CHALMERS

Exploring the Opportunities of Wearable Technology within Siemens AG

Prototyping a Wearable Solution to Reduce Workplace Injuries

Master of Science Thesis
in the Management and Economics of Innovation Programme

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Cover:
The developed app running on a Samsung Galaxy Gear Watch, page 37

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Anders and Martin
March 2015, San Francisco, California

Abstract

Wearable Technology is thriving in the consumer segment and is starting to gain momentum also in the business segment. Enterprises anticipate that big opportunities exist as utilizing Wearable Technology imposes several advantages over conventional technologies and methods. Implementing Wearable Technology into industrial environments is a new area. Hence, little research has been conducted in this field. This thesis seeks to contribute to this field by conducting a case study at Siemens. The aim of the project is to analyze how Wearable Technology could be used by the focal company and to prototype a solution using wearables.

The overall research purpose is divided into three distinct sub purposes. The first sub purpose is to analyze the overall market landscape of Wearable Technology. The second sub purpose is to evaluate the fit between the technology and the company. The third sub purpose is to develop a concept utilizing Wearable Technology targeting the focal company's current business areas. Industry experts interviewed state that the wearable landscape is non-uniform and must be divided into categories to be analyzed in detail. However, the unique value proposition of wearables is the ability to collect data about vital signs and the environment around the user, which will yield future business opportunities. They further argue that Wearable Technology, in its current state, is governed by constraints in terms of user privacy, battery power and connectivity.

This thesis concludes that great opportunities for Wearable Technology are within reach but technical as well as non-technical constraints must be addressed before the rate of adoption will increase. There are many application areas where Siemens would benefit from implementing Wearable Technology. The authors argue that a good starting point are areas where the unique value proposition of wearables mentioned above could be utilized. Such an application area is arguably occupational health and safety. The authors therefore developed and prototyped a concept using Bluetooth beacons and a smartwatch to ensure usage of personal protective equipment in the workplace. The authors suggest the developed concept as a point of departure in order to gain a competitive edge in this field.

Keywords:
Wearable Technology, Wearable sensors, Web of Things, Internet of Things, Industry analysis, smartwatch, Bluetooth beacons, Occupational Health and Safety

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1. Introduction & Background

Information entails power and has always been essential to mankind. The means to collect, store and distribute information have improved significantly due to technological breakthroughs during the last decades but are still considered as bottlenecks to data management. The demand for information drives the development of devices, sensors and information systems that collect, store and display information. More importantly, the technology is embedded into new kinds of objects. Already today, an increasing number of objects are becoming *smart*, i.e. have integrated sensors that collect, transmit and receive data. This evolution, where all types of things in our everyday-lives are connected to other devices via internet, is called the Internet of Things (IoT). IoT is considered the next big technological revolution since smartphones was introduced 10 years ago (Ali Feki et al. 2013). Analysts predict that more or less all of our everyday objects, that would benefit from being connected, will be smart in the future. (Accenture, 2014; PwC, 2014 ; Goldman Sachs, 2014; Deloitte, 2014)

A decade ago there were around 500 million connected devices in the world, which mainly consisted of computers (Cisco, 2011). With the entrance of smartphones, smart TVs etc. in the last decade, the number of connected devices has risen to approximately 14 billion in 2014 (Cisco, 2014). Analysts predicted that this number will have risen to around 50 Billion units in 2020 (Cisco, 2014). As depicted in figure 1.1. below, the estimated number of connected devices per person will exceed six after 2020.

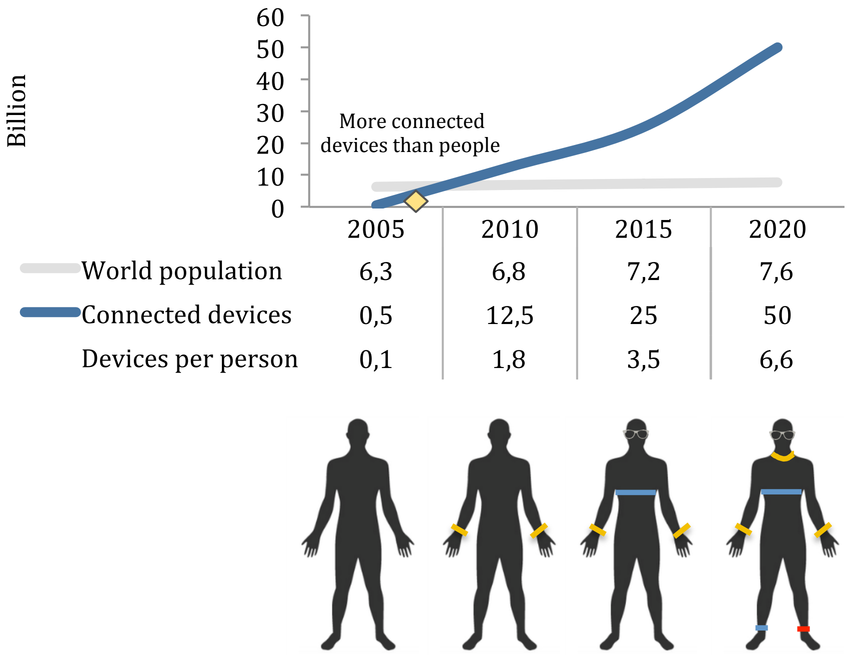

Figure 1.1 Connected devices per person. Source: Consensus and Master Thesis Analysis

An increasing number of connected devices will boost the generated amount of data significantly and the collection of data will not necessarily be a future constraint. The challenge will rather be to process and analyze data to gain insights that are essential to make decisions. This process, to collect and draw conclusions from a vast amount of information, is called *Big Data* and will imply new businesses for some companies but major challenges for others. (McAfee & Brynjolfsson, 2012)

1.1. Wearable Technology

The advances in technology have yielded smaller components with better performance, which today makes it possible to fit computers into devices that could easily be worn on the body. *Wearable Technology, wearable user interfaces* or simply *wearables* could be seen as a subset of Internet of Things and is both a way to collect more data but also a way to provide the user with information faster and more convenient.

Neither academia nor practice has yet agreed upon a single definition of wearables, but a definition by Gartner (2014) highlights that:

"Wearable user interfaces describe the interaction between humans and computing through electronics designed to be worn on the body"

However, this definition does not describe the main capabilities of wearable devices. In this thesis, the main characteristics of wearables are the ability to use sensors to collect data, display data to the user, receive information from other data sources and transmit data to other devices or to the cloud, as depicted in figure 1.2. All kinds of wearable devices must be designed to be worn on the body, which excludes conventional smart phones, tablets and iPods to be considered as wearables. Examples of wearables are smartwatches, smartglasses and wrist bands with sensors.

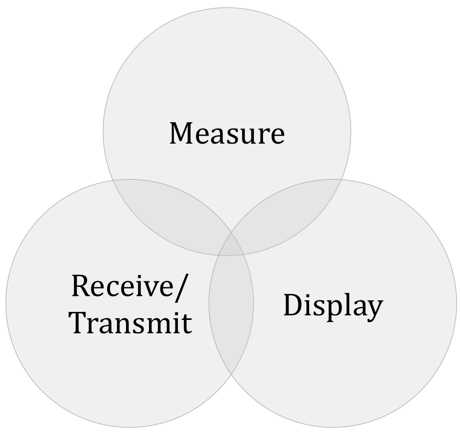

Figure 1.2. The three fundamental properties of a wearable. Source: Own illustration

During the last few years, the interest for Wearable Technology has grown steadily. The number of Google searches for "Wearable Technology" grew by 588 per cent in 2013, which is a good indicator of an increasing interest. In 2014, many new devices were launched onto the market which proves that the actual use of the technology start to gain momentum too (Vandrico, 2014). The first wearable devices, using modern technology, were introduced by small start-up companies in the beginning of the 21st century. Today, IT-giants such as Apple, Intel, Google and Samsung have entered the market and started to gain market shares. As depicted in figure 1.3, the number of shipped wearable devices has increased steadily during the last five years. The majority of the devices are focused on fitness applications but during 2014 products targeting several other application areas were shipped. However, analysts forecast that the adoption of wearables will accelerate significantly in the near future and pave its way into new application areas. (IHS, 2013)

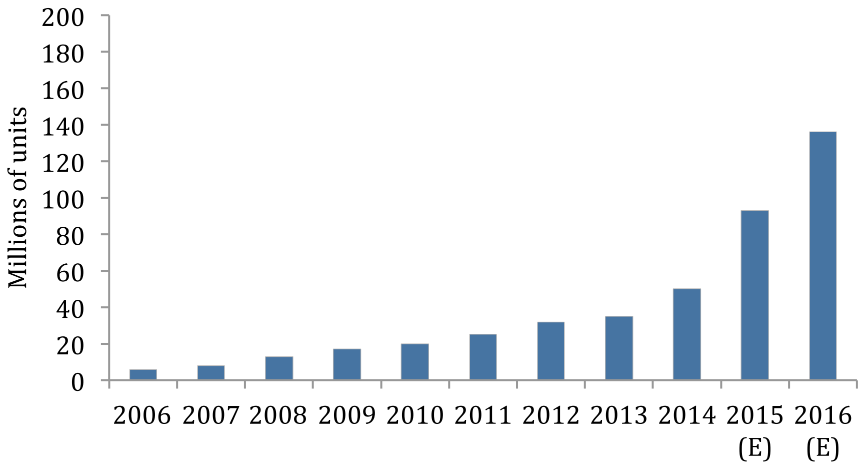

Figure 1.3. Volume of shipped consumer wearable devices. Source: IHS, 2013

Analysts predict that wearable devices will be increasingly used in industrial application areas and support important business activities. In traditional organizations, managerial decisions are based on reports and analysis where data often is outdated, invalid and stems from manual observations. Physical objects with embedded sensors, such as wearables, can not only provide management with accurate, real-time information but also increase the efficiency in several different operational activities. Analysts point out that these kinds of sensors also can be used to track behavior, enhance situation awareness, optimize processes and resource consumption and as an important component in complex autonomous systems. However, one must bear in mind that even though companies have started to explore opportunities for Wearable Technology, there is still a significant gap between ideas and existing technology that has to be bridged before companies can start to implement this kind of technology into their organizations (McKinsey, 2014).

1.2 The Focal Company

Siemens is a German multinational company, founded in 1847 by Werner von Siemens. The company is headquartered in Munich and is the largest engineering company in Europe with approximately 360 000 employees. Siemens had a turnover of around €76 billion and made a profit close to € 4.2 billion in 2013. The company is publicly owned and its shares are listed on all major German stock exchanges and also in London. The largest shareholder entity is the descendants of Werner von Siemens, which currently holds six per cent of all outstanding shares. The company has been restructuring its business units and since October 2014 Siemens is organized into ten divisions; power and gas, wind power and renewables, energy management, building technologies, mobility, digital factory, process industries, power generation services, financial services and healthcare. (Siemens, 2013). The company has not yet released any annual financial statements based on the new structure. Thus, figure 1.4 depicts revenue and profit breakdown based on Siemens' former organizational structure.

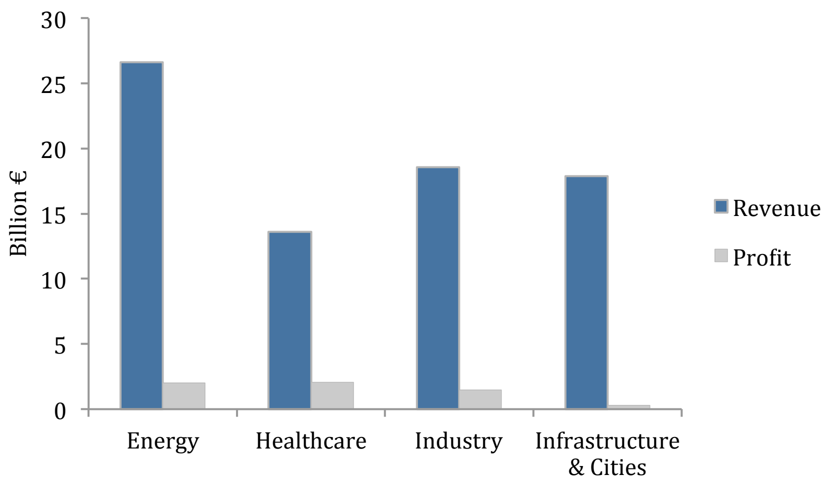

Figure 1.4. Revenue and profit, division breakdown. Source: Siemens annual report, 2013

Siemens has always been an R&D intensive company and in the two previous years it has been investing €4.3 billion per year into research and development. The investments are directed to develop new technologies and bring them to the market. In 2012 Siemens was ranked number 3 in number of patent applications filed in Germany and number 2 in applications filed to the European patent office. As number of patent granted in the U.S. the company were ranked number 11. In total, 60 000 patents were granted worldwide. The number of employees working within R&D were roughly 29 800 in fiscal 2013, where 13 300 of them worked in Germany and 16 500 worked in other countries around the world. (Siemens, 2013)

2. Purpose of the Thesis

This section will outline the purpose of the project and introduce the reader to the research purposes. It will also briefly present the focal company and state the delimitations of the report.

Simultaneously as exploiting their current business, large companies have to initiate projects to evaluate new technologies that may become essential to the industry of tomorrow. Wearable Technology is considered as such a technology. Companies that neglect new technologies might miss important business opportunities and risk to lose market shares to more innovative competitors. As of 2014, companies developing wearable devices have focused on the consumer segment creating products such as fitness bands and smartwatches. Many analysts predict wearables to be an even more important tool for the business segment but little research on how Wearable Technology can be exploited in companies has been made.

