Customer and product validation for physical product development in a startup context
A study on Lean Startup methods and Design For Six Sigma tools

Christoffer Lindkvist
Niclas Stjernberg
Abstract

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The application of Lean principles to new business ventures created the movement “Lean Startup”. The methodology has been well received by startups as well as established companies, and is largely seen as the way forward when it comes to product and business development. However, previous studies have highlighted difficulties with the methodology when it is applied to physical product development. This study aims to examine how Lean Startup methods (LSM) can be complemented with Design for Six Sigma (DFSS) tools to develop and validate physical products in a startup context – a combination which has received limited attention in today’s research.

First, LSM and DFSS literature was compiled into a number of principles and tools, which were then applied to the challenges of a young startup developing a physical product for the skiing industry, in their pursuit to achieve customer and product validation. A number of semi-structured interviews revealed false assumptions about customer requirements and the technical solution, which were used to pivot on several parts of the business plan and to make product design changes.

Based on our research, we perceive LSM’s ability to gather customer input and creating a highly competitive business plan superior to previous customer research and business development methods mentioned in DFSS literature. However, we also conclude that LSM lacks the systematic and data driven approach to evaluate physical product design where DFSS tools are better suited, primarily due to the preventive mindset in DFSS and its rigorous way to design experiments and test hypotheses. Therefore, we conclude that startups developing physical products can extract powerful synergy effects if both methods are utilized, as long as the entrepreneur considers the current development phase and its related tools and methods, time and resources available to the startup, and the consequences of making the wrong decision. Finally, we urge the need for further research on this subject to increase credibility for our findings.
Acknowledgements

It has been interesting to research how Lean Startup methods (LSM) and Design for Six Sigma (DFSS) tools can contribute to better support daily decisions in a startup developing physical products. As well as to experience the excitement and thrills when spending time in a startup. The findings we have done wouldn’t been possible without SkiCorp and the respondents at the ski resorts. They have all welcomed us and provided support during the interviews; we would like to thank all of you for taking part in this research. We would also like to thank Gunnar Malmquist at GE healthcare for taking his time to give us a glimpse in how LSM is utilized in larger companies. Finally we would like to send a special thanks to our supervisor Ulrika Persson-Firschier, Uppsala University, who always supported us when needed. Your knowledge and guidance has been an important asset for us, especially during the early phase with the research methodology and discussions around research objectives and the research question. These discussions eased the completion of this research.

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Christoffer Lindkvist & Niclas Stjernberg
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## Abbreviations

<table>
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<th>Description</th>
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<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CTO</td>
<td>Chief Technical Officer</td>
</tr>
<tr>
<td>CTQ</td>
<td>Critical To Quality Characteristics</td>
</tr>
<tr>
<td>DFSS</td>
<td>Design For Six Sigma</td>
</tr>
<tr>
<td>DMAIC</td>
<td>Define, Measure, Analyze, Implement, Control,</td>
</tr>
<tr>
<td>DMADV</td>
<td>Define Measure Analyze Design Verify</td>
</tr>
<tr>
<td>DOE</td>
<td>Design Of Experiments</td>
</tr>
<tr>
<td>DPMO</td>
<td>Defects Per Million Opportunities</td>
</tr>
<tr>
<td>FMEA</td>
<td>Failure Mode Effect Analysis</td>
</tr>
<tr>
<td>JIT</td>
<td>Just-In Time</td>
</tr>
<tr>
<td>LSM</td>
<td>Lean Startup Methodology</td>
</tr>
<tr>
<td>LSL</td>
<td>Lower Specification Limit</td>
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<tr>
<td>MSA</td>
<td>Measurement System Analysis</td>
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<tr>
<td>MVP</td>
<td>Minimum Viable Product</td>
</tr>
<tr>
<td>QFD</td>
<td>Quality Function Deployment</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium sized Enterprises</td>
</tr>
<tr>
<td>SMART</td>
<td>Specific Measurable Agreed to Realistic and Time bound</td>
</tr>
<tr>
<td>PDCA</td>
<td>Plan Do Check Act</td>
</tr>
<tr>
<td>TQM</td>
<td>Total Quality Management</td>
</tr>
<tr>
<td>USL</td>
<td>Upper Specification Limit</td>
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<tr>
<td>VoC</td>
<td>Voice of the Customer</td>
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1. Introduction

This section includes an introduction of why we will examine the combination of Lean Startup Methodology (LSM) and Design for Six Sigma (DFSS) and why we will conduct research to answer the research question: How can Lean Startup and Design for Six Sigma contribute to verify new physical product concepts entering new markets?

1.1 Background

Most startups fail. Feinleib (2012) claim eight out of 10 startups fail within three years. According to Blank (2006) that number is nine out of 10. Regardless of whom you choose to use as your source of information, we can with certainty conclude that the majority of startups fail to sustain a long term profitable business. So, what is a startup? Throughout this thesis we will use Ries’ definition: “A startup is a human institution designed to create a new product or service under extreme conditions of uncertainty” (Ries, 2011 p. 37)

Extreme conditions of uncertainty imply that the odds of succeeding are against you. Yet, 49% of the population in Sweden between ages 18 – 70 entertains the idea of running their own business (Tillväxtverket, 2012). Why would someone take this giant leap of faith and start a new company, in spite of the extreme risks attached to such an endeavor? Perhaps it’s the joy of being your own boss, or having an impact on the future, or maybe it’s the thrill and excitement of pursuing a new idea. The reasons could be infinite.

Entrepreneurship is important for a number of reasons. It nurtures new capabilities and skills; it opens up new markets, creates new jobs and companies, and is the engine of economic growth for a country. In the aftermath of the 2008 financial crisis entrepreneurship became more important than ever (European Commission, 2013). Small and medium sized enterprises (SMEs) account for nine out of 10 enterprises in Europe and provide two out of three jobs (European Commission, 2015). Over 23 million people in Europe are still unemployed and the majority of SMEs are yet to reach their pre-crisis levels of performance (Eurostat, 2015). Since SMEs are defined as “businesses with fewer than 250 employees and an annual turnover of less than 50 million euro” (European Commission, 2015), most startups fall into the SME category. Considering 85% of new jobs is created within this category (European Commission, 2015), we think it is in everyone’s interest to help them succeed.

1.1.1 Lean Startup

This thesis sets out to study how the Lean Startup Methodology (LSM) could contribute to increase the entrepreneur’s chances of success. The case company used in this report has been using this methodology for some time, but experienced significant shortcomings when it comes to product development for physical products. To explore how gaps of LSM can be bridged, Design for Six Sigma (DFSS) will be studied in the search for how both product development methods might complement each other in the pursuit of achieving customer and product validation for a new physical product.

The high failure rate of startup companies has not gone by unnoticed. A significant amount of literature has been written on the subject in an effort to identify key characteristics and factors leading to failures in new ventures (e.g. Feinlieb, 2012; Shane, 2008; Zimmerman & Zeitz 2002), as well as key factors contributing to failed government programs in efforts to promote and boost entrepreneurial activity and how to avoid spending billions of taxpayer money (Lerner, 2009). However, some researchers have taken a hands-on approach and provided a framework for how to navigate through the early stages of a startup in order to increase the chances of success.

The theory behind these methodologies emphasizes customer driven product development where entrepreneurs are encouraged to start talking to customers as soon as possible to gain learning and insight about their problems. The idea behind this approach is to build something based on the customer’s actual wants and needs, not based on your own, potentially false, assumptions. To maximize learning the riskiest part of the business plan are written in falsifiable hypotheses, which are empirically tested in short iteration cycles to validate or reject hypotheses. It is a scientific approach to test each element of your vision against reality by running experiments. This validated learning will provide the entrepreneur with valuable insights which can be used to make decisions for the business about how to steer, when to turn, when to accelerate and when to persevere on a pre-decided direction, and thereby maximize business growth with limited resources. The creation of products from an idea, which are then measured against how customers respond, and later used to make data-based decisions on whether to pivot or persevere, provide a feedback loop during all phases the new company has to go through. It also emphasizes only to build what needs to be built in order to test a hypothesis to minimize waste, resulting in a low cash burn rate until the company has found paying customers to validate its business model with (Blank, 2006; Ries 2011).

We must keep in mind that Lean thinking and customer development within a startup context is still in its early years of development and not a lot of research has been done on the subject. However, Bosch et al (2013) points out at least five recognized researchers have accepted the idea as the way forward. Several other researchers have pointed out a number of factors which contribute to the success of new ventures (Zimmerman & Zeitz, 2008; Gelderen et al, 2005; Feinlieb, 2012). But few have taken the Lean startup approach further to provide a practical framework for new ventures to use in the early stages of product development. Perhaps the most renowned author to provide such a framework is Ash Maurya (2012) with his book “Running Lean” based on the concepts presented in Blank’s customer development approach (Blank, 2006) and Ries’ principles of a Lean startup (Ries, 2011). The framework Maurya presents as a process for new ventures to follow could be distilled into three steps:

1. **Document your plan A.** This is the first step the entrepreneur takes, where their initial vision is written down as a starting point and consists of hypotheses about the business model as it is at the moment. The format used is a one page business model diagram called the “Lean Canvas”.

2. **Identify the riskiest parts of your plan A.** The riskiest parts of your plan A are identified and prioritized, where the highest risk part should be dealt with first. Three key categories of risks are identified as the customer, the product and the market.

3. **Systematically test your plan.** In an iterative process, key hypotheses are tested through running a series of experiments in order to validate those hypotheses, focusing on one at a time starting with what has been prioritized as the riskiest part of your business model on your Lean canvas.
The framework provided by Maurya was developed particularly with new software ventures in mind. Although, the model has proved to be a valuable tool for a number of new ventures software companies have had trouble implementing some of the lean principles in their startup processes. Some of the problems identified with LSM are a lack of guidance on when to abandon or when to move forward with a product idea. The reasons behind this lies in whether the exit criteria has been reached or not when experiments start to show diminishing returns. The exit criteria provide a decision point on whether a company should pivot, abandon or persevere on an idea. While the exit criteria provide a clear and common goal for the team, the problem seemed to be deciding how many people to talk to in order to validate a hypothesis and how to gauge their feedback and reactions. There was not a clear connection between risks, techniques and exit criteria (Bosch et al, 2013). Similar shortcomings have been discovered by the case company of this thesis. While Maurya’s process provides a good starting point and guide for how to set up a business model and prioritize risks, no clear guide has been presented about how to run experiments and when a hypothesis has been validated. If iteration cycles are longer and more expensive to go through, which it typically is for startups developing physical products, a different mindset has to be developed to consider all inputs required to produce a high quality product.

It is simply too expensive for a resource sensitive enterprise such as a startup, to go back on a commitment when developing physical products, especially if such a commitment means buying manufacturing equipment for millions of dollars. If that commitment is based on false assumptions it would probably mean the end of the startup company. Therefore, a systematic approach to test and verify our assumptions is needed.

1.1.2 SkiCorp

The case company requested confidentiality if they would participate in the research, to fulfill their request we have used SkiCorp as a pseudonym. SkiCorp is a startup company located in Uppsala, Sweden, targeting the ski resort industry with a new innovative product in a new market niche. In this thesis SkiCorp will be the case company used for conducting the research. The new venture believes it has a solution for a specific problem the majority of ski resorts in Europe have. The product is a new seat design to the existing T-bar system which aims to provide a more comfortable T-bar ski lift ride for ski resort visitors. The company was founded by two students at Uppsala University, one of whom is also writing this thesis. From early on during the product development process the team stumbled upon the LSM during the incubator program SkiCorp attends, where it is used as a framework to conduct business development. Lean principles have been implemented as a way to make fast progress with minimum waste. This meant writing down the current business model on the Lean canvas at the point of founding the company.
The next step the company took was identifying the riskiest parts of their business plan. This was done through a series of in depth interviews with numerous different minor and major ski resorts within Sweden to uncover false assumptions and discover new learnings. These learnings forced the company to pivot many parts of the original business model several times as new learnings lead to new decisions. At this point in time the company feels confident they have identified the key problems and their target market segment, which is also known as the “problem-/market-fit”. Parallel to this interview process the company started to develop their new product which is now ready for prototyping.

The next challenge SkiCorp faces is to achieve what is called “problem-/solution-fit”, which means that the solution, in SkiCorp’s case not only their product but also their entire business model, must solve the top two or three problems their customers experience today to a large extent. This is where SkiCorp feels that LSM lacks the systematic view on how to test and verify key assumptions tested on potential customers. To get the product to up-scaled production, hypotheses related to customers actually wanting to buy enough quantities of the product, to support investments necessary to provide manufacturing capabilities has to be validated. As this thesis move forward, SkiCorp’s pursuit of achieving problem-/solution-fit will be used as a case study to test new ideas and theories developed by the authors empirically.

1.1.3 Quality engineering and industrial research

As mentioned in the Lean startup section, the LSM lacks a systematic approach to verify and test assumptions. With its roots from quality engineering with systematic methodologies to test and verify hypothesis, we will examine how DFSS could bridge that perceived gap.

Designing and launching a new product is a process with many possible pitfalls and challenges, but it is possible to make the development process easier. If you want to succeed with a product you need to understand who your customers are and their needs. Product development based on the different methods within the field of quality engineering takes a data based decision making approach rather than decisions based on untested assumptions. This will make sure that the end product will fulfill the customer’s needs and not what the founders/designers believe they need. This way a firm can stop a new product if there isn’t a true need for it (Bergman & Klefsjö, 2007).

The development of industrial research and scientific methods is based on a hypothesis driven systematic approach, which have been conducted for decades and is what you now could call a mature field of research. The early methods demanded a high level of mathematical skills and weren’t optimized for industrial use (Ackoff, 1962). From these methods many others have evolved both for improving performance in production but also during the product development phase, for example Total Quality Management (TQM), Six Sigma and its sub-component Design for Six Sigma (DFSS), where the latter will be explored and applied thoroughly during this thesis.

In DFSS, statistical analysis is an important element to verify that the design will conform to what the customer expects and will make sure that the product conforms to the demands of the market. When using DFSS there is a focus on making decisions based on data in the product development phase, which have shown to be beneficial for the success of new products, processes, or services. This creates better chances for the product development to end up with a successful product with a verified market potential and robustness in its design. It emphasizes putting a lot of energy during the planning phase, which will lead to a more efficient flow in the later part of the development, with less problems and defects of the product seen from the market and customer point of view (Fouquet, 2007).
1.2 Purpose and research question

Every startup failure potentially means that a possible improvement for the society and its population whom would have been affected by the product, have been wasted. The founders of SkiCorp are using the LSM to improve their chances of success, but they feel that the method are lacking the systematic approach and built-in robustness of the product, as well as the data driven connection to the customers they are trying to please, the problem they are trying to solve and the market which it acts on. The data driven approach and how to think about data collection in DFSS could provide an opportunity to bridge that gap. Therefore, the founders of SkiCorp want to explore whether concepts in DFSS can complement the LSM, to validate high risk parts of their business plan where the LSM does not provide sufficient information how to do so.

Any findings could be useful, not only for SkiCorp, but also for other startups struggling with similar issues when trying to verify new physical product concepts in new niche markets. It is important to know how to approach each category and whether the company should pivot, abandon or persevere on its current business model. Making data based decisions to mitigate these risk factors will lead to a more successful path, which could save a significant amount of resources. If this could lead to greater startup success rates and eliminate waste such as unwanted products, it would benefit the society and its population, which makes this thesis interesting in a broader perspective.

Steven Blank (2006) points out that a crucial step for startups is for development, marketing, and sales staff to stop proceeding product and business development based on untested assumptions about the wants and needs of their customers. The LSM was developed to assist startup teams to better test their assumptions, and subsequently to make better decisions. The purpose of this study is to identify gaps in the LSM which prevents early stage startups developing physical products to validate their assumptions. To bridge those gaps, mindset and methods originating from DFSS will be explored and applied to the LSM as a complement.

To test new ideas and theories arising from this research, SkiCorp will be used as a case company during their process to verify a new product concept. Guidelines will be provided to SkiCorp how to test and validate key assumptions at this point in time, in order to maximize learning, and help them make better decisions to proceed forward. Learnings from SkiCorp will then be discussed and analyzed concerning how it could be used in a broader startup context. To achieve the purpose of this thesis, we will answer the following research question: “How can Lean Startup and Design for Six Sigma contribute to verify new physical product concepts entering new markets?”

1.3 Scope and aim

The aim of this thesis is to evaluate whether parts of DFSS can be used as a complement to LSM; to improve decision making in the early stages of a startup developing physical products. This will be achieved through elaborating on, for example, how to write hypotheses, how to design and analyze experiments, and how to use customer input to produce a high value product. An attempt to implement concepts from DFSS, with the purpose to complement LSM will be made. The aim of this effort will be to bridge gaps where data based decision making is necessary, but how to do so is not provided by literature covering LSM. This study will be based on, and therefore limited to, the unique challenges startups with new physical product concepts face during their product and customer verification phase. Theory about the subject of this thesis will be explored in chapter three to generate ideas and tools applicable to the current situation of SkiCorp. Tools chosen will then be tested and applied on the case company empirically in chapter four to evaluate how DFSS can complement LSM. Results and conclusions will be delivered to SkiCorp as an output of this study, in addition to an in depth discussion about our findings in a broader startup perspective.
2. Theoretical Framework

In this chapter we will present the Lean philosophy, LSM principles, the Six Sigma framework and DFSS principles. A selection of principles will give an overview of the Lean philosophy, which will later be followed by a detailed description of LSM and how it is derived from the Lean philosophy. The same approach will be used for explaining Six Sigma and DFSS to lay the foundation for the research.

2.1 The Lean philosophy

The Lean philosophy is all about producing more value with less waste. Womack and Jones (2006) describe what the practitioner needs to focus on within the lean philosophy; by focusing on defining customer value, defining value streams which provide that value, creating flow between processes, and aiming for perfection, the practitioner can increase value added and reduce waste. The Toyota Production System, which inspired the Lean movement, are using 14 management principles which can be divided into four categories 1) a long-term philosophy, 2) the right process will produce the right results, 3) add value to the organization by developing your people, and 4) continuously solve root causes which drive organizational learning (Liker, 2004). Womack and Jones (2006) and Toytas 14 management principles have different structures but are striving for the same goal: to provide as much value as possible with resources available. A profound understanding of the philosophy is the most important step to gain the benefits from Lean, since the different tools are more or less useless if the practitioner doesn’t know why he is using them. (Bhasin, Burcher, 2006).

Within Lean customer value is fundamental with the goal of maximizing the amount of value delivered to the customer. Within businesses that aren’t fully utilizing Lean, it is often common that managers and engineers define the value for the customers, without truly understanding how they could deliver it. If the customers are not included, the definition of value as defined by the customer in comparison to how it’s defined by the provider, might be different, which inevitably will lead to waste. To bridge this gap the Lean philosophy emphasizes customer understanding. It’s a challenging task since there is a risk that the customers only ask for what they know and not for new possibilities. To truly create value for the customers it is crucial to analyze and understand their underlying needs and to challenge previous solutions to see new possibilities. This can be done by talking to the customers and listen to their needs and which attributes is the most crucial for them (Liker, 2004).

When customer value is well understood among employees, it is important to be able to see the bigger picture to identify where waste is created throughout the entire value chain; from the initial idea to delivery at the customer. Historically managers have been focusing on optimizing production steps within individual departments, without regard to the entire value stream from raw material to delivery at the customer. To optimize the flow and decrease waste, each process step can be defined to one of the following categories: 1) those that actually create value as perceived from the customer, 2) those that do not create value but are needed by some other step and therefore cannot be eliminated, and 3) those that do not create value as perceived from the customer and therefore can be eliminated directly. When waste has been identified, it is possible to apply Lean methods and tools for eliminating that waste. It is important to start from the customer’s point of view and a profound understanding of the Lean philosophy. Without this profound understanding, there is a risk that the practitioner applies copies of what other firms have succeeded with on their specific problems, to a unique problem of his own (Womack & Jones, 2003).
The goal is to create flow between production processes, without inventory waiting between production steps. Where idling exists waste exists. Taiichi Ohno envisioned a method called Just-In-Time (JIT) that deals with many of the issues with flow in a workshop or service delivery. But before JIT will make a significant contribution to achieve flow, the system for batches needs to be overviewed. No product or service will be initiated for delivery unless there is a real demand from a customer, which emphasizes the need for small batch sizes and a focus on rapid changeover. To succeed with this, the company needs to be more flexible and adaptive to new situations, which promotes the use of cross-functional departments within the organization. This supports the overall thought behind Lean, that every worker should be responsible and have the authority to make changes of his own. To manage JIT systems with an optimal flow is demanding and complex. For example, the most common accounting programs are striving for 100% machine utilization. This is contra productive since it will lead to waste in overproduction and material waiting later in the process. With the Lean philosophy you only produce if there is a true need for it and an idle machine is better than the inventory it produces (Womack & Jones, 2003).

Many are the ones that have failed with the deployment of Lean philosophies and the reasons are many, but one crucial step is Policy Deployment (Hoshin Kanri). To reach perfection the management needs to decide which waste they want to attack first. To management it is important to select a few well-chosen problems and create visibility for the objective of the policy deployment. Policy deployment is a top-down method in the beginning, but evolves into a top-down/bottom-up methodology to make sure that all employees have the possibility to contribute (Womack & Jones, 2003). One of the crucial elements is the focus on being a learning organization; a mistake should be viewed as a possibility to learn and to get better from it (Liker, 2004).

2.2 Lean startup

This thesis will use the work of Blank (2006) and Ries (2011) as a framework for how to proceed forward and move between the different customer development phases. However, the work of Maurya (2011) provides simplified tools to support the principles within Lean startup presented by Blank and Ries. These tools will be used throughout this thesis, but we would also like to acknowledge that Maurya does not provide anything significantly new to LSM and will solely be used for the benefits of the simplified tools he developed.

