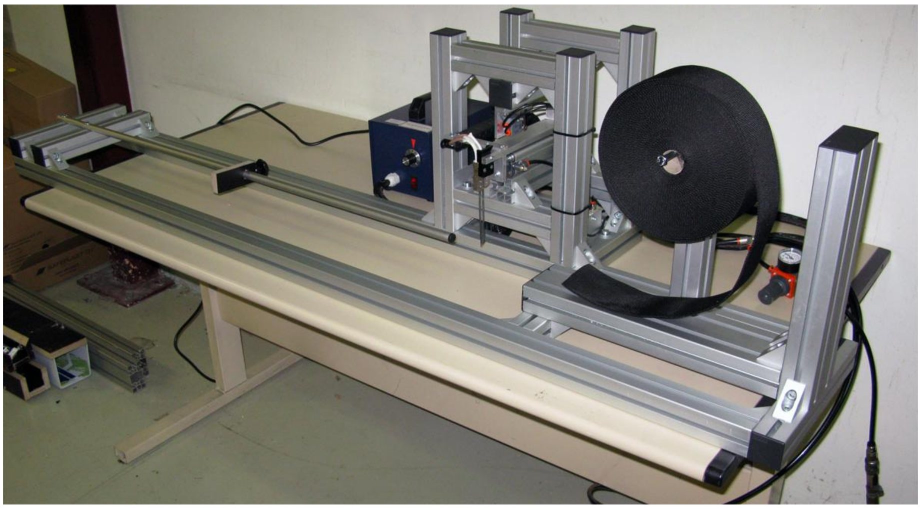

Figure 96. Sleeve cutting machine.

A final time study was carried out with the sleeve cutting machine shown in the figure above. The sleeve cutting machine was found to have an average process time of 10 seconds per sleeve, almost the same as that obtained using the fully functional wooden mock-up. Therefore, calculations based on the time study for the wooden mock-up were proven to be accurate. An initial version of sales material and user manual were then prepared based on information gathered through sales personnel, customer feedback and in-house tests. Sales materials were created to help the sales team in introducing the new machine to their customers, and the user manual was written to provide customers with enough know-how to work with the machine. Figure 97 shows the use of the sales material for communicating with a customer.

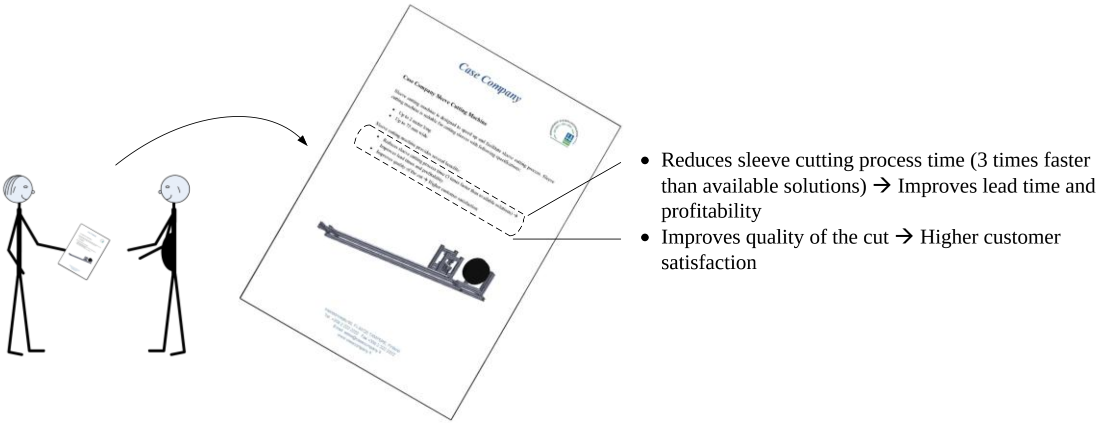

Figure 97. Sleeve cutting machine sales material.

In addition to traditional sales materials, which included the main benefits and differentiation factors of the sleeve cutting machine, a table was designed to help customers see the value of the sleeve cutting machine themselves (Table 13).

Table 13. Payback period table designed for customers.

Volume (Annual)	Payback Period (Years)
10 000	1.44
15 000	0.96
20 000	0.72
25 000	0.58
30 000	0.48

The table above has two columns: volume and payback period. By looking at this table and comparing their annual sleeve usage, customers could immediately see how long it would take them to get back the money invested in the sleeve cutting machine. These figures reduce the customers' degree of uncertainty about purchasing the cutting machine, while at the same time increasing the level of trust between the customers and the case company. Figure 98 shows the application of the payback period table in the sleeve cutting machine sales materials.

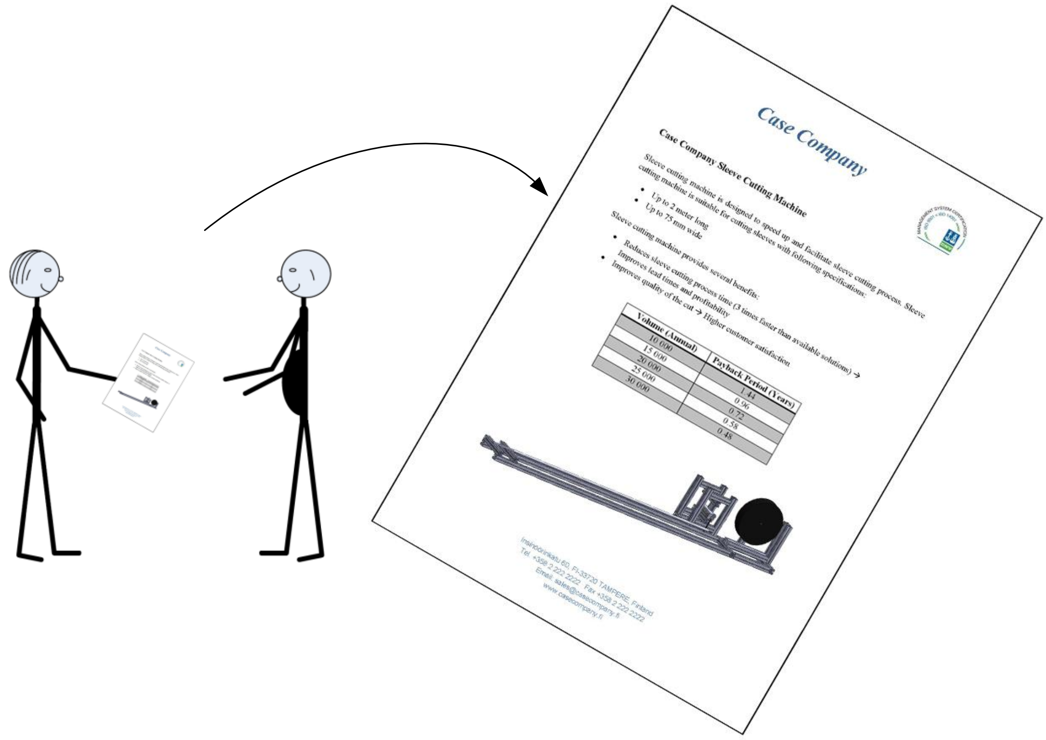

Figure 98. Application of payback period table in sales material.