The focal company, Siemens, has recognized the potential of Wearable Technology and initiated projects for industrial applications of wearables. Previous projects at Siemens have exclusively targeted Wearable Technology in the context of Professional Health Care. This particular project will instead focus on Siemens' other business areas. Thus, the purpose of this project is to identify a new use case for Wearable Technology to be used within Siemens, build a prototype and evaluate the concept through stakeholder interviews. In order to achieve this purpose, the market for Wearable Technology will be analyzed. Based on this analysis, this thesis will evaluate the fit between the technology and the focal company in terms of current business units and context. Three sub purposes are formulated to support the overall purpose presented above. The sub purposes are:

- To analyze the industry of wearables with regards to existing and emerging technologies, application areas and key stakeholders.
- To outline Siemens' business areas and discuss the fit between the company and the technology.
- To identify a specific Wearable Technology-use case, with knowledge gained from unfolding previous research purposes, and build a prototype based on the findings.

Thus, the overall aim is primarily to find a use case within Wearable Technology that Siemens could use and benefit from internally. Given the size of the company there are potentially several different units that could reap the benefits from implementing wearable devices, e.g. to facilitate routines and everyday activities and to make processes more efficient.

This report aims to discuss the market of Wearable Technology and unfold potential use cases specifically related to the focal company. However, conclusions made in this report about Siemens could arguably be valid for other large engineering companies. Furthermore, Internet of Things and Wearable Technology are considered radical innovations. Thus, on a higher level of abstraction, this thesis will also contribute to the field of innovation research through outlining the development process of technological innovations in large technology companies.

2.1. Delimitations

Since the research was primarily conducted in the United States, the focus of the thesis is to answer the research purpose with regards to the business context in this country. As previously mentioned, Siemens is a multinational company and conclusions drawn in this report can most likely be transferred into other areas and other countries with similar business environments.

The overall aim of this study is to evaluate different application areas for Siemens within the Wearable Technology industry and develop a use case, which would create value based on the technology that is available. Hence, this thesis does not propose use cases based on predictions of the development of technology used in wearables. Furthermore, this thesis focus on the value created for the user but do not further evaluate profitability, predict future demand or cost of development and production.

2.2. Disposition

This report has a non-conventional structure compare to other Master's Thesis. Instead of having an overall section to describe the theoretical framework, empirical findings and discussion, this report is structured so that each research purpose has its own section of theory, findings and discussion. The rationale behind this structure is that research purpose two and three build on previous research purposes. Research purpose two is analyzed in relation to research purpose one and research purpose three is analyzed in relation to research purpose one and two. Therefore the previous research purpose had to be analyzed and discussed before presenting and analyzing the next.

The report is structured as follows; firstly the reader is introduced to Internet of Things, Wearable Technology and to the focal company. Then the purpose of the project is presented followed by the methodology and approach used to conduct the research. In chapter four the market for Wearable Technology is analyzed and chapter five discusses the relation between Wearable Technology and the focal company. Chapter six presents the development and prototyping process of the authors' invention to ensure usage of personal protective equipment. This is followed by a general discussion, where all three research purposes are discussed in conjunction. The report ends with a conclusion.

3. Methodology

In this chapter the overall research strategy and process, research design and research method used in the project are presented.

The greater part of the research for this Master's Thesis was conducted at Siemens Silicon Valley research group, located in Berkeley, California. This area is a cluster for technology and computer science and getting access to interviewees knowledgeable within the area of Wearable Technology was considered more convenient than if the project was carried out in Sweden. The research group, which consists of ten researchers, was established in 2013 and is part of Siemens USA Corporate Technology. This group conducts research within the field of Computer Science and Web of Things.

3.1. Research Strategy and Process

Although the overall aim of this project was clearly stated from the start; to analyze the market for Wearable Technology, identify the potential of using Wearable Technology within Siemens and to develop a specific use case for Siemens, it was a comprehensive topic and not a straightforward task. Therefore the research of this project started broadly. In the initial steps, the authors strived to get an overview of the Wearable Technology landscape, to see what type of devices that were available on the market and how they could be used to improve everyday life for consumers. Also, an examination of any obvious trends within the Wearable Technology industry and in what direction the market was heading was examined. As a part of the initial steps in the research process, the potential for using Wearable Technology within industrial environments was investigated.

The project could be considered as taking the approach of *technology push*, where a technology is pushed through R&D and production into the market with high uncertainties if there is a demand for the technology. This approach stands in contrast to *market pull* where a new technology is developed as a response to an identified market need (Martin, 1994). This study sought an application area for Wearable Technology within Siemens instead of first finding a problem within a particular business area and then searching for a solution to that problem. As this was the case, the task at hand was not only to argue for using Wearable Technology over other types of technology or solutions but to argue why investing in it at all. Therefore, as an obvious next step, an examination of Siemens' business areas was performed in order for the authors to get a better understanding of the company's business and the potential challenges they were facing. This was paramount in order to evaluate how Siemens could benefit from using Wearable Technology. The overall research process is depicted in figure 3.1 below.

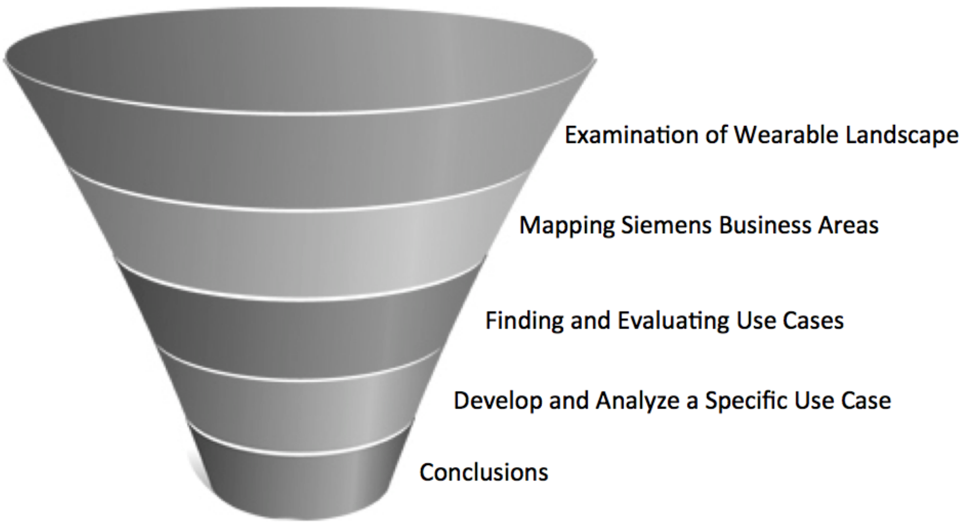

Figure 3.1. Funnel illustrating the steps in the research process. Source: Own illustration

The process of identifying and evaluating use cases was an iterative process. Ideas about potential use cases and real use cases were identified through browsing the internet, conducting interviews with industry experts and interviewing startups and companies that were developing products or systems for wearables. The use cases that were considered most interesting were evaluated through reading about Siemens and its business areas and interviewing employees at Siemens. Also, the overall process was iterative, where new use cases were identified and simultaneously evaluated if they could fit into Siemens' business. After several iterations, as depicted in figure 3.2, a specific use case was developed based on the knowledge gained from the interviews and readings described above. The final use case, developed and prototyped by the authors, was a system to ensure that personal protective equipment is worn by workers in hazardous environments. This was achieved through an application running on a smartwatch to detect beacons emitting a Bluetooth signal. The application was developed based on an open source project initiated by Google called *the Physical Web*.

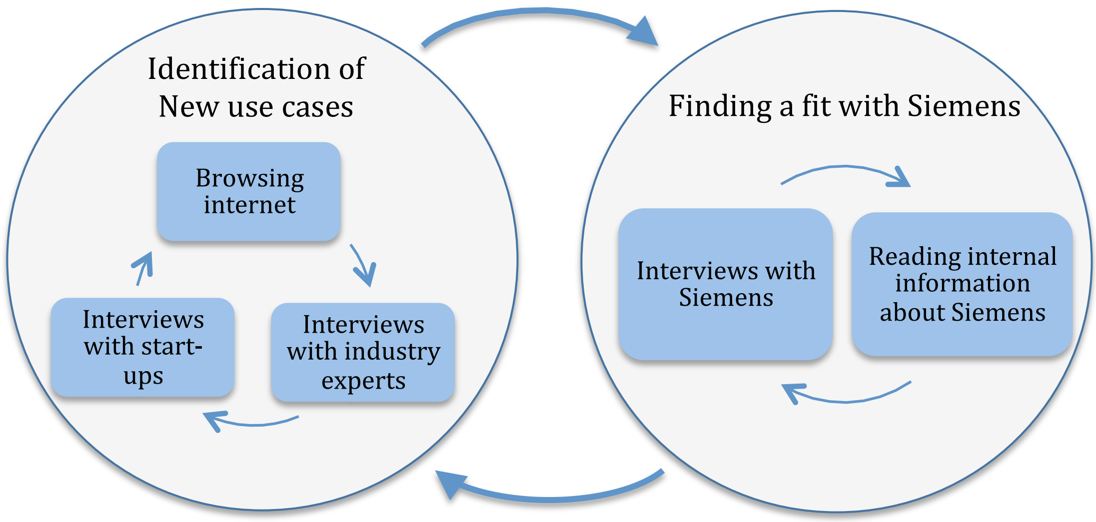

Figure 3.2. Iterative process of identifying and evaluating use cases. Source: Own illustration

Simultaneously as examining the wearable market and potential use of wearables within industrial firms, a literature study was performed. As the focus of the project was initially broad the search for appropriate theory that could support the analysis of the market and the use case was not finalized in an early stage. Instead it was performed during the whole project, although more intense in the latter part. The empirical findings and the theoretical framework were analyzed in conjunction with each other in order to understand the market for Wearable Technology and evaluate the identified use cases. Hence, the theory strengthens the arguments that are made in the analysis sections.

3.2 Research Design

A case study is a research design that implies a comprehensive and in-depth investigation and analysis of a specific case or situation, e.g. an organization, a location or an event (Bryman and Bell, 2011). Yin (2009) states that a case study is preferred when the investigator has little control over events and when the issue is about a contemporary phenomenon in a real-life context. In this study, this type of design is chosen since the aim of the project could be considered a specific case, i.e. to investigate the market potential and industrial application areas for Wearable Technology and to evaluate the value of the developed and prototyped use case for Siemens.

In a case study qualitative methods are preferred over quantitative methods. Qualitative methods seek to find an in-depth understanding of a certain phenomenon or situation while quantitative methods instead seek to answer a specific question through statistical and numerical data (Bryman and Bell, 2011). This study made use of both qualitative and quantitative data but since a case study was chosen as research design and to answer the purpose of this report, quantitative data was used to a limited extent.

3.3 Research Method

Research method describes how data is collected (e.g. through interviews, questionnaires, observations) and analyzed. Data can be of either primary or secondary nature (Bryman and Bell, 2011). This report consists of both primary data, mainly collected through interviews but also of secondary data through the use of articles, reports and other publications.

3.3.1 Interviews

All of the interviews conducted were semi-structured as opposed to strictly following a template with question or having no structure at all. In a semi-structured interview, Bryman and Bell (2003) state that the interviewer has a series of open ended questions. The order of these questions can be varied during the interview. The questions are usually more general in their frame of reference than typically found in a structured interview guide. Additionally, the interviewer has some freedom to ask further questions in response to what is seen as significant replies. This approach was chosen since the authors had obtained a basic understanding of the wearable landscape beforehand, through reading articles online, and therefore wanted more specific information from the interviews that not easily could be found on the Internet. Through the use of semi-structured interviews the interviewee was encouraged to elaborate further on topics we found interesting and follow-up questions that were not initially written down could be asked.

The initial interviews were conducted with the main purpose of getting familiar with the wearable landscape and in what direction the industry was heading, as much as for regular consumers as for industrial companies. In total, nine interviews with experts within the area of Wearable Technology were conducted. As our knowledge of the market increased, interviews with people that had more specific knowledge were conducted. The interviews followed the same funnel structure as the report; first obtain a broad picture of the market and later conduct interviews with more specific purpose. A list of interviewees was not made before the first interview was conducted. Instead, new interviewees were continuously found throughout the project partly through reading articles and partly through snowballing sampling, i.e. asking the interviewee if he or she could refer to another relevant interviewee. Bryman and Bell (2011) state that this form of non-probability sampling is especially beneficial in qualitative research and that it is a convenient approach in order to reach more people related to the research topic.

Once an interesting use case was identified, the sample of interviewees shifted from industry experts to employees within the focal company. The first four interviews were conducted to better understand Siemens and the potential for Wearable Technology within the company. Then, since the invention is an approach to reduce the number of occupational injuries, interviews were conducted with Siemens employees working as EHS (Environmental, Health and Safety) managers at different factories in the US. In total six interviews were conducted with employees working at five different locations in the US. The main aim of these interviews was to test the hypothesis related to the project, in accordance with the customer development methodology developed by Steve Blank and Bob Dorf (2012). Hypothesis made up by the authors were tested through the interviews and the interviewees also identified issues with the invention that had to be addressed. With new insights from the interviews, hypothesis about the idea were altered to achieve a better product market fit.

The interviews were conducted both through telephone and in person. Interviews in person have many advantages over telephone interviews, as they allow for non-verbal communication and it is therefore easier to understand each other and build rapport (Bryman and Bell, 2011). However, as Wearable Technology is a rather new phenomena experts in the field are few and the knowledge is scattered, i.e. knowledgeable people in the field are located worldwide. With the given timeframe and budget for this project it was therefore not deemed feasible to conduct all interviews face-to-face. In total 19 interviews were conducted with experts and university researchers within Internet of Things and Wearable Technology, start-up owners and CEOs of wearable companies and Siemens employees.