Many are the entrepreneurs that have tried to make it with new ideas, some do others do not. Steven Blank (2006) was the pioneer within what later came to be known as the field of Lean startup. In this section we will present the work from Steven Blank, Eric Ries and Ash Maurya to give an overview of the Lean startup origin and how it has been embraced. The methods and ideas behind Lean startup derive from the Lean philosophy presented above. They are using the philosophy with placing the customer in focus, eliminating waste and maximizing learning. This is noticeable since all three authors use the work from Toyota (Liker, 2004) and Womack and Jones (2003) as references in their research.

The four steps to epiphany (Blank, 2006) present a structured framework for entrepreneurs to follow. Blank’s method is presented in Figure 2-1Fel! Hittar inte referenskälla., which supports entrepreneurs in discovering the market, locating the first customers, validating assumptions and to grow their business. This structured method is focusing on how to truly understand the customers and what their needs are for the specific product or service. Each one of the four phases consists of several different steps and methods to validate hypotheses. Each step is then iterated until assumptions are validated, which works as an exit criteria to proceed to the next phase. It’s designed to force the entrepreneur to go through each one of the four phases several times, which is a fundamental part of Blanks work since the aim in a startup should be to learn as much as possible during each step, which will generate decisions that are tested and verified. This creates a learning atmosphere that will make it easier in later steps since you have a solid foundation to work on (Blank, 2006).
Eric Ries (2011) also emphasizes the learning process in a startup, but adds the creation of systems to measure what is important for the startup. His experiences as a manager at a large corporation was that managers could show that they were making progress according to plan, but if they failed a common excuse was that they at least learned something. To avoid empty statements like this happening in the LSM he developed something called validated learning.

2.2.1 Lean startup principles

There are some key principles that need to be explained to understand the philosophy behind the idea of Lean startup and how it derives from the Lean philosophy. These principles are the foundation for the different phases during the customer development process.

**Leave the building**
You will not be able to fully understand your customer from inside the walls of your office building; you have to actually meet them. During the early development phases you will state several hypotheses, but you also need to validate them. Lean startup demands you to visit potential customers to understand their needs and the intended market you wish to enter. This needs to be done from day one and be a continuous effort throughout the development phase. The end result of such activities will be a deep understanding about what your targeted customers actually value and what they are looking for (Blank, 2006).

**Validated learning**
To validate learning and maximize the often scarce startup resources, the learning cycles have to be shorter. Learnings can be drawn every day and experiments can be updated accordingly, to verify the new learnings which will improve the end result for the customer. Maurya uses the “Build-Measure-Learn loop” (Figure 2-2), which was developed by Eric Ries (2011). It starts with a set of ideas and hypotheses and leads to some object that can be presented for potential customers. Their feedback helps the developers in their work with developing the product. The LSM emphasizes the importance in performing experiments to support any decisions about whether to pivot or persevere with the path taken. Each experiment aims to test a hypothesis and each experiment is also an intended learning experience. The learning leads to a deeper understanding about, and a validation of: the customer, the problem and the market (Mueller & Thoring, 2012).
Pivot or persevere
Is our hypothesis correct or do we need to change? If the hypothesis has been validated you will persevere with the knowledge you have and continue on the decided path. If not, you need to pivot. A pivot is a structured course correction to test new hypotheses about the product, strategy and engine of growth. LSM supports this decision with the underlying scientific methodology that is the foundation of LSM. The employment of these methods is a way of using human creativity to verify that decisions to persevere are not made when you actually need to pivot. This is not taking away the human element in the decision, but it is adding a more scientific approach to support it. The aim is to support the founders in taking the right decision for pivoting or persevering, and it is common to persevere on a decided path due to fear of pivoting. This have led to many companies getting stuck without growing their business because they are still making it and therefore stay on the path they are on. However, they are not maximizing the value for their customers which LSM is all about (Ries, 2011).

Minimum viable product
The purpose of a product is to fulfill an important need that customers have, which will lead to a growing market for the founders to act on. To validate these assumptions the founders need to present a solution that is complete enough for the potential customers to understand how it could provide value for them, and this unfinished solution is referred to as a minimum viable product (MVP) (Moogk, 2012). It needs to possess the minimum set of features to attract the early customers, which aims to give developers feedback and hints about the mainstream market. This feedback supports the evaluation of the product features to assess if they match the needs of the larger market. One important learning is that the MVP is often more minimum then you would believe. The features of the MVP are supposed to find the early customers who are as visionary as the founders. This particular early customer base is commonly referred to as earlyvangelists (Blank, 2006). Therefore it is crucial to find the minimum amount of features needed, which will also keep the cash burn rate of the startup at a minimum. The earlyvangelists will then be able to support the product development with their feedback to improve the product. The iterations with feedback from them will either lead to the product having better chances to fit the market, or discovering that there is no need for the product (Ries, 2011).
Small batches in entrepreneurship

The idea behind small batches comes from Toyota where they could see that small batches made their factories more efficient in comparison to larger batches. It may come as a surprise that small batches can be used in a startup context, but for startups it is actually a perfect philosophy. It is a way of rapidly gaining validated learning (Mueller & Thoring, 2012). For startups it is important to keep expenses low and to build a sustainable business as fast as possible. Batch sizes in this meaning are the different steps during the development phase, and with smaller steps less possible waste is made. Because of the smaller steps conducted, the new iteration of a step demands less resources and is faster to adapt to new circumstances. In a startup this means that customer feedback is collected frequently and changes to the product or service based on that feedback are done iteratively throughout the entire development process. This stands in contrast to launching a finished product without knowing how the customers will experience or respond to the features included. With small batch sizes the different features have already been tested during the development on a small scale. This leads to less expensive changes if necessary to satisfy the needs of the customers, which leads to less resources wasted (Ries, 2011).

2.2.2 Customer Discovery

The customer discovery is the first of four steps within LSM (presented in Figure 2-1) and we will present the four phases within this step in this subchapter.

Phase 1 – State Hypotheses

During phase one the team get agreement on what features the product should have, what benefits it should offer and schedules for release. This is what is described as the “Product hypotheses”. Next, a series of hypotheses are described for the customers the team think will buy and use the product; who they are, what their problems are, and why they will pay you money to use your solution. A strategy for how to channel and price your product are then described, combined with hypotheses about how to drive demand in to that channel. In addition, market type hypotheses (a description about what kind of market you are in) and a competitive analysis are developed to complete phase one in the customer discovery process (Blank, 2006). Even though the entrepreneur at this point operate under extreme uncertainty, it is important to describe a plan A. This plan will change, perhaps multiple times, as you move forward and discover new insights about your customers and market. It provides a foundation and stepping point for how to proceed and iterate to a plan that works.

The traditional way when starting a business is to create a comprehensive business plan that is a static plan for what the founders believe to be true. It’s often created at a desk with limited inputs from customers and are rarely changed during the development phase. This is an ancient method that lacks the flexibility entrepreneurs need (Blank, 2013). To help the entrepreneur summarize his hypotheses and quickly be able to pivot and change parts of the plan as he learns more, a one page document called “Lean canvas” was developed by Ash Maurya (2011) and is illustrated in Figure 2-3 below.
Here, the previously described hypotheses in phase one is written down in simple sentences to reflect the plan at any given point in time. This also gives the possibility to easily make changes in the canvas if some assumptions aren’t correct. After documenting your plan A in this document, it is time to move into phase two where hypotheses developed in phase one are tested and qualified, to identify the riskiest parts of the plan (Maurya, 2011).

### Phase 2 – Test and Qualify Hypotheses

This is where you try to understand your customers and can only be done through customer conversations. The goal during this phase is to schedule first customer contacts, develop a presentation of their perceived problems, current solutions, understand their workflow, understand the decision influencers and develop market knowledge. Rarely do hypotheses made during phase one survive the second phase, because as you gather feedback from your customers you will modify your plan as a result from what you learn. All you have within the company up until this point is opinions, the facts lies with the customers outside in the real world, which is why you have to get out of the building to get it. Only when sufficient data has been gathered to understand the customer do you go back and present your solution and get feedback on the product itself (Blank 2006).

As a foundation for this type of interview, the “problem interview” (Maurya, 2011) is appropriate to use. The main focus with the problem interview is to understand the customer’s worldview and how they solve the problems today. To conduct these you will use the hypothesis from the canvas but rephrase them in to falsifiable hypothesis. Then you use this to conduct interviews with potential customers, it’s important to record or take notes and also interpreted their body language. After each batch of interviews the script is updated by dropping problems that customers don’t agree with and add more if new needs are discovered. This leads to incrementally improvements and true understanding of the customers, which supports the reiteration of hypotheses.

### Phase 3 – Test and Qualify Product Concept

Phase two is all about understanding your customer’s needs and problems. In phase three you proceed to test your product assumptions on potential customers in the potential market to gather feedback. The data from the interviews are used to test the hypothesis, which could answer questions, such as: Is the product solving their problems? Will customers pay for the new solution? How are customers solving their problems today? (Blank, 2006)

This works as a reality check to see if there is a potential market for the product as it is designed now. If weak interest during the first demonstrations in front of potential customers is shown, it’s important to ask yourself if they were the right customers. Since the aim for this step is to find customers that would be interested in the product, only when it is concluded with certainty no customers want to pay for the current solution should it be redesigned (Blank, 2006).
By using a demo product that can make it easier for the customer to visualize and understand the end product, more knowledge from the interviews will be obtained. It doesn’t have to be a perfect demo of the end solution but a more realistic demo will lead to more accurate result from the test of the solution (Maurya, 2011).

Phase 4 – Verify
From the findings made so far about the problem and the product a summary is made to conclude that the problem, the product solution and the business model is verified based on what has been discovered up until this point. If the business model does not make financial sense with these new learnings the company needs to decide whether to iterate the customer discovery loop again or to exit (Blank, 2006).

2.2.2 Customer Validation
The major output from the customer validation stage is a proven and tested sales road map. Just as the customer discovery process, customer validation is a four step process. Since this step will not be covered in this thesis we will only present the outline to give you as a reader an understanding about how the different phases of the LSM are connected: Phase 1: Get ready to sell. ➔ Phase 2: Sell to visionary customers. ➔ Phase 3: Develop positioning. ➔ Phase 4: Verify (Blank, 2006).

To create this roadmap, the focus lies in connecting with the earlyvangelists. The significant difference between earlyvangelists and other customers is that they are willing to share the risk with the entrepreneurs. They will buy the product before it has been produced, and they are willing to wait for it because they believe in the product. It is crucial during this stage to identify and attract these individuals to try out the product for themselves and study their reactions. During this phase the focus is not in making revenue through sales, it is all about validating your product against the market to find a place for it. During this time you are building up the knowledge and a foundation for when the sales organization are formed during the latter part of the customer validation process. After this step you have understood the customers’ problem and have a product that they are interested in buying. Furthermore you have created a scalable sales process and demonstrated that the business model is profitable (Blank, 2006).

2.3 The Six Sigma Framework
The pioneering work behind Six Sigma started as a strategic initiative at Motorola in 1987. As customer requirements demands increasing improvements when it comes to reducing variation and significant changes in performance, the deployment of Six Sigma initiatives have grown exponentially among companies worldwide since (Magnusson, Kroslid & Bergman, 2009). The tools and techniques used within the Six Sigma Framework are similar to those approaches deployed previously within quality management (e.g. TQM and ISO 9000), but emphasize more so the organizational structure that makes problem exploration between different organizational members possible – in a rigorously controlled way (Schroeder et al, 2007). The methodology relies heavily on the profound understanding of variation and how to reduce it, all in the name of breakthrough improvements for results of strategic importance to the company. So, what is variation?

At some level of measurement resolution, no product is exactly the same. The output produced as a product is influenced from many sources of variability of different magnitude, but they are always present. The output variation is a function of all these sources (input factors) of smaller variation combined (see Figure 2-4). Some usual sources of variation could be e.g. people, machines, materials, methods, measurement or environment and could affect the output additively or interactively, and can vary gradually or make sudden big changes (Luftig, 1997).
The Greek letter used for variation is σ (sigma), which stands for standard deviation of a population (Sheskin, 2000). How much variability a distribution is affected with is called variance, and is \( \sigma^2 \). So, another way to describe how the input factors contribute to output variation would be:

\[
\sigma^2_{\text{total}} = \sigma^2_1 + \sigma^2_2 + \sigma^2_3 \ldots \sigma^2_n
\]

There are two distinctive forms of variation: special and common cause variation (see Figure 2-5 and Figure 2-6). The latter is naturally occurring within the system and changing common cause variation requires a change in the system. Special cause variation occurs due to special circumstances which are more or less easy to identify. Most often are improvement efforts focusing on eliminating these types of variation deployed, where input factors contributing to special cause variation which makes the system deviate from target are identified. Deviation from target translates to excess costs and unhappy customers. However, most breakthrough improvements is done when both common and special cause variation are reduced (Magnusson, Kroslid & Bergman 2009). It is not until only common cause variation is occurring in a process that the process could be determined to be in a state of control (Luftig, 1997).
To achieve Six Sigma status the variation in the individual product or process characteristic must not produce more than 3.4 defects per million opportunities (DPMO). However, this goal is almost impossible to achieve for most companies. Instead a more generic improvement rate of 50% annually for critical-to-quality characteristics has been adopted as best practice. In practice this would mean 50% reduction in e.g. rejects, late deliveries, claims and rework every year (Magnusson, Kroslid & Bergman, 2009). The first step to achieve that goal is to remove any special cause variation and then to systematically reduce common variation around a customer defined target, or mean value, commonly labeled μ (Luftig, 1997).

This mindset significantly differs from the traditional approach to quality where products were accepted as good as long as it performed within tolerances. Instead a process control-approach should be adapted by letting the process naturally vary around the target and systematically reduce that natural variation. This way a model of operation that fosters prevention rather than detection can be achieved; which forces the practitioner to focus on improvement of the process and attacking the root cause of variation rather than treating the output symptoms (Luftig, 1997).

By gathering information about performance over time, special cause variation can be detected and prevented and common causes of variation can be reduced. This allows for manipulation of specific inputs, to study its impact on output which will determine what is contributing to variation (for example, pressure, cycle time, temperature), and will ultimately lead to an overall improvement of the process and its output (Luftig, 1997). This phenomenon is illustrated in Figure 2-7 where common cause variation is systematically reduced from state A to state C to allow for more output to conform between the upper specification limit (USL) and lower specification limit (LSL) and cluster around a customer defined target, leading to fewer product defects and more products that perform better to the needs of the customer.
Although no clear definition or theory can explain Six Sigma, the concept of variation is an important element that permeates the approach, which is why the underlying concept behind it is important to understand. Schroeder et al. (2007) made an attempt to lay out the base definition and the theoretical basis of Six Sigma through a series of in-depth observations and literature on the subject. Their suggestion as a result from that study will be adopted throughout this thesis as the definition of Six Sigma:

“Organizational performance will tend to improve with the use of a parallel-meso Six Sigma structure to reduce variation in organization processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives” (Schroeder et al, 2007, p. 543).

The parallel-meso Six Sigma structure refers to the Six Sigma hierarchy of responsibilities and roles the employees at a Six Sigma company have. To provide an indicator for what role each employee has the belt rank system originating from martial arts is usually adapted (Magnusson, Kroslid & Bergman, 2009).

A structured method and performance metrics refers to the pragmatic approach towards problem solving and the tools available within the Six Sigma framework available to the practitioner. One of those methods is DFSS (Design for Six Sigma) which will be one of the main research subjects of this thesis.

Companies utilizing Six Sigma principles have discovered that the only way to surpass five sigma quality (233 DPMO) is to completely redesign the product, process or service bottom up (He, Tang & Chang, 2009). DFSS recognizes that cost, manufacturability, and performance of the product are determined by its design (Montgomery & Woodall, 2008). In fact, it is estimated that 75 % of the product cost is determined whenever a design is released (He, Tang & Chang, 2009). DFSS spans the entire development process of a new product from customer input to final release. Not only does the methodology keep customer requirements in mind but it simultaneously focuses on process capability, that is, “is the product designed to meet quality requirements as produced during the manufacturing process?” Broadly speaking, it is a structured methodology for efficient commercialization of technology that results in new processes, services, or products (Montgomery & Woodall, 2008).

We will focus our attention for the remaining of this sub-chapter to the general methodology behind DFSS and zone into detail where an entrepreneur can take advantage of efficient tools provided in the methodology, in order to achieve product and customer validation.
2.4 Design for Six Sigma

DFSS is applicable for all types of projects. While the logical structure remains the same, the deployments of the tools and specific methods have to be customized and tailored to fit the respective development task (Staudter et al., 2009). During this section, DFSS will be described in general terms and each phase will be described systematically. From what is available in the DFSS toolbox, we will describe each tool we chose to use. This means we limited ourselves to only use tools which were justifiable in terms of the current product development phase of the case company, are applicable to achieve customer and product validation, and applicable in a startup context, that is, the time and resources available of the case company have to be taken into consideration when a tool is chosen to be utilized. The theory presented here will then help us provide a theoretical framework customized for our development task.

In its essence, DFSS is a quality concept for improving product development processes. It is a systematic approach spanning from customer input to the final release of a product by requiring a specific application of tools along the way (Ericsson, Gingnell & Lilliesköld, 2014). The approach is heavily customer oriented during all process phases and derives the elimination of defects and waste based on facts. If quality is defined by the customers, one could argue every increase in quality also represents added value customers are willing to pay for. Therefore, the goal of every DFSS project is to create marketable products with perceivable quality for the customers of the company.

DFSS usually consists of the five Six Sigma phases Define, Measure, Analyze, Implement, Control (DMAIC) to provide a structural model aiming at satisfying customer needs. Other acronyms popularized are e.g. IIDOV, CDOV, IDOV, DMADV, DCOB, and IDEAS (Soderberg, 2004). Despite the different acronyms, the fundamental strategy for DFSS remains the same: to create a data driven product development process that produces winning products. That is, satisfying customer requirements with the application of scientific and statistical methods (Soderberg, 2004). The strategy is similar to the Build-Measure-Learn cycle applied in the LSM as explained by Ries (2011). The striking similarities between development cycles used in DFSS and LSM can be found in the Shewhart cycle which is the basis which they were developed from. The Shewhart cycle was later popularized by the quality guru who helped rebuild Japan after WWII, Dr. W. Edwards Deming, as the PDCA-cycle, which stands for Plan (1), Do (2), Check (3) and Act (4) (Juran & Godfrey, 1999).

![Figure 2-8 The Shewhart Cycle, later popularized as the PDCA cycle (Deming, 1986. p. 88)](image-url)
For the purpose of this thesis, we sought to find literature that provides a hands-on toolset with a clear stringent structure to follow. For this reason the work of Staudter et al. (2009) and Roush et al. (1994) was chosen as reference literature, which provided a robust foundation on which to build the theory framework around. Staudter et al. (2009) uses the Define, Measure, Analyze, Design, and Verify (DMADV) cycle and Roush et al. (1994) uses the PDCA cycle (Figure 2-8) to provide structure for the development phases. As described earlier, the DMADV cycle originates from the PDCA cycle, and for this reason we will use the PDCA cycle for the remainder of this thesis when describing each step of DFSS.

2.4.1 Plan

During the planning phase, the goals of the project are defined as well as its team members. The market and customer needs are identified and design requirements set. If no customer requirements are set, the goal of Six Sigma of 3, 4 DPMO have no meaning. How else would you know if a defect occurs if no values which the products must conform to exist? Traditionally, marketing, manufacturing and product design have acted isolated from each other during the product development process. DFSS encourages a cross-functional development team (Roush et al. 1999) according to Figure 2-9.

![Figure 2-9 The DFSS-Team (Staudter et al., 2009. p. 17)](image)

The business case is described and project planning and scope is determined (Staudter et al., 2009). During this phase, it is essential to understand your customers. But before that can happen, the market must be defined through segmentation and selection of target market (Roush et al, 1999). Before any development processes can take place, it must be determined if a new design is even necessary or if simply an improvement of the process is enough. If the problem supports the design of a new product, the goal of the project should be formulated, preferably according to the SMART rule (Specific, Measurable, Agreed to, Realistic, and Time bound).

When target market and customers have been identified the customer research process can take place. DFSS does not stress the importance of this task enough, as it provides the basis for what requirements the product must be designed to conform to. To create well-defined customer needs is a critical starting point to start the development of a high quality product, because these will later be translated to the critical-to-quality characteristics (CTQs) (Roush et al, 1999; Staudter et al 2009; Ericsson, Gingnell & Lilliesköld, 2014). A common term for this exercise is the “Voice of the Customer” (VoC) (Roush et al, 1999; Staudter et al 2009) and includes any customer input available. Besides the traditional approach such as customer interviews, questionnaires, and surveys, input is also obtainable from sources such as: benchmarking, competitive studies, things gone right/things gone wrong reports, warranty reports, capability indicators, media analysis, field service reports, government requirements and regulations, internal customers, and team experience (Roush et al, 1999).
To gain an understanding about what is important to the customer, the practitioner must perform a critical-to-quality analysis. The needs of the customer are ordered in a hierarchy of needs, spanning from primary to secondary (and tertiary if necessary). The customer statements must then be analyzed to determine what they mean in terms of need. There are various tools available for this purpose such as customer need table, affinity diagram (Tague, 2005) and tree diagram (Staudler et al, 2009). The general idea here is to interpret and derive customer statements into smaller more manageable and specific statements in a breakdown structure. From the smaller statements, it is possible to classify the statements into factors of delighters, satisfiers and dissatisfies. Statements from the customer are specified according to the Kano model in figure Figure 2-10 which are essential to not build a product with attributes customers are not willing to pay for or develop a product based on false priorities (Staudler et al, 2009; Tague, 2005). It could also be used for marketing purposes. If delighters are identified and applied properly the customer could get unexpectedly excited about the product, e.g. collision avoidance systems in a car or simply free dessert after dinner at a restaurant. Considering 20 to 50 percent of all purchasing decisions is based on word-of-mouth recommendations from a trusted source (McKinsey, 2010), identifying delighters can be a powerful tool.