After constructing the sales material and value proposition, another machine was built and sent to the case company to replace their current sleeve cutting process and to conduct a final production test. An operator in the case company was trained and was asked to prepare 400 sleeve pieces (60 cm) using 75-mm flat sleeve (Figure 99).

Figure 99. Sleeve cutting machine production test in the case company.

When the order was finished, both the operator and the production supervisor were asked to give their feedback. The production supervisor was happy with the performance of the machine:

> *"Sleeve cutting machine is operating in significantly faster pace in comparison with our current process. In addition, quality of the cut is as good as what we had before."*

However, she also had a few comments to improve the performance of the machine and safety for the operator:

> *"First of all, blade needs to be protected to prevent operator's fingers from touching the blade by accident when inserting the sleeve. Also it is necessary to prevent sleeve from touching the blade during installation and removal. Second, sleeve roll holder should be modified in a way that there is more space for pulling the sleeve and there is a mechanism to prevent sleeve from dropping. Finally, plastic cap at the end of the tube should be removed because sleeve after cut tended to attach to the plastic cap."*

In order to address the production supervisor's comments, the alpha prototype was modified. Two aluminum profiles were added beside the hot knife to protect the operator's hand and the sleeve. Figure 100 shows the aluminum profiles which shield the hot knife.

Figure 100. Protecting hot knife for safety reasons.

The sleeve holder was then disassembled and replaced with a new system. In this new system, the sleeve roll is positioned horizontally to prevent the sleeve rounds from dropping during the sleeve cutting process. In addition, it made the sleeve insertion process easier for the operator (Figure 101).

Figure 101. New sleeve roll holder.

Finally, a plastic cap covering the end of the tube was removed to eliminate the possibility of the sleeve touching and becoming stuck to the plastic cap after the cutting process (Figure 102).

Figure 102. Removing plastic cap covering end of the aluminum tube.

This section has thoroughly explained the development process of the sleeve cutting machine. The following chapter discusses sleeve cutting machine project from the perspective of the theoretical framework built in this thesis. Furthermore, the results of the study are analyzed and practical limitations identified.

7. DISCUSSION AND LESSONS LEARNED

7.1 Overview of the Problem and Framework

In order for companies to maintain their competitive advantage in the market place, they need to develop attractive products (Brown & Eisenhardt, 1995; Cooper & Kleinschmidt, 1991). Customers consider a product attractive only if the benefits perceived from the product surpass the sacrifices made by the customers to acquire it (Khalifa, 2004). Therefore, it is essential to apply customer feedback continuously in the product development process to increase the success rate of development projects (Cooper, 2008). However, gathering reliable feedback from customers is challenging, since customers perceive the real value of the product mainly after experiencing product usage (Lanning, 1998, Woodruff, 1997).

Customers are usually able to experience product usage in the late stages of the development process or even when the product has already been commercialized. The main problem with a real product in use experience in the late stages of the development process is that any changes to the product would be very costly for the company (Thomke, 2003). The main reason for this is that when the design phase of a product is finished, around 80 percent of the product life cycle costs will have already been committed (Belay, 2009; Dowlatshahi, 1992). Hence, the earlier the design changes are made on the product concept, the less costly they will be to implement (Sauer et al., 2006). Mock-ups and prototypes can be utilized to share ideas with customers (Cooper, 2008) and to receive their requirements and feedback (Liou, 2007). Thus, prototyping in PDP can be an effective tool to reduce uncertainties (Brandt, 2007) and may have a significant impact on product cost and quality (Liou, 2007). For this reason, it is suggested that mock-ups and prototypes be built from the very beginning of PDP.

According to Yang & El-Haik (2003), prototypes can be categorized into physical and analytical prototypes. A physical prototype is made from materials to show one or more aspects of a product concept (Campbell et al., 2007; cited in Lie et al., 2013). An analytical prototype represents a product in mathematical or computational form (Wang, 2002). From another perspective, prototypes can be focused or comprehensive. Focused prototypes represent only part of a product function, while comprehensive prototypes demonstrate most or all the functions of the final product (Yang & El-Haik, 2003). Finally, prototypes can be categorized based on fidelity (low fidelity and high fidelity), which is the degree to which a prototype demonstrates the final product. (Liou, 2007) Rudd et al. (1996) made a comparison between low- and high-fidelity prototypes by stating the advantages and disadvantages of each group (Preece et al., 2002).

Yang & El-Haik (2003) categorized physical prototypes into experimental, alpha, beta and pre-production prototypes. However, a large gap still remains between experimental and alpha prototypes, indicating a need for revising the categorization of physical prototypes presented by Yang & El-Haik (2003). This thesis argues that this gap should be filled by introducing a new prototyping group: the fully functional mock-up. Fully functional mock-ups share characteristics of both low- and high-fidelity prototypes. A fully functional mock-up has all the functionalities of a final product but can be built from different materials and components, thus making it a great tool for evaluating performance and the market potential of the final product in the early stages of PDP. At the same time, a fully functional mock-up provides customers with an opportunity to experience product usage before committing the majority of costs. Thus, in case customers require any changes to the product idea, no significant financial losses would be incurred by the company.

A company also needs to build a value proposition to communicate the core competencies and unique characteristics of its offerings to its customers (Rintamäki et al., 2007). Anderson et al. (2006) have shown resonating focus to be the best approach to build a convincing value proposition, though it requires deep understanding of customers and competitors. This thesis argues that for cost-reducing innovations, it is possible to build an accurate resonating focus value proposition by utilizing fully functional mock-ups. Fully functional mock-ups have almost the same performance level as the final product and expose the real value of the product to customers. Hence, reliable time and cost studies can be implemented based on them. The result of the time and cost study can then be used for calculating the cost savings (Δ) of the new process in comparison with the old one. Later on, based on Δ and other information gathered from fully functional mock-ups, a convincing value proposition can be constructed early on in the development process. Figure 103 shows the final framework of this thesis and how it was constructed.