3.3.2 Observations

Observations are often a fundamental part of the research process and an important tool to find the context to the research problem. Stenhouse (1975) points out that it is important to make observations in a structured manner. Since our human brains are bombarded with impressions and sensory information one must be selective and conscious about where to direct the attention. Observations are often an important part in both quantitative and qualitative studies. In this project, mainly qualitative observations have been made. Geertz (1973) states that qualitative observations can provide the researchers with rich data, also referred to as *thick data*.

The observation that led the researcher to the use case, presented in chapter six, is considered as essential to the outcome of the project. It was made during a factory tour at Siemens' light rail factory in Sacramento, California. The researchers had a clear and coherent understanding about what to look for: a use case where Wearable Technology could enhance occupational health and safety. When the researchers observed a worker grinding without using safety glasses, this was considered as a safety hazard that could be mitigated with wearables.

3.3.3 Documents and Article Readings

Documents and articles, both offline and online, have made a major contribution to this report. Secondary data, e.g. from articles and documents, is data that is not collected directly by the researcher, but instead by another researcher at a different point in time. Secondary data is less time consuming and often requires less resource in contrast to collecting primary data. It can therefore provide the researcher with good knowledge with little effort (Bryman and Bell, 2003). In the initial stages, when the authors had limited knowledge in the field, reading articles gave an overview of the Wearable Technology landscape. These insights could be used to point out the direction of the project and what further knowledge needed to be obtained. In latter stages, reports and articles were used both as an input to the empirical part of this report and also as a mean to verify facts stated in the interviews.

3.4 Methodology Discussion

In business research there are mainly three criteria for evaluating the quality of the collected data; *reliability*, *replicability* and *validity*. In this report reliability and validity are considered most relevant, as replicability is less applicable for qualitative studies (Bryman and Bell, 2011).

3.5.1 Reliability

Reliability relates to if the results of a study are repeatable and if the results are consistent when several measures are made (Bryman and Bell, 2011). Repeatability should not be confused with replicability. Replicability relates to if a study could be performed again by another researcher while repeatability relates to if a measure within the same study could be made several times. If a measure produces similar results when conditions are remained unchanged it has high reliability. Reliability does not however imply validity. A measurement of e.g. the weight of a person can be reliable and repeatedly produce the same result of the weight, but the result would not necessarily be correct, i.e. not correspond to the actual weight of the person. Reliability is particularly relevant for quantitative studies since qualitative research in general and case studies in particular are considered to be biased and difficult to replicate.

Since this study is mainly qualitative, with a specific case, the reliability of it could be regarded as rather low, as it is challenging to replicate a specific case and have the exact same set-up as the original case. However, the authors have addressed these issues by having a rather comprehensive methodology chapter which clearly states the process and chosen strategy, design, data collection methods and also including a methodology discussion. All of the interviewees, participating in this study are active in the field of Wearable Technology but have individual areas of expertise and interest. Hence, the conclusions drawn from the information unfolded in the interviews would probably be different if a different set of interviewees was selected.

3.5.2 Validity

Validity relates to if the measures correspond to the real world and if they actually measure what is intended to be measured. Validity can further be divided into four categories; *measurement validity, internal validity, external validity,* and *ecological validity* (Bryman and Bell, 2011). Measurement validity applies primarily to quantitative research and relates to whether the measure can be considered as an appropriate method to measure a certain concept, e.g.; does IQ tests really measure intelligence? Internal validity addresses causality, e.g. if the variable x causes changes in variable y, can it be assure that it is changes in x that causes the changes in y. External validity relates to whether the results of a study can be generalized beyond that specific study. Ecological validity deals with whether or not the findings in a study are applicable to a natural setting in people's everyday life or exclusively to the environment of study (Bryman and Bell, 2011). In this case, measurement and internal validity are not being evaluated as they relate more to quantitative studies.

Ensuring high validity is crucial for a report to be trustworthy and for any conclusions made in it to be relevant and useful. Therefore, strengthening the validity of this report has been a major concern. Creswell and Miller (2010) state that triangulation is a good way to increase validity. Triangulation is a method where data is collected through several different sources and might also include collection of data by using several different data collection methods. In this way, a statement or conclusion is not based on a single incident or data point. To increase the validity of this report through triangulation, the authors have deliberately selected interviewees with overlapping areas of expertise. Thus, conclusions drawn from one interview could be confirmed by other interviewees to prevent biased opinions to affect the results. Also, data has been gathered through several different methods, primarily interviews and articles on the internet, which further increased the validity of the report.

External validity could be regarded as high as the first part of the report, which involves an investigation of whether wearables could have industrial applications, is applicable beyond the focal company. Also the latter part, which examines the possibilities for Siemens to use Wearable Technology within their firm, could be claimed to have high external validity as the results could be applicable and of value for other engineering or manufacturing firms. As the interviews are conducted with people in real life environments, also the ecological validity could be considered high.

The authors of this thesis may have been affected by biases related to their educational background. Furthermore, the theoretical framework is likely the most affected section by this bias since many of the concepts presented are important building blocks in the authors' Master's degree. However, the awareness of such biases has likely reduced the impact of this bias.

4. Market overview

This chapter intends to address sub purpose one; to analyze the Wearable Technology industry with regards to existing and emerging technologies, application areas and key stakeholders. The theoretical background is presented, followed by a description of Wearable Technology and industrial use cases. The chapter ends with a discussion.

4.1 Theoretical Background

The theory below describes how technologies evolve and improve over time and how they are diffused in the society. Wearable Technology can be predicted to experience a similar development.

4.1.1 Patterns of Innovation

Abernathy and Utterback (1978) suggest a framework to describe the patterns of innovation processes, depicted in figure 4.1, which will be used to analyze Wearable Technology. The purpose of this framework is to understand the underlying driver when an innovation emerges. Thus, an organization that understands these drivers can improve its capabilities to embrace new opportunities. The authors behind this framework argue that the pace of product innovation is initially high. This reasoning is supported by Anderson and Tushman (1990), who use the term *Era of ferment* to describe this part of the innovation process, which often is characterized by high degree of uncertainty. In this phase, production process performance is poor, with deficient product quality and low production speed as a consequence. Subsequently, when the products are improved, the rate of product innovation slows down as a dominant design evolves with reduced uncertainties as a consequence. Development of product standards and lower uncertainties enable companies to shift focus from product to process innovation. This phase poses major challenges to smaller companies that often contributed to the development of the technology but struggle to scale up production. As a consequence, the industrial landscape shifts, where large companies outcompete smaller firms. This phenomenon is termed *industry shakeout* (Scott, 1998). In the end of this cycle, as both products and processes reach a certain level of improvement, companies in general focus their value creation processes on lowering cost (Abernathy and Utterback, 1990).

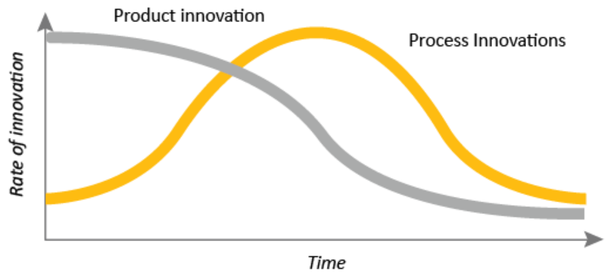

Figure 4.1: Patterns of Innovation. Source: Abernathy & Utterback (1978), Own Illustration

4.1.2 Diffusion of Innovation

Diffusion of technical products and services is the process by which new technical systems spread through a population and potential adopters (Lindmark, 2006). Applying this framework to Wearable Technology is interesting in this point in time when the technology starts to gain momentum. Obviously, the framework states that only if an invention is adopted it will have a sustained economic importance. Rogers (2003) describes five attributes that affects the speed of adoption in a social system:

- *Relative Advantage* - To what degree the new innovation is perceived as better than the idea or product it supersedes. This could be in terms of functionality, technical performance, cost or conveying social status.

- *Compatibility* - The degree to which the innovation can be assimilated with existing products and services and how it is compatible with existing values, needs, past experiences and needs of potential adopters.

- *Complexity* - To what extent the new innovation is perceived as being relatively difficult to understand and use. A more complex idea will most likely slower the process.

- *Trialability* - To what degree the innovation can be tested and tried out before a purchase or adoption. Being able to see how the innovation works generally implies a more rapid adoption.

- *Observability* - The visibility of the results of a new innovation are and how easily they can be communicated to others.

According to Rogers (1995) 49 – 87 % of the variance in adoption rate can be explained with these five factors. Thus, increasing the relative advantage, compatibility, trialability, observability and decreasing the perceived complexity of the innovation will increase the diffusion rate. The most significant predictor for the rate of adoption is relative advantage. Important to point out however is that the degree of the different factors depends on the perception by different adopters and may therefore differ between individuals.

4.1.3 Characteristics of High Technology Innovations

In 1965, Intel's director of R&D and co-founder Robert E Moore observed that the number of transistors in an integrated circuit doubles every eighteen months (Moore, 1965). This observation has proven surprisingly accurate and has been used to describe the extremely rapid change that has shaped the industry of computer science during the last decades. Thus, it is not farfetched to argue that **Moore's law** also holds true for wearable devices as they could be considered small computers. Today, Moore's law is used in the computer and semiconductor industry to predict the pace of innovation within high technology sectors, set goals for research and development and as a guide for resource planning (Disco and van der Meulen, 1998). The rapid development in this industry poses many challenges to high technology companies. For example, products that are still under development may render obsolete before they have been brought to market or companies have to scrap components in stock due to low performance.

Metcalfe's law states that the value of a network is proportional to the square of the number of connected users (Shapiro and Varian, 1999). This relationship was discovered by Robert Metcalfe and originally presented in the context of fax machines and telephones (Simeonov, 2006). Metcalfe's proposition has been used to explain the growth of many other technologies that benefits from being connected, such as cell phones and social networks. When the Internet started to evolve during the 90s, this relationship was also carried over to this area. (Hendler and Goldbeck, 2008)

Even though Metcalfe's law is both elegant and intuitive, the validity of this relationship has been debated recently (Hendler and Goldbeck, 2008). On one hand, Briscoe et al. (2006) argue that the value of the network increases at a slower pace since the nodes cannot be valued equally. On the other hand Reed (2001) suggests that the networks consist of sub networks, whose value must be added to the value proposed by Metcalfe. None of these perspectives have been scientifically validated but one can conclude that the network effects are substantial, despite evaluating network effects from its most pessimistic point of view. (Hendler and Goldbeck, 2008)

Previous research about the Internet has focused on valuing the network effect with regards to the users using World Wide Web. With a rapidly increasing number of interrelated devices, wearables and sensors, contemporary research suggests that network effects from these networks will be as significant as for connected users. However, this is not reality today. To achieve these effects, data architectures such as Web 2.0 and Semantic web must be developed and implemented further. (Hendler and Goldbeck, 2008)

4.2 History of Wearable Technology

The definition of a wearable device, outlined in the first chapter, states that it has computational power and is worn on the body. Given this definition, the first wearable dates back to the 1960's when Ed Thorpe and Claude Shannon invented a gambling machine, not bigger than a cigarette package, to calculate roulette odds (Thorp, 1998). Since then computers have become smaller, more powerful and with improved battery life. At the same time the cost of computers has decreased significantly, which has made them omnipresent in today's society.

As of 2014, the most obvious application area for Wearable Technology is fitness trackers. These kinds of devices, most notably wristbands, have gained momentum in 2013 as people are interested in of quantifying their fitness activities in order to improve their performance and their overall wellbeing. Another application area that is experience rapid improvements within the field of Wearable Technology is the healthcare industry. Wearables can be used to monitor the health of a patient in the same manner as consumers use fitness trackers. Instead of evaluating the health status during a short and stressful medical appointment, physicians and other health professionals can collect data during a longer period of time when the patient is performing everyday activities. This data is likely more reliable and can be used to improve the diagnosis and treatment of various illness. (Thorp, 1998)

Wearable Technology was initially targeting the consumer space and has up until today mostly been applied to track fitness activities. However, analysts predict that Wearable Technology have even higher potential within enterprises and industrial environments (Accenture, 2014). As wearables are sufficiently small to be worn on the body, they can be used in settings where technology previously has been prohibited by safety regulations and other practicalities. Wearables can be the first technology that seamlessly stores and provides workers with digital information. Using wearables, workers in harsh environments can access and input data without removing gloves or other equipment and without being obligated to move to a sheltered workstation. Thus, wearables have the potential to make processes and work tasks more efficient. (Deloitte, 2014)

4.3 Market Outlook for Wearable Technology

Many analysts forecast wearables to be a technological revolution and of equal importance as the introduction of personal computers, the Internet and smart phones (Gartner, PwC, Deloitte, Accenture, Vandrico, Mars). Few consider wearables as a fad and question the need for wearables. Nevertheless, experts emphasize that the wearables must offer a value proposition that is different from devices such as smart phones, laptop computers or LCD displays. Furthermore, analysts urge that one must be able to choose the device that is most suitable to do the job. This task is considered as far more complicated than choosing a computer or smartphone because the user has to take other consideration than performance and size into account. Decisions about where the device would be worn and how the user would interact with the device must be made. Furthermore, issues about privacy, performance and battery power also have to be addressed. (Accenture, 2014)

There are numerous estimates about the number of wearables that will be shipped the next few years and the revenue wearables will generate for suppliers (Gartner, PwC, Deloitte, Accenture, Vandrico, and Mars). It is hard to evaluate which analyst predicts the future most accurately. However, the characteristics of the market outlooks of wearables have much in common with how the market for tablets developed. When the iPad was launched in 2010, few could point out the need for tablets. Two years later, 20 % of the adults in the US owned a tablet and today, 40 % own an iPad or a similar device. Like tablets, the need for wearables was questioned when the first lifestyle trackers were introduced to the market in 2012. Today, 21 % of the American adults own a wearable device. However, the question remains if wearables would achieve a penetration rate on par with tables. (PwC)

The market for wearables consists of many sub categories, which have different characteristics. Hence, it is difficult to discuss the maturity of the industry without segmenting the industrial landscape. Some segments are in early stages and dominated by startups whereas large companies have outcompeted smaller companies, e.g. in the market segment of smart watches and fitness trackers.