When all customer requirements have been identified, organized, prioritized and the VoC has been identified in detail it is finally possible to derive the CTQs. The DFSS approach is driven by CTQs throughout the development process, from identifying CTQs to decomposing, optimizing, synthesizing, verifying and testing CTQs (He, Tang & Chang, 2009). The goal of identifying CTQs is to transform customer needs into measurable and specific requirements (Staudler et al, 2009). The language used by the customer has to be translated into technical terms to be measurable. These variables are the carriers of product quality and must be interpreted from qualitative statements into a manageable quantitative business specification (He, Tang & Chang, 2009).

According to Juran and Godfrey (1999) developing key factors is a prerequisite to develop the quality assurance activities. They emphasize to focus on the “vital few” and not the “trivial many” (Juran & Godfrey, 1999). To develop key factor CTQs the practitioner must consider three dimensions of quality characteristics: the fulfillment of customer requirements, marketing and competitive requirements and design requirements of engineers. In other words, CTQs align design efforts with customer requirements and represent the product characteristics defined by the customer. They include USL and LSL or any other factors related to the product. Variation, non-conforming, or even the absence of CTQs will evidently have consequences of the released product such as poor performance, function, safety, reliability, or satisfaction (He, Tang & Chang, 2009). A simple demonstration of this concept would for example be: “Customer requirement: The chair must support the weight of a person → CTQ: Load strength specification: >150 kg.”
2.4.1.1 Quality Function Deployment

A common method for translating customer requirements into target CTQs and displaying the relationship between them is Quality Function Deployment (QFD). A completed QFD is available in appendix 4.1 “Updated QFD”, which can be used as a guide for the reader during this section. The key tool in QFD is the “house of quality”. It starts with the VoC and relates them to CTQs in a matrix. From the house it is decided which factors should be emphasized and which targets to aim for during the design, which is why it is so important to perform a CTQ-analysis before using QFD (Tague, 2005).

The VoC is placed in the rows of the matrix and CTQs in columns. To signify the relationship between VoCs and CTQs, a rating system is usually employed where 0 = no effect, 1 = weak effect, 3 = medium effect and 9 = strong effect.

Some practitioners adds a “roof” above the CTQs to indicate positive or negative interrelationships or correlations between CTQs, which could be exploited during the design work to find synergy effects or avoid risks between different components included in the design. It is also often helpful to include importance, current product satisfaction, sales points and competitive relationships ranked on a 1-5 scale to allow for prioritization of customer needs to focus on when deployed throughout the system.

Each “customer need weight” are then multiplied with each correlating CTQ value. The sum of each QTQ column is then calculated and standardized across all columns so that the column total equals 100. This way each CTQ gets a weighted value (“characteristic weight”) on a 1-100 scale, which will help the DFSS team to focus on the “vital few” CTQs that have the biggest impact on customer satisfaction and success of the product.

Now when the team knows what CTQs matter most for the customer criterion measures, design targets and preliminary specification ranges should be developed (Staudler et al, 2009).

2.4.2 Do

When selecting the prioritized concepts the team should assess the following: Customer focus, manufacturability, competitive design, reliability, safety, time-to-market capability, chance of technical success and commercial success (Roush et al. 1999). To identify existing and potential weaknesses in the design concept(s) chosen early during the project, a suitable tool to use is Failure Mode and Effects Analysis (FMEA).

2.4.2.1 Failure Mode and Effects Analysis

Roush et al. (1999) emphasizes that appropriate design characteristics have been considered simultaneously with manufacturing and assembly capabilities, to optimize the relationship between the product design and the manufacturing processes producing the product. FMEA provides a guide to detect weaknesses in the design and the manufacturing processes. It will also help to derive those measures necessary to counteract the weaknesses. Performing an FMEA in detail will later result in less variation when producing the product and better conformity to customer specifications.

Following is a step-by-step guide provided by (Staudler et al, 2009) about how to perform an FMEA (see Figure 2-11):
1. Start by noting the general information about the project.

2. Describe the product in detail, or the function of the product in particular, conducting the FMEA for.

3. Describe what purpose the component has for the product, why is it important for customer satisfaction?

4. Describe any potential failure modes; why did the component fail to meet the requirements of the customer?

5. Describe what effect(s) the failure has on the component and the end product.

6. List any potential causes of the failure or what is triggering the failure.

7. List the compensating provisions or any evidence verifying the design prevents the failure.

8. Specify how the failure cause is going to be identified or for avoiding its occurrence.

9. Rank the occurrence of the failure on a 1 – 10 scale, where one signifies low occurrence rate (zero to 5/100,000) and 10 a high occurrence rate (5/10 or more).

10. Rank the severity of the failure on a 1 – 10 scale (how bad is the consequences of the failure should it occur?), where 1 is that the failure would cause any noticeable effects on product quality and probably would not be detected by the customer, and 10 being a very high severity ranking involving safety problems or conformance to specifications.

11. Rank the likelihood the failure or defect would be detected on a 1 – 10 scale, where 1 is a remote likelihood the failure or defect would not be detected before occurrence, and 10 being a very high likelihood the failure or defect would not be detected and probably reach the customer.

12. Multiply the ranks of occurrence, severity and detection to calculate a risk priority number (RPN), where the highest number should be the main focus and requires a more detailed analysis.

13. Describe and define the countermeasures necessary to reduce the frequency of occurrence and/or likelihood to detect an occurrence, which will reduce the overall RPN.
14. List the persons responsible for implementing the countermeasures.

Estimate new occurrence and identifying rates after the implementation and calculate the new RPN.

2.4.2.2 Product optimization and refining

When a product FMEA is performed, the output of that study will leave the team with a prioritized list of weaknesses and ideas about how to counteract those weaknesses. This will more than often lead to the development of alternative designs of sub-functions of the product, to optimize performance and improve capability to conform to specifications. To optimize the cause-effect relation a number of tools and techniques are available such as scamper, additional QFDs or Ishikawa diagrams (Staudler et al, 2009). These will not be elaborated on here, but one of the most powerful tools to use when optimizing the product design is Design of Experiments (DOE). This can be employed to compare alternative design elements to conclude the optimal settings or design characteristics through statistical analysis. To develop and perform DOEs the implementation of one or more prototypes is necessary. It can either be developed the traditional way where prototypes are produced in its physical form, or developed and analyzed using CAD software which is cheaper and less time consuming (Staudler et al, 2009), but may not be suitable for all experiments depending on what is going to be measured and the purpose of the study. Following is an introduction to DOE.

2.4.2.3 The Design of Experiments process

To defend beliefs with methods such as authority, intuition and tenacity is less than optimal since a high degree of subjectivity in an individual is involved in those beliefs as a basis of what is established as the truth (Stone, 1979). Unlike these methods, the scientific method “aims at knowledge that is objective in the sense of being intersubjectively certifiable, independently of individual opinion or preference, on the basis of data obtainable by suitable experiments or observations” (Hempel, 1963, p. 141).

To produce such knowledge one has to conduct research. The detailed methodology used to conduct such research will be referred to as research design during the remainder of this section. In a narrower context, when we refer to experimental design, we refer to the description of the plan of study determined by statistical procedure. Experimental design is a type of method designated to the assignment of test units to experimental conditions for the purpose of generating data. It considers the sampling plan, which is dealing with the number of procedures that will receive some sort of treatment, and the plan of statistical analysis, to be included in the experimental design (Kirk, 1968). Figure 2-12 further describes the interrelationship between these terms.
Luftig (1998) describes three different reasons that will motivate applied research and the development of a statement of the problem. 1) Efforts regarding strategic initiatives generated through product-market analysis or competitive benchmarking. It is common during these initiatives that gaps are discovered between where you currently are and where you want to be. The company would then target these gaps for closure through applied research. 2) Strategic questions discovered during quality improvement efforts, to bring critical quality characteristics into a state of control. 3) Efforts to eliminate product or process dissatisfiers (Luftig, 1998). Any reasons to deploy applied research in this thesis fall under the first category.

**Developing a statement of the problem**
This is usually the first step of any research study to serve as a “stage setting” description. The general procedure to write a statement of the problem is: 1) to classify the background data/information. This refers to the description and significance of the problem which would be generated through data or information gathered during strategic initiatives or options. 2) To delineate the research problem. This refers to the parameters of the problem developed, which will generally result in the identification of the population – that is, the units or conditions to which the researcher would like to make inferences as a result of the research efforts. 3) To delimit the research problem. That is, in order to perform the study in an effective and correct manner, the research problem has to be concise, precise, testable and obtainable (Luftig, 1998).
Define the Research Study Framework

Not all problem statements lead to the design of an experiment. However, it is important to make the distinction between experiments and non-experiments. Non-experimental procedures refer to the degree of which the researcher is able to manipulate subjects or conditions. In such a case, the researcher may be able to identify conditions and variables, but may not be able to assign subjects or units to those conditions. In designs of experimental nature, the researcher is capable to freely assign test units or subjects to the conditions of interest for testing. Those conditions are referred to as “treatments”. In addition, a hybrid of the two approaches where the researcher is able to manipulate all variables associated with the study with the exception of the ability to manipulate the treatment schedule or the ability to randomly assign subjects to treatments or both, is called quasi-experimental procedures. For research studies of non-experimental nature, research questions should be employed, and research hypotheses should only be employed for experimental research (Luftig, 1998). While the authors of this thesis acknowledge that this convention is not universally accepted, it will be used as a guideline for any experiments designed in this report.

This guideline is not used within LSM. For example, when the hypothesis presented is “problem interviews will validate our belief in parents as a viable customer segment” (Maurya, 2011, p. 93), the research is of non-experimental nature because the researcher are not capable to freely manipulate all variables associated with the study (one does not simply control all parents in the world). In this case, a research question should be employed rather than a research hypothesis. However, this does not prohibit the researcher from conducting research and validate that question, but the tools available to the researcher are limited to do so. A status study would be better suitable for this type of question, which attempts to acquire data related to the situation or attitude at a given point in time. The researcher should bear in mind that greater measures regarding validity and reliability has to be taken into account when conducting this type of study, which typically means talking to more people with a more detailed segmentation than just “parents”.

Only in cases where the research design could be categorized as experimental or quasi-experimental was an experimental design employed in this thesis. This is typically only possible when a problem has been narrowed down to the extent that a single or a few product characteristics or business plan characteristics can be specified as a characteristic of interest to validate an assumption. Non-experimental research design is therefore preceded by any experimental design, to be able to narrow down the assumption to that specified level.

Each hypothesis will then be tested using experimental design, because it could now be categorized as quasi-experimental or experimental, following the experimental design cycle. This would mean:

Writing the research hypothesis → Define/select the dependent variable(s) and criterion measures → Identify and classify treatment, independent and nuisance variables → Create the most appropriate and efficient experimental design available and possible → Design the sampling plan → Assess the data collection instruments → Conduct the study → Design/select appropriate plan for the statistical analysis of the data → Analyze the data → Answer the research hypothesis → Provide results.
Design the sampling plan
To test hypotheses the researcher has to set up a null and an alternative hypothesis. The null hypothesis states, that the experiment showed no effect and that there is no difference between the comparisons which were done in the experiment, and its symbol is \( H_0 \). The alternative hypothesis’ symbol is \( H_1 \) and states that we have sufficient statistical evidence to reject the null hypothesis and includes all other conditions except \( H_0 \) (Staudler et al, 2009). For example, the researcher may be interested to test the hypothesis that the population mean is 100, therefore;

\[
H_0: \mu = 100 \\
H_1: \mu \neq 100
\]

Usually all statistical analysis is done in software nowadays, where the researcher will obtain a test statistic with a corresponding p-value. The interpretation of this p-value would be the probability to get a value of the test statistic which is extreme or more extreme than the one we have by chance and chance alone. Subsequently, it means that if the p-value is low we reject \( H_0 \), and the alternative hypothesis is true. When a researcher conducts hypothesis-testing, he must use appropriately representative sample data to make a decision about rejecting \( H_0 \) or not. This results in four conditions for the experimental outcome (Staudler et al, 2009):

![Figure 2-13 The α- and the β-error, (Staudler et al, 2009, p. 258)](image)

When in reality \( H_0 \) is true but a decision to reject it is made, the researcher has made a Type-I error, a false signal. The probability to commit such an error is known as alpha (\( \alpha \)), and is chosen by the researcher based on how certain he wishes the experiment to be. To accept \( H_0 \) correctly is called confidence, and is \( 1 - \alpha \). If the researcher, however, accepts \( H_0 \) but in reality it is false, he has made a Type-II error, and the probability of making such an error is called beta (\( \beta \)). This could be interpreted as a missed opportunity, because a difference actually existed but the researcher failed to discover it. When the researcher correctly rejected \( H_0 \), it is known as power and is \( 1 - \beta \). Power is the ability to detect a difference (or effect) when it truly exists (Staudler et al, 2009).

How certain the researcher wants to be to detect a meaningful difference (power) is related to the sample size (\( n \)) the study is based on. The larger sample size, the greater the power. Therefore power, or certainty that a true difference has been detected by the researcher, must be “bought” with sample size, in addition to an appropriate experimental design. So, the researcher needs to consider both \( \alpha \) and \( \beta \), or in other words: how much is the researcher ready to risk making a Type-I or Type-II error? Alpha must be chosen by the researcher based on which confidence interval he would like to have when making his conclusion, and is usually 0.1, 0.05, or 0.01 (Luftig, 1997). \( \beta \) must be chosen by calculating which power the study needs to have to detect a true effect, and is determined by sample size. Therefore the researcher has to conduct sample size calculations, which is based on the magnitude of effect the researcher needs to detect. If sample size calculations are not made and simply based on cost or “gut feeling”, it will generally result in low power and high \( \beta \) (Luftig, 1997). Therefore, one could make the argument that studies made where data has been determined to not show a significant effect, but without calculating an appropriate sample size, is subject to a high risk of missing out on an important opportunity.
When a proper research design and sampling plan has been made, executed, and the data has been gathered, the researcher needs to determine an appropriate plan for the statistical analysis in order to extract any meaningful information and conclusions from the experiment. Staudler et al (2009) provides two standardized matrixes which cover most basic statistical tests:

**Tabell 2-1 Statistical test matrix, discrete data (Staudler et al, 2009, p. 260)**

<table>
<thead>
<tr>
<th>Test</th>
<th>When/What for</th>
<th>Hypotheses</th>
<th>Prerequisites</th>
</tr>
</thead>
</table>
| Binomial Test         | Compare a proportion with a theoretical or given proportion with binomially distributed data, e.g.: good (non-defective) bad (defective) test. | $H_0 : p = p_{theor}$  
$H_1 : p = p_{exp}$ | Binomially distributed data $n \geq 100$ and/or $n \cdot p \geq 5$ and $n \cdot (1-p) \geq 5$ |
| One Proportion Test   |                                                                              | $H_0 : p_1 = p_2$  
$H_1 : p_1 \neq p_2$ | Binomially distributed data $n \geq 100$ and/or $n \cdot p \geq 5$ and $n \cdot (1-p) \geq 5$ |
| Binomial Test         | Compare proportions of a characteristic in two samples.                      | $H_0 : p_1 = p_2$  
$H_1 : p_1 \neq p_2$ | Nominal data $n \geq 100$ and/or $n \cdot p \geq 5$ and $n \cdot (1-p) \geq 5$ |
| Two Proportion Test   |                                                                              | $H_0 : p_1 = \ldots = p_k$  
$H_1 : p_1 \neq \ldots \neq p_k$ | Nominal data $n \geq 100$ and/or $n \cdot p \geq 5$ and $n \cdot (1-p) \geq 5$ |
| Chi-Square Test       | 1. Compare proportions of a characteristic in two or more samples.          | $H_0 : p_1 = \ldots = p_k$  
$H_1 : p_1 \neq \ldots \neq p_k$ | Equal variances of equal samples, independent samples |
|                       | 2. Compare proportions in two or more populations.                          | $H_0 : p_1 = \ldots = p_k$  
$H_1 : p_1 \neq \ldots \neq p_k$ | Equal variances of equal samples, independent samples |

**Tabell 2-2 Statistical test matrix, continuous data (Staudler et al, 2009, p. 261)**

<table>
<thead>
<tr>
<th>Test</th>
<th>When/What for</th>
<th>Hypotheses</th>
<th>Prerequisites</th>
</tr>
</thead>
</table>
| One Sample t Test | Compare the mean value of a sample with a target value                      | $H_0 : \mu = \mu_{target}$  
$H_1 : \mu \neq \mu_{target}$ | $n \geq 30$ and/or normally distributed data                                     |
| Two Sample t Test          | Compare mean values of two independent samples                             | $H_0 : \mu_1 = \mu_2$  
$H_1 : \mu_1 \neq \mu_2$ | $n \geq 30$ and/or normally distributed data, independent samples               |
| Two Sample paired t Test    | Compare mean values of two dependent samples                               | $H_0 : \mu_1 = \mu_2$  
$H_1 : \mu_1 \neq \mu_2$ | $n \geq 30$ and/or normally distributed data, paired, dependent samples         |
| One Way ANOVA            | Compare mean values of several independent samples                         | $H_0 : \mu_1 = \mu_2 = \ldots = \mu_k$  
$H_1 : \text{at least one mean value is different}$ | Equal variances of equal samples, independent samples |

25
2.4.3 Check

Experiments utilizing statistical analysis will help determine the final design through e.g. optimizing product attributes, or combination of attributes, or comparing different concepts against each other. When the final design is complete or very near complete, the product is ready to be tested internally or in the field. From these tests some minor modifications might be necessary, and will be updated in the product design scorecard. The design scorecard is a living document for the product and every sub-component of the product in different hierarchy levels, which will be modified iteratively throughout the product development process and will include: High level design element, the transfer functions of the high level design concept to the detailed design element, the measurement analysis corresponding to that element, the target value and USL and LSL, the mean, the standard deviation, capability measures and resulting DPMO (Staudler et al).

2.4.4 Act

When the design scorecard is capable to perform according to customer requirements, external manufacturers can be contacted to bid on the production contract of the product if the company developing the product does not have manufacturing capabilities themselves. To insure the equipment they use will be able to achieve what is desired, the team should ask the supplier with these eight points for review (Roush et al, 1999):

2. Reliability Model.
3. FMEA of the process.
5. Design review.
6. Reliability testing.
7. Root cause analysis.
8. Maintainability testing.
3. Research methodology

In this chapter we will present the methods we have used and our scientific approach to collect empirical data, how we extracted data, the reliability, validity and bias of the study. The chapter will end with a description of how this was put into practice when conducting the interviews and extracting knowledge.

3.1 Research approach

To approach the research problem this thesis set out to answer, the PDCA-cycle was used to get a structured framework for the planning, the executing and the analyzing phases during the study. The goal of business research at its core is to gain insights about aspects which are believed to be inadequately understood, for example where one may notice a gap in literature on an inconsistency between a number of studies (Bryman and Bell, 2015). Therefore we as researchers took an active part in driving the product and customer validation process, to fully explore it and get in the action. To fully be able to answer our research question in its right context, we as researchers had to be a part of a real startup, but at the same time step back from the action and analyze the process. This gave us a holistic perspective of the process and enabled us to better understand its complexity. The process by which we approach each problem is presented in Figure 3-1 and to conduct this approach we used the methods presented in this section.

![Figure 3-1 The problem solving strategy.](image)

It is important to remember that customer development does not replace product development; it should rather be seen as a companion to it. The founders of the company and the product development team define the product to fit their vision. The job of the customer development team (in this case, the authors of this thesis) is to explore and validate whether there is a market and customers for that vision, not to add features to the attribute list (Blank, 2006). To do this the researchers of this thesis will have to get out of the building and test the assumptions that the vision of the company relies on against facts which are only obtainable in the real world by real customers.
3.2 Study Methods

3.2.1 Abductive Study

An abductive study is a combination of the inductive and deductive methods that is commonly used. The deductive method uses already known theories and makes observations to infer results and test the theories. The inductive method starts on the other side with observing something and thereafter generalizing it to theories. The abductive method is a combination of these two which makes it possible to start with a theory, make an observation and draw conclusions between the observation and the theory (Alvesson, Sköldberg, 2008).

The abductive method gives us the possibility to build theories from the observational data but also to empirically validate hypotheses through research which gave us the possibility to use the large amount of research from the industry and study how it could be used in a startup context. This made the abductive approach suitable since we saw potential in several already known theories but which weren’t adopted for the startup environment. To generate and test ideas on the case company we both needed to use existing theories and collect data from interviews to examine our result on the case company.

3.2.2 Mixed methods research

To be able to generate the data we needed to answer our research question we have been using both qualitative and quantitative methods. This is commonly known as mixed method research which means that the different methods are used integrated or to support the other method. As an example, interviews or observations can be used to create the foundation for a survey that will be sent out, or the opposite, a survey creates the foundation for the interviews. This is one of the strengths when using mixed methods research. The combination and use of each side’s strengths helps bridging the gaps that they have (Hesse-Bieber, 2010).

Mixed methods research made it possible for us to use several different methods both qualitative and quantitative and use the outputs from them to validate our results. The semi-structured interviews were used to test hypotheses about the business model and the product, to uncover false assumptions or validating them. The qualitative input from the interviews was then used to create quantitative experiments to verify the product against the customers’ demands. Based on the input from the customers we interviewed, a number of CTQs could be identified and quantified through QFD. The quantified metrics provided the basis of analysis to figure out what was really important to the customer and how the case company’s product conformed to those customer requirements. In addition to the QFD, an FMEA was performed to analyze preventative activities for eliminating or reduce the chance of defects occurring and reaching the customer.