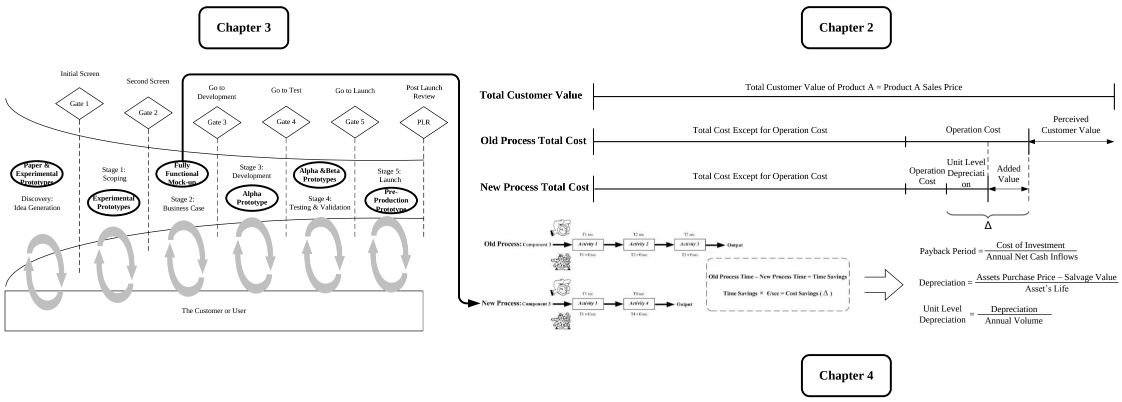

Figure 103. Framework of thesis.

To sum up, this thesis claims that fully functional mock-ups can fill the gap in the categorization of physical prototypes. Fully functional mock-ups are medium fidelity prototypes which can shift customer usage experience of the final product idea to the early stages of product development in order to study customer value. In addition, for cost-reducing innovations, they can provide enough input to build a convincing resonating focus value proposition very early in the development process. In this way, the value of the final product can be communicated to customers before committing the majority of the development costs. Thus, even if the product was not attractive or the customer required changes in the product, this would not incur significant financial losses for the company.

7.2 Reflection of the Case in Framework

As discussed in Section 6.1, the main goal behind the development process was to reduce time in the sleeve cutting process by combining the cutting and finishing steps. For this purpose, several experimental prototypes were built in the idea generation stage of PDP, as shown in Figure 104. Two of the ideas passed the first gate of the development process. In the scoping stage, experimental prototypes were redesigned and built from better materials to be able to reliably test core functions of the product idea. For instance, a hot knife used in the idea generation stage was replaced with a new model that could offer higher temperature.

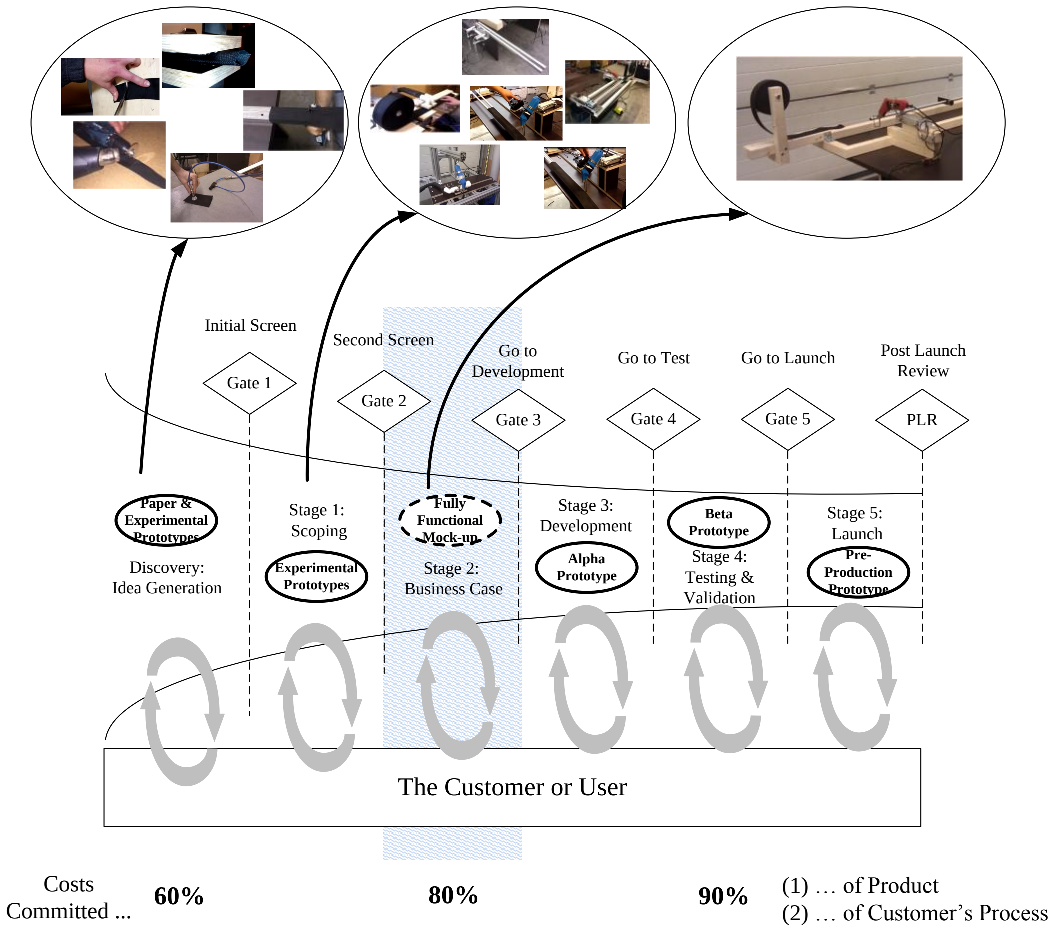

Figure 104. Sleeve cutting machine development process.