4.4 Devices and Sensors

There are a many different wearables that use various kinds of sensors. There are also several possible ways of categorizing the different devices. These devices are designed to be worn on different parts of the human body. This report divides wearables into three main categories; Visual Input/Output, Other Input/Output and Measurements.

Visual I/O are wearables that use a visual interface to communicate with the user. Most prominent is smartglasses where a small screen on the inside of the lens provides the user with visual information. These glasses can also have an integrated video camera which records the user's vision and upload the video to the cloud or store it internally. Thus, for visual I/O devices the communication, both to the user and from the user, is done in a visual manner.

Even though the most rumored and spectacular pair of smart glasses, Google glass, have not been released for the consumer market yet, many other products in this category are available today. Besides numerous glasses developed by startups, Microsoft and Sony have started to develop their first generation of smart glasses that will be released in 2015. The most important sensors in this category of wearables are accelerometers, gyroscopes, light sensors and sensors to detect magnetic fields. Analysts argue that smart glasses are set to trump smartphones in terms of users within ten years and predict that they will surpass shipments of mobile phones by 2025. (Wearable.com, 2015)

There are also devices where the interaction is done in a non-visual manner. Wearables can be controlled by the user through e.g. voice control or gesture control. The communication from the device to the user can be made e.g. by vibrations or audio. Two examples of devices in this category, i.e. **other input/output**, are Logbar's ring and Thalamic Labs' armband to enable gesture control of other computer interfaces. The ring includes a 6-axis acceleration speed motion sensor to be able to identify pre-defined gestures performed with the index finger. The sensors included in the armband track muscle activity and through e.g. swiping the hand or spreading the fingers, the user can conveniently control the smartphone or smart glass. Both the ring and armband are currently shipping even though it is evident that the primetime of these devices is yet to come. However, it is clear that gesture control future is not far off. (Geek, 2014)

In the **measurement** category lie devices and sensors that can collect data about vital signs and the environment surrounding the user. Several different sensors exist, e.g. sensors that measure heart rate, sensors that measures body temperature or an EEG (Electro Encephalo Graphic) sensor which can measure brain activity by recording electrical signals along the scalp (Vandrico, 2015). Also, sensors that can measure the quality of the ambient air, i.e. if the air contains particles that are harmful to inhale, and sensors that measure the level of UV radiation exist (TZOA, 2015). This wide set of sensors can be applicable in many areas and hence a vast amount of wearable devices for measurements exist.

The most obvious use case in this category is fitness trackers. During 2014, the market for such devices boomed and consumers have a hard time to choose the right device among all trackers that are available. Fitness trackers are in most cases worn on the wrist but there are also some clip-on devices that could be attached to the user's clothes. Even the simplest fitness devices have an accelerometer to track number of steps taken. The more advanced the fitness tracker becomes; the more sensors are included in the device. High end devices often have sensors to track heart rate and collect data about sleep quality. Fitness devices also offer a mean for insurance companies to track the physical activities among their customers. In 2014, Oscar insurance offered fitness trackers to their customers as a part of their plan to reward customers that stayed physically active (Wired, 2014).

The step from fitness trackers to devices that collect information related to health, such as vital signs and biochemical changes, is not far. Much research is currently conducted in this area, especially to target chronic diseases such as obesity, cardiovascular diseases and diabetes.

The most common location for wearables is on the wrist as Wearable Technology took off as fitness trackers. However there are devices designed to be worn all over the body. The Canadian based company Vandrico has created a database for wearable technologies where they list all wearable devices on the market. The distribution of the devices on different parts of the body is displayed in figure 4.2 below.

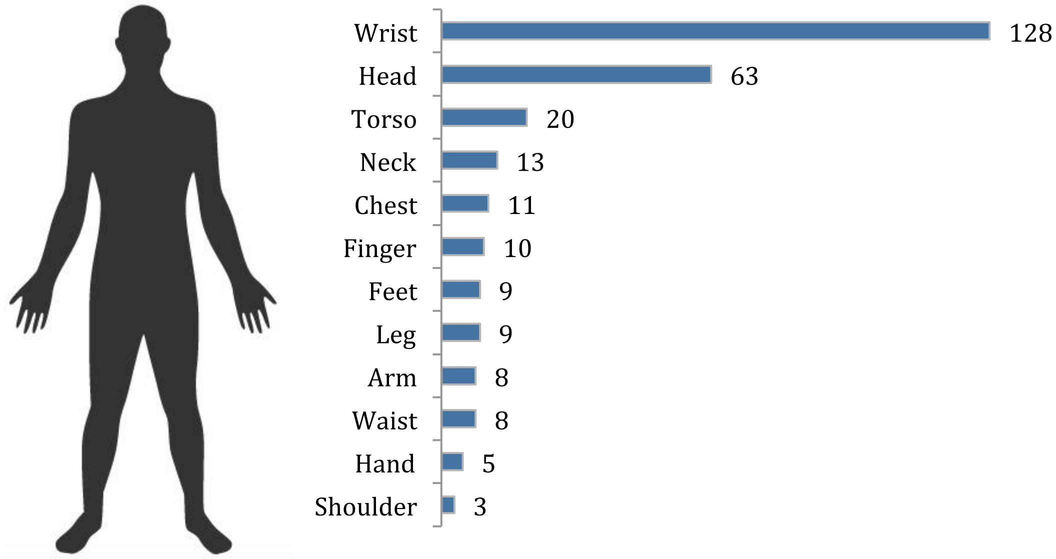

Figure 4.2. Distribution of devices on different parts of the body. Source: Vandrico and own illustration.

4.5 Application Areas for Wearable Technology

With a variety of wearables on the market there are also many application areas. Currently there are many different types of sensors that can be incorporated into a single device and as the technology improves, the components are expected to become even smaller in the future. Thus, wearables of tomorrow will most likely hold even more sensors. This means that making a distinction between different types of use cases for wearables is somewhat troublesome as the boundaries between what one type of wearable can do and cannot do are not always perfectly clear. E.g. a pair of smart glasses core benefit might be to provide the user with visual information on a screen, but they could potentially also have sensors that measures the heart rate of the user. Listed below are use cases where the core value of a specific wearable is utilized. The use cases below are, according to the authors, the most attractive ones for industrial companies.

4.5.1 Augmented Reality for Heads up Display

Operation and maintenance of oil and gas field equipment is highly critical. Even a short interruption in production may cause a significant. Today, an extensive amount of physical papers with checklists and procedures support oil and gas field technicians as they perform maintenance. This workflow is related to several issues. Firstly, a ream of papers decreases the ability for technicians to work with both hands simultaneously (Bloomberg, 2014). This is a major drawback since operations are performed in harsh environments and are often related to severe security issues. Secondly, using physical papers implies that field technicians are limited to their own knowledge and cannot get feedback in real-time while performing critical tasks.

In a setting like this, smartglasses could be utilized to solve these issues. When papers with procedures are translated into digital information displayed in the visual field of the worker, field technicians have convenient access to all documents required and are able to use both hands simultaneously. Smartglasses, used in this application area, are equipped with a video camera and wireless connection. These features enable real time interaction with experts through a video link but also make it possible for engineers to evaluate and improve the procedures to improve quality of the tasks performed. (Bloomberg, 2014)

There are safety concerns related to this application area. The glasses are designed to improve workplace safety through enable the field technician to work with both hands. However, the flip side of the coin is that information in the visual field may distract the worker from the actual task performed and thus may degrade the level of workplace safety. Such an issue must be addressed before smart glasses can be implemented in this environment.

4.5.2 Improve Workplace Safety and Health with Fitness Trackers

Companies suffer significant financial losses every day due to illness and poor health of their employees. According to a survey made by the Integrated Benefits Institute (Forbes, 2012) poor health costs the U.S economy approximately 576 billion dollars per year. That includes costs of lost productivity due to illness, wage replacement costs and costs for medical treatment and pharmacy related costs. If the health of the workforce were to be improved, employers and companies could potentially save large amounts of money on reduced health-related costs.

Activity trackers are today almost exclusively used by individuals with an active lifestyle or by "quantified self"-people that want to monitor their daily activities, but in a near future these activity trackers could be applicable also in industrial environments. If blue-collar workers at a factory floor would use activity trackers or shirts with embedded sensors, information on the workforce's wellbeing, such as heart rate or muscle activity, could be obtained. When workers perform repetitive labor and their muscles fatigue they are more prone to injuries. If there is data on every individual worker's health, preventive actions could be taken, e.g. extra brakes could be scheduled in order to prevent illness or muscle fatigue. Even if no preventive actions could be made to stop the illness or the related absence from work, managers could still plan the work in a better way if they know in advance that some workers will not be able to work the following days or weeks (Enterprise Efficiency, 2013).

Additionally, during certain activities it is crucial that the worker is perfectly healthy when performing the job, e.g. loading/unloading containers, and that doing the task "unhealthy" would impose a safety hazard not only for the worker performing the job but also for people in his surroundings. If a worker is not showing satisfying levels of health he could be replaced or instructed to take a break in order to prevent a potential accident. (Jonathan Lee, 2014)

4.5.3 Improve Efficiency in Warehouses with Augmented Reality

The order picking process in a warehouse is an important function for many firms, especially for e-commerce companies as it affects the distribution chain and customer satisfaction. In most companies, the picking process is still performed in an old fashion manner and based on using printed documents to get information about what to be picked to a specific order and where to find it. This process has high potential for improvement as it involves many mistakes due to human error. Errors in the picking process account for a significant costs for many retail and e-commerce companies as order picking is a cost intense operation (Rammelmeier et al. 2011). Lowering the number of errors made in this process can therefore reduce the overall costs of logistics.

Augmented Reality (AR), e.g. through the use of smart glasses, could provide warehouse workers with information about what to pick and where to find it in the workers field of vision. Many of these smart glasses have indoor navigation capabilities to guide the worker to the fastest route, which further improves lead times. It also eliminates the need to pick up e.g. papers to get information and scanning of barcodes can be made directly by the glasses without the need of using an additional device and the worker can focus on the actual work at hand (DHL, 2014). As all information needed for picking an order is displayed in the worker´s field of vision, less procedures and knowledge is needed to be kept in the worker's mind and thus making it easier for workers to perform the task. Consequently fewer errors will most likely be made.

4.5.4 Improve Seated Posture Ergonomics

Research proves that back pain related to bad posture has increased from 20% to over 60% over the last 20 years. Only in United States, these problems are estimated to cost between $15 and $20 billion every year due to absence from work and medical claims (Lindegård et al. 2005). There is a vast amount of research on how to improve ergonomics using ergonomic chairs, desks and computer equipment. However, there is limited research made on how to enable real time monitoring of posture (Dunne et al. 2007).

Today, standardized scorecards in combination with physiotherapists are used to evaluate seated posture among workers. This approach is time consuming and since these initiatives often are made without a plan for future evaluation, the problem is not solved in the long run (Marc Schwerdtner, 2014). Recently, new consumer products were launched to the market to make it possible for users to get real-time feedback about their posture, using a simple accelerometer and software to interpret the generated data. These products, such as the LumoLift, are simple to use but currently quite inaccurate and have some flaws with regards to its design (Trusted Reviews, 2014). Products with more accurate sensors built into a garment are available today but currently only used for research purposes. These kinds of smart garments would not only be suited for people that are sitting in front of the computer all day but also for blue collar workers performing highly repetitive activities. (Dunne et al. 2007)

4.5.5 Video Database Recorded by Wearable Devices

Many professions are built upon many complex physical tasks, especially within the area of craftsmen, which takes time to master. Plentiful knowledge and skill get lost when an experienced worker change employer, transfer to a different part of the organization or retires. Smartglasses could solve this problem by having a built-in camera and record the activity from the workers point of view. This makes it easier to see and comprehend how that particular activity is ought to be done. Through recording experienced professionals performing these tasks companies are able to keep essential knowledge within the organization. In this case, Smartglasses become an enabler for education of less experienced employees. Potentially instructional videos could also be made and used to teach new workers on how to perform a specific task. (Aaron Sallow, 2014)

In addition to education, if video recording glasses are used at all time and constantly on recording mode, they can also be used to find errors made in the production process by backtracking to when the product was created or assembled. If there is a common flaw with a product the root cause of the problem could be found more easily. (Aaron Salow, 2014)

4.6 Constraints Related to Wearable Technology

As described in previous sections there are interesting use cases for Wearable Technology in the business segment. However, there are today several technical and non-technical constraints that need to be addressed in order for the implementation to be successful.