Using quantitative research has received some critique, implying that quantitative research leads to a static view of the social reality which is separated from those individuals creating this reality (Bryman, 2008). Therefore, quantitative research cannot cover every eventuality that may occur, and results from the quantitative research described in this thesis should be seen as a generalization of a common tendency.
3.2.3 Data collection

During the customer discovery process we have been using mainly qualitative methods to collect the data needed. The qualitative data comes from semi-structured interviews to collect customer inputs and preferences. We started with semi structured interviews at different ski resorts face-to-face and on two occasions performed phone and skype interviews. The use of phone and skype interviews were justified to complement the face to face meetings since it were too time consuming to go visit ski resorts, more than often located in geographically desolated locations. The use of skype and phone was not used until the last two resorts were interviewed, because at this point we had learned what different body language was associated with specific answers to questions. However, we do acknowledge the impact not meeting face-to-face has on the external validity of this research.

Since the product developed has a very niche segment of customers (ski resorts), randomization of respondents to interview proved problematic. Bryman (2008) points out that to remove the human factor from having an impact on the validity of the research; randomization must be adapted when selecting objects to study. The number of ski resorts in Sweden representing the target market of the product is very limited and randomization was achieved through contacting as many resorts as possible that we could get adequate contact information on, that number was 15 resorts. Out of those 15 resorts, eight resorts responded on our request and agreed to an interview. They included major as well as minor ski resorts, to be able the generalize inputs across all types of ski resorts in Sweden, but also to be able to identify differences in customer input between large and small resorts.

We never did an interview if we could not get in contact with the head supervisor of the ski lifts of the resort. This meant that all respondents or respondent groups interviewed included the chief technical officer (CTO) of the resort. The reason behind this demand on respondents lies in our research question, to be able to validate the product. The CTO is usually the most experienced employee when it comes to safety and regulations, and how ski lifts behave in certain conditions. In total, the respondents of the semi-structured interview process were in charge of 84 T-bar ski lift systems, which are approximately equal to 10, 5% of the total T-bar market in Sweden.

3.2.4 Semi-structured interviews

Interviews are one of the most used methods within the qualitative research since it gives the researchers a possibility to gain large amounts of information. The design of interviews can be more or less structured which also affects the validity of the data that is gathered. By using the right design of the interviews the researcher can overcome this issue and gain the positive effects which is the possibility to more wieldy analyze the respondent. One interview method to achieve this is the semi-structured interviews (Bryman, 2008).

Semi-structured interviews give the possibility for a researcher to design a structured framework but with the possibilities for the respondents to be open with their questions. This creates a flexible but repeatable framework for each interview where the respondent will be able to answer the questions broadly and according to their own preferences and knowledge. This will also assist with creating an atmosphere where the respondent will feel safe to express honest opinions and well thought true answers (Kvale, 1997). It also gives the researcher the possibility to maintain a good flow in the interview since different questions don’t have to be answered in the same order in each respective interview, if the respondent takes the interview in a new direction. This ensures that the respondent will get the possibility to give their thoughts on what they believe is important. This may also lead to new information that the researchers didn’t expect (Bryman, 2008).
The researchers designed a template that was followed during the interviews which was designed to make it possible for the researchers to answer the research questions for this study. To add as little bias as possible in the interviews it was always the same researcher that led the interviews while the other took notes. After each interview the researchers immediately sat down and evaluated the different reactions from the respondents during the interview to gain as much knowledge as possible from the interview while it was still fresh in memory. This increased the output from the interviews and helped solve misinterpretations when they occurred. The researchers behind this thesis who were leading each interview was also one of the founders of the company. This decision was made based on two reasons, the first being that Blank (2008) suggests that a person with decision making power should always be included in the customer development team when applying LSM. This way the respondents get a true sense that their input has a true influence of the end result of the product. The second reason is that the case company wanted to develop a relationship with its customers early on, which later could be used for sales purposes. It is also essential, that the founders truly know the needs and wishes of their customers to create customer oriented solutions to their problems.

Since the interviews were semi-structured the different respondents had the possibility to express themselves freely, we used indexing to compare different responses which is a suitable tool for these kinds of interviews (Michrina, Barry P, 1996). This was conducted by underlining statements, repeated phrases, key words and emotions to understand why the respondent answered as they did. When each interview were indexed we analyzed it to find similarities and differences between the respondents which were later used in the QFD design, FMEA and when we eventually decided to pivot in various Lean canvas sections.

3.2.5 Action research

There isn’t any clearly defined definition of what action based research is, but the interviews that we conducted had parts that could be called action based research (Eden, Huxham, 1999). Since the interviews have been semi-structured the respondents had the possibility to give feedback on the product. Some of the interviews became problem solving interviews where special features and attributes were discussed. This discussion took shape as a problem solving together with the respondent focusing on their existing problems. According to Eden and Huxham (1999) action research is when the researcher works with members of an organization over a matter which is of genuine concern to them and they also need to be determined to take action against it. There were only a few interviews that had elements of action research but it was helpful in understanding the ski resorts challenges and what they wanted. We as researcher didn’t force the discussion that could be defined as action based, it was more a natural part since one of the researcher also is the founder of SkiCorp.
3.3 Methodological approach

*In this section we will present a methodic description on how the interviews were conducted and why we structured them as we did. This is done to give you as a reader an understanding of the setting of the interviews. The output from the interviews will be presented in chapter 4.*

3.3.1 Find and contact potential customers

Swedish ski resorts organization (SLAO) have 220 ski resorts as members which represents 8.5 million ski days. Out of these 802 ski lifts about 70% are T-bars (Gerremo, 2015). These figures can be used as the total market in Sweden because the amount of ski resorts that aren’t members of SLAO are only a few and are negligible compared to the members in SLAO. The top 50 largest ski resorts in SLAO cover 85% of the market which shows that the market is skewed with a few actors that have the majority of visitors. The Swedish market is a well segmented market when using ski days as factor. You can also use geographic location but due to the skewness in the market with a few large actors, the research team and founders of SkiCorp decided to segment on ski days. The three segments and the amount of ski resorts in each segment are presented in the Tabell 3-1 Segmentation of Swedish ski resorts. The data used comes from SLAOs report (Branschrapport, 2015).

<table>
<thead>
<tr>
<th>Segment</th>
<th>Ski resorts</th>
<th>% of total skidays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large ski resorts</td>
<td>4</td>
<td>42%</td>
</tr>
<tr>
<td>Medium ski resorts</td>
<td>13</td>
<td>29%</td>
</tr>
<tr>
<td>Small ski resorts</td>
<td>203</td>
<td>29%</td>
</tr>
</tbody>
</table>

When deciding which ski resorts to interview we wanted to have a spread over the segments and also on geographic location and weather conditions. Since SkiCorp already had made initial contact with several ski resorts they wanted us to elevate that initiated contact with a few of them and also find others to validate the product on the Swedish market. The eighth respondent groups had responsibility over resorts which represented 37% of the total annual skiing days in Sweden with a spread over all three segments.

3.3.2 Stage setting

This is the point where the research study of this thesis begins to take place. To analyze and learn as much as possible from phase one and two of the customer discovery process, a statement of the problem was written in a word-picture – a story. This served as a contextual setting before each interview when testing the solution on potential customers. The story contained the background of the problem, how the SkiCorp team as entrepreneurs came up with the idea, and the results from the previous interviews when SkiCorp conducted research about the problem we now were trying to solve. The responses during the problem validation process revealed a pattern of problem statements, which showed that most ski resorts had problems achieving acceptable comfort levels during the ski lift ride and cost efficient alternatives to the current T-bar ski lift system. We were very open and frank about focusing on these two problems when we tested the solution. It is emphasized in LSM literature to give customers a complete background to the problems to make them understand the purpose of your new venture (Blank, 2006). Therefore, we briefed respondents on the background of the problem we were trying to solve to answer the question “why?” for each problem we focused on.
For contextual purposes regarding the comfort problem, we referred to the stagnated development and lack of innovation for the T-bar ski lift. And when we explained why we chose to focus on economic viability, we referred to the costly alternatives to the T-bar ski lift, which is the chair express lift which is a 10 times more expensive investment than a T-bar system. At the end of the context setting stage, we asked if what we had told them resonated with the respondents and if they would like to add or ask something. Next, we collected demographics from the resort to collect any data that we later used for segmentation and database purposes. They included: Name and title of respondent, areas of responsibility, number of T-bar systems at resort, T-bar manufacturer(s) of those systems, the capacity of the T-bar system, annual visitors of the resort and whether or not they used advertisement at the resort.

3.3.3 Presenting and testing the Minimum Viable Product (MVP)

The prototype of the product had been built with CAD-software and was delivered to the research team for the purpose of this study. The prototype was rendered into images to match the contextual stage setting we had previously designed. This meant a rendered image showing the product in a collapsed state and installed in its natural habitat was used for stage setting purposes related to comfort level. For economic viability stage setting purposes, we rendered images of the product in an exploded state to show the mountable function of the product on current T-bar systems and sequential images to describe how the actual function of the mounting would work. Lastly, we rendered images showing the built in ad space with a couple of examples of potential advertisers with their respective logos or campaign slogans, to trigger the imagination of the respondent and allow him to see the possibilities the ad space provided. We also rendered the logo of the resort we were currently visiting into this space with matching colors of the MVP and mixed those renderings into the rest of the images. The ski resort logo renderings were the only images that changed from respondent to respondent when we tested our solution, which allowed us to also test each individual’s reaction to have their own brand displayed on the ad space.

During the first image we explained the thought process behind the design and how it would contribute to a more comfortable T-bar ski lift ride in comparison to what is currently available. We also explained how we had taken into account all types of skiers and snowboarders of all sizes and skill levels and what consequences should be expected from that improvement, such as increased capacity utilization and better flow of visitors across the mountain.

During the second and third image we demonstrated the shell design and how the mounting function worked. We explained how it would lead to a cheap solution compared to the value it provided for their own customers, since their current T-bar ski lift systems could still be utilized which eliminated any need for large capital investments. We also noted that the flexibility of the mounting shell design could open up opportunities to exchange T-bar seats into different colors and later updated designs since it could easily be exchanged.

The last images showed the advertising space with a couple of different examples how an advertisement on the product could look, both when the rights to the surface were sold to a third party or when the ski resorts decided to utilize the space for themselves and increase their own brand recognition. We told the respondents during this stage about the implication long term exposure of messages had on the recognition and recall rate of human beings (a typical T-bar ski lift ride takes 5 – 10 minutes) and how SkiCorp’s product provided a more efficient marketing tool within the alpine environment.

When all attributes had been shown and described for the respondent, we asked if they had any questions or concerns. Then, they were asked to rank the three attributes of the product from one to three, where one related to the product attribute which the respondent felt resonated most with him.
3.3.4 Testing business model hypotheses

When the demo was over we started the semi-structured interview, which consisted of about 25 basic questions distributed across four categories to test and validate hypotheses about channels, solution, revenue streams and early evangelists. We divided the questions into the categories workflow, product attributes, channels, marketing, and pricing.

**Workflow**

It’s important for SkiCorp and their customers to identify every possible person or entity that may be affected by the new product since it inflicts a change in how things are done. To avoid ripple effects previously not thought about when the product is launched, we asked the respondent to help us identify anyone who may be affected by the product. We started with stakeholders we had identified ourselves and listened carefully if they agreed or if they wanted to add someone else. We also listened carefully about first reactions after we were done presenting.

**Product attributes**

Next we asked about whether or not the product attributes matched their needs as a ski resort. At this point we want to know what the first produced MVP needs to achieve to satisfy the customer. Therefore we asked questions like: “What attributes must the product have on day one?”, “What attributes are missing, what is a complete product in your mind?”, “What obstacles do you see for the majority of ski resorts around the world to use our product?” This part of the interview is the VoC part used in the updated QFD, now that the current solution had been presented to the customers. It is not uncommon for customers that were also previously interviewed for the initial two phases of customer discovery (which SkiCorp had done before this study took place) to change preferences when they’ve actually received a sneak peak of the product. Now they have something tangible in front of them as a basis for their input, which is why using an MVP is so powerful (Maurya, 2012).

**Channels and Marketing**

To test our hypotheses related to which channels to use for marketing and distribution, we asked how they found out about similar new products today and whose opinion they ask for when they feel uncertain about using something new at the ski resort. This way we could identify key people within the skiing industry whose consent and approval was important for the success of the product. We would also ask about which magazines or trade shows they usually go to, which would be a valuable tool when formulating the marketing strategy. We also asked how they would like to buy the product, which answered our hypotheses about distribution channels. But more importantly, we asked who had the buying power for the type of product we presented and how the decision making process worked. This way we identified the person who had to say yes at every resort we interviewed which will be valuable information for future sales strategies once the product is launched. We even asked if they had a specific budget for ski lift improvement and when during the year purchases for the upcoming season takes place.
Pricing
When we had covered a major part of the interview we shifted focus to reveal clues about what the product is worth to the respondent. A key element here is to first make the respondents aware of the benefits provided by the product and then to ask questions to put the respondent in a state of mind where the product already exists in their day-to-day life and they can take advantage of those benefits (Blank, 2006). Some examples from our study would be “Which T-bar ski lift would you install the new seat first on? Why that one? What do you think your customers would think of you when it is installed?” Then we asked if they would try the product if they could have it for free (just as a precaution, if five respondents in a row said no to this it is time to get back to the drawing table and rethink the strategy). Obviously, giving the product away is not an option. But it would be if SkiCorp could exploit the rights to the advertising space. So we asked how the respondents would use the advertising space and if they would be willing to give up the rights to the advertising space in exchange for getting the product for free. If they did not want to give up advertising rights or did not have the authority to commit to such a request, we suggested a higher price than expected and if they would think the product was worth spending that kind of money on again the following year. This way we would get a counter-offer, and we learned exactly how much the product is worth (today) as perceived by the customer. Remember that according to Ericsson, Gingnell & Lilliesköld (2014) the goal of every DFSS project is to create marketable products with perceivable quality for the customers. So by definition, any increase in perceived quality for the customer should translate to higher sales price. Asking respondents what they think the product is worth like this, gives us an indication on how well we perform on quality and how we should price the product.

To summarize, the following hypotheses were primarily tested during the semi-structured interviews with ski resorts:

<table>
<thead>
<tr>
<th>Solution</th>
<th>Customer Segment</th>
<th>Revenue Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution Interviews will validate minimum feature set. <strong>Feature set:</strong> 1. Comfortable T-bar seat. 2. Attractive appearance and space for long term exposure advertisement. New advertising space to generate extra income for the resort. 3. Mountable shell/case design takes advantage of already existing T-bar systems</td>
<td>Solution Interviews will validate smaller family ski resorts with at least one T-bar system installed and use advertisement as an extra source of income as earlyvangelists.</td>
<td>Solution Interviews will drive verbal commitments to test SkiCorp for one season on current T-bar system(s) at ski resorts.</td>
</tr>
</tbody>
</table>

3.4 Validity
When conducting experimental research conclusions drawn from the experiments should be assessed based on the validity of the results. We need to know that our tests measures what is supposed to be measured. There are four different types of validity: statistical, construct, external and internal (Graziano A, M. Raulin M,L. 2007) but we will focus on the external and internal validity.
Since we have used semi structured interviews when one of the researchers took notes and then interpreted by the researchers together the internal validity were affected. This has been taken into consideration during the interpretation of the data as Bryman (2008) points out in his book. The respondents have worked for ski resorts all over the spectrum, from small resorts to large, family friendly to extreme skiing and with different weather conditions based on their location in the country. This has affected the validity and made it possible for us to draw conclusions that can be more generalized.

The degree of validity in the result is closely linked to how well we have handled the bias in our research. As presented further in to the report we have several different factors contributing to bias which also affects the validity of our results.

3.5 Reliability

Reliability refers to the consistency of a measure of a concept. Bryman and Bell (2015) has identified three prominent factors when considering if a measure is reliable: stability, internal reliability, and inter-rater reliability. For the purpose of this thesis, the researchers have focused on stability. It is not common for researchers when reporting on findings to conduct tests for stability. The reason behind this is the way stability is measured, where the most common method is the test-retest method, which means testing one measure on one occasion and then retesting the same measure on the same sample on another occasion. The researcher should expect to find a high correlation between the first and second test, which signifies high stability. However, the respondents’ first answer may influence their answer on the same question the second time. In addition, the researcher has to take into account events that may intervene during the interval between the two tests, which may influence how the respondents answer the second time as well (Bryman and Bell, 2015). This would very quickly turn into a complex problem and develop into a project of its own. For this reason the researchers will not carry out any tests for stability when gathering qualitative data. However, responses on standardized questions and rankings, e.g. preferred product attribute, will be analyzed for its correlation between different respondents to find positive or negative correlation effects which can then be used to create ski resort profiles based on, e.g. ski resort size and location. Internal reliability, or equivalence, is defined by Luftig (1999) as the extent of internal consistency between scores or observations obtained for the same subject to correlate on parallel analyses.

When gathering and analyzing data from experiments, stability and equivalence in measures is achieved through measurement system analysis (MSA) and must be performed before the experiment takes place. The purpose of such a study is to assess the capability of the system or person conducting the experiment. If such an analysis is not performed before gathering and analyzing data, the researcher may draw false conclusions from the result and react to the measurement system itself, and not what is actually measured. Therefore, the measurement equipment must be tested through repeated measures. Variability contributing to measurement error is categorized as a) failure of the device to repeat itself and b) failure of a measurer to in reproducing his or her measurement method (Senol, 2004). This phenomenon is described as (Senol, 2004, p. 132):

\[ \sigma^2_{\text{measured value}} = \sigma^2_{\text{real value}} + \sigma^2_{\text{measurement error}} \]

where

\[ \sigma^2_{\text{measurement error}} = \sigma^2_{\text{repeatability}} + \sigma^2_{\text{reproducibility}} \]
Low variability in repeatability and reproducibility will result in high precision of the measurement system. To avoid high variability of the total measurement system, accuracy must be taken into account as well and has to do with bias of the measurement system. This will be explained in the next subchapter. To clarify how precision and accuracy contribute to measurement error and why it is important to analyze this phenomenon through an MSA before gathering and analyzing data when conducting experiments, see Figure 3-2.

Any experiments designed as an output of this thesis must always be preceded by an MSA.

### 3.6 Bias

There is always an amount of bias when you are conducting research, the more variables the higher risk for uncontrolled bias. Especially when there is observational studies involved. Bias can affect the generalizability but as long as the researchers are aware and have taken it into consideration the results will still be solid (Bryman, 2008). Since we were two researchers during this study we decided to have one as the main interpreter and taking notes and one who were asking the questions. This was done to standardize the flow of questions and the observational part of the interviews as much as possible. This also made it easier for the respondents to know who to focus on which created an open environment where the respondents felt safe. Kvale (1997) points this out as a key part to create meaningful interviews. However, by standardizing the interviews there is also a risk that we are adding bias due to fact that the same researcher were asking questions. If we would have altered the different roles it would have been possible to detect researcher bias in how we lead the interviews differently. The risk is that age, gender or ethnic origin will affect the answers which could be noticed if the researcher asking questions where altered between the interviews. Bryman (2008) presents difficulties in seeing the differences dependent on the researchers and especially when the researchers aren’t differentiable in the three categories. How the question is phrased is also important especially since the interviews were semi structured. Due to the decision that the same researcher asked the questions it was hard to extract these differences and therefore the researchers decided to focus on standardizing the interview settings.

The researchers discussed every interview immediately afterwards to get a unified view on the reactions from the respondents while the memory of the interview was still fresh. To do this directly afterwards and analyze their answers helped us controlling the bias in a better way. Since we are interpreting not only what they say but also how they say it and how they react on the questions, it was an important tool for us to controlling the bias.
We conducted both face to face interviews but also skype interviews due to the time consuming and expensive travels. Since the setting is quite different between these two different settings there is a potential that the result from them differ dependent not on the interviewed individual but due to the environment (Bryman, 2008). This has been taken in to consideration by the researchers when analyzing the result.

3.7 Ethics

During the studies we have identified two different ethical dilemmas, research ethics and the ethical impact on the society from the research.

Research ethics

Bryman (2008) states that there are four ethical principles that you need to consider as a researcher: the transparency of information, consent of participation, confidentiality demand and the data utilization. These principles have been used when planning the research.

The interviews were conducted with individuals that were chosen due to their position at the ski resorts and the interviews were confidential. The information isn’t traceable in the report but SkiCorp have received the full information which the participants were informed about before the interviews. This is an interesting setting from an ethical stand point, normally the firm won’t receive the full interviews due to the confidentiality in research interviews. In this research it was transparent for the respondents that SkiCorp would receive the full information but their inputs would be confidential in the report. During the interviews the researcher that took notes also interpreted how the interviewee reacted to the questions and the introductory presentation of the product. The interviewee was informed that the researcher took notes during the interviews to be able to conduct further analyzes. We mentioned but didn’t emphasize that we also interpreted their reactions because this could have made them feel uncomfortable and have negatively affected the atmosphere during the interviews. Kvale (1997) describes the importance of creating an atmosphere where the interviewee feels comfortable with the situation and if we would have emphasized the observation part this could have been unbeneifical for the interview. Bryman (2008) also touches this subject and emphasize the importance of discussing the issue and compare the benefits for the research verses the ethical view. The researchers noticed the possible ethical dilemma but since this wouldn’t affect them we accepted the possibility for it.