At the end of scoping stage, only one idea was selected to proceed to the business case stage. The business case stage was started by designing and building a fully functional mock-up. Since this first fully functional mock-up could not satisfy all the needs, it was modified until it attained a reasonable level of performance. The final fully functional mock-up frame was built of wood and aluminum and was equipped with a pneumatic system and hot knife. Despite using cheap materials in building the components of the machine, it provided all the functionalities of the final product at almost a similar level of performance. The only difference was that the hot knife used in the fully functional mock-up needed to cool down after cutting 10 sleeves.

At the end of the second stage in the development process, a time study was carried out on the manual sleeve cutting, automated cutting with manual finishing and fully functional sleeve cutting mock-up. The new solution cut and melted sleeves much faster than the current methods. Therefore, a cost analysis was done by comparing the new solution with the best available method (automated cutting and manual finishing). Figure 105 shows the result of the cost study.

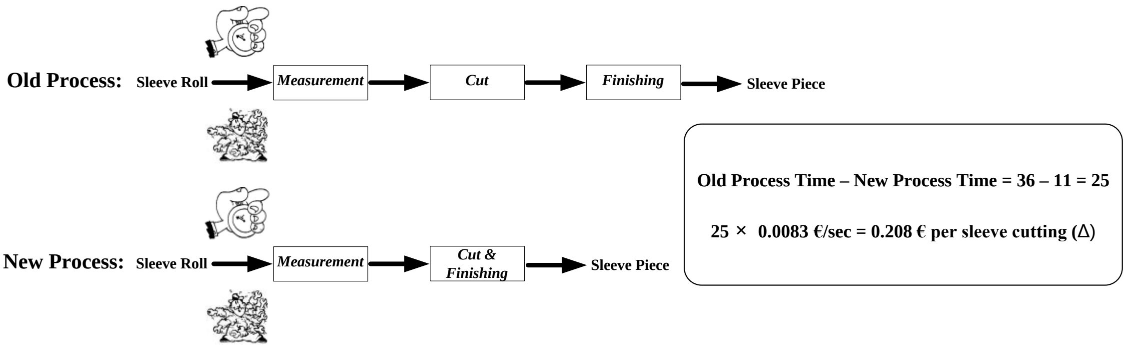

Figure 105. Sleeve cutting time and cost study.

As shown in the above figure, the sleeve cutting machine saves 0.208€ per sleeve in comparison with the best available solution. However, this cost saving does not come for free. Customers need to invest a certain amount of money to acquire the sleeve cutting machine. Figure 106 shows how unit-level depreciation included when calculating added perceived value using the framework.

The following figure shows that total customer value does not change for the old and new processes, since changes in the production process have no impact on the final product offered to the customers (sleeved hose assembly). In addition, the total cost for making one hose assembly is the same for both old and new processes because the hose assembly manufacturing process is completely independent from the sleeve cutting process.

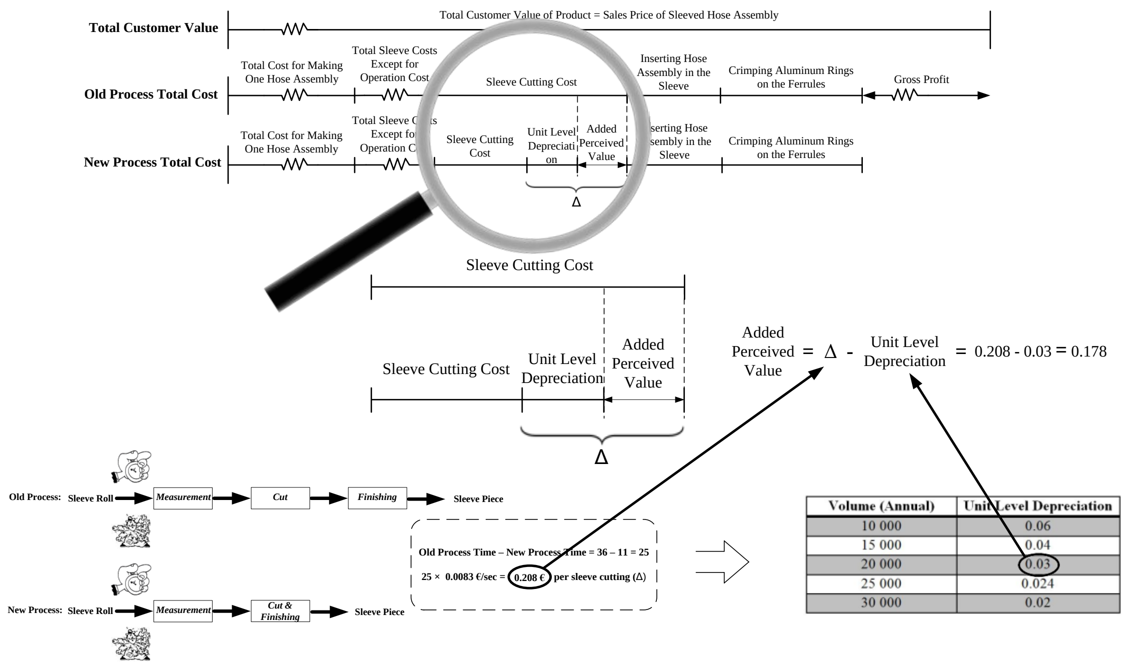

Figure 106. Customer value model and financial analysis for sleeve cutting machine.

The above figure divides the sleeve costs into two groups. In the first group, the majority of sleeve costs is related to the purchase price. The second cost group is the sleeve operation cost. Sleeve operation costs mainly result from the costs of three activities: sleeve cutting, inserting the hose assembly into the sleeve and crimping aluminum rings onto the ferrules. From these activities, only the sleeve cutting changes while the other two remain the same for the both the old and the new processes. Hence, the case company, by providing a sleeve cutting machine, only targets sleeve cutting costs, with all the other costs for making a sleeved hose assembly remaining the same.

Compared to the old process, the sleeve cutting machine saves 0.208 € per sleeve. In order to accomplish this cost saving, the customer needs to pay for the sleeve cutting machine, which adds a unit level depreciation of the machine to the sleeve cutting operation cost. This trade-off is beneficial for the customer (increase perceived value) only if the unit level depreciation of the machine is less than 0.208 €. Thus, the proportion of one sleeve cutting from machine depreciation is directly related to annual sleeve cutting volume. For instance, if the annual sleeve cutting volume of the customer is 20000, the unit-level depreciation is 0.03 €, and the added perceived value of utilizing the sleeve cutting machine is 0.178 €. Thus, for a customer with an annual sleeve cutting volume of 20000, can save 3560 € per year by utilizing the sleeve cutting machine.