4.6.1 Technical Constraints

Supplying a wearable device with power is perhaps the biggest technical constraint to adoption (Paul Tate, 2014). Wearables preferably have long battery life and short charge time so that the device can be used at all time. E.g. the more time an activity tracker is connected the better picture of a person's health status can be obtained and the longer time smart glasses can record video the better. At the same time the device needs to perform many power draining tasks, e.g. collect and send different kinds of data. Also, since it is a wearable it needs to be smooth and convenient to wear and use and therefore needs to be small and light. This imposes big challenges for battery manufacturers and as for now, it is the biggest bottleneck and the major obstacle that hinders wearables from becoming smaller and more widely adopted. (Wearable World News, 2014)

In order to send and receive data from the wearables they need to be connected to the Internet in some way. In industries located in remote areas such as oil rigs or sawmills there might not be possible to have a strong and reliable internet connection. Without an internet connection it is still possible to use wearables in order to collect data but not to send data and receive feedback in real time. (Paul Tate, 2014)

As wearables are becoming ubiquitous and as many of them use Bluetooth to connect and send data problems with interference might occur, especially in environments where many devices are located in a limited geographical area, e.g. a factory floor. If there are interferences it could lead to that the wearable lose its connection, resulting in loss of data. (Jonathan Lee, 2014)

Wearables that use sensors to collect data from the body might not need to be controlled by the user when used, e.g. a wristband is strapped on and collects data throughout the day without the need of input from the user. Smartglasses on the other hand need input from the user and are controlled either by voice control or by a keypad on the device. In noisy industries the voice recognition might not be able to pick up commands from the user and temporarily taking off work gloves or safety gloves in order to use the keypad on the device might impose a safety hazard. (Sallow, 2014)

Wearables that collect data through sensors generate vast amounts of data and while collecting and storing data might not be a big concern, managing and analyzing the data might be. E.g. collecting individual health data every day from thousands of workers accumulates to big amounts of data but without any tools for analyzing the data is more or less useless. Also, after the data has been analyzed there is still a need for knowing what actions to be made, e.g. give the workers extra brakes, in order to improve the health of the workers. (Paul Tate, 2014)

4.6.2 Non-technical constraints

In order for the wearable to be adopted in industries it needs to fit into the current working environment and be a natural part of the workers equipment. Wearables, such as smart glasses, are used to help the worker and give information and guidelines that could make the labor more efficient. But used incorrectly, it could imply a safety hazard instead of an aid (Sallow, 2014). E.g. smart glasses can be equipped with a screen on the lens which could provide the worker with augmented information, but the screen can also block the vision and distract the user from the task at hand.

Closely related to the challenges stated above is how wearables are perceived by workers and users of the devices. Wearing a new device at work entails a change in wear and there might be reluctance towards using and wearing new devices from the workers, especially if it forces the workers to change their behavior and daily routines. The magnitude of the change depends on what kind of wearable device being used and to what extent it disrupts the current activities (Paul Tate, 2014). Jochen Teizer (2015) emphasize that senior employees and workers with long experience in the field most likely will be most hostile towards a change as they are usually less prone to adopt and use new technology in general. He also states that in certain heavy industrial sectors there exists a “macho culture”, where ensuring that the work is performed safely is not considered to be important and sometimes even discouraged among the workers.

Perhaps the greatest constraint and one of the biggest challenges with Wearable Technology is whether how and what data will be collected, how it will be stored and who will have access to it. Measuring how many steps an employee has taken during a day’s work might not be a big concern for anyone but a video that records everything the worker do, including interactions with other people, might impose a bigger concern and will most likely be seen as an infringement of privacy. According to a survey made by Kronos Incorporated where around 9000 workers in 8 different countries were interviewed, 48 percent of the workers in the U.S believed that wearables would be beneficial in the workplace but 44 percent believed that privacy could be an issue. Privacy and data security were ranked as the highest and second-highest concerns of using wearables in the workplace in the survey (Kronos, 2014). There are also concerns about who will have access to the data. If the data could be used also by third-parties, it raises bigger concerns than if the data is solely kept proprietary.

Another issue is whether how company specific data should be managed and who will have access to it. Companies have sensitive information about their business that needs to be managed carefully and kept inaccessible from other parties. Contracting a supplier to implement wearables into the workplace might impose a security risk as the data is managed by a third party and might not be as safe as when the data is used only by the own company.

4.7 Discussion

As Wearable Technology is a wide concept with different devices and application areas it is somewhat more complex to analyze the development of it compared to e.g. digital cameras where the products are less diverse. Different types of wearable devices, e.g. smartwatches, smart glasses and fitness trackers, have to obey different constraints and be developed along different trajectories. Thus, different kinds of wearables should be analyzed separately. However, as they are all part of the same category, i.e. wearable devices, they share many characteristics and the development in one category will follow the development in another. In this discussion wearables will partly be analyzed as a whole and partly in its separate categories.

4.7.1 Diffusion of Wearable Technology

Wearable Technology holds several advantages over technologies and products previously used. In many industries no technologies are currently used to record results, instead workers use papers and rely on their memory. This is exemplified by the use case presented in chapter 4.5 about workers in the oil and gas industry. In this setting Wearable Technology could have a significant value. However, for someone outside the industry it might seem obvious that using a wearable device would improve the daily work tasks, but as a new technology is perceived differently by different individuals it is not obvious that professionals in the field envision the same advantages. In order for the technology to be adopted by professionals *the relative advantage* versus conventional methods, e.g. using paper to register results, must be conveyed. The common denominator for all wearables is that they are worn on the body which implies fast and easy access to information while still being able to perform activities with both hands. If the new technology is seen as having relative advantages and overall is seen as a system that is easy to switch to, depends on the attributes *compatibility, complexity, trialability, observability,* presented by Rogers (2003).

As of 2015, most of the wearable devices are *compatible* with other existing devices and systems in some way, e.g. many smartwatches and fitness trackers are connected to smartphones. However, this thesis reasons that wearables will have to be more seamlessly integrated into existing system to be more widely adopted in industries. If e.g. smartglasses are about to function in warehouses, as in the use case presented in chapter 4.5.3, they will have to be integrated into the company's current ERP system. Also many of the constraints presented in this thesis restrain the technology to be used in this setting. In many cases, the battery must last for at least one working day and the Internet connection must never fail etc. Currently the technology is available, but has to reach a certain level of performance to be adopted.

The development of user interfaces for computers and smartphones has yielded products that are easier for users to understand and use. Smartwatches and other wearable devices share many of the characteristics of these technologies and can take advantage of this. Most people are already using smartphones, hence it might not be a great step to start using a wearable device since the interface on many wearable devices are similar to smartphone's. Also, given the technical constraints of wearables, it is not possible to incorporate the same amount of features into the device as in a computer or smartphone. Thus, the *complexity* of the device would be considered lower as only the core features of the wearable are put into the device.

With the current hype of Wearable Technology the technology is highly visible and many are familiar with the concept. Although most people might link the technology to fitness trackers, which is the most well-known application area, firms that develop Wearable Technology devices for industrial application areas can benefit from the hype. If workers are familiar with the technology they can more easily understand how it could work in an industrial setting. Presently this holds true for fitness trackers, which has been available in retail stores for several years. Smartglasses are not equally common, and fewer have seen or used this kind of wearable device. Hence, potential customers cannot try out and test how these devices work to the same extent as fitness trackers, which implies lower *trialability.* This thesis reason that, the diffusion of smartglasses therefore lag compared to other types of wearables that have reached a higher level of diffusion.

As Wearable Technology has not been used within enterprises, the results of using the technology are not obvious. The use cases presented in 4.5 show what is possible to do and what value Wearable Technology potentially could yield for enterprises. But as the technology is still in a phase of prototyping and piloting projects, the long term effects and benefits from using it is not clear. With this background, Wearable Technology could be seen as having a rather low *observability*.

As of 2015, 21 % of American adults own a wearable device and given the development of Wearable Technology presented in chapter 4.3, the technology will most likely become ubiquitous in coming years. Improvements in terms of Rogers' (2003) five attributes will support the diffusion process. A technology that is well used by peers will most likely be considered less complex, it will be easier to test it and see the result of it. Furthermore, with greater demand for the technology more effort will be put into incorporating it into other systems. This thesis reasons that these improvements will sum up to a technology that is considered having a relative advantage versus currently used technologies and methods.

4.7.2 Patterns of Innovation

As described in the introduction of this discussion, Wearable Technology is a wide concept and the market for wearable devices is diverse. On one hand, some application areas, like smartwatches and fitness trackers, are mature and the market is to a large extent dominated by large companies. On the other hand, smart glasses are still in an early stage and many uncertainties exist. Thus, when analyzing the industry of wearables, it is essential to consider the non-uniform industry landscape.

Considering the market of smartwatches and fitness trackers, this thesis argues that many of the characteristics of a mature industry, presented by Abernathy and Utterback (1990), can be identified. In 2014, large technology companies acquired startups, which consolidated the industry. The different companies largely use the same set of sensors and the competition is rather about price and services than hardware and focus has shifted from radical product innovation to process innovations. Thus, the requirements of dominant design have been satisfied for smart watches and fitness trackers, according to Scott's (1998) definition.

When shifting focus to other application areas of wearables, it is evident that logistics, professional healthcare, occupational health and safety etc. are in an early stage. Aaron Sallow (2014) and Paul Tate (2014) point out technical constraints as one important bottleneck for the development of the technology. E.g. many products in this category require high capacity batteries that are small enough to fit inside the device. As the interviewees emphasize, radical innovations have to be made before products are good enough to be launched onto the market.

4.7.3 Characteristics of Wearable Technology

Most wearable devices are connected directly or indirectly to the internet and create value through sharing information with other devices and data sources. Obviously, an increasing number of devices will further increase the value of the network and speed up the rate of adoption. This theory, as presented by Metcalfe, partly explains the boom of shipped wearable devices in 2014 and helps to understand why analyst predicts wearables' rate of adoption to increase in the next five to ten years.

As of 2014, there are many different companies within the same category of wearables that use their own standards and protocols to collect and share information. Thus, users with devices from different manufacturers often lack the ability to share information. This thesis hypothesize that generic standards will be developed to enable sharing of data over boundaries of ecosystems. In line with the reasoning above, this will entail even more connected nodes and hence a greater value of the network.

With Moore's law in use, wearable devices will become physically smaller, more powerful and have more functionality. Some of the constraints of today could therefore be solved and more sensors could be put into the devices. Although, the performance of batteries has improved at an equal pace as other key components, incorporating more powerful processors into the devices or has the power supply to last longer is a tradeoff. In general, when new devices are developed processor performance is prioritized over battery life. Hence, battery performance will most likely continue to be a constraint in the foreseeable future.

5. Siemens and Wearable Technology

This chapter intends to address research purpose two; to outline Siemens' business areas and discuss the fit between the company and Wearable Technology. A theoretical background on how big firms manage new innovation and enters new markets is presented. This is followed by a description of Siemens business areas in order to understand how and in what areas the focal company can make use of Wearable Technology. The chapter ends with a discussion on how Siemens can make use of Wearable Technology.

5.1 Theoretical Background

A big challenge for large firms, such as the focal company, is to keep focus on their current business and be operationally efficient and at the same time be prepared for new business environments and meet demands of the future. Leonard-Barton (1992) argues that there is a risk that core capabilities that have previously been a competitive advantage for a firm can become a disadvantage or *core rigidities.* This occurs when new technologies, e.g. Wearable Technology, enter the market that renders the existing technologies obsolete. Sandström (2013) seeks to explain the reason to why big incumbents fail to meet the challenges from new innovations and presents three main arguments. Firstly, established firms competencies have been built and refined by a certain technological paradigm and the knowledge connected to this paradigm is often path dependent and not easily changed. Firms tend to operate according to a particular logic and have routines and ways of doing things that can be hard to change, both in terms of technical skills and of cognitive behavior of the employees. Secondly, incumbents lack incentives for investing in new, small and uncertain markets as they offer low initial profits coupled with high risk. Investing in new markets might also jeopardize their current business. A third argument used is that the industry structure could change when a new technology enters. Established relations and bonds to other firms in a network that has previously been a competitive advantage might instead become a disadvantage. Also, a technological shift might lower entry barriers to the industry and thus increase the competition (Sandström, 2013).

There are however several examples of firms that have been successful at exploiting the present and at the same time taken advantage of the opportunities that new technologies bring. O'Reilly and Tushman (2004) have been investigating firms that achieve both of these targets and have found that these firms share important characteristics. First and foremost, these firms separate their new exploratory units from their current exploitative units. This allows for different processes, structures, and cultures to be used in different units simultaneously. O'Reilly and Tushman (2004) name this setup *Ambidextrous Organization,* as depicted in figure 5.1. When the emerging business was put outside of the established organization or put in the established organization but outside the existing management hierarchy or integrated into the existing organizational structure O'Reilly and Tushman (2004) found that far less companies reached their goals. In contrast more than 90 percent of companies using ambidextrous organizations managed to reach their goals. Zi-Lin He and Wong (2004) also support ambidexterity and in their research they have found two distinct relations. Firstly, the interaction between explorative and exploitative innovation strategies is positively related to sales growth rate. Secondly, the relative imbalance between explorative and exploitative innovation strategies is negatively related to sales growth rate. Hence, big firms could benefit from reorganizing into ambidexterity in order to be better prepared for the new technology.