The interviews were conducted for research purposes but indirectly it was also a sales meeting due to the composition of the researchers. The participants knew that one of us also were the cofounders but that we were there as researchers for a master thesis. The participants didn’t express any thoughts about this but as researchers we put efforts in making sure that the interviews only brought up what the research needed and not making sales for the case company. However, all interview responders were informed before each interview about the dual role one of the researchers had during the study.
Impact on the society
The failure rate for startups is high and the majority won’t make it (Feinleib, 2012). This would affect society since every failure is a lost opportunity for improvement and it could have financial effects on families and individuals. Since the majority of new jobs is generated in small to medium sized firms (European Commission, 2015) the society could benefit from a higher success rate. Our research is aiming for making it easier for startups to validate if their product and business idea has a place in the market. Making the right decisions will create less waste in resources and potentially lead to a higher success rate. If this is the outcome it would benefit the society by creating more opportunities for work, more taxes paid and increase well-being among the citizens of the society. It’s not only about helping more startups succeed it’s also important to kill an idea that has no place in the market as early as possible. The difference in wasted resources between a bad idea that is killed early and a bad idea that is killed too late could be redistributed and used in new projects that potentially could succeed and benefit society.

Since 49% of the people in the age 18-70 (Tillväxtverket, 2012) entertains the idea of running their own business, the potential for creating growth in employment rates and innovation is high. If the outcome from this research could bridge the gap between the idea of running your own business to realizing it in the form of a startup developing physical products, this could help individuals to follow their dreams. This would affect the society positively and especially in Sweden where the research is conducted. Sweden’s government has identified innovation and startups as two critical parts they need to succeed with to develop the Swedish economy and generate growth (Utrikesdepartementet, 2015).
4. Empirical Results

In this chapter, we will describe the findings we did as a result from the semi-structured interviews and how they contributed to achieve product validation. A summary of our learnings as a result from that study will be completed, which will be used as customer input for the quantitative exercises. Learnings from indexing the interviews are written in italics. The quantitative study included a QFD and FMEA, the results of which will be described here as well. The empirical results chapter is completed with the design of an experiment which will test a key assumption and contribute to achieving product validation.

4.1 Customer Validation

The purpose of this thesis is to validate that the product actually provides perceived value to the customers by combining DFSS and Lean startup in different phases of the customer discovery process. The purpose of achieving customer validation is to validate that the product provides so much value for the customers that they are willing to pay for the solution. We would also like to clarify that SkiCorp conducted customer discovery phases one and two previous to this study, which served as input parameters for this research case. That input is summarized in a Lean canvas:

<table>
<thead>
<tr>
<th>T-bar users</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROBLEM</strong></td>
</tr>
<tr>
<td>1. T-bars are uncomfortable</td>
</tr>
<tr>
<td>2. Ski resorts need innovative means to attract visitors</td>
</tr>
<tr>
<td>3. More comfortable alternatives to the T-bar is too expensive</td>
</tr>
<tr>
<td><strong>SOLUTION</strong></td>
</tr>
<tr>
<td>1. Comfortable and attractive T-bar seat</td>
</tr>
<tr>
<td>2. Advertising space facing backwards</td>
</tr>
<tr>
<td>3. Mountable shell/face design takes advantage of already existing T-bar systems</td>
</tr>
<tr>
<td><strong>EXISTING ALTERNATIVES</strong></td>
</tr>
<tr>
<td>1-3L, 2-3L, treadmill, chair lift, gondola</td>
</tr>
<tr>
<td><strong>UNIQUE VALUE PROPOSITION</strong></td>
</tr>
<tr>
<td>Increase customer satisfaction through comfortable T-bar ski lift rides</td>
</tr>
<tr>
<td><strong>KEY METRICS</strong></td>
</tr>
<tr>
<td>Aquisition: Number of new resorts contacting us to learn more about Boardie (e-mail, phone call, web questionnaire etc.)</td>
</tr>
<tr>
<td>Activation: Number of ski resorts willing to test Boardie</td>
</tr>
<tr>
<td>Revenue: Number of ski resorts committed to one year subscriptions</td>
</tr>
<tr>
<td>Success metric: Number of T-bar systems with Boardie installed</td>
</tr>
<tr>
<td><strong>HIGH-LEVEL CONCEPT</strong></td>
</tr>
<tr>
<td>The iPhone case for T-bars</td>
</tr>
<tr>
<td><strong>UNFAIR ADVANTAGE</strong></td>
</tr>
<tr>
<td>Design protection within EU, First Mover</td>
</tr>
<tr>
<td><strong>CUSTOMER SEGMENTS</strong></td>
</tr>
<tr>
<td>Tourism guide, ski shop owner, professional skier</td>
</tr>
<tr>
<td><strong>CHANNELS</strong></td>
</tr>
<tr>
<td>Direct, Word of mouth, Whisby.com, Website, Social media</td>
</tr>
<tr>
<td><strong>EARLY ADOPTERS</strong></td>
</tr>
<tr>
<td>Smaller family ski resort with at least one T-bar lift, generates revenue through advertising.</td>
</tr>
</tbody>
</table>

Figure 4-1 Lean canvas inputs from SkiCorp

4.1.1 Solution Hypotheses

The first hypothesis SkiCorp formulated related to the solution offered to the customer was that “a more comfortable and attractive looking T-bar seat” would solve the top two problems on their verified problems list, which were 1) T-bars are uncomfortable and 2) Ski resorts need innovative means to attract visitors. SkiCorp had created a T-bar seat that they assume would provide perceived quality to the customers through a more comfortable seat. SkiCorp also put some emphasis on the design of the product to create a more esthetic look.
When it comes to the question if the respondents believe the product would fulfill their demands the responses were positive in every single interview. The word that was most common to describe what they were looking for was customer experience. They all pointed out in different ways how the product could improve the satisfaction of their own customers. One respondent said "We hope that this product will help us show our guests that we care for them, that the product is for them" (CTO at resort 4, October 2015). One other respondent said the following "We are focusing on being a family friendly ski resort and a couple of years ago we changed an entire lift from T-bar to platter, to make it easier for kids to ride. With this product it could be an option to change back" (CTO at Resort 7, November 2015). All respondents agreed that the product looked more comfortable from the renderings, but most would’ve wanted to test it themselves to get a better feel for it. It was hard for them to assess how large the improvement would be but they all saw the potential in what they called an innovative product.

In the product attribute ranking exercise respondents were asked to do; improved comfort was rated number one in six out of eight cases. Respondents also emphasized that the product would need to create a clear perceived increase in comfort for the ski resort visitors when they used the T-bar if they would consider the product. They also added that they saw great value in being first on the market with the product because that would create an image of their resort as being innovative and willing to try new tools to improve the customer experience at their resort. Therefore, we will check solution hypothesis number one as validated; “A more comfortable and attractive T-bar seat”. However, a quantified empirical test where the product will be tested by actual customers of resorts will be designed for SkiCorp to execute (see chapter 4.2.4). Solution one will solve validated problem number one and two; “T-bars are uncomfortable” and “Ski resorts need innovative means to attract visitors”.

Solution hypotheses two and three were “Advertising space facing backwards” and “Mountable shell design which takes advantage of existing T-bar system” to solve validated problem number three “Alternatives to the T-bar are too expensive”. The responses related to these product attributes were scattered across the respondents. From “I think this is much better than the existing advertising space on the T-bar...the marketing solution on this product is word class” (CEO at Resort 1, October 2015), while another said “We already have commercial in the slopes, adding more could shatter the nature experience” (CEO at Resort 4, October 2015). The ski resorts would use the advertising space differently but the ones that weren’t interested in having more advertisements in the slopes saw the benefit with branding their resort on it instead. The majority of respondents emphasize that it’s a harsh market where you need to be visible to remain in business. To have their brand on the product would potentially increase their visibility in media, especially in the first years when the product is new and guests take pictures. It was obvious during the indexing that all the respondents wanted to be first with the product to attract more visitors. This could assist them in striving for a better customer experience and be more visible in social media.
Agreement could be found regarding the shell design; they agreed it was an easy upgrade from what is currently available on the market. One respondent ranked the shell design highest on the product attribute scale. They all emphasized the *easiness to install* as an important factor they would take into account when buying the product. The shell design supported that, since the original seat did not need to be detached for SkiCorp’s solution to work. However, on a couple of occasions, respondents expressed wishes to exchange the entire T-bar seat to SkiCorp’s product. “*Initially there will be a higher cost but eventually the original T-bar will break and then we will have twice the cost. Then we firstly need to disassemble the shell, then exchange the T-bar and re-mount your product again*” (CTO at Resort 7, Nov-2015). They did however agree that a shell design would decrease the risk level with testing a new product in their T-bar systems, since the new product could easily be removed if anything did not work out as planned. *Up-keeping of the lift system* is what is most important to the visitors of the resort, and *decreasing the risk of stoppage* due to SkiCorp’s product would provide a better sense of assurance when buying it.

Therefore the solution hypothesis “Mountable shell design which takes advantage of existing T-bar systems” is validated. However, SkiCorp should bear in mind that this solution is a form of MVP when launching the product, and developing a new product to completely replace the current T-bar seat should be considered as a fast updated alternative version of SkiCorp after a year or two, to better serve their customers when the design has been validated over a longer period of time.

The final solution hypothesis, regarding the advertising space, was on one occasion ranked as highest. We would like to note that we deliberately talked to the CTOs of the resort, since this is a product centered study. Therefore, a bias towards technical feasibility in the answers was obtained. The advertising space is not covered in their area of expertise, which would explain their lack of interest of it. The most common phrase connected to the advertising space was that they need to involve their sales team in the evaluation of it. However, it did not create much perceived value for the respondents during this round of interviews, although, they did express beliefs about perceived value for their respective marketing department. Therefore, solution hypothesis “Advertising space facing backwards” is not checked as validated. However, we do not suggest to pivot or exit but to persevere on the same path, since the solution showed a lot of potential value. A second study will be recommended to conduct separate research regarding customers of the advertising space and a second Lean canvas should be created for this purpose with other experiments to validate that business model.

4.1.2 Customer Segment and earlyvangelists hypotheses

Customer segment hypotheses were pretty straightforward. This is a very niche product and can only be used for the sole purpose of riding the T-bar; therefore user hypothesis “Ski resort visitors” is validated. The ski resort is the owner of their T-bar systems, which they buy from either ski lift manufacturers or second hand from other resorts, and they are responsible for maintaining and improving it. Therefore, customer hypothesis “Ski resorts providing T-bar ski lift rides” is validated. We do acknowledge that there is a second potential customer, the advertiser, but as noted earlier a second study needs to be deployed to validate any assumptions related to the advertising space.

The early adopter hypothesis, or “earlyvangelists”, was “Smaller family ski resort with at least one T-bar lift and generates income through advertising”. This assumption can be broken down in four key characteristics: 1) Small resort, 2) Family resort, 3) Resort owning T-bar systems, and 4) Advertisements at the resort. From the eight interviews, with a total responsibility for 12 resorts, we learned all 12 resorts fulfilled assumption two, three, and four. The one thing that divided them based on our assumption attributes was the size of the resort.
To find our earlyvangelists, a few key questions were asked. Based on the answers from the respondents we could discern earlyvangelists from early followers or conservatives. The first question related to this was “Would you use it if it was for free?” In all eight cases the respondents said yes to that question.

A typical earlyvangelist would share the vision of the entrepreneur and therefore want the product so much so they are willing to share the risks of the venture, because they can see how it will improve their own business. The benefits of the potential success are greater than the potential losses if the venture would fail to an earlyvangelist. So, if respondents answered yes to the question “Would you use the product in its current state” they qualified to the next round. Six respondents said yes. The final question to designate the top prospects of an earlyvangelist was “Would you pay for the product in its current form to test it for a season?” An earlyvangelist would say yes to this question as well. There is no better validation for your solution than to actually get paid for an unfinished product and will discern earlyvangelists from mainstream customers. These are the only ones who are willing to take the leap of faith to buy from a startup. Not from a traditional sales person, but rather from one of the founders or someone from the technical team. Since one member of the research team behind this thesis also was one of the founders, we could perform this test.

Blank (2006) points out two main reasons an earlyvangelist would take such a leap: 1) the product solves a mission critical process which they are actively searching for a solution to fix. 2) They are driven by the competitive edge the product offers and will take the risk on a new paradigm to get it (Blank, 2006). For the product studied in this thesis, the later was true. T-bars have worked for 80 years and none of the respondents had actively looked for an improvement. During all interviews, the competitive edge the product provided was mentioned and would therefore be the reason an earlyvangelist wanted the product. From the six cases that qualified for this question, two agreed to pay for the product before it was produced if they could be the first to have it. One of them said “It would be okay for us to pay to test a small series, it wouldn’t be a large cost for us but maybe important for you to get the support you need” (CTO at Resort 8, November 2015).

The other six interviewees were also interested in the product but weren’t willing to share the risk by financial support. They wanted the solution to be tested and technically validated before they would think about paying for it. The two resorts that said yes were satisfied with the information SkiCorp had supplied and they would conduct the testing together with SkiCorp before testing it to the guests of the resort. We uncovered the fact that smaller ski resorts are generally more financially unstable than larger resorts, they have to work hard to attract customers. This was noticeable during all the interviews that they are acting on a market with overall growth but also with higher cost for the ski resorts. This was especially noticeable for the smaller resorts where one of the interviewees said “We cry every time we change a T-bar seat and that’s about 400 Swedish kronor” (CEO at Resort 1, October 2015). The respondent laughed afterwards and said that they really need to consider every cost they have if they want to be a profitable resort. Another respondent from a small resort said the following “We aren’t doing as good as we want, but in the industry there is a willingness for large investments, last year I believe new lift systems were built for about 250-300 MSEK (CEO at Resort 2, October 2015). The two resorts which we now could identify as our earlyvangelists were not small resorts, as we earlier assumed was one of the attributes of an earlyvangelist resort, instead they were of medium and large size.
This was on the one hand good for us since they were willing to test the product and be part of the first few resorts that got to use it. On the other hand they were hesitant to pay for something that was new and untested. This hesitation did not seem to exist with the larger resorts, which were willing to pay for the product if they could be one of the first to try it. To them, what we asked for in financial compensation was a small cost compared to other costs necessary to run the large resort and the financial benefit it could possibly bring was perceived as greater than a potential loss should the venture fail. For these reasons, we will pivot our earlyevangelist hypothesis to “Larger family ski resort with at least one T-bar lift and generates revenue through advertising”.

4.1.3 Revenue Stream Hypotheses

We discovered during the interviews that smaller resorts had financial difficulties and wanted a low cost version of the product. Therefore we constructed two revenue stream models, one where revenue was generated directly from the resort and another where SkiCorp attained advertising rights to the product. When revenue was generated through advertisement buyers, the product could be delivered for free to resorts choosing this option, thereby making it possible for smaller resort to also benefit from the value provided by the product. During our interviews, three out of 12 resorts that the study covered considered the free alternative.

The revenue stream hypotheses are validated, both revenue models are necessary if SkiCorp want to deliver to every type of resort. However, we recommend only delivering to resorts that can pay for themselves in the early launch stages. The second revenue model requires in-house or outsourced workforce to sell advertising space. This option can prove very time consuming and expensive for a resource sensitive enterprise like a startup. Since all of the resorts have a few chosen firms that have exclusive rights for their respective type of product, which SkiCorp would have to take that into consideration. This was mentioned during the interviews as a challenge for SkiCorp if they would be responsible for selling the advertisement space. One example of this was that the majority of the ski resorts had a car brand tied to the resort with exclusive rights. To protect SkiCorp any other specifics of revenue streams will remain undisclosed in this thesis.

4.1.4 Channel Hypotheses

As mentioned earlier, questions related to marketing were asked during the interviews. After the study we can conclude that Swedish ski resorts relies heavily on a well knitted network amongst the leadership. During an interview at resort 1 the CEO said “If he says it works, people will by it. This is both strength and a weakness when it comes to supporting or rejecting new ideas for the skiing industry” (October 2015). He referred to a CTO at another resort that is well respected for his knowledge within the ski industry in Sweden and this is an example on how well knitted the network is. The indexing showed that this quote sums up the overall decision process for the ski resorts when it comes to gathering information before making an investment. This was an important finding, since one or two persons whose opinions were highly esteemed by the rest of the community were identified. Getting them on-board and included during product development would certainly increase the probability of success of the product. Treated correctly, these can serve as the ultimate reference accounts and an advocate for the rest of the industry to follow.

We also uncovered other promising marketing channels such as ski resort specific trade shows held annually in Sweden and Norway, and ski resort related magazines which decision makers of ski resorts frequently read. One channel that was really important was the word-of-mouth channel: “We are both good friends but also harsh competitors, but we exchange a lot of information to help each other against the large distributors” (CEO at Resort 2, October 2015). Since the network with ski resorts is rather small, managers exchange a lot of information during the different events, for example at trade shows.
Initially, our assumption was that skiing leaders such as “jibbers” and youths with a passion for skiing would act as the driver behind the need to improve the T-bar with SkiCorp’s product. After the interviews we learned that this customer segment is very small, ski resorts are much more concerned with what the typical family of four thinks about their experience at the resort, because they spend more money during their visit. Therefore, the user driver behind the success of SkiCorp’s product would be the traditional family on skiing vacation. They value the customer experience the most, and if SkiCorp as mentioned before can improve that, the resorts find the solution interesting. We also learned that customers would rather buy the product directly from us than from a website or a second distributor. From these learnings one channel hypothesis was validated, two were pivoted, two remained unchanged due to lack of certainty and two channels were added.

4.1.5 Summary Customer Validation phase
To summarize our learnings and the structure of the new path towards success of the product, the Lean canvas was updated as illustrated in Figure 4-2.

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>SOLUTION</th>
<th>UNIQUE VALUE PROPOSITION</th>
<th>UNFAIR ADVANTAGE</th>
<th>CUSTOMER SEGMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. T-bars are uncomfortable</td>
<td>1. Wide, ergonomic and attractive T-bar seat</td>
<td>Increase customer satisfaction through comfortable T-bar ski lift rides</td>
<td>Design protection within EU</td>
<td>Ski resort visitors (user)</td>
</tr>
<tr>
<td>2. Ski resorts need innovative means to attract visitors</td>
<td>2. Advertising space facing backwards</td>
<td></td>
<td>First Mover</td>
<td>Ski resorts using T-bar ski lifts (customer)</td>
</tr>
<tr>
<td>3. More comfortable alternatives to the T-bar is too expensive</td>
<td>3. Mountable shell/case design takes advantage of already existing T-bar systems</td>
<td></td>
<td>Customer Relationships</td>
<td></td>
</tr>
</tbody>
</table>

**KEY METRICS**
1. Acquisition: Number of new resorts connecting us to learn more about Boardie (e-mail, phone call, web questionnaire etc.)
2. Activation: Number of ski resorts willing to test Boardie
3. Revenue: Number of ski resorts committed to one year subscriptions
4. Success metric: Number of T-bar systems with Boardie installed

**EXISTING ALTERNATIVES**
1-5, 2-5, treadmill, chair lift, gondola

**HIGH-LEVEL CONCEPT**
The iPhone case for T-bars

**CHANNELS**
Direct
Word of mouth between resort leadership network
Advertising in industry specific magazines
Website
Social media
Industry specific trade shows
User-driven by family visitors

**EARLY ADOPTERS**
Larger family ski resort with at least one T-bar lift and generates revenue through advertising.

Figure 4-2 Updated Lean canvas, post-interviews

4.2 Product validation
In this step we will present the input from the interviews that is directly connected with the characteristics of the product, which will then be used to create the QFD and FMEA.

4.2.1 Voice of the Customer
The respondents wanted to be sure that the new solution was safe and functional. “For me it’s only one attribute that is necessary, it must be as safe for the guest as the old version” (CEO at Resort 2, October 2015), and for the functional part one typical answer could be explained with “Thoroughness in the weight calculation, how the tear on springs will be affected, how the accumulation of snow will affect the function. We want all of this and a bit more in a product specification delivered with the product that shows you have tested it” (CTO at Resort 1, November 2015).
They did however differ in which attribute they valued the most but it all boiled down to operations safety and not being worse than the existing T-bar. The key words extracted from the interviews have been used as input to the DFSS framework and is presented in the updated QFD matrix (See appendix 4.1) which will be thoroughly explained in chapter 4.2.2.

During the analysis of the interviews it was clear that the different ski resorts experienced different challenges due to weather conditions. Some of them had extreme conditions with ice and snow accumulation and high winds while others didn’t suffer as much. This proved crucial for the product characteristics since there were T-bar systems affected with more extreme conditions than others. Some of the T-bar systems had a very short distance between the release of the T-bar to when it needed to be withdrawn and stabilized. The spring-back function has to be taken into consideration, and cannot be negatively affected when implementing a new T-bar seat. As the CTO at resort 8 said (November 2015): “When we test the solution in the high zones with extreme weather and it doesn’t work there we would still be interested in the slopes where it works. It doesn’t need to be functional everywhere”.

The output from the interviews showed that the MVP for the customer doesn’t need to be better than the T-bar in all tests. From the interviews it’s clear that the specifications can be divided in two groups, must have and nice to have.

**Must have**

“Must haves” refers to specifications that the product must fulfill at a minimum standard compared to the original T-bar. If this isn’t the case the lift system will be less reliable and all the different ski resorts have emphasized the importance of reliability. What exemplifies these attributes is that these are needed in the entire lift system and is dependent on everyday use. No matter where it’s mounted the spring needs to be able to pull up the T-bar with the added weight of the new seat. The design needs to manage hitting hard objects in cold temperatures which happens frequently when guests drop it midway up the slope. All guests need to be able to ride it, it shouldn’t matter if you are a snowboarder, skier or riding in a ski cart. In addition, when you release to step off the T-bar your clothes must not get caught. When starting the ride a lift operator often assists with placing the T-bar and it’s important that they will be able to conduct their work as before. Since the lift system are CE-certified it’s a demand that this won’t be affected when mounting the new seat on it. This is a safety demand for their insurances and the pleasance of their guests when they visit the ski resort. To maintain the reliability and cost efficiency it’s also important that the added weight won’t affect the lifetime of the spring mechanism that pulls up the bar after it has been dropped. The extra weight needs to be low enough so the spring can pull it up at the same speed as before since the construction of the lift sometimes just have a short distance for this to happen.