Figure 107 shows the application of the framework in the sleeve cutting machine project. The wooden fully functional mock-up built in the second stage of the product development process provided the possibility for a time study. A time study comparing the fully functional mock-up and the average process time of the old sleeve cutting solution showed a time and cost saving when using the new process. The result of this time and cost study was then used for calculating the payback period and added perceived value.

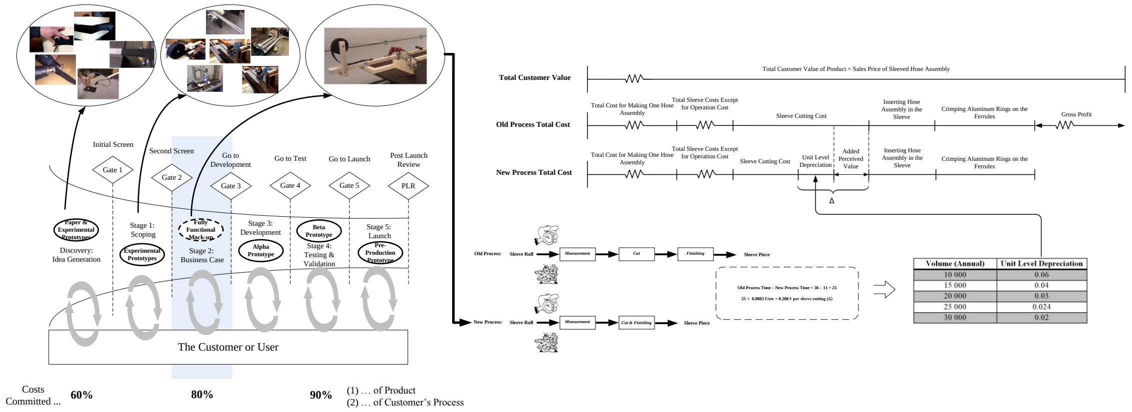

Figure 107. Application of the framework in the sleeve cutting machine project.

The next step was to construct a resonating value proposition in order to communicate the value to the customers. Two key points were chosen for building a convincing value proposition. The first point was the quality of the cut which was very important for the customers. In other words, without having a high-quality cut, customers would not even consider buying the machine. The second key point was the sleeve cutting process time, as it was the main feature customers have been looking for in the past years. In addition, cost savings resulted from a faster sleeve cutting process was highlighted in the form of a payback period table to improve the level of trust between the case company and the customers.

The final step in the sleeve cutting project was to build an alpha prototype of the sleeve cutting machine to reevaluate all the calculations made based on the fully functional mock-up. A time study was conducted on the alpha prototype, with the results of the time study showing that the sleeve cutting process time is almost the same as that recorded with the fully functional mock-up (10 seconds). This shows that the fully functional mock-up can provide almost the same level of performance as the final product and offers a great tool for product development teams and managers when performing time studies and financial analysis.

7.3 Analysis of the Case Based on Framework

The theoretical framework presented in this thesis was applied in a sleeve cutting machine project to evaluate the viability of the framework. The main reason for developing a new solution for cutting textile sleeve was that the customers had been looking for a new solution to reduce the cost of the sleeve cutting process. Studying available sleeve cutting solutions indicated that combining the cutting and finishing steps would provide the best approach to improve the process time. Therefore, in the idea generation stage of PDP, several ideas were generated to combine these two steps. Mock-ups and prototypes were built from the beginning of PDP for various reasons. First, since the sleeve cutting project members and stakeholders were from different countries, mock-ups and prototypes made it easier to communicate ideas and avoid any potential misunderstanding between team members and stakeholders (Brandt, 2007; Preece et al., 2002). Second, prototyping provided the possibility to test the functionality of the ideas and made it easier to identify problems (Liou, 2007; Preece et al., 2002). Finally, tangible mock-ups and prototypes could provide an opportunity to "feel" the product (Campbell et al., 2007; cited in Liu et al., 2013) and made it possible to involve customers more easily in the brainstorming sessions.

The business case stage of PDP (Stage-gate International, 2014) involved building a fully functional mock-up of the sleeve cutting machine. In order to build the first fully functional mock-up, a sketch of the machine was drawn to identify the components and materials needed for building the mock-up. Core components for the pneumatic system were ordered, and it was decided to build the frame and other parts of wood and aluminum. The first fully functional mock-up was built and tested. The results of the tests showed that more features were required to improve the speed and quality of the sleeve cutting process. Therefore, the sleeve cutting machine was redesigned and some new parts were ordered. The second fully functional mock-up was built by modifying the structure of the previous mock-up and attaching new components to it. Hence, the development team could save time and money mainly because of flexible nature of the first fully functional mock-up. Figure 108 shows the utilization of the fully functional mock-ups in the business case stage of the sleeve cutting machine PDP.

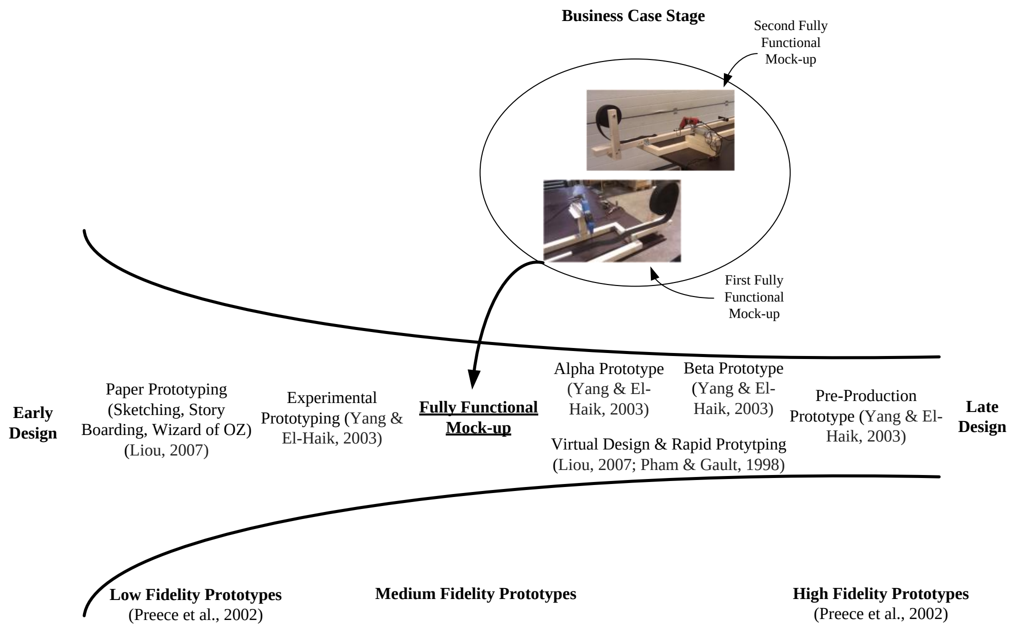

Figure 108. Fully functional mock-ups in business case stage of sleeve cutting machine PDP.