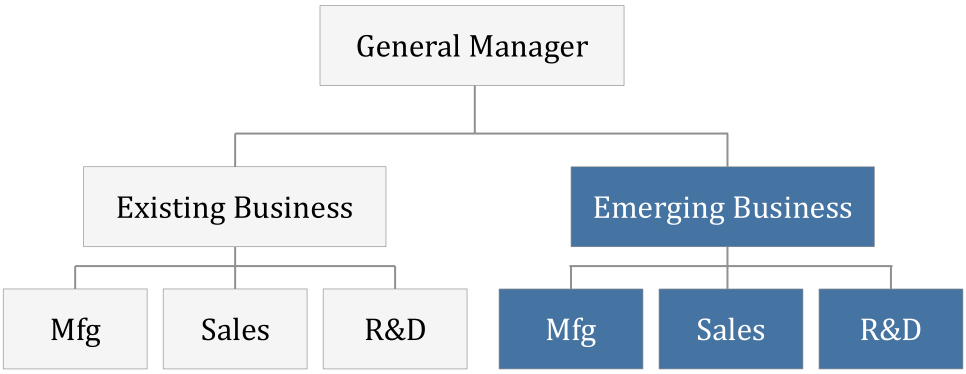

Figure 5.1: Ambidextrous organization. Source: O'Reilly and Tushman (2004)

5.1.1 Timing of Entry

The timing of market entry is one of the major reasons for new product success or failure (Lilien and Yoon, 1990) and is an important factor to consider with regards to the focal company's plan to start research initiatives to target wearable devices. The risk and opportunities of market entry vary due to changes in the general economy, customer preferences and evolution of the industry's life cycle. If the situation allows for it, companies have to manage and strategically make a decision if they want to be first or want to enter the market later. There are both advantages and disadvantages of being a pioneer as well as being a follower. Being a pioneer implies a big financial burden as most of the cost of developing the product is borne by the company being first. A follower can usually imitate the pioneer and reverse engineer some of the features and hence make lower investments into R&D. Being pioneer, by definition, implies that no other actor has been exploiting the opportunities with this product. This entails that there is a high risk that the new venture is not going to be profitable. A follower can evaluate the outcome of the pioneer's investment and make decisions accordingly.

On the other hand, a company can gain recognition and establish reputation in the marketplace by being first. Andersson (1996) argues that being the market leader and in customer's top-of-mind is crucial and a company that holds this position does not have to invest as much in marketing. Customers also tend to stick to a brand as there are switching costs in changing supplier and they are willing to pay more for a product of a brand they are familiar with than for a product from a company that is unknown to them (Lilien and Yoon, 1990). Although pioneers have to make big initial investments in R&D, their production cost are, in long term, usually lower compared to later entrants due to learning curve effects and potentially also economies of scale and scope. This lower the production cost per unit and the company can decide to either lower the price and gain a bigger market share or improve marginal profits. (Lilien and Yoon, 1990). Large investments in R&D might also lead to highly valuable intellectual property rights that could cause high entry barriers for potential competitors (Lieberman and Montgomery, 1988). Being pioneer and becoming the market leader can also imply that the company can set the development of the product in their desired direction and have a big influence on future industry standard and dominant design. Suárez and Utterback (1995) state that firms which are able to achieve larger scale more quickly than their competitors may have a better chance of winning the race to settle the standard.

Given the reasoning above there is no single answer to if a company, on the whole, benefits from being first or if it is detrimental to be pioneering into a new market. It rather depends on the specific context and situation at hand and also what competencies and capabilities the company has. In this specific case, many of the use cases related to Wearable Technology are in a very early stage and one must bear in mind the benefits and drawbacks for Siemens to be either a pioneer or a follower in this field.

5.2 Siemens Business Areas and Company Overview

In October 2014 Siemens restructured their organization going from four business areas (Energy, Industry, Healthcare and Infrastructure and Cities) to nine divisions plus Healthcare, which will be managed autonomously. The new organizational structure will come into effect in the beginning of fiscal 2015 (Siemens, 2014p). The nine divisions and Healthcare are listed below.

The Power and gas division is focused on delivering products and services for power generation. Their customers are mainly utilities and independent power producers. The product spectrum of this unit spans from power plants using fossils as well as renewable fuel to solutions to enable transportation of fuel. However, a common goal within the unit is to maximize energy efficiency and minimize environmental impact. (Siemens, 2014b)

An increasingly important part of this business unit is oil & gas. Due to the shale gas boom in USA, the demand for energy services and equipment have increased rapidly during the last few years. To position itself to meet this demand, Siemens purchased the US oil service firm Dresser-Rand in September for $7.6 billion. (BBC, 2014)

Siemens develops and manufactures wind turbines and offers services and solutions related to **Windpower and Renewables**. Wind power plants, manufactured by Siemens, generate over 25 000 megawatts of renewable energy from onshore and offshore installations around the world. Siemens has long experience in the field and developed the first offshore wind power plant in Denmark 1991. The company holds the record for the largest offshore wind power plant; the London Array Project where 175 Siemens 3.6 megawatt wind turbines generate 630 megawatts. (Siemens, 2014c)

Siemens also provides solutions connected to hydropower and implements turnkey projects of small hydropower plants. In addition Siemens develop power plants in the ocean that make use of the power created by tides, where power generation is much more efficient compared to wind power. The wind power and renewable business sector has an annual turnover of around €5 billion which makes it the smallest of the ten business sectors. (Siemens, 2014a)

Siemens offer products and services connected to **Power Generation** within the utility, oil and gas, and industrial processing industries. As a part of this service they perform maintenance, repairs, replacements, and upgrades of components such as gas, steam and generators in industrial power plants and for the oil and gas industry. In addition, the company offers remote monitoring and diagnostics to detect if something in the factory is not working properly. Proactive actions can be taken to address the issues accordingly. (Siemens, 2014d)

The **Energy Management** Division provides utility companies and industries with facilities and systems for the low-voltage and distribution power grid level, smart grid and energy automation solutions, power supply for industrial plants and high-voltage transmission systems. The division also develops new innovative solutions in the field of energy, e.g. solutions for transmitting bulk volumes of green power over long distances in a more efficient way or enabling power exchange between power grids by connecting micro grids with the main grids. (Siemens, 2014e)

Siemens' **Building Technologies** Division strives to make buildings safer and more energy-efficient, environmental-friendly and thereby lowering the operating costs of the buildings. The division offers products and energy management services connected to building automation, heating, ventilation and air conditioning. In addition they offer services in the fire safety segment for fire and gas detection, automatic extinguishing and alarm and danger management systems. Customers for this division are hospitals, airports, hotels, commercial buildings for international companies as well as infrastructures in cities. (Siemens, 2014f)

The **mobility** division seeks to make transportation of people and goods by railway and road more efficient. It comprises of five business units; Mobility Management, Turnkey Projects & Electrification, Mainline Transport, Urban Transport and Customer Services. These units develop several types of vehicles for rail traffic such as high speed trains, intercity trains, metro cars, locomotives and driverless vehicles. The division also develops electrification solutions for rail and road traffic and handles maintenance and service of vehicles and infrastructure. (Siemens, 2014g)

The **digital factory** business unit enables seamless integration of data along the industrial value chain through both software and hardware. This business unit has experienced significant growth during the last few years as the importance of data integration have increased within manufacturing companies. This division benefits from synergies from the Process Industries and Drives division, where the divisions develop new solutions closely together to meet customer demands. Besides providing hardware and software, the business unit also offers services such as integration, configuration and education to enable the systems to operate effectively and safely. (Siemens, 2014h)

The main goal of the **process industries and drives** division is to increase customers' productivity and reduce time to market through technology integration across the value chain. The business unit comprises of four segments: Process automation, integrated drive systems, sensor systems and plant engineering software. (Siemens, 2014i)

The process industry is one of Siemens' core businesses. To improve automation of processes, Siemens has installed countless of applications and hence increased safety, reliability and quality for clients in many different market segments (Siemens, 2014i). Integrated drive systems help customers to add functionality and continuously monitor their drives to prevent the system to be shut down and improve the quality of predictive maintenance (Siemens, 2014j). Sensor systems enables the customer to measure, monitor and analyze flow, temperature, pressure to better understand their processes (Siemens, 2014k). Plant engineering software supports plant engineers in designing new or existing factories to be as efficient as possible while reducing cost. This is carried out using COMOS, which is a software developed by Siemens (Siemens, 2014l).

Financial Services is a competence center for managing financial risks within Siemens. Besides evaluating risks in internal projects, this division is an important part of customer acquisition. Investing in potential customer's projects, and hence share the financial risk, might be a key to be chosen as the preferred vendor. Financial services also enable alternative payment solutions for customers, i.e. pay-per use financing model or enabling private-public partnerships, which is a widely used financing model for large scale infrastructure projects. (Siemens, 2014m)

The importance of the Financial Service division is steadily increasing and an example where the business unit enabled realization of a project was the wind power project Gemini in the Netherlands. In this this case, Siemens provided a 20 % equity stake to secure the financing of the € 1.5 billion project. (Siemens, 2014n)

Siemens' **Healthcare** division is one of the company's largest business units by revenue and employs approximately 52,000 people. The division is one of the world's biggest suppliers of technology to the healthcare industry and is focused on the areas of medical imaging, laboratory diagnostics and healthcare IT. Siemens Healthcare possess an important portfolio of patents and drives innovation to provide better quality of healthcare. (Siemens, 2014o)

Compared to Siemens' other business areas, Siemens Healthcare have completely different customers and few synergies can be identified. Hence, when Siemens announced that they planned to restructure the business in May 2014, Siemens Healthcare was given a large measure of automation. The division is now fully in charge of its R&D budget and are able to react more quickly to changes related to its business.

Going forward, Siemens Healthcare will continue to focus on medical imaging and laboratory diagnostics and healthcare IT and see great business opportunities in the latter. CEO Joe Kaeser points out that thousands of healthcare devices made by Siemens produce 2TB of data each month and the demand for storage, management and analytics of this data increases rapidly. Furthermore, the margins in this segment are high and will hence be a prioritized area for Siemens. (Radiology Business, 2014)

5.3 Business Culture at Siemens

As mentioned in the background, Siemens has over 350,000 employees, with business activities in nearly all countries of the world. As summarized by a Siemens employee that has been with the company for over fifteen years Siemens has always been in the forefront of improving its existing product portfolio but is less agile than small companies when new opportunities emerge. The company rarely develops a technology from scratch but rather acquires startups or initiates joint ventures when companies with novel technologies have started to generate positive cash flows.

Even though only 15 per cent of the revenue is generated in Germany, all major strategic decisions are made at Siemens' headquarters in Munich. This is considered an advantage since the company can make decisions more efficient. The flip side of the coin, however, is that business units far from the headquarters may experience troublesomeness in getting attention and funding for their projects, i.e. all business units have to sell internal projects at market price and R&D units have to be partly funded by business units. This entails that employees can experience a catch 22 problem; the group researching about new potential technologies needs funding for their project but at the same time does the business unit need to see something tangible before deciding on whether they should invest or not in the project. Business units have pressure from stakeholders higher up in the organization to generate profit, therefore they need projects and products in which they can clearly see the benefits the new technology yields for them. But as the research group is in an early stage of the development there might only be a vision on how the new technology could be used and nothing tangible. Furthermore, as research and development department are scattered around the world, time difference, language and different culture further amplify this problem. (Interview Siemens Employee, 2014)

5.4 Discussion

Wearable devices, as discussed in the background, have infinitely many use cases and since Siemens has a diverse portfolio of products and services, wearables could clearly be used in many business units. Even though the application areas in Siemens are many, this thesis argues that it is important to consider the unique value proposition of wearables and use it as a starting point to find the most suitable use case. As outlined in previous section, the most prominent feature of wearables is the ability to collect data about vital signs of the user and data about the environment in the absolute proximity of the user. Thus, this thesis argues that the best fit between Siemens and Wearable Technology is achieved when a use case where this unique value proposition could be utilized, is discovered.

As outlined in the previous section, Siemens focuses on the business to business segment and not goods and services for consumers. Hence, Siemens does not intend to develop a wearable, similar to Samsungs' and Google's devices. Therefore, this thesis argues that the best fit between the focal company and Wearable Technology is achieved when wearables are used to support current operations within the business units. As presented by Sandström (2013) and Leonard-Barton (1992), large companies like Siemens, are challenged by path dependencies and rigidities, which could render the company's products and services obsolete. Using Wearable Technology when performing a service, e.g. maintenance at a wind power plant, could potentially entail that the service is performed faster and with more accuracy and reliability. This can imply a service that is considered better compared to currently offered services. How Wearable Technology can improve services is further exemplified in chapter 4.5. Hence, embracing Wearable Technology in an early stage could help the company gain a competitive edge.

As concluded in chapter 4 Wearable Technology is still in an early stage but is developed enough for analysts to predict that technology has great potential. Large companies, e.g. Apple, Samsung and Google, have entered the market as they see a value and potential of making significant revenues outside their current product portfolio. As Siemens is not intending to develop and produce wearable devices in-house, but instead develop services connected to Wearable Technology, the companies mentioned will not be direct competitors. The entry of these companies should thus not be seen as detrimental for Siemens, but rather as favorable as it gives credibility to that the market for Wearable Technology is big enough for large firms to invest in.

Currently there are a few small companies doing pilot projects in the market for Wearable Technology in industrial environments, as concluded in chapter 4, but still no large firm has entered the field. Thus Siemens has the opportunity to pioneer the market and therefore has to make a strategic decision on whether they should enter the market now or wait. If the intention was to only make use of Wearable Technology within the firm and not sell services to external companies, it would be rational to wait and let other firms develop the initial technology. But as Siemens is also planning on selling services related to Wearable Technology to other firms, there is a great value in being first and in the customer's top-of-mind, as described by Anderson (1996). There are both advantages and disadvantages of being first into a new market, as described by various authors in the theoretical background presented above. However, this thesis argues that the benefits of pioneering this particular technology and market outweighs the downsides and that Siemens would profit from entering the market now, albeit in a niche segment.

6. Product and Customer Development

This chapter intends to address research purpose three; to identify a specific Wearable Technology-use case and build a prototype. First a theoretical background is outlined followed by the background, proposed solution and implementation of the authors' wearable invention to improve workplace safety through Wearable Technology. The chapter ends with a discussion of the customer development process of the invention.

6.1 Theoretical Background: Product Market Fit and Customer Development

In order to arrive at a good fit between product and market, a good understanding about customers' needs is required. Blank (2013) states that launching a new enterprise, whether a startup or a project within a large corporation is a risky venture and that 75 percent of all startups fail. Other sources (The Guardian, 2014 and Business Insider, 2013), state that the failure rate may be as high as 90-95 percent. Hence, an important part of the product development process, outlined in the section below, is to conduct customer interviews to understand customers' needs.