**Nice to have**

If the first must have are fulfilled the ski resorts can accept that some characteristics only partly are fulfilled. They want it to be stable in strong winds but if it starts oscillating in strong winds they can accept that, because it’s only a few of the T-bar systems in place that actually needs to be stable in those conditions. Then they will just use it where these extreme conditions don’t exist. It’s the same with the snow and ice accumulation on the seat, they would prefer not to have the risk but if it happens a few times more they can accept it. This is due to the potential gain in customer satisfaction they see from the product. Long term they would prefer even these attributes to be must have but on the first series this is definitely only a nice to have criteria.
These learnings are crucial; the client wants a product that works but not necessarily in the most extreme conditions and the lifts with the worst weather. They want to try it and show to their guests that they are doing efforts for improving their ski resorts so they can improve competitiveness against other resorts. This was also seen during the interviews that the majority of the interviewed were more interested in the guest experience than the additional revenue streams from the new marketing possibility. The individuals we talked to had both the market and technical viewpoint but we could see a difference between resorts in how they would use the marketing. We won’t go in to the marketing possibilities in this research but we can conclude from the interviews that all resorts saw a possibility to either increase their brand recognition or increase their revenue streams with a new marketplace. This increased the interest for the new T-bar seat as a product since it can give more than a delightful ride; it can also pay for itself of with marketing revenue.

4.2.2 Quality Function Deployment (QFD)

Critical To Quality (CTQ) analysis

The data gathered during the semi structured interviews with the respective CTO at every resort visited; product CTQ characteristics could be derived. We started off by making a VoC-list using indexing, which helped us to detect themes and patterns from the respondents’ answers. Examples of reoccurring themes and patterns could be wind resistance, minimal snow and ice accumulation, or resisting hard impacts. In total, we identified 13 specific customer needs that we deemed as important enough to incorporate in our CTQ analysis and subsequently our QFD design and is illustrated in appendix 4.1 in the Voice of the Customer section of the matrix. An important finding we did was that the hierarchy of needs for this product did not span very far, which we learned when we tried to divide customer needs into more manageable and specific statements using a tree diagram according to Staudler’s et al (2009) guideline, which proved unnecessary since no secondary needs were uncovered during the interviews. The most likely explanation for this is the simplicity of the product. It is very low tech and does not contain a lot of components.

Another learning we did related to product characteristics is our failed attempt to classify customer specifications into delighters, satisfiers and dissatisfiers according to the Kano model as explained by Staudler et al (2009) and Tague (2005). This too could be explained by the lack of components and simplicity of the product. It actually turned out that the customers see the entire product as a delighter. The T-bar seat SkiCorp has invented is actually a complementary product to the product it is trying to improve, the T-bar system, and therefore could be classified as a delighter component of the entire T-bar system. This could prove as useful knowledge when formulating the marketing and sales strategy.

From the primary customer needs we tried to discern which corresponding product characteristics, the CTQs, had an impact on those customer needs. Those qualitative statements need to be translated into manageable quantitative business or technical statements, which means they have to be specific and measurable (He, Tang & Chang, 2009; Staudler et al, 2009). To account for every customer specification a total of 9 corresponding CTQs were identified. Examples could be “Surface short side radius” or “Wall thickness” where the rule for formulating the CTQs was: “unless the CTQ is a material it must be measurable on a continuous scale”. Since these are the carriers of quality, the measurability ensured us that design targets and upper and lower specification limits could be set, which later will allow us to run experiments where design targets consciously are being manipulated to test their impact on customer satisfaction. CTQs identified are shown in appendix 4.1 under the CTQ section.
**Computing characteristics**

VoCs were placed in rows and CTQs in columns of the house of quality. In each intersection of a specific customer need and CTQ, the effect the CTQ had on the corresponding customer need was assessed on a scale of zero to nine, where zero equals no effect and nine equals strong effect between need and product characteristic. To further screen vital CTQs from trivial ones to develop our key factor CTQs as described by Juran and Godfrey (1999), we weighted each customer need on a 1–5 scale. Firstly from importance, which was assessed from the frequency of themes in answers from the respondents, also using indexing like we used when identifying the VoC. Next, we assessed how well the current product design achieved each of the individual customer needs, where a 1 equals low achievement to customer need and a 5 equals high achievement to customer need.

The same assessment was made based on the competing product’s ability to achieve customer satisfaction on the same needs. Since this product is in a new market niche, and has no direct competitors making the same type of product, the existing T-bar seat was used as competitor reference. Depending on how well SkiCorp’s product compared to the scores of importance and competitor, each customer need received a rank between 1–5. For example, if our product scored a 2 on a need that had a 4 in importance and where the competitor scored a 3, the planning rank was set to 3, since the goal should be to not rank worse than the competitor but not better than needed, unless the customer need has a high selling point rank. These inputs formed an “improvement ratio”, which simply is the planning rank divided with current product satisfaction rank.

Importance rating, improvement ratio and sales point ranks were then multiplied into an absolute weight for the customer need. In each of the columns representing the CTQs, the effect ranks were multiplied with the corresponding customer need weight and then summed across the entire column for each CTQ respectively, to form an absolute weight for each CTQ. Those CTQ absolute weights were then recalculated to form a characteristic weight, which are simply all the scores for each CTQ distributed on a 1–100 scale. The characteristic weights then revealed the vital few CTQs we need to work on to improve the chances of success with the product.

This analysis showed that SkiCorp needs to focus their resources to reduce oscillation, improve re-springing on release, and reduce spring tear. This will be achieved through focusing the attention to the following CTQs: Wall thickness, Structure material, and surface geometry radiuses.

**4.2.3 Failure Mode and Effects Analysis**

The goal of the Failure Mode and Effects Analysis (FMEA) for this product is to draw out and uncover potential weaknesses in its design. The reasoning behind this analysis is to fix any problems that may arise during use, prior to manufacturing the product, while design changes are still relatively cheap and flexible. Since this is a physical product, conducting an FMEA is aligned with a part of our research question; to validate the product performs according to the customer’s specifications.

From the interview study, the coherent message from all the respondents was very clear: the product must not contribute to more operation stoppages than today and it must be safe. Therefore, we focused our FMEA on failure modes that had the highest potential to prevent the T-bar system from running normally or cause injuries, which were: 1) Excessive oscillation during operation, which could lead to cable detachment or causing the T-bar to get stuck in lift pillars. 2) T-bar does not spring back properly in towing unit, which will lead to the T-bar running along the ground and not in the towing unit. 3) Play along splitting line of the halves, which may lead to the user’s clothes getting stuck in the appearing gap.
A root cause analysis showed that should oscillation during operation occur, it would likely be caused by the wider design of the product since a wider surface will catch more wind. If such a failure should occur, the recommended corrective action is to redesign the geometry or choose a smooth coating material of the product to become more aerodynamic. However, empirical test results need to validate this problem before the corrective action is implemented.

The root cause making the T-bar not spring back into the towing unit properly was determined to be the weight of the new T-bar seat. The spring inside the towing unit is pre-calibrated to support the current weight of the T-bar seat. If too much additional weight was added it would not spring back inside the towing unit and the T-bar system would be non-operational. Corrective actions determined is to redesign and re-dimension the new seat to reduce weight to 1,5 kg with an USL set to 2 kg, to guarantee reliable operation and allow for snow and ice accumulation without the detachment of the T-bar from the towing unit during harsh weather conditions.

Corrective action to prevent clothes getting stuck in the gap appearing along the splitting lines of the two halves when they are mounted together during operation was simply to split the halves across the opposite direction along the short side of the product. This will decrease the possibility to get stuck when seated, because no body parts have any contact on those surface areas near the split or any gap that may appear over time, thereby securing a reliable product which is safe to use. Complete FMEA analysis is available in appendix 4.2

4.2.4 Design of Experiments

Throughout our interviews, the importance of the new T-bar seat making a noticeable difference was a reoccurring theme. For instance said CTO at ski resort 4 (Okt-2015) “It has to be a significant improvement when it comes to comfort, and it has to be better for every type of visitor”. Another CTO at ski resort 3 (Okt-2015) said “It would be interesting to install the new seat on one of two T-bar systems running parallel to each other, and then observe which T-bar system our visitors preferred”. Based on these inputs, in addition to the results from the QFD and FMEA, we could determine that the top prioritized problem to validate the product was to reduce the weight of the product to make it operational. But further design improvements would be pointless if SkiCorp cannot prove their new T-bar seat was significantly more comfortable than the old T-bar seat. Therefore, we decided that the second prioritized activity SkiCorp should conduct to validate their product, would be to test that a true difference in comfort exists between the new T-bar seat designed by SkiCorp and the old T-bar seat currently in operation at the ski resorts. To test that hypothesis we designed an experiment according to the principles of experimental design presented in chapter 2.4.2, which was delivered to SkiCorp with this report, and is available to read in appendix 4.3.
5. Discussion - Lessons learned

In this chapter we will discuss our findings. We will firstly discuss learnings from each method respectively. Then discuss similarities and differences, to finally arrive at synergy effects extracted from the methodologies.

5.1 Lean Startup Methodology (LSM)

5.1.1 Fast iterations

Acting in a startup environment means that funds are limited and it’s important to move forward with ideas. LSM is designed to be used in this environment and to use funds and knowledge wisely by conducting fast iterations. Instead of creating comprehensive presentations based on false assumptions, the team takes small steps forward and iterate often. This leads to less waste when a hypothesis about the product or market is moved forward. Subsequently, it leads to smaller course changes continuously when the company makes decisions of pivoting or persevering instead of being forced to make radical changes (Ries, 2011). We as researchers used these fast iterations and small batches by using every interview as a learning experience. After every interview we discussed it to reflect around what we had learned and what we could use in the next interview. In our case we did make small pivots several times when we understood what the respondents needed. If we would have continued without making these small pivots we probably wouldn’t be able to extract as much information as we did from the interviews.

These changes could be done without risking the scientific part of the study since it was well planned before by the researchers. Although, it’s important to note that making changes during the interviews may affect what kind of data you receive and the traceability of it. The LSM is designed for the startup environment which is a challenging by default since it can change rapidly. The risk is that you as an entrepreneur lose the comparability between the interviews if you make changes without understanding the consequences on the data you gather.

The input from the customer could be thought of as if the customer is pulling the product from the startup. The customer is explaining for us as researcher what their needs is and why they need it. We as researchers translate that to product characteristics that can be validated and tested by SkiCorp. This could be parable to how the Kanban system is used within the Lean philosophy to “pull” material between processes to reduce inventory (Liker, 2004). From a startup perspective, inventory could for example mean unnecessary development costs, and this argument could find support in LSM’s focus on conducting small iterations instead of extinctive design changes. When conducting extensive design changes you create a stock with untested designs that cost time and resources for the startup, which are still of no value until customers have confirmed it. If there is a gap between what the developers believed and what the client wanted, the time and resources may have been wasted. With the LSM you use smaller inventories of business and product solutions which lead to less waste and faster feedback on smaller iterations. This leads to a faster pace forward since potential mistakes during the design phase haven’t used as much time compared to extensive design changes. SkiCorp’s management team had before we initiated our study seen a potential market and instead of making a significant investment in time and money for producing a physical product they wanted to research if their current solution provided enough value for their customers. By doing this in small iterations we could see that there are customers interested in the new product, and that they are actually asking for it. By explaining what they want, how they want it, and why they need it, customers revealed their true needs for the researchers. All SkiCorp need to do is to translate those inputs to a marketable MVP with a scalable business model that fulfills the customers’ needs – they pull the final product solution from the SkiCorp team.
These small iterations work well in the case company since they are trying to explore an unknown market. Our feeling around these small iterations is that they aren’t only suitable for startups, it would probably fit every firm that are entering or exploring an unknown market. To explore this we conducted a benchmark interview with Gunnar Malmquist at GE healthcare (Uppsala, December 2015) since they have implemented FastWorks, a customized version of LSM at GE. Since GE are well known for using Six sigma principles in their processes and is a large corporation acting worldwide within several different sectors, it was of interest for the research to understand why they started using Fastworks (Snee, Hoerl, 2003). GE is the opposite from what a startup is. They have excessive resources available, established structures and markets they already act on. They implemented LSM to create an environment within the company where they could be more flexible and adaptive to change. “Somehow I believe it’s easier to use Lean startup when you are entering deep water and thin ice at the same time. You don’t know how the world works, then the framework from Lean startup will act as a protective net. It will give you the courage to walk on a thin line and help you rationalize you mistakes.” (Malmquist, 2015).

5.1.1.1 Leave the building

The LSM emphasize the importance of leaving the building when conducting development of a product. This is not unique for lean startup but the focus on doing it as often as possible with just a few new attributes is a central part of lean. The aim for each time you leave the building is to learn from the meetings, and by doing it often decrease the waste in the development and time spent developing something nobody wants (Ries, 2011). For the researcher it was easy to find and contact the potential customer since the skiing industry is a well-defined market. To find potential customers could have been more challenging if the research would have been done on a market that weren’t that defined and with more competing actors. This made it easier for us to be sure that we had targeted the right customers which made it easier for us to define the MVP.

During this study we have had learnings during each interview which we have used as input for the next one. What we have presented each time was what SkiCorp believed was the MVP at the time we started the study. From each interview we received information that could be used to support the testing and validating of the MVP. We could see benefits in conducting the first interviews face-to-face since this helped us to build up a certainty in our roles as researchers in relation to the respondent. We chose to conduct skype interviews and since we had already been out and talked to potential customer and validate our learnings from these interviews, we could save time and resources. Time and resources is often limited in startup firms and depending on where the market and customers are located this could be time consuming and expensive. But it could be even more expensive if you don’t leave the building since you lose the close customer interaction, the core of LSM. Without that interaction you will increase the chances to accept or reject a hypothesis incorrectly. Malmquist (2015) explains the importance if this interaction with the clients, but also how it in their case is a challenge to change mindset and be comfortable in showing customers an early prototype. He believes that this could save resources for them, especially when they are developing new products on markets that they haven’t explored yet.
To involve potential customers in the development have more benefits than just retrieving their inputs. We have seen during this case study that they get a personal interest since they have had the possibility to give feedback and their thoughts behind the product. This creates a dual effect for a startup since they both get customer buy-in, customers feel ownership of the product they helped building, and retrieving knowledge about them simultaneously. Without this interest and connection to the potential market it would be a matter of pushing the product out on the market. Their knowledge about the market also served as input for the parts that weren’t connected to the product. The respondents gave information about the parts on the Lean canvas that were connected to the business model as well. The business model went through the same process as the product did, with the interviews as small iterations to improve the business model. The output from the interviews weren’t only what they wanted but also how they wanted it and when.

5.1.1.2 Minimum Viable Product (MVP)

There are several different types of MVPs depending on where you are in the process. SkiCorp supplied us with an MVP that we could use during the interviews. This MVP weren’t ready for production but it had the minimum set of features and appearance to show the respondents the idea. This is something that Ries (2011) emphasizes, the MVP need the full set of features to conduct the build-measure-learn-cycle but with a minimum development time. These minimum features will evolve during the loop, and features will be added or withdrawn after each new iteration based on the inputs from the potential customers. Steven Blank (2006) expresses the importance of this input because if this isn’t done you can’t go to the next step. If you go to the next step there is an overwhelming risk that you waste efforts on people that aren’t interested.

To create a product with as simple design as possible, only the characteristics needed in order to test customer feedback about the attributes of interest can keep the cash burn rate at a minimum. The semi-structured interviews showed that the most important attribute for ski resort managers was that the customer experience with the lift ride would be significantly improved, that a true effect exists. Therefore, the first test that needs to be conducted is the evaluation of the customer experience; if there isn’t a significant difference compared to the old version that problem needs to be solved first. SkiCorp’s management team was planning on conducting a number of comprehensive testing to validate other product characteristics, but to conduct these tests on the product before a true difference in user experience is proven would have been a waste of resources. This shows the importance to specify the MVP with as few attributes as possible and to only test what needs to be tested. It should be mentioned that it can be hard to separate some characteristics from others, which also was the case during this study. To make it possible for guests to ride the product to test the customer experience it needs to be functional on the lift it’s mounted on. Therefore some functional tests need to be done but not as comprehensive previously planned.

5.1.1.3 Testing and validating hypotheses (running experiments)

When creating the Lean canvas SkiCorp had set hypothesis that we as researchers had to verify or falsify with our experiments. The theoretical framework we compiled from LSM literature in this research emphasized the importance to test and validate hypotheses. When we as researcher read through the LSM literature presented, we could see that there is more to wish for when using the methodology for research purposes. Therefore we started to search for other literature that would be suitable for conducting these tests.
It’s actually interesting that LSM is presented as a structured method to test and validate assumptions, without the key part of research design and the understanding of it. This is probably due to the context it’s used in, where the uncertainty is high and the knowledge in research design may be limited. When validating the MVP and conducting the interviews we used validated learning over time and therefore we made changes in the setting of the interviews. This could be confounding for the result if our design didn’t allow this and we analyzed the data incorrectly. It’s a narrow path to walk, on one hand you don’t want to make false assumptions but on the other hand you may not have the time and knowledge to make all necessary tests. This is the challenge for startups and something we needed to take in to consideration both when designing the interviews, but also when delivering the output to SkiCorp.

5.2 Design for Six Sigma (DFSS)

5.2.1 Critical To Quality (CTQ) analysis and Quality Function Deployment (QFD) design

Though the use of QFD is, by large, normal practice today when conducting product development (Staudler et al., 2009; Roush et al., 1999), the approach taken by the researcher when it comes to deriving CTQs are many. We are making that statement because we found during our literature studies, that the authors in almost every case presented different approaches. The reason behind this seems to lie in the fact that the researcher need to quantify a qualitative statement to derive the CTQs from the customer’s needs and wishes (voice-of-the-customer, VoC), and have to decide which CTQs that are going to be included in the QFD to satisfy all customer needs.

The action of interpreting what the customer actually want or ask for includes a lot of subjectivity and leaves a lot of room for interpretation, which is why we found it difficult to decide 1) how the VoC are to be formulated when it was inserted in the QFD, since no respondent formulated their answers and needs word-for-word and 2) which customer needs to insert in the QFD. We tried to eliminate the risk of missing out on important customer needs by indexing themes and patterns from the notes from each interview. De did this first independently, then compared with each other to debate over any differences, and eventually found common ground for what to be included in the QFD under the VoC section. To facilitate the importance of customer needs the researcher could take a quantitative approach right from the start, by having a questionnaire designed to let the respondents fill out. However, this method drastically lowers the probability of uncovering needs previously not thought about since the method doesn’t allow an open discussion. A combined approach, where the researcher started with structured interview to gather customer inputs and then funnel their responses into a questionnaire would be the best approach. However, this was not done for this research study because the case company did not want to send out questionnaires with pictures of the product digitally, since we were studying the solution, the MVP we used had to be displayed for the respondent in order to extract any useful information, due to intellectual property reasons.

We also found it difficult to find any practices and approaches to gather customer data from what was provided in DFSS literature. For instance, Roush et al. (1999) simply states that customer research should be conducted before designing the product and then suggests a number of approaches to do so such as interviews, questionnaires or studying warranty reports. However, no approach was described in detail and we will therefore argue that DFSS lacks a robust framework for how to conduct customer research. One could make the argument that it is up to the DFSS practitioners to take the responsibility upon themselves to find out about customer research methods. After all, the DFSS approach should be considered a toolbox rather than a well-defined development method.
One could also make the argument that DFSS practitioners would benefit to find a common customer research method, which was better suited than others, to derive CTQs from. For now, we will simply acknowledge that no consensus about how to conduct customer research among DFSS practitioners seem to exist. Subsequently, different DFSS practitioners conducting customer research for the same project may come to different conclusions about which customer needs should be inserted in the VoC and their respective weighed importance, which eventually will have an effect on which CTQs are calculated as the most vital from the QFD. This leaves the risk of focusing resources and effort on improving CTQs less important than others, from the customer’s point of view. This is where we found the LSM very useful, because of the lack in structure of DFSS customer research methods the LSM on the other hand provided a helpful and mind opening framework when we conducted our customer research. The input from that effort which was related to the product characteristics was eventually included in the VoC-section of the QFD.

In a startup context, verifying which product attributes is desired by the customer and what the product needs to achieve to satisfy the customer is extremely important. When time and resources are scarce, the speed of learning what the customer values could make or break a new venture. However, our view is that it is equally important to know how to translate those inputs into something the customer can actually use. This translation process, to be able to quantify qualitative statements by the customer is where DFSS proved its strengths. While it may take more time to conduct such analyses, it can produce a superior technical solution on the first attempt based on customer input. In this case, the entrepreneur needs to ask himself: Which product attributes are most important to get right on product launch? The answer to that question lies at the customer, but the probability that the product can deliver those attributes on product launch is greatly increased if DFSS tools are employed.

