INDUSTRY 4.0:
DIGITIZATION IN DANISH INDUSTRY

An Interactive Qualifying Project submitted to the faculty of
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Report Submitted To:

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Abstract

Economic stagnation, increased industrial outsourcing, and a decrease in productivity have negatively impacted Denmark's industrial sector. The goal of this project was to work with the Copenhagen School of Entrepreneurship to identify attributes of companies capable of implementing Industry 4.0 (I40) technologies — a means of increasing industrial productivity through the use of data management and automation. From interviews with I40 company representatives, we discovered the obstacles impeding I40 implementation are primarily due to inexperience with and uncertainty regarding these technologies. Using these findings and supplemental research, we developed a readiness assessment tool to assist companies in implementing I40 and a list of recommendations to encourage I40 usage in Denmark.

Executive Summary

Background

This project focuses on the implementation of Industry 4.0 technologies in the Danish industrial sector. Over the past decade, Denmark has suffered a decline in business investment, increase in industrial outsourcing, and decrease in GDP (Denmark | Data, 2018). To stay competitive in the global market and decrease the country's dependence on foreign countries, the Danish Government encourages manufacturing companies to adopt Industry 4.0 technologies (Ministry of Industry, 2017).

Industry 4.0 (I40) is an umbrella term that encompasses several different digitization technologies (see Figure 1). For this project, we split these technologies into two groups. The first group, data management technologies, focuses on the ability to manage and analyze large quantities of data (Burke, et al. 2017). The second group, cyber-physical systems, focuses on the combination of hardware and software to automate manual processes (Rodriguez, et al., 2018). As a whole, I40 technologies augment existing practices with the goal of increasing productivity in industry.

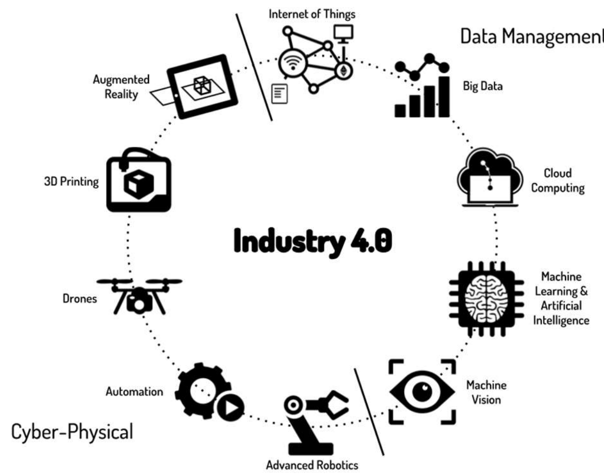

Figure 1: I40 Technology Groupings

To implement Industry 4.0 in Denmark, several Danish organizations run startup accelerator programs focusing on I40 technologies. Our sponsor, the Copenhagen School of Entrepreneurship (CSE), runs one such program: the Digital Growth Path (DGP). DGP nurtures startups producing or using I40 technologies by helping these entrepreneurs develop business models and providing them access to investors and other resources. The goal of this project was to identify attributes that indicate a company's readiness to adopt Industry 4.0 technologies to help participants in DGP find clients.

Methodology

In order to achieve our project goal, we developed the following research objectives:

1. *Identify SMEs involved with Industry 4.0 technologies*
2. *Determine the applications and effectiveness of digitization from Industry 4.0 producers*

3. *Evaluate characteristics of companies using Industry 4.0*
4. *Determine method of assessing I40 readiness in companies*

Using databases provided to us by the Copenhagen School of Entrepreneurship, we first identified SMEs developing or utilizing Industry 4.0 technologies. Our initial list contained over 130 companies, 60 of which we contacted through email. From these companies, we ultimately arranged interviews with representatives from nineteen companies; fourteen produced I40 technologies, and five used I40 technologies. During our interviews, we asked representatives questions about their companies and their I40 solutions. Additionally, we asked about the benefits, drawbacks, and obstacles of I40 implementation. In order to supplement the data from our interviews, we researched academic journals and government reports. The insight from our interviews and research ultimately provided us the necessary information to create an Industry 4.0 readiness assessment tool. While performing our research, we also discovered companies that met the parameters for participation in the Digital Growth Path. From our discoveries, we created a list of these companies to deliver to our sponsor contact, Claus Birkedal.

Findings

From our interviews and scholarly research, we developed the following findings:

<u>Applications of Industry 4.0 technologies</u>

1. *Coordinated data management technologies improve business operations.* Many digital companies use data management technologies