Blank and Dorf (2012) suggests that conventional wisdom in the development of a viable business plan should be exchanged with a new methodology. This methodology favors experimentation over elaborate planning and customer feedback over intuition and gut-feeling. Blank and Dorf (2012) further argue that a minimum viable product should be developed; meaning that initially a product that works and only performs the most basic features should be developed. In this way, the product can be shown to potential customers early on in the process, which both spares the development team from unnecessary work on features that are not demanded and makes it easier to alter the product to fit potentially new demands incurred during stakeholder interviews. Pivoting, i.e. the act of structurally changing the course to test a new hypothesis about the product, strategy or engine of growth, is fundamental in this process in order to develop a product that has support from the market (Ries, 2011).

Blank and Dorf (2012) further accentuate that listening to customers and understanding their problem in a specific situation is essential in order to find a fit between the product and the customers. They present a four-step approach for startups, divided into two distinct phases; search and execution, depicted in figure 6.1. In the search phase the initial idea is translated into a business model and hypothesis and assumptions about customer needs are tested. When hypotheses have been validated, a minimum viable product is created and shown to potential customers to gain further insights. The interest from customers can be tested through early orders or product usage and if there is a mild or no interest at all, the idea could be pivoted and new hypothesis could be tested which might have a better fit. Both steps in the search phase are iterative and first when a product has been received with enthusiasm from customers, it is advisable to proceed to the next phase.

Finding this fit is also emphasized by Christensen et al. (2007) as they argue that companies should find a product that does the job for the customer. Customers are not interesting in additional functions and excessive features; instead they search for a product that solves their problem and facilitate their living. In the last phase of Blank and Dorfs (2012) four-step approach the business plan is executed and the product is launched onto the market. However, they emphasize that before continuing to this phase, extensive knowledge about the customer has to be gained, which in most cases requires more than 50 interviews. The next step is to scale up the company and transform it into a viable company.

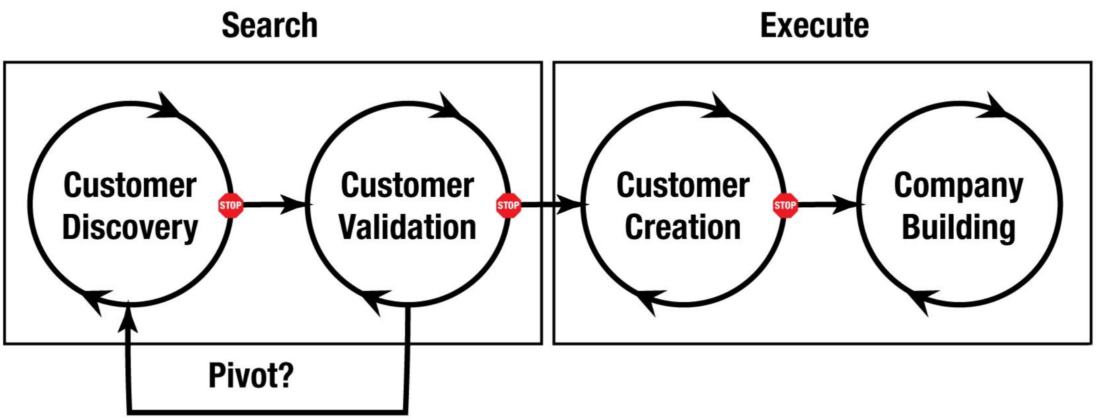

Figure 6.1. The customer development process. (Source: Blank and Dorf, 2012)

Moore (2001) argues that in order for the business to grow and become profitable, the company is most likely better off if they initially focus on a small niche market. The company can flourish in the small market and when it reaches a point where it dominates that niche, they can use that as a base for entering bigger markets. A company that is market leader in one segment can build credibility with references and useful knowledge that can be used to easier persuade people in other sectors and markets to invest in your solution. Christensen (1997) states that new companies are usually too small to compete with the big players in mature stable markets. At the same time niche markets are usually neglected by big firms as they are too small for them to invest in and not big enough to satisfy the growth needs of big firms. As Wearable Technology is new and it is not obvious how people will benefit from it, focusing on a niche market and having a specific use case could help to convince people about the advantages. As it is a small market the competition might be less fierce and the new technology can succeed even though it contains flaws and is not fully developed.

Both Blank and Dorf (2012) and Ries (2011) write about the lean startup and how the techniques described above could be used in new and small firms, but emphasize that the methodology is applicable also to large enterprises. General Electric, Qualcomm and Intuit have all begun to implement the lean startup methodology as a way to meet the challenges of today's business characterized by rapid change and continual disruption (Blank and Dorf, 2012).

6.2 Use Case: Wearable Technology to Ensure Usage of Personal Protective Equipment

The most prominent use case that we found and the one we chose to elaborate further on was to use wearables to ensure usage of personal protective equipment in the workplace. Ensuring high occupational safety for employees is top priority for employers. Since working in an industrial environment is hazardous, accidents occur on a regular basis on workplaces and workers get injured. A way to protect workers from these hazards is to wear personal protective equipment. As this is an easy and effective way to protect workers from injuries there are laws and regulations instituted to ensure that personal protective equipment is used. In United States, the authority in force of these laws is the Occupational Safety and Health Administration (OSHA). OSHA 1915.152a states that:

"The employer shall provide and shall ensure that each affected employee uses the appropriate personal protective equipment (PPE) for the eyes, face, head, extremities, torso, and respiratory system, including protective clothing, protective shields, protective barriers, personal fall protection equipment, and lifesaving equipment, meeting the applicable provisions of this subpart, wherever employees are exposed to work activity hazards that require the use of PPE."

This means that the employer has the responsibility to both ensure that PPE is available and used by workers. Not being compliant with OSHA's regulations can entail significant fines and blacklisting by OSHA, which can deteriorate the company's reputation. Today, ensuring that PPE is worn is solely done without technical means. It is the employer's responsibility to ensure that PPE is available and worn and if workers are not wearing what is required they will most likely get notified by their peers or their supervisor. However, as there is not always someone around that looks after each worker, it is ultimately the individual's responsibility to comply with regulations and be in charge of its own safety. Workers tend to forget to wear PPEs or simply underestimate present hazards why this non-systematic approach is an important problem to address. (Brian Lammi, 2015)

In addition to the requirements from OSHA there are also significant financial incentives for employers to ensure the use of PPE. According to US Bureau of Labor Statistics and as depicted in figure 6.2, in a majority of the cases where workers suffered serious injuries, personal protective equipment was not worn. These injuries occurred most frequently when workers performed their normal tasks at their regular worksites and could most likely have been prevented if safety equipment had been worn. Every year, approximately 9 million work related accidents occur in the United States. The cost related to these accidents amounts to 250 BUSD. Bedsides personal suffering, workplace accidents are also related to a major financial loss for employers. On average, the employer is responsible for 25 % of the claims, which accounts for 7.000 USD per injury in medical cost and lost productivity. (Leigh, 2011)

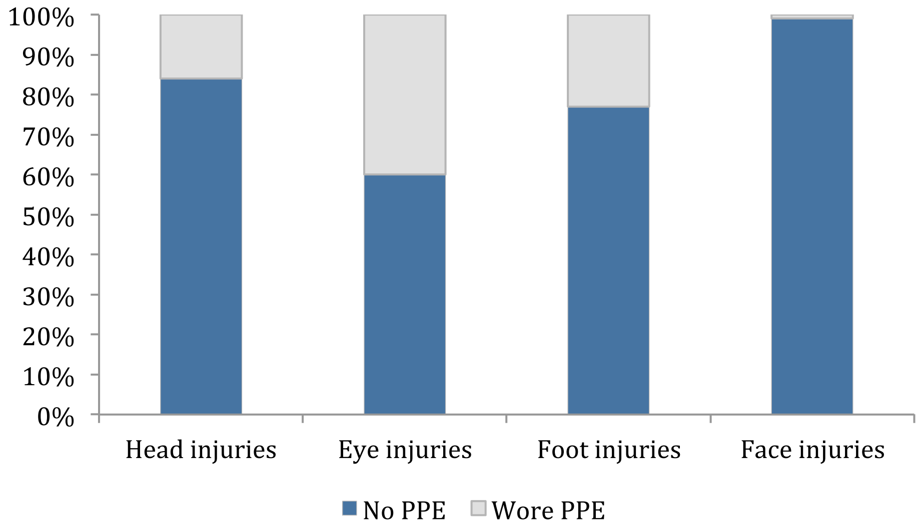

Figure 6.2. Injuries where personal protective equipment were worn versus not worn. Source: OSHA Fact Sheet 92:08

6.2.1 Proposed Solution

An application developed for a wearable device to detect beacons is used to ensure that personal protective equipment (PPE) in the workplace is used by workers. A beacon is a small and light device that constantly emits a wireless signal that could be received and registered by the wearable device.

The beacon is attached to a piece of personal protective equipment, e.g. a helmet, safety shoes or safety gloves that are required to use when performing a task that imposes a safety hazard for the worker. Each beacon has a unique identity and each PPE has its own beacon attached. The application developed for the wearable device makes use of Bluetooth to search for nearby PPE (i.e. beacons) and finds and registers the ones that are nearby. Consequently the wearable device can ensure that the worker is wearing all PPEs required for a specific task.

Furthermore a beacon is attached to the workstation, e.g. a welding station or an assembly station. The beacon attached to the workstation emits a signal to identify what PPE is required for working at that specific station. A list of PPE needed for that station is fetched from the database by the wearable device. Simultaneously, the wearable checks if all required PPE are worn. If the worker proceeds to another station, the wearable detects this and updates the list of required PPE at the new workstation.

This solution is not limited to a specific kind of wearable or a specific interface. In this case, an LCD screen on a wearable wrist watch is used. However, other kinds of wearables such as Smartglasses or simple wristbands could be used to notify the user with e.g. audio or vibrations. As implemented in this case and depicted in the pictures below, if a piece of PPE is found a green check mark is displayed and if not a red cross is displayed. If no red cross appears, i.e. all PPE are found, the worker is allowed to work. If a worker is taking off a PPE while still working and thus ceases to be in compliance with safety standards, the worker gets notified by the wearable device.

The beacons emit a signal, which is received by the wearable device. The signal strength from each beacon is identified and stored as a data point. Theoretically, the distance between the device and the beacon could be measured accurately. In the real world, signals from beacons are influenced by absorption, refraction and reflection, which make the measurement less accurate. However, the signal strength could indicate if the beacon is far away or located near the device, i.e. a strong signal implies short distance while a weak signal is likely received from a beacon far away. With technology present today, one could quite reliably tell if the PPE is within a radius of approximately one and a half meter. This data is essential to tell if the worker is wearing the PPE or not. As technology improves, it is likely that the ability to measure proximity will improve significantly.

The beacons attached to the protective equipment emit a signal with a unique id. Hence, this solution makes it possible to ensure that every individual worker wears its own personally fitted equipment and not equipment that belongs to another worker. Wearing a too big helmet or glasses may be a safety hazard itself. Furthermore, one could hypothesize that making sure that the protective equipment is personal, strengthens the ownership of the equipment and lowers the likelihood that the PPE get lost or are used by someone else.

Figure 6.3 below illustrates how the id signals from the beacons are processed and matched with data about which protective equipment are required for a specific workstation. The processing of data takes place in an online database.

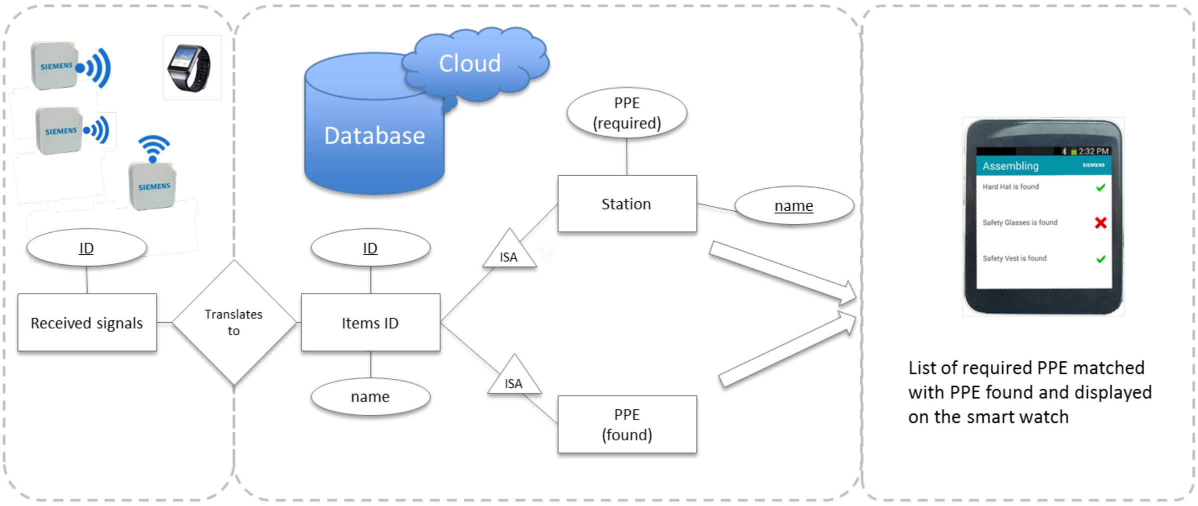

Figure 6.3. Relational diagram to illustrate the relations between the data sets. Source: Master's Thesis

6.2.3 Scenario

In this particular study, the implementation is based on a real case for a welder working at a manufacturing plant in California, USA. The welder, in this case, is not only working at his welding station but also performing assembly tasks as a part of his job description. Hence, the worker has to wear a different set of protective equipment at the two different work stations. In the very start of the day, the worker puts on the necessary equipment to start working at the welding station. However, the list of required protective equipment for this task is extensive and it is easy to forget an item. When the welder walks up to the workstation, the wearable device, will first identify that the current workstation is welding and matches the list of required protective equipment with what the worker is actually wearing. If the worker is not wearing all of the required protective equipment, he will get a notification to stop working and assure that he is compliant with safety standards before getting back to work.