Tools related to the technical feasibility, and thereby product validation, of the product studied in this thesis was QFD and FMEA. These tools were specifically chosen for the speed at which these analyses can be executed, which is suitable for time sensitive enterprises such as a startup. We would argue that the execution of the QFD helped us move forward with what technical attributes to focus on when conducting improvement efforts, to discern the vital few from the trivial many. The FMEA analysis forced us to find root causes of flaws, or defects, of the product in its current state, so that they could be treated and not the symptoms of the defect. By treating one root cause, many defects could be avoided, which saved SkiCorp both time and money. It should also be noted, that both the QFD and FMEA can be executed on different levels and individually on multiple different product attributes (Staudler et al, 2009). Therefore, they can quickly become many and complex and the entrepreneur should carefully determine at what level of detail the QFD and FMEA needs to be. Factors determining this decision are time available and the risk associated with the consequence if an error occurs.

5.2.2 The phases of Design For Six Sigma

Our benchmark study at GE Healthcare revealed that, in their mind, one of the best advantages the methodology offers is its stringent structure of the product development phases. At GE, the DMAIC structure is used (a reworked PDCA-cycle as described in chapter 2.4), which provides an advanced quality planning process. Before DFSS was implemented, decisions in product development were made on gut feeling to a larger extent. This led to carelessness in the planning phase of product development projects which had costly repercussions later in the development process when mistakes or miscalculations were revealed (Malmquist, 2015).
The classical S-curve displaying the increase in cost as a function of time in projects supports this statement, as does the estimation that 75% of the product cost is determined by its design (He, Tang & Chang, 2009) as well as the performance and manufacturability is determined in the design stages (Montgomery & Woodall, 2008). These are some of the reasons DFSS is very planning-oriented. But perhaps the strongest reason for such a heavy emphasis on planning within the DFSS framework is the fact that it is largely based on the modern approach to the scientific method. No universally definition exists but The Encyclopedia of Sciences (Kotz and Johnson, 1985) provides some generally accepted attributes of the modern scientific method. Figure 2-12 describes the application of those attributes of the modern scientific method when designing the research process (Luftig, 1998). One may notice that the planning phase contains more steps than the following three phases combined, which gives us an idea how much planning is emphasized before executing a task when following the DFSS methodology.

In a startup context, time is of essence, as was our experience during the period of time this research study was conducted. The fast iterations promoted in the LSM are there for a reason, time is the scarcest resource in a startup enterprise. Therefore, we argue that the planning activity and how much time an entrepreneur spends on it need to be tailored to the specific goals the startup is trying to achieve. For software development related startups, spending time on planning each release might be seen as wasteful, since the product is based on code which is relatively cheap and fast to change, which opens up for much more flexibility and supports more releases of the product in incremental updates. In such a startup context, the DFSS approach to product development may be inappropriate. However, the mindset of DFSS would still be an advantage for the software startup when employing Lean startup principles for their development activities.

When designing a physical product, each phase forward will be more expensive than the previous phase with greater magnitude, in comparison to non-physical product development projects. When we were done with the customer research for testing and validating SkiCorp’s solution we felt certain that a need for the product existed. However, after going through the DFSS related tools to attempt to validate the product from a technical perspective, some serious flaws in its current design were discovered. If we had not uncovered those flaws, they would have cascaded down to the specifications of the final concept to go to manufacturing and reach the customer. Through applying DFSS principles the product flaws were detected and the product could be redesigned to eliminate them. In addition to preventing a defect product reaching the customer, which is bad enough, millions were saved in manufacturing expenses since the tooling needed to manufacture the product don’t need to be discarded due to a poorly designed product. If a mistake was made in product design of similar magnitude as it was in our case study, but in startup developing a software product, the cost might have been lower and therefore justified in the name of learning. Therefore, our findings point to the notion that the amount of time spent on planning has to be tailored to the unique goal the startup is trying to achieve and carefully balanced against the consequences a design error might bring.

5.2.3 Design of Experiments

The data driven approach is central in DFSS and a large contributor to that is the experimental part of the approach. Luftig (1999) refers to the act of planning and conducting research, to research design. This is the type of data gathering and analysis which will break a research problem into smaller elements. Each element then needs to be narrowed down in order to delineate the research problem enough to be able to identify the population of interest, which is the population of the specific parameter the researcher is interested in. That will allow the researcher to identify the units or conditions he would like to make inferences from samples to their sample population, which is the population obtainable to the researcher (internal validity), and the entire population of all existing units in the world (external validity). Only then can the researcher write a hypothesis to be tested, because he his freely able to control or manipulate all variables associated with the study (Luftig, 1999).
The research question eventually leading up to the design of an experiment in this study, was the product validation part of the original research question “how can LSM and DFSS principles contribute to customer and product validation?” The LSM helped us to delineate what attributes of the product were important to the customer. That was eventually interpreted and inserted under the VoC part of the QFD, which would allow us to derive CTQs to also be included in the QFD as per above described. The QFD helped us to further delineate the problem into a few key attributes of interest. Improving these would have a significant impact on the customer. However, in order to properly run an experiment, the researcher needs to compare different designs and their respective impact on the attribute of interest. To help the product development team come up with alternative designs to improve the product features related to the attribute of interest an FMEA has to be made.

The key attributes of interest to us after conducting the research up until this point, after the QFD and FMEA, showed us that the most important attributes and therefore justified to test were “impact on spring” and “wind resistance”. CTQs related to these were predominantly “Wall thickness”, “Structure material”, and “Outside/short side surface radiuses”. These would have to be tested in order to validate the product. On an additional note, testing these would be done after the experiment designed for this thesis has been conducted, because we deemed the validation of the need for the product precedes validating those CTQs, which is why the experiment designed in this study was related to “Preferred T-bar seat”.

Doing the QFD and FMEA helped us to delineate the research problem. However, it seemed pretty clear to us early on in the project that these attributes were going to be most problematic for the product. Therefore, we were questioning the value QFD and FMEA had. But we followed through on them despite our hesitation and after finishing them it became clear why they are helpful to DFSS practitioners. Because the entrepreneur is forced to go through these rigorous methods, he has to think about how the attributes he wishes to study can be measurable. For someone not familiar to the world of statistics and quality engineering, that could prove a challenge. The QFD and FMEA can be seen as “training wheels” for the inexperienced practitioner to create measurability for the attributes of the product he is studying, because without measurability no experimental activities can take place. This was useful for us because we really had to think about a) what to be tested, and b) how it is going to be measured. That is later cascaded down into sufficient information to be able to design an experiment, because now it can be narrowed down from the product characteristics into a single or a few measurable characteristics of interest to validate an assumption.

For the characteristic of interest we chose to study, which were “preferred T-bar design”, we would like to discuss the role of sample size calculations and sample sizes in general. When we were conducting our literature studies, it could be found that DFSS practitioners pointed out three characteristics of the study which would determine the proper sample size: The significance level, Preciseness of the values calculated e.g. mm, cm, m, and Costs of the study. In addition, practitioners can generally be divided into two camps when it comes to sample size calculation: 1) Practitioners who insist on sample size calculations, like Luftig (1999) who states “Optimum sample size (or number of replications) is not a matter of opinion; it is a calculation based on variability, effect size, and risk” (Luftig, 1999, p. 136), and 2) Practitioners who see sample size calculation as a non-scientific decision and could be estimated, like Staudler et al (2009) who states “In general using rules of thumb suffices for calculating the suitable sample size” (Staudler et al, 2009, p. 256).
We performed a sample size calculation for the experiment we designed and could determine two things when putting our experience in a startup context. Firstly, calculating sample size would probably be a tiresome process to the entrepreneur who has had little or no exposure to the world of statistics. We as a research team have had some previous exposure to statistics, but had only been conducting statistics in university classes with no experience from real world problems, and calculating sample size was not necessarily time consuming, but included many basic concepts of statistics to be able to understand the activity, e.g. effect size, $\alpha$- and $\beta$-values, and the difference between an independent or dependent experimental design, and would therefore require a lot of time from the entrepreneur with no experience in statistics.

Secondly, if a development team is able to adequately calculate a proper sample size to detect a true effect with protection against Type-I and Type-II errors that sample size to be tested might be too expensive to produce or obtain to even be able to test it at all. This proved true in the experiment designed for this study. To detect a true difference which was significant enough to validate the assumption that “Ski resort visitors preferred the new T-bar seat design before the old T-bar seat design”, the study had to have a sample size of $n = 14$. In this case, one specimen is a physical prototype of the new T-bar seat design developed by SkiCorp. Being a startup, producing that many prototypes might be too expensive, as was the case with SkiCorp who could only afford producing 10 prototypes for the study. When the proper sample size calculation is not obtainable, Luftig (1999) points out that power must be calculated after the study is completed to be considered by the researcher when making his recommendation based on the results of the study.

On an additional note about sample sizes, with 3D-rapid prototyping taking giant leaps each year, the future of utilizing DOE when testing physical product hypotheses looks promising, and could be a possibility to more and more startups as funds necessary to produce proper sample sizes to properly validate their product is significantly decreased year after year. Because calculating sample sizes can be extremely valuable. When it comes to the level of certainty the development team in a startup would like to have when testing a hypothesis related to a key decision in order to validate a business or product assumption, proper sample sizes is economical. It is economical because it is cheaper to make the right decision based on the cost of a sample size, in comparison to the cost of making the wrong decision based on the implication that decision has. For instance, it might cost $10,000 to produce prototypes to be used as samples in the study, which in turn will give you a better chance to make the right decision. Even if that decision turns out to be to abandon the project, it is cheaper than persevering which could mean buying manufacturing equipment for $200,000 to produce the product, but which will not sell. It could also be economical from the aspect not to include more specimens than necessary. If the proper sample size is $n = 15$ and the researcher uses $n = 55$ in the study, the researcher would have come to the same conclusion with a sample size of 15 but would not have to pay for the additional 40 specimens. From what has been discussed in this subchapter related to sample size calculations, one could make the argument that the entrepreneur can “buy” certainty with the size of the sample used in an experiment to test his hypothesis.
5.3 Comparing Lean Startup Methodology (LSM) and Design for Six Sigma (DFSS)

5.3.1 Similarities

**Importance of the Voice of the Customer (VoC)**
Both LSM and DFSS emphasize the need for customer input as a fundamental part for the respective method. LSM has its build-measure-learn-loop where the importance of extracting the potential customer’s inputs is emphasized through the entire loop. Using this loop created a structured way of understanding and extracting the VoC during the research. During the study we have mainly focused on the LSM methodology to retrieve the VoC but the DFSS literature used in this research also emphasizes the importance of retrieving the VoC. There is a clear difference between how they describe this which will be elaborated further in the differences section. The similarities when it comes to the VoC are that both methodologies acknowledge and emphasize the importance of understanding the customer.

**Targets for LSM and DFSS**
Both DFSS and LSM strive for delivering the same output, a product that will fit the customer needs and expectations. There are differences in the focus and how it’s used, LSM is designed for both testing and validating the product and business model (Ries, 2011), while DFSS doesn’t have the same structure since the method doesn’t have a well-defined methodology as we discussed in chapter 5.2.1. DFSS is mostly used to validate and test products, but with the right design when extracting the VoC, we as researcher can see that it could also support the business model creation and validation. DFSS’ strength isn’t creating business models but if you can understand the customer as we did during this research the business model may emerge. We won’t elaborate more on this since this research isn’t aiming for changing the utilization of DFSS to be a more business model creating methodology.

**Identify riskiest parts**
Both methodologies acknowledge the importance of focusing on the vital few, but in different ways and with different terminology. The methodologies both have a comprehensive risk management thought, LSM by meeting the customers often, DFSS by planning and structuring structured experiments to validate hypotheses. The agreement is that the VoC is the way for handling risks and decrease waste.

**Executing customer research**
LSM have a well-structured framework for conducting customer research and to understand the potential customers. The foundation is on meeting potential customers frequently with only slightly changes since the time before. LSM is a practical method where the interaction and open discussions is the most crucial part. Without leaving the building and understanding your customer you won’t learn anything. DFSS emphasizes the customer research but what can be interpreted from the literature this has already been done when the DFSS starts, at least the identification of potential customers. DFSS emphasizes the importance and utilization of customer research as much as LSM but they differ in how.

**The role of experiments and the importance of iteration**
The role of experiments plays a vital part in both the LSM and DFSS. This, in part, could be due to the overall role of experiments when it comes to early principles of quality engineering, which both methodologies are derived from. This is clearly represented in the early days of TQM and the quality pioneer Dr. Deming’s days, and illustrated in Figure 5-1 where the organization is described as a system.
As the value chain of an organization’s interrelated connections depicts, all processes, machines, methods etc. should always be tested before and after it is implemented (Deming, 1986). If a new product is seen as a new process, like Figure 5-1 shows, then it is clear that it should be tested before and after implementation. It also becomes clear that it should be developed based on customer research with an iterative design. In chapter 2.4 we derived the DMAIC cycle as well as the Build-Measure-Learn cycle from the PDCA-cycle (or the Shewhart cycle). They are all built around the assumption that iteration where learnings are acquired after each cycle and used to the advantage of the team during next cycle. In the LSM this is known as “validated learning” (Ries, 2011) and in DFSS it is most apparent in what is commonly referred to as “Product optimization and refining” (Staudler et al, 2009). Both methodologies use experiments to quickly and cost effective learn what works best and what does not, in order to retain or discard strategies, product attributes, suppliers, or whatever is tested to find out about its implication towards a commonly set goal. It is when and how during the product development process the LSM and DFSS differ, which will be elaborated on in the following sub-chapter.

**The importance of cross-functional teams**

It should come as no surprise that the LSM emphasizes cross-functional highly interrelated organizations. Firstly, the LSM has been designed specifically to fit the unique conditions of a startup, which rarely have the luxury of an army of labor and therefore each person has to take multiple roles and areas of responsibility. Secondly, because the LSM highlights the importance to learn fast and create shorter development iterations to support that activity, the organization driving the startup forward need to stay flexible. An organization with high barriers between departments such as legal, accounting, marketing and R&D have a harder time to remain that type of flexibility which is required, or any flexibility at all for that matter. What is more interesting though is the emphasis put on cross-functional teams in DFSS (Roush et al, 1999; Staudler et al 2009). Even though DFSS is more common in larger organizations with a built up Six Sigma culture, it tries to remain the flexibility and speed of a startup.

That supports our assumption that, despite DFSS is not used to a large extent in startups; it is well-suited to do so if an entrepreneur would like to take advantage of the toolbox DFSS offers. This theory is also supported by the benchmark study we made, where in contrast when asked about the purpose of the implementation of LSM at GE Healthcare, answered that LSM helps the company to act as if it was as small and agile as a startup, which lately has become more important than ever when large companies like GE becomes more and more software centered and the rapid speed of change which comes with that (Malmquist, 2015).
5.3.2 Differences

**Batch sizes**
The batch size means the amount of information or amount of products handled in every steep, the less amount the easier for making changes (Womack, Jones, 2003). The DFSS literature that have been used in this research haven’t shown signs of emphasizing the thought behind small batch sizes as a method to decrease waste or optimize the method. DFSS is more focused on conducting proper tests on specific parts of the product and to verify that the end product will fulfill the criteria decided by the test group. For LSM the small batch sizes are fundamental since the small iterations help prevent waste and generate possibilities for validated learning. When looking into the DFSS framework it’s not of the same importance, the focus in DFSS is on the statistical part. The research have showed that the DFSS framework works well with small iterations, the limiting part is what kind of data is used and the amount of knowledge the user possess.

**Importance of the Voice of the Customer (VoC)**
We have already concluded that both methods emphasize the importance to use the VoC but there is a distinct difference between how they do it. LSM emphasize a rigid version of extracting it with a well-structured methodology for this part with short iteration cycles to frequently listen to the customer and their demands. When it’s extracted LSM doesn’t have a clear methodology for analyzing and understanding what the customers want. DFSS is the opposite, the method verifies the importance but a unified view on how to conduct that part isn’t presented. Instead they have a rigid methodology to use when the VoC has already been retrieved. When we as researchers had understood the potential customer’s demands the DFSS framework provided a well-structured system for using that knowledge. In this study it resulted in QFD, FMEA and a designed experiment but for other studies it could end up in other tools. To sum up the differences we can conclude that DFSS doesn’t present a structured way of extracting the VoC and LSM doesn’t provide a methodology to scientifically use the output from the customers. This opens up for the methodologies supporting each other as they have done in this study.

**Identify riskiest parts**
LSM works with risk management by conducting small iterations to verify that they have understood the customer correctly and their needs. This means that the closeness and short iterations decrease the risk for making false assumptions. Every time a new solution is designed, it will be demonstrated to the customers and validated through their input. Compared to DFSS it doesn’t prioritize the statistical process, instead LSM emphasizes to find earlyvangelists to be willing to share the risk with you. This is probably due to the startup context but LSM uses customers to decrease the risk rather than finding the right characteristics on the product.

DFSS emphasize the importance on focusing on the vital few instead of the trivial many. The thought about this is that there are a few characteristics that matter most for the majority of customers. If these are fulfilled it will have a significant impact on the success of the product compared to the trivial many. By focusing on fulfilling the vital few, test and validation can be more rigid, in the DFSS case this could be statistical tests to verify that the product confirms with the customers’ demands. One of the reasons for these differences is that they have different focuses; LSM is focused from idea to end product with a large degree of uncertainty in both market and product. DFSS are mostly used for the design of the product and not focus on the market.
Focus on waste
LSM has an extensive focus on minimizing the waste during the development, from the first idea to entering the market. It’s an iterative methodology where you are working with validated learning. This means that a waste shall be seen as a learning experience and since every iteration is small, the waste each time is small. In the DFSS framework waste is more about the end product, that the end product should fulfill the client’s demands and reach the desired quality level. Industrial companies uses DFSS to validate that the product is designed according to the demands from the clients to make sure that when it’s done, no changes will need to be done. If the end product hasn’t reached the quality demands that were specified it should be seen as a failure and waste have been produced. Both methodologies focuses on waste, LSM explicitly, and DFSS implicitly.

Executing customer research
LSM have a well-structured framework for conducting customer research and to understand the potential customers. The foundation is on meeting potential customers frequently with only slightly changes since the time before. LSM is a practical method where the interaction and open discussions is the most crucial part. Without leaving the building and understanding your client you won’t learn anything. DFSS do emphasize the customer research but what can be interpreted in much of the literature this has already been done when the DFSS starts, at least the identification of potential customers. DFSS emphasize the importance of customer research as much as LSM but they differ in how. The DFSS way of presenting customer research is similar to LSM’s way of emphasizing experiments. The importance is emphasized but there are no guidelines on how to verify and conduct it.

Experiments
The role of experiments is imminent in both the LSM and DFSS, but when they are employed through the phases of development is most of the time different. The LSM promotes the use of experiments in the early days of a startup to find a mission critical or competitive edge problem for a high value market segment. The LSM is more focused with the iterative process to discover a profitable business plan, while DFSS already assumes that the company has a profitable business plan and a fixed set of customers. The role of experiments is more product-centered in DFSS to find an optimal solution for the customers of the company. However, we could not find any information or evidence to reject the assumption that DFSS tools like DOE could be employed in the early days of a startup as well. Actually, our experience when following the LSM to achieve customer validation for the solution, while simultaneously studying literature for how to design and conduct experiments based on DFSS principles, was that the LSM could use a healthy reality check in order to increase internal and external validity for the hypotheses tested based on tools provided in LSM literature. In fairness, LSM literature does state that their hypothesis testing procedure is based on the modern scientific method, which is in part is true because it revolves around the Build-Measure-Learn cycle which is derived from the PDCA cycle, which subsequently is the foundation of industrial research related to the modern scientific method.
However, the LSM does not consider the type of research design, which cascades into failing to pick the category of study. The category of study the researcher is conducting will then determine what kind of inferences the researcher is allowed to make (Luftig, 1999). Since the LSM does not account for this, we argue that the type of experiments described in the LSM literature is unfit to make inferences to reality from. The most probable cause for the LSM’s lack of proper experimental and research design is the complexity involved in it. The researcher needs basic understanding of statistics and research methods. The LSM is developed for your everyday entrepreneur and its procedures have been designed to be simple and understandable to follow, therefore our belief is that proper hypothesis testing procedures had to be compromised. Instead, a proper hypothesis in LSM is described as being written with falsifiable terms into a yes-or-no question (Maurya, 2012). But the entrepreneur following the LSM procedure should beware of its flaws in research and experimental design, because what is considered as “validated” in the LSM might not be significant enough to describe the complete reality, and the entrepreneur should consider that when making a decision about whether to pivot, persevere or abandon a direction. Again, it all depends on what kind of risks the entrepreneur are willing to take and the time and resources available, and we refer to chapter 2.4.2 and “Design the sampling plan” where alpha- and beta values and their associated levels of risk are described, if the reader is interested in more information about this subject.

Another difference between the LSM and DFSS is related to sample size calculations. Though not all DFSS practitioners promote proper sample size calculations, we think it is worth discussing. Startups employing the LSM have had trouble determining when to pivot, persevere or abandon a direction, and are referencing this to the lack of guidance provided by the LSM about whether or not the “exit criteria” has been reached, or in other words, when a hypothesis has been validated. For instance, Bosch, Olsson, Björk & Ljungblad (2013) described their experience with the LSM as a great way of setting a clear and common goal for the team, but the problem seemed to be in deciding how to set up a proper exit criteria and know when that criteria had been reached and the hypothesis could be validated: “The biggest problem was deciding on how many people to talk to, and how to gauge their reactions and feedback” (Bosch, Olsson, Björk & Ljungblad, 2013, p. 13). Their conclusion was that exit criteria should not be blindly trusted but rather as a guide to be combined with common sense to validate hypotheses (Bosch, Olsson, Björk & Ljungblad, 2013).

Now, entertain the idea that common sense cannot be trusted, especially if a big decision needs to be made which might make or break the startup. An entrepreneur faced with such a dilemma could have great use of DFSS principles and tools when the success of the startup depends on a single or few decisions. It can take advantage of the principles behind research and experimental design, the sampling plan, how to make statistical analyses on data and how to make inferences to reality from it, which would greatly influence his decision. To answer the concerns stated by Bosch, Olsson, Björk & Ljungblad (2013), “how many people to talk to” could be answered by calculating a proper sample size and “how to gauge their reactions and feedback” could be solved through a QFD exercise to create measurability and assign targets from the VoC inputs.