The fully functional mock-up had characteristics of both low- and high-fidelity prototypes (Preece et al., 2002). Since this mock-up was made from cheap materials and components available in the market (Liou, 2007), it had a low development cost. At the same time, the fully functional mock-up included all the functionalities of the final product concept and facilitated communications between stakeholders (Brandt, 2007). The fully functional mock-up enabled the development team to thoroughly test the product concept. More importantly, the fully functional mock-up provided an opportunity for customers to feel and experience product usage very early in the PDP which is the only way for customers to perceive the real value of the final product (Lanning, 1998; Woodruff, 1997) (Figure 109).

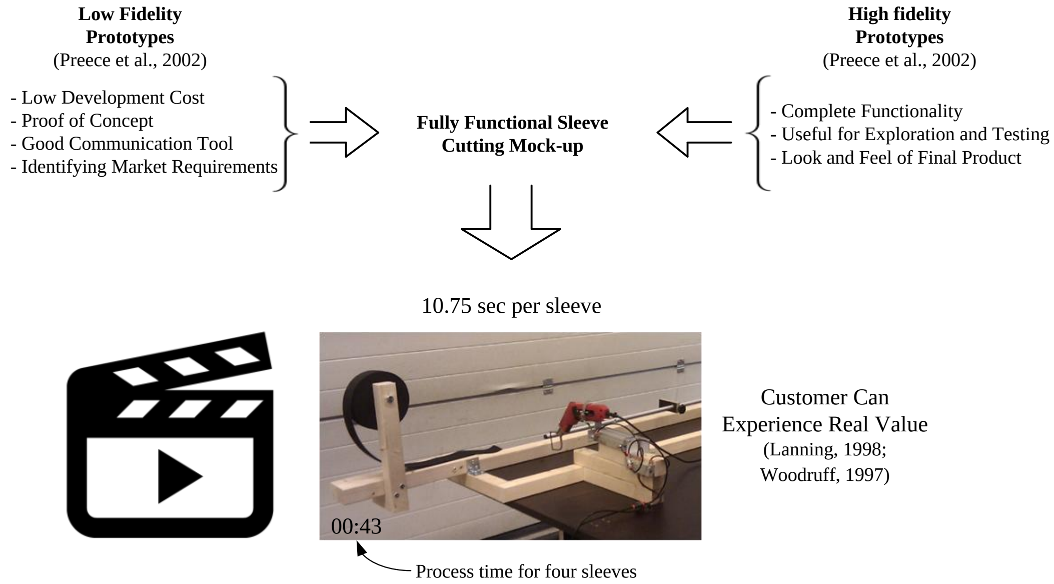

Figure 109. Characteristics and benefits of the fully functional sleeve cutting machine mock-up

One of the interesting aspects in evaluating the sleeve cutting process time was performing the time study on video. It has been common to use a stopwatch in direct observation timing (Zandin, 2001). However, during the sleeve cutting machine project, it was realized that performing the time study based on videos can be a good addition or even an alternative to traditional methods such as a stopwatch. A video-based time study can provide various benefits. First, it allows documentation of the time study process and allows development team members to go through the process as many times as they want (Nuutinen et al., 2008). Second, it reduces the possibility of an error in the time study. There are many software packages available to help attain more accurate results from the video, for instance, by going through the video in slower speed than the original version. Finally, the video can be sent to any of the project stakeholders including customers, thus allowing the customers to see the process and time it themselves.

The aim of the sleeve cutting project defined by the case company was to significantly reduce the sleeve cutting process time. In the idea generation stage of PDP, it was realized that developing current sleeve cutting solutions will not considerably reduce sleeve cutting process time. Basically, since the current sleeve cutting solutions were at a maturity phase, they were close to reaching their performance limit (Christenson, 1997).

Therefore, resources were allocated for generating new ideas, leading to the generation of a very promising idea at the end of the first stage of PDP. The time study conducted on this idea showed that it can reduce the sleeve cutting process time from 36 to 18 seconds by combining two steps into one (Figure 110).

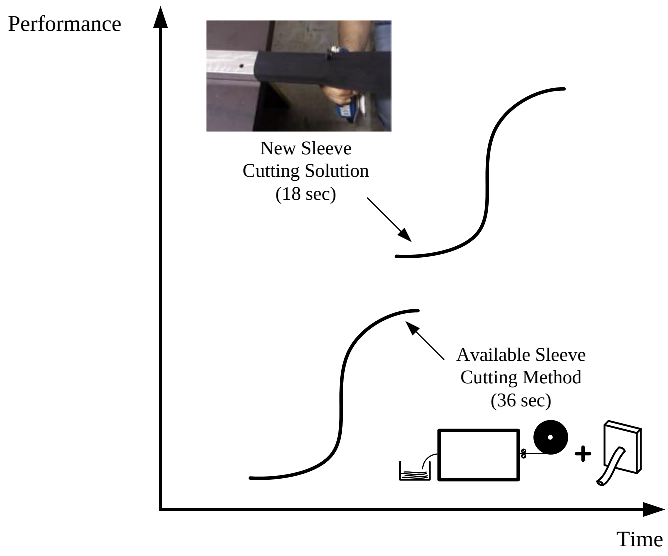

Figure 110. Sleeve cutting technology jumped to a new S-curve.

The new sleeve cutting machine idea had the potential to be a starting point for a new technology S-curve (Foster, 1988) because the difference between the new sleeve cutting solution and the current one was so great. After this stage, the idea was further developed and the performance level increased rapidly leading to the building of the sleeve cutting fully functional mock-up. Figure 111 shows the incremental development of the new sleeve cutting machine idea.