Figure 6.4. System overview. Source: Master's Thesis

When the worker has finished his welding tasks he takes off the PPE needed for welding and puts on the PPE for assembling and then walks over to the assembly station. Subsequently the wearable detects that the workstation has changed. The wearable displays the required PPE for the assembly workstation and matches it with the equipment the worker is wearing. If the wearable displays only green checkmarks and no red crosses, i.e. all required PPE is found, the worker is permitted to start working at the new station.

6.2.4. Development Process

The presented use case was identified during a visit to Siemens' light rail factory in Sacramento, California. Prior to the visit, occupational health and safety was an area of focus and the authors specifically tried to find use cases within this field. A worker that was grinding without wearing a visor was identified and made the authors think that utilizing new technology may prevent this from happening. Another insight from the factory was that ensuring a safe workplace and preventing accidents were a top priority and complying with regulations from OSHA (Occupational Safety and Health Administration) was considered as highly important.

Further research was conducted to see if there were statistics to support the hypothesis. It seemed like an important problem since statistics from US Bureau of Labor Statistics showed that workers were not wearing proper protective equipment in the majority of cases when injuries occurred. From OSHA's point of view, this was also identified as a major concern, which strengthens the hypothesis that this solution would be interesting to the company. The authors strived for a solution to this issue by using some type of Wearable Technology and came up with the idea presented above. However, the idea was abstract and the authors started to build a prototype to be able to communicate the concept to potential stakeholders more efficiently. When the prototype was developed, the authors interviewed EHS Managers to gain knowledge and inputs about the domain in order to adjust the solution and find a product that would fit customer's needs.

6.2.6 Initial Customer Response

Initial response from Siemens employees (i.e. EHS Managers) was positive and interviewees could see value in implementing this invention into the factory they were in charge of. However, the interviewees pointed out some issues with the idea in its current state and that improvements had to be made in order for them to invest in it.

Interviewees highlighted that workers are generally reluctant to being monitored while working. They do not want someone constantly watching over their shoulder and wearing a watch that controls if PPE is worn could be seen as a mean for controlling and monitoring the worker. Workers were also suspicious of what the wearable device is actually used for. The sole purpose of the authors developed invention is to ensure that proper PPE is worn while working, but as the smartwatch used for this is relative advanced it has several other features incorporated that could potentially also be used (e.g. monitoring heart rate, number of steps, GPS location etc.). As these features could be used by superiors to monitor workers there is a reluctance to use this type of wearable device.

Interviewees worked in heavy industries where the environment is rough and strenuous. In these conditions equipment needs to be robust and solid in order to endure over time and not break. A wearable device with a glass screen might not endure for a long time in these environments as the glass is sensitive to hits. Also the beacons could fall off as they are attached to the PPE and stick out from the surface of the item.

The idea entails that one and each of the workers are to wear their own wearable device and have beacons attached to every piece of their personal protective equipment. As there are hundreds or sometimes thousands of workers at a factory, it sums up to a big investment in purchasing smartwatches and beacons to all employees. This investment may be profitable on long term as it lowers costs related to injuries, but on short term it entails a significant cost that cannot be paid back directly. However, several interviewees pointed out that the invention should not solely be seen as an investment to lower costs due to fewer injuries but also as a way to protect their workers and increase employee satisfaction. It could therefore be easier to motivate the investment of the invention.

One interviewee stressed the risk of relying on a technology which could result in less carefulness by workers. To protect themselves they need to be engaged in their work and think about their own safety. An idea, like the one presented above, could lead workers to shift the responsibility of wearing proper safety equipment to the wearable device. In general employee safety is improved when workers are engaged in the process and injury reduction comes from thinking about the process and the associated risks before starting the activity. One interviewee therefore argued that the presented idea goes against the move in the safety industry of engaging workers in the safety process. He advocated for more education about safety hazards and how to increase safety over investing in a new technology. On the contrary, another interviewee argued for the opposite and that the invention actually increased workers engagement and safety. Instead of worrying about what PPEs are required for every work stations, the workers can use the wearable device as a simple tool to ensure that they can perform all tasks in a safe manner. Furthermore, the largest advantage of the solution is that it also controls if the PPEs are worn or not.

6.3 Discussion

As outlined by Blank (2013), over 75 % of startups fail. Hence, a vital part of the development process was to ensure that the proposed solution actually solve a problem that a potential customer encounter. According to Blank and Dorf (2012), customer interviews should be conducted as early as possible to avoid spending time on a problem that is not considered relatively important to solve. The next step is to build a prototype based on the insights gained from the initial interviews. In this case, this was not a straightforward task since the concept itself was hard to explain to potential customers. Therefore and opposed to Blank and Dorf's (2012) suggestion, the authors started to develop a minimal viable product before conducting any customer interviews. On one hand, presenting the prototype helped the interviewees to grasp the concept quickly. On the other hand, through showing the interviewees the prototype, their minds were less open to provide the authors with an alternative solution to the problem. Furthermore, it was also challenging for some of the interviewees to understand that the prototype was only a proof of concept and not a finished product. This confusion would easily been avoided if no prototype was shown at all. However, the authors conclude that the advantages gained by revealing the prototype to the interviewees was essential and outweigh the potential disadvantages discussed above.

As suggested by Moore (2001), the likelihood to succeed with a new product is higher if the product targets a niche market with a specific application instead of a broader market, where the applications are more diverse. In this project, a welder was identified as a key persona and the solution was developed to meet the requirements of such a worker. Developing a product to a specific worker helped the authors to focus on core functionalities. The six interviews conducted prove that the solution address an important problem safety managers encounter on a daily basis. However, Blank emphasize that over 50 interviews have to be conducted in order to validate a business idea. Hence, in order to proceed from *search phase* to *execution phase* in the customer development process, more interviews have to be made.

7. General Discussion

This section intends to analyze the developed solution described in Chapter six with regards to the market of Wearable Technology, presented in Chapter four, and to the fit within Siemens business areas, as outlined in Chapter five.

As Wearable Technology is still in its infancy, major improvements related to battery capacity, processing power and communication protocols have to be made before the technology can be carried over to new application areas. Given the development presented in chapter four, Wearable Technology is evolving rapidly and smaller components among others would facilitate improvements of the author's invention. Interviews with potential customers, i.e. Siemens employees, revealed that using the invention in Siemens' factories would yield significant value in terms of health and safety. However, a few minor constraints with the current invention was pointed out which must be mitigated in order to be used within Siemens industries.

A limitation of the invention is that it can only detect if PPE is in the proximity of the worker, not actually worn properly. This means that a worker could, for example, hold his helmet under his arm instead of wear it on the head and the smartwatch would still consider the helmet to be worn as intended. However, some of the interviewees argued that having PPE nearby or wearing them incorrectly would be more troublesome, especially when working. It is therefore more likely that workers wear them why this limitation does not seem to be as important as the authors initially thought.

Two interviewees emphasized that the prototype, a smartwatch with an LCD display and attachable beacons, would not endure harsh industrial environments. The screen on the watch would likely break and the beacons, which are quite bulky, would eventually fall off. This was considered as important feedback rather than criticism about the solution since the presented prototype only was displayed as a proof of concept and not as a finished product. A product ready to be launched onto the market would be altered to better fit into industrial environments. An alternative solution, suggested by the authors, would be to use a thin rubber wristband that indicates what PPE is worn by LED-lights. In this way the devices would be more durable and be able to take hits without breaking and as the technology evolves the beacons will become much smaller. It also highly probable that the technology used in the beacons could be integrated into the fabric of the PPE, which would eliminate the problem with attached beacons that fall off.

Another important aspect to consider is to manage workers privacy concerns. Wearable devices do have the potential of carrying several different types of sensors. These could be used to monitor workers heart rate, number of steps taken etc., which could be seen as a violation of privacy, if utilized. The presented system does not intend to utilize these features, but as workers are aware of the potential of the technology they might not be willing to use the system as they believe that these features can be used without their knowledge. It is therefore essential to persuade workers and convey that the devices are only used for ensuring that PPE is worn and that there are no hidden features. What also should be communicated is that the system's main purpose is to protect the worker from hazards and it should therefore be seen as a tool for the worker and something they would benefit from using instead of something that solely supervisors or managers demand. As devices are becoming smaller they also have the ability to better and more seamlessly fit into the industrial environment, which would facilitate the use of the system.

Currently a smartwatch like the one used in the solution presented and beacons for each PPE would sum up to a significant investment if deployed to all employees in a factory. This is the case since each worker would have their own wearable device and beacons attached to all of their PPE. As the technology becomes ubiquitous the price of the different components will most likely fall. It will however, always entail an initial cost to invest in the proposed solution but something that the company can benefit from in the long term.

The invention presented is not limited to a specific industry or business but can be utilized in a variety of different areas. As most industry workers, regardless of sector, are required to use personal protective equipment this invention arguably targets a large market. Currently the system is not compatible with all Siemens divisions as it is limited to stationary workplaces. For field workers that are working at several different locations and switch workplace daily, the system has to be adjusted to fit into that particular context. Adjusting the system for different workplaces and activities, such as field workers doing maintenance on wind turbines, is indeed possible.

For Siemens the presented solution could be seen as a good starting point for entering Wearable Technology. This project clearly utilizes the unique value wearables can offer in a business context: to collect data about vital signs and the environment in the proximity of the user. Another benefit of this proposed solution is its scalability. The solution could easily be run as a pilot and further be rolled out to other business units. Valuable insights and learnings about Wearable Technology, e.g. with regards to the privacy concern that this technology raises, could be carried over to larger projects.

8. Conclusions

This chapter aims to conclude the analysis with regards to the threefolded research purpose. Hence, the first section presents the results of the industry analysis. The second section outlines key considerations regarding the fit between Siemens and Wearable Technology. The last part presents the conclusions drawn from the prototyping and customer development process based on findings from unfolding previous research purposes.

Wearable Technology is thriving in the consumer segment and is starting to gain momentum also in the business segment. Enterprises anticipate that big opportunities exist with deploying the technology within industrial environments. Utilizing Wearable Technology imposes several advantages over conventional technologies and methods. It can improve efficiency in the workplace by providing access to real-time data while freeing the hands to hold tools and equipment. It could also collect data and provide the user with information that previously has not been possible.

Since Wearable Technology is a wide concept with a diverse set of products and application areas, it is somewhat troublesome to uniformly analyze the development of the technology. This thesis' analysis of the market has therefore considered each segment separately, but at the same time taken the common characteristics of each segment into account. Considering the market of smartwatches and fitness trackers, this thesis argues that many of the characteristics of a mature industry can be identified. However, looking at smartglasses the market is still in an early stage where much development has to be made in order to be adopted by companies. As of 2015 several constraints exist, e.g. battery performance, compatibility with existing systems and work routines, which hinders the devices from being adopted. Analysts predict that these constraints will be mitigated as the technology evolves and the wearable devices become physically smaller, more powerful and have more functionality.

Siemens is a big company and Wearable Technology could potentially be applied in several of the company's divisions and business areas. However, the most prominent feature of wearables is the ability to collect data about vital signs of the user and data about the environment in the absolute proximity of the user. Thus, this thesis argues that the best fit between Siemens and Wearable Technology is achieved when a use case is discovered, where this unique value proposition could be utilized.

Furthermore, this thesis argues that the benefits of pioneering this particular technology and market outweighs the downsides and that Siemens would profit from entering the market now, albeit in a niche segment. Waiting to invest in Wearable Technology would jeopardize the potential revenues streams that this technology will generate.

The majority of startups fail why the authors in depth evaluated several business ideas before arriving at the presented use case. As outlined in previous section, the unique value proposition of wearables is the ability to collect data about vital signs and the environment in the proximity of the user. This was used as a starting point for the invention, as many severe workplace accidents occur because workers do not wear all personal protective equipment required to perform a specific task. To solve this problem, a system based on Bluetooth beacons and a smartwatch running Android OS was developed. The beacons, which are attached to personal protective equipment and workstations, emit Bluetooth signals. These signals are received by a wearable device and thus it can be ensured that workers are using the required PPE.

The customer development process, as presented by Blank and Dorf (2012) was applied to the problem and several interviews with stakeholders were conducted. Both strengths and weaknesses about the solution were pointed out, which are important to consider when further developing the concept. Based on the conducted interviews, this thesis conclude that there is a need for the solution but more customer interviews have to be made in order to strengthen the product market fit. The prototype developed by the authors used the latest available technology. However, Wearable Technology is in an early stage and the technology is evolving rapidly. Thus, the authors conclude that some of the flaws, pointed out by the interviewees, will be eliminated when the technology matures.

Conclusively, Wearable Technology is in an early stage but great opportunities are within reach. This thesis unfolds many cases where Wearable Technology would create significant value for industrial applications and arrives at an invention, developed by the authors and customized to a part of Siemens' current operations. Thus, this thesis argues that Siemens should continue to explore the area of Wearable Technology and that implementing wearables, in areas where the full potential of the technology could be realized, would create a competitive edge for the company. The invention to improve occupational health and safety, outlined in this thesis, is an appropriate starting point for this process.

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