Even everyday decisions about whether to pivot, persevere or abandon a direction based on hypothesis testing would be made good from healthy questions like “Which category of study am I conducting? What kind of data am I gathering? What kind of risk am I willing to accept being wrong? Which are the confounding variables of this experiment? What is the root cause of this problem? ” We acknowledge the difficulty in answering these questions in the early days of a startup when the company strives to find a working business model, all we are saying is that having a DFSS mindset during the early iteration cycles of the LSM to find a profitable business model will help the entrepreneur to make better decision and increase the probability of success because he has awareness.
When it comes to validating a physical product, the LSM doesn’t explain how to test your solution other than verifying that the customer is willing to pay for it. So, to be able to gauge and test different attributes of your product our experience is to take advantage of DFSS tools because they go into much more detail. The tools will allow the entrepreneur to not only test his concept or several different concepts against the customer, it will also allow for comparing different combination of components through DOE. Employing these tools will surely have a great impact on the probability of customer satisfaction and will contribute to fewer iteration cycles. This will decrease the speed of development, but will improve certainty.

However, we do see a potential for DFSS to increase speed and flexibility during the product validation phase if it were to apply some basic LSM principles. For instance, DFSS would be made good to employ the principle “get out of the building” more often than what is being emphasized. Also, the “MVP” concepts could be highlighted in regard of its importance in DFSS literature. It is mentioned that e.g. CAD-renderings can be used to measure reactions from the customer, but further emphasizing the benefits of this, especially with the DOE tools available in DFSS which can e.g. measure early combinations of attributes with a customer, could potentially increase the speed and flexibility of achieving product validation. Earlier customer interactions during the product design phase will reduce waste such as time spent on designing unwanted product attributes. We could find support for this theory at GE, who are trying to take the mindset of the LSM and apply it in everything they do; such as exposing yourself to the customer more often, rationalize failures as learnings, and testing your assumptions, and making the assumptions visible, for instance (Malmquist, 2013).

At the same time, we do acknowledge that DFSS tools might not be especially efficient for startups whose products are services, software or of another non-physical attribute. But if the product needs to be manufactured, DFSS seem to be able to help guide the entrepreneur through the product validation process better than the LSM, to arrive the correct decision. If, however, LSM were influencing DFSS during the product validation phase when developing a physical product, the process may be faster. As we know, time is the most valuable resource to a startup, and keeping the cash burn rate at a minimum will increase its chances of success.

5.4 Synergy effects combining Lean Startup Methodology and Design For Six Sigma

The combination of LSM and DFSS is a way of extracting data with a close relation to the customers. Depending on the need from the business the combination of the method will change, but the combination of the method’s philosophies is the most crucial part. LSM will strengthen the systematic and pragmatic approach that DFSS utilizes. If we use the case company’s different hypothesis from the lean canvas as examples, these were created with the LSM and in that methodology it says that they need to be verified and tested on the clients. How this should be performed was mostly described with the interview setting which had a good design for extracting the customer’s thoughts but lacked methodologies to analyze it. It did emphasize that it should be done but not how, with the usage of DFSS we could translate the customer’s thoughts into characteristics of the product.

LSM can give hints about which hypotheses are important to test and validate. There are several different methodologies that could be used to properly conduct those tests, but we can from this research see that DFSS fits the needs for the case company. Since the need of the case company is similar to what other startups conducting physical product development might face, this realization could also prove useful for others.
It should be noted that if you are using LSM and have experience of industrial research and methods for validating products, that knowledge may deliver the same results as the combination of DFSS and LSM in this research. The founders may already have the understanding of how to validate assumptions, how to quantify qualitative input from customers, questioning the results and using a systematic approach. All of these are some of the synergy effects when combining the two methods.

LSM emphasizes the validated learning and decrease of waste as fundamental for the methodology. By adding a more scientific approach from the DFSS framework the validated learning with more confidence and power, and waste can decrease even further. The challenge in the combination is that it’s only the right combination for the specific firm that will give synergy effects. If adding too much DFSS in a startup context there is a risk that the validating phase will be too extensive which adds waste due to longer lead times and resource demanding tests. Similar to when new firms want’s to start using Lean it’s not the specific methods that will make or break the implementation, it’s the understanding of the philosophy (Liker, 2004). To use LSM and combine the philosophy from DFSS with some of the tools from it will be helpful for all startup firms, as long as the entrepreneur can motivate the deployment of tools and methods used in relation to strategic objectives of the startup.

5.5 A final word about Design for Six Sigma and Lean startup methodology

When summarizing the empirical result and theoretical findings of this study it’s clear that the two methods have several similarities and attacking challenges in similar ways. These findings is interesting since the two methods are generally used in different contexts, DFSS in product development at large manufacturing firms with a lot of resources – LSM in small startups with a high degree of uncertainty and lack of resources. In chapter 2 we presented how the LSM was sprung out of the lean philosophy but if we go further back in the history we can find explanations for the similarities between Lean and Six sigma. If we go back to the 1960’s when the first steps were taken for the quality science as we know it today, it was the Japanese Total quality control (TQC) that started the quality movement and much different spin-offs followed with Lean, TQM, Six sigma and several more. DFSS and Lean evolved from similar methods and therefore these similarities we have found have a natural explanation (Chiarini, 2012).

This can be one of the reasons that the two methods have shown positive results when combining them due to their heritage and utilization of structured methods. Since both methods use cycles in their approach, parts of the cycle can be exchanged or added on to the next which leads to a more adopted cycle for new specific needs. Since the quality sciences emerged, quality methodologies have changed over time by using the existing methods and evolving them further to better fit current more specific needs.

During our benchmark interview with Malmquist (2015) the synergy effects that GE had experienced and what he believed their deployment of LSM would lead to were discussed. He expressed the similarities in the aim but also how the DFSS is closer to the technology while LSM in contrast is closer to how to make money of the product. They will use parts from each and adopt it to the specific needs of projects to gain as much synergy effects as possible. They will let the different methodologies integrate with each other without creating a new methodology. He expressed that this would probably be unnecessary since there are similarities and differences, but which to use is unique depending on the project. His thoughts about the synergy effects are similar to what we have experienced; the practitioner must let them interact and be used in different development phases if chances of success are to be improved.
6. Conclusion

The problem of high capital initial investments for startups developing physical products and the slow iteration cycles that come with it motivated this research. The purpose of this study was to explore how DFSS could complement the LSM, to make up for LSM’s lack of guidance related to product validation. To explore that perceived gap we set out to answer the research question “How can Lean Startup and Design for Six Sigma contribute to verify new physical product concepts entering new markets?”

Specific tools used during this study to achieve product validation for a new seat design for the T-bar ski lift, were Quality Function Deployment, Failure Mode and Effects Analysis and Design of Experiments. We can conclude that the least a startup developing a physical product should do is to design and analyze the technical specifications using QFD. It is cheap and relatively fast in comparison to the value of learnings extracted from it. Not only does it force the entrepreneur to think through the technical solution of the product, it is also a way to create measurability in how well the product in its current state performs to customer requirements and where the team should focus their improvement efforts on. That will reduce waste and the often resource sensitive enterprise such as a startup can get as much as possible out of the resources they have available.

The FMEA is also an inexpensive and non-time consuming tool to be used to identify root causes of potential failures and decrease the chance of any defects ever reaching the customer, and should be used in combination with the QFD. That will force developers in the startup team to think through possible pitfalls and prevent them from happening, before any investments are made to build prototypes, which also reduces waste.

When it comes to the design of experiments (DOE), we can conclude that it is one of the most convincing ways to validate a product, both its technical solution and the need for its attributes. However, conducting DOE activities requires statistical skills and experience which few entrepreneurs have. Therefore, the need for the deployment of an experiment must be motivated in relation to the level of certainty required to test the hypothesis, while also considering resources available to the startup.

In this study, we will conclude that at least three experiments should be deployed by SkiCorp before committing to manufacturing investments, to validate three key product hypotheses: 1) That there is a significant difference in comfort between the new seat and the old seat design. 2) That there is no significant difference in snow and ice allocation between the new seat and the old seat design. 3) That there is no significant difference in wind resistance between the new seat and the old seat design.

We can conclude that the LSM is better suited for customer validation than DFSS, and the principles of the methodology will not only be helpful in providing an in depth understanding of the customer, but also has the potential to create a highly competitive business model. The LSM has the ability to generate high value inputs from the right customer to be transferred into the product development funnel, as inputs for the design of the product.

Further, we can conclude that DFSS is better suited for achieving product validation than the LSM when the startup is developing physical products. It forces the team to plan its product development activities which subsequently creates a high quality product in advance, before launch. This will drive out waste such as rework and redesign, because defects are identified and prevented during the design stage. Through the DOE the team can also test different combinations of product attributes to find the best combination, or test different concepts of the product to find an optimal solution based on customer requirements.
However, we can also conclude that the two methodologies can create synergy effects between each other, where one methodology complements the other depending on which phase of development the team is currently in. In other terms, having a DFSS mindset when trying to achieve customer validation using LSM principles will tend to improve certainty when testing hypotheses and lead to better decisions. For particularly important decisions, the entrepreneur can increase certainty through the data driven approach taken by DFSS, but has to “buy” that certainty with the additional resources necessary to design and run the experiment, which could potentially lead to reduced waste in form of decreased rework due to poorly designed products or reducing the risk (and related costs) of ramping up production to manufacture a product nobody wants.

In the same way, having an LSM mindset when trying to achieve product validation with DFSS tools will tend to lead to reduced waste by arriving at the correct decision faster, because product developers in the team are encouraged to surface and test their assumptions about how the product should be designed and which attributes to include, which will force them to meet with customers earlier and more often during the development phases.

This yin/yang relationship will create balance during all phases of development, whether the current phase is more customer-centered or product-centered. Both methodologies feed each other information, and the development team of a startup is able to extract more knowledge between each development phase when both methods are used, than if one would have been used in absence of the other. This relationship is illustrated in Figure 6-1 and depicts how LSM should be applied to achieve customer validation with influences from DFSS, and how DFSS should be applied to achieve product validation with influences from LSM, to create balance throughout the validation process. However, we are not recommending a “super method” where both LSM and DFSS are combined. The two methods should rather be seen as a buffet of tools, related to distinctive phases of a startup, which the entrepreneur is free to use considering 1) the goal he is trying to achieve, and 2) how much resources are available to the startup. This approach will subsequently create a tailored solution to the unique challenges of the startup developing physical products, and increase its chances of success.

Figure 6-1 The DFSS/LSM relationship
We have lived and breathed these two methodologies during the five months we conducted this research study. As mentioned earlier in the thesis, one of the researchers was also the founder of the case companies, which gave us the unique opportunity to continuously implement and test the principles empirically, and evaluate the results immediately to study its implications. For instance, a lot of the information which surfaced during the structured interviews were used to rebuild the business plan. To see how well SkiCorp performed against other startups, they entered that rebuilt plan into two contests to compete for best business plan; the contests were “Venture Cup” which they won (Venture Cup, 2015) and “Flipday” (Flipday, 2015) which they came in second place. From what can be credited the DFSS part of the study, the results from the QFD and FMEA were used as input to the mechanical engineers SkiCorp employed to redesign the product, who successfully reduced the weight to allow for the product to be tested empirically. As we are finishing this report, SkiCorp has recently placed an order on a prototype series which they were able to pay for with funds allocated from investors who wanted to invest in SkiCorp based on a lot of the information acquired during this research study.

It's impossible to determine which factors - and by how much - those different factors has contributed to these success stories, but we feel confident the methodologies Lean startup and Design for Six Sigma had something to do with it. To improve the validity and the reliability of this research, more startups developing physical products using LSM and DFSS need to be researched. If our findings are applicable to other ventures in similar situations as SkiCorp, the improved decision making process could potentially lead to less time wasted on unwanted products. However, it could also potentially improve the chances of survival for high value product concepts, subsequently increasing the success rate of new ventures. Therefore, the theoretical contribution of this thesis would be beneficial for society in a broader perspective, as it could potentially e.g. increase employment rates, increase tax revenues, and allow its citizens to harness the value of innovations.

6.1 Recommendations for SkiCorp

The case company needs to conduct the experiment we as researchers have provided them with and use that result in their further development. They will also have to design and run experiments to test 1) snow and ice allocation, and 2) wind resistance to make sure the product perform according to the customer’s specification. If those two tests in addition to the experiment delivered, show promising results, the product would be considered completely validated and pre-production engineering can take place. This research did not focus on advertisement buyers for the advertising space of the product, which need to be further evaluated to properly design SkiCorp’s business model. The output from this research concerning SkiCorp should be used as learnings for future iterations.

6.2 Further research

There are many articles and news coverage about how startups have used LSM but there isn’t much research done in the area. Our starting premises came from the LSM literature, data on the environment for startups and SkiCorp’s experiences. It could be useful to research strengths and weaknesses other practitioners of LSM have experienced, both for successful startups the.

It would also be interesting to further research the hypothesis testing part of the LSM, to be inspired by DFSS. For example, the role of sample size calculations which could possibly play a role in providing a better guideline for how to set up exit criteria and specify when a hypothesis has truly been validated. That could potentially help entrepreneurs to better be able to make inferences from their experiments, which would lead to better decisions and higher success rates of startups.
This research is a start in the exploration of how LSM and DFSS can contribute to increased startup success. We have seen positive tendencies in this relationship but questions to answer remain. More research on this combination needs to be conducted to increase credibility for our results. Since it is important both from an individual standpoint, as well as from a societal perspective, to increase startup success rates, methods which can contribute to that improvement are important.
7. References


Luftig, J. (1997). Quality with Confidence. SPSS Inc.


Tillväxtverket (2013). Entreprenörsbarometern. www.tillvaxtverket.se


Interviews:

Hans Gerremo, VD SLAO 2015

Gunnar Malmquist, GE health care October 2015

<table>
<thead>
<tr>
<th>Resort</th>
<th>CTO</th>
<th>CEO</th>
<th>15/10/16</th>
<th>Type of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resort 1</td>
<td>x</td>
<td>x</td>
<td>15/09/07</td>
<td>Face-to-Face</td>
</tr>
<tr>
<td>Resort 2</td>
<td>x</td>
<td>x</td>
<td>15/10/15</td>
<td>Face-to-Face</td>
</tr>
<tr>
<td>Resort 3</td>
<td>x</td>
<td></td>
<td>15/10/19</td>
<td>Face-to-Face</td>
</tr>
<tr>
<td>Resort 4</td>
<td>x</td>
<td>x</td>
<td>15/10/21</td>
<td>Face-to-Face</td>
</tr>
<tr>
<td>Resort 5</td>
<td>x</td>
<td></td>
<td>15/11/02</td>
<td>Phone</td>
</tr>
<tr>
<td>Resort 6</td>
<td>x</td>
<td></td>
<td>15/11/09</td>
<td>Skype</td>
</tr>
<tr>
<td>Resort 7</td>
<td>x</td>
<td>x</td>
<td>15/11/13</td>
<td>Face-to-Face</td>
</tr>
<tr>
<td>Resort 8</td>
<td>x</td>
<td></td>
<td>15/11/19</td>
<td>Face-to-Face</td>
</tr>
</tbody>
</table>
8. Appendix

Appendix 4.1 Updated QFD................................................................. 72
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## Boardie QFD Matrix

### Voice of the Customer to End of Line Characteristics - CTQs

<table>
<thead>
<tr>
<th>Customer Need</th>
<th>Customer Need Weight</th>
<th>Importance Rating</th>
<th>Wall Thickness</th>
<th>Shell finish in tolerance</th>
<th>Ad surface depth</th>
<th>Original size in tolerance</th>
<th>Structure material</th>
<th>Surface outside point radius</th>
<th>Surface short side radius</th>
<th>Improvement Ratio</th>
<th>Sales Point</th>
<th>Customer Need Weight</th>
<th>Characteristic Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provides a comfortable ride for the user</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2. Intuitive to use</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3. Fast and easy installation</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>4. Suits the individual T-bar model of the resort</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>5. Resistant to wind</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>6. Minimal snow and ice accumulation</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>7. Satisfying for all means of ski transportation in the slopes</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>8. Resistant to hard impacts</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>1.333</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>9. No clothes stuck</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0.8</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>10. Springs back on release properly</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>100</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>11. No oscillation at turn station</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>80</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>12. No extra amount of work for lift operators than necessary</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>13. Resistant to cold weather and UV light</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>0.8</td>
<td>1</td>
<td>3.2</td>
</tr>
<tr>
<td>14. No increase in spring of line gear</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

### Absolute Weight

| Characteristic | 2.33 | 2.14 | 5.59 | 0.80 | 0.55 | 1.04 | 1.32 | 1.85 | 5.42 | 482.9 |

### Characteristic Weight

| Characteristic | 11.1 | 10.2 | 26.6 | 3.83 | 2.6 | 4.96 | 6.26 | 8.8 | 25.8 |

---

**Appendix 4.1 Updated QFD**
<table>
<thead>
<tr>
<th>#</th>
<th>FMEA for Design</th>
<th>Failure Mode and Effects Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design Failure</td>
<td>Function failure of the system</td>
</tr>
<tr>
<td>2</td>
<td>Manufacturing Failure</td>
<td>Material defect</td>
</tr>
<tr>
<td>3</td>
<td>Environmental Failure</td>
<td>Temperature change</td>
</tr>
<tr>
<td>4</td>
<td>Operating Failure</td>
<td>Overloading of the system</td>
</tr>
<tr>
<td>5</td>
<td>Maintenance Failure</td>
<td>Incorrect maintenance procedure</td>
</tr>
</tbody>
</table>

**Appendix 4.2 FMEA**
Appendix 3 Matched pairs randomized blocked experimental design

Two students have developed a new design for a T-bar ski lift seat to make it more comfortable for users during the ski lift ride. The concept has been demonstrated for a number of ski resorts which have explicitly showed an interest to implement the new seat design on their current T-bar ski lift system. Before any decision to implement the product is made, the ski resorts want to see that the new seat design has a true effect on comfort level for users utilizing the T-bar ski lifts at their resorts, respectively. To test their assumption that the new T-bar seat is more comfortable, the students ordered 10 prototypes to be manufactured from silicon molds to test the new concept empirically on resorts of different size and location in Sweden. The tests were conducted on “normal” skiing days, which means tests were not conducted during e.g. weekends or holidays when increasing amounts of visitors would be expected which could potentially, nor conducted during harsh weather conditions, which could introduce confounding variables.

The critical characteristic of interest is the amount of people using the T-bar seats during a typical day in the slopes, to determine if there are any meaningful differences in preferred T-bar seat design between the old seat design and the new seat design among ski resort visitors. To find if such a difference exists, a randomized blocked design using matched pairs were chosen. First, the students randomly selected 20 T-bars from one of the T-bar ski lift systems (25 – 100 T-bars per system) in operation at each ski resort (the T-bar system to run the experiment on was chosen by the ski resorts themselves). For one day, the researchers counted how many times each seat (all specimens) in both groups were used. After data was gathered the specimens were ranked based on criterion measure into pairs of two to form two groups. The groups were then analyzed to determine no meaningful difference existed between the two groups when untreated. Then, one group of ten T-bars was randomly chosen to be fitted with the new seat design. The same sampling procedure was conducted the next day and data was gathered for both groups for further analysis, to find out if a true effect existed between the old and the new seat design in regards to T-bar utilization.

<table>
<thead>
<tr>
<th>O1</th>
<th>Xtr</th>
<th>O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>Xc</td>
<td>O2</td>
</tr>
</tbody>
</table>
Report of the Statistical Analysis of the Data

Title of the Experiment / Research Study:
Matched Pairs Analysis for preferred seat design during T-bar ski lift rides:

State / Restate the Research Question(s) To Be Answered by the Research Study:
Is the old or the new T-bar seat design preferred by the T-bar ski lift users?

Design Detail Tables (Factorial Designs):

Table I
Dependent Variable Information

<table>
<thead>
<tr>
<th>Criterion Measure(s) (Name, Specifications &amp; Cost data)</th>
<th>Underlying Distribution (N/O/C)</th>
<th>As Measured (N/O/C)</th>
<th>Performance Objective of the CM(s) (Bigger Better, Smaller Better, Nominal [Target] is Best)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of times T-bar seat is used in a day</td>
<td>C</td>
<td>C</td>
<td>Bigger Better</td>
</tr>
</tbody>
</table>

Remember to identify any relevant cost information:

Table II
Treatment Factor / Independent Variable Information

<table>
<thead>
<tr>
<th>Name of Treatment Factor / Independent Variable (Sources of Variability)</th>
<th>Category Treatment (T)</th>
<th>Fixed (F)</th>
<th>Underlying Distribution N/O/C</th>
<th>As Measured N/O/C</th>
<th># Levels and (df)</th>
<th>Relationship to other variables (Crossed v Nested)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat design</td>
<td>T</td>
<td>F</td>
<td>N</td>
<td>N</td>
<td>2(1)</td>
<td>Crossed</td>
</tr>
<tr>
<td>Specimens (Repetitions or Experimental Units)</td>
<td>n/a</td>
<td>R</td>
<td>n/a</td>
<td>n/a</td>
<td>n - 10</td>
<td>(df = 9)</td>
</tr>
</tbody>
</table>

75
### Table III

**Blocked & Limited Effects**

<table>
<thead>
<tr>
<th>Blocked Variables</th>
<th># Levels</th>
<th>Limited Variables</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day-to-day T-bar system utilization</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test for 1) Shape. 2) Dispersion. 3) Location