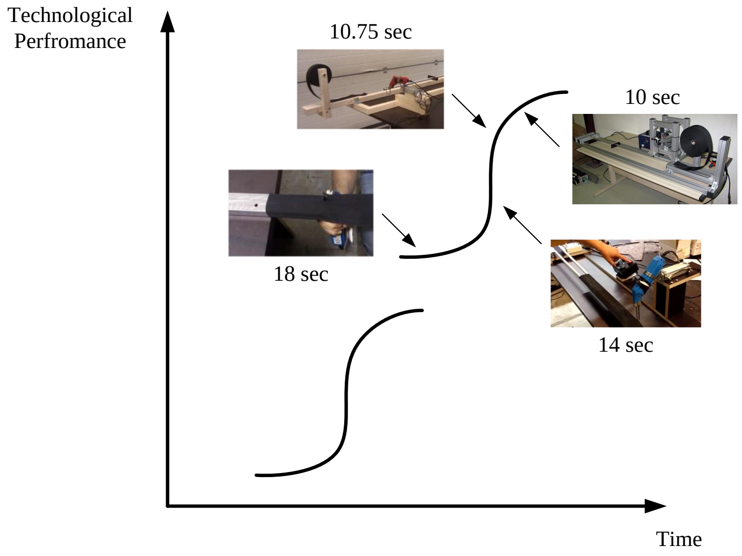

Figure 111. Incremental development of the new sleeve cutting machine idea

The fully functional mock-up showed that performance level of this technology approaching its limit. Therefore, it was time to build an alpha prototype of the sleeve cutting machine and send it to the customers for evaluation.

7.4 Analysis of the results

Empirical study of this thesis showed that fully functional mock-ups can have a significant role in building value proposition in the early stages of development, especially in the case of cost-reducing innovations. Similar results were achieved when applying the framework in the hose spiraling project. The results of initial tests and analysis done on the hose capping mock-ups were similar to those in the hose spiraling and the sleeve cutting machine projects. However, the hose capping project was cancelled in the middle of the development process, thus preventing a fully functional mock-up of the hose capping machine from being built.

The case company managers and customers at the beginning were skeptical about the functionality and reliability of the fully functional mock-ups. Surprisingly, they changed their minds as soon as they saw the first fully functional mock-up. Therefore, the idea of using fully functional mock-up in evaluating perceived customer value passed the weak market test (Lukka & Kasanen, 1995). The case company managers saw the benefits of a fully functional mock-up and were willing to invest more in the development project. The customers were happy with the fully functional mock-up mainly because they saw it as an opportunity to feel and experience product usage. In addition, they became more interested in cooperating in the development process and in sharing their ideas.

The sleeve cutting fully functional mock-up was a great tool to gather almost all the information needed for building a resonating focus value proposition (Anderson et al., 2006). One point of parity and one point of difference (Anderson et al., 2006) were chosen to build the value proposition. The quality of the cut was the point of parity, and sleeve cutting process time was the point of difference. With only these two points, a convincing resonating focus value proposition was made to communicate the value of the sleeve cutting machine to customers. Figure 112 illustrates the comparison of value proposition accuracy made in stage 2 and stage 4 of PDP.

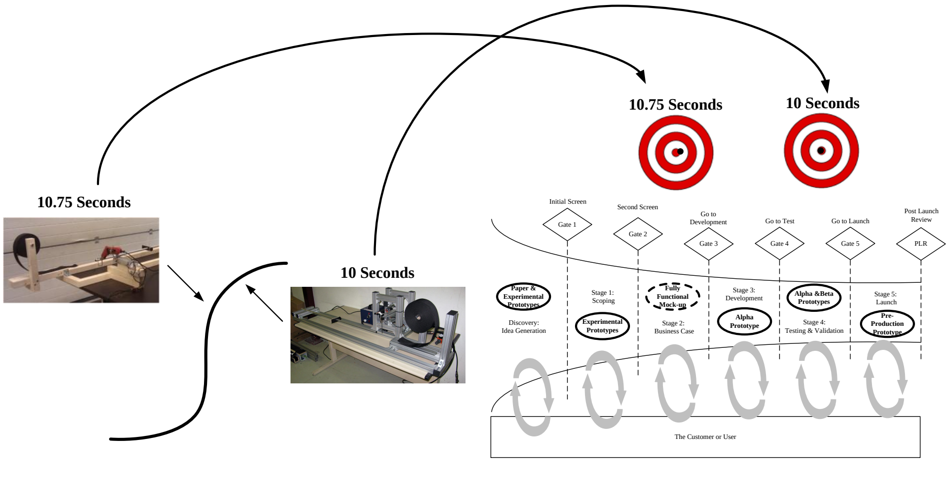

Figure 112. Comparison of value proposition accuracy made in stage 2 and stage 4.

The above figure shows that the result of the time study on the fully functional mock-up and the alpha prototype were almost the same (10.75 vs. 10), thus confirming the reliability of the calculations made based on the fully functional mock-up.

After the alpha prototype was tested in the case company production facility, a new idea was generated. This idea made it possible to speed up the sleeve cutting process from 10 to 7 seconds as well as to cut and melt sleeve pieces at any length. Due to confidentiality of the idea, the development process of the new idea was not discussed in this study. However, comparison between value proposition accuracy of the fully functional mock-up and the alpha prototype of this idea are presented in Figure 113.

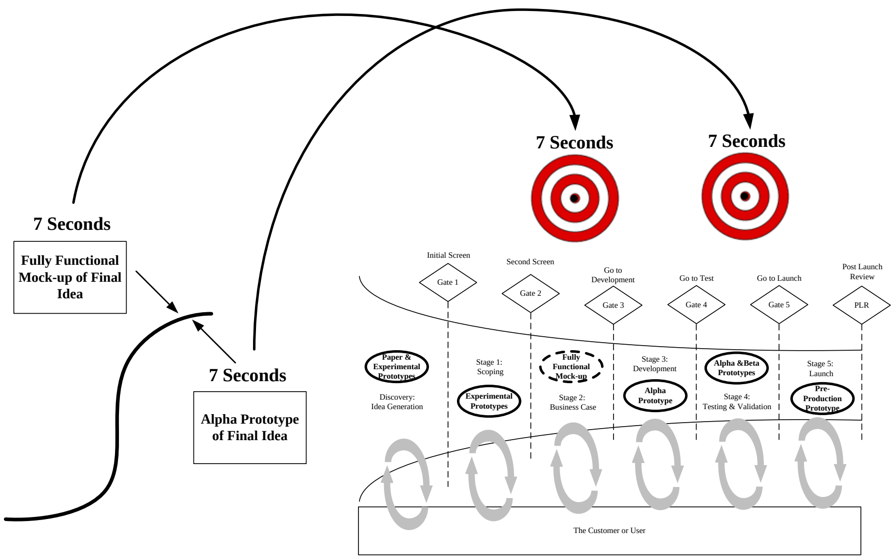

Figure 113. Value proposition accuracy validation.

Despite the interesting results achieved in the empirical study, there are some limitations. First, the empirical study of this thesis was done only in the case company and documented with only one product. More importantly, the technical complexity of all three projects that theoretical framework was applied in were low. In other words, it was possible to build fully functional mock-ups out of various materials and available components. However, it might not be the case for all cost-reducing innovations. In other words, it may be more challenging to design a cheap fully functional mock-up for highly complex products or at least demonstrate all the functionalities. As a result, the viability of this framework should be limited to simple cost-reducing innovations until the framework can be tested with more complex innovations.

8. CONCLUSIONS

In today's highly competitive market, companies are fighting to keep their competitive advantage and even outpace others. Product development is one of the companies' functions which can have a major role in this endeavor. Companies that develop products which are appealing to customers are likely to win. Therefore, companies are increasingly focusing on understanding customers' real needs and involving them in the development process. However, reliable feedback from customers can only be received after customer experience a product in use. As a result, although customers are sometimes asked to give feedback about product ideas in the early stages of development, the overall opinion of customers are mostly gathered at late stages of development. At these stages, the product has already been designed and the majority of the costs already committed. Hence, even if customers ask for changes in the product, it would be too costly for the company to implement those changes, even though they might have an impact on the competitive position of the company in the marketplace.

This study was conducted to discover alternatives for companies to test the market potential of their products and to gather customers' overall feedback about their products as early as possible in the development process. For this purpose, this thesis introduced the concept of a fully functional mock-up and discussed the role of this mock-up in constructing value proposition for cost-reducing innovations in the early stages of product development process. The objective was limited to cost-reducing innovations due to limitations in the empirical study. To address the objective of this thesis, a theoretical review was conducted and a framework was designed. To test the viability of this framework was tested in a real-life situation involving three cost-reducing development projects, of which only the sleeve cutting project has been discussed in this thesis.

The important findings of this thesis were that fully functional mock-ups can offer a great tool for communicating the whole product concept, its functionality and performance at the early stages of the development process. A time and cost study on fully functional mock-ups enabled the gathering of enough information to build a convincing and accurate value proposition and to communicate this proposition to customers. Moreover, since fully functional mock-ups are made in the early stages of the development process, the product idea can be easily and quickly modified based on customers' feedback before committing the majority of product life cycle costs. The result of the empirical study proved the practical validity of the theoretical framework presented in this thesis. The fully functional mock-up built for sleeve cutting machine also proved to be a very useful tool for communication between the case company and customers. In addition, the value proposition made based on the fully functional mock-up was almost as accurate as the one later built based on an alpha prototype of the machine.

In the sleeve cutting machine project, building the fully functional mock-up was begun at the business case stage in the product development process. However, it would even have been possible to start building fully functional mock-ups at earlier stages of PDP. The sooner the customer is given a chance to work with the product and to experience and feel the product in use, the less costly it would be to modify the idea based on customer feedback or even cancel the project. Figure 114 shows idea of shifting customer usage experience of product idea as early as possible in the PDP by utilizing fully functional mock-ups.

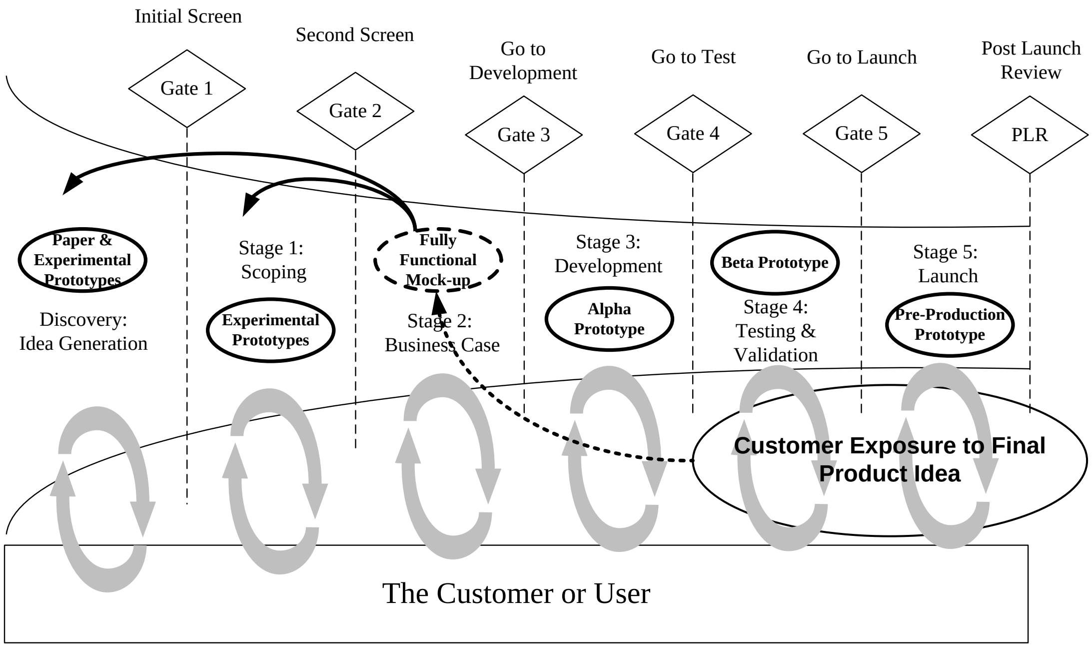

Figure 114. Building fully functional mock-ups as early as possible in the PDP.

Despite the interesting results achieved from the empirical study in this thesis, there are some limitations. Since this study was only implemented in one industry, there is no evidence to support the viability of the framework in other industries. Moreover, the framework of this thesis was only tested for cost-reducing innovations with a low level of technical complexity. It may be more challenging to design a cheap fully functional mock-up for highly complex products or at least demonstrate all the functionalities with that mock-up. Hopefully, in the future more research are conducted in this area to test practical usage of fully functional mock-ups in various industries and building value proposition for different types of products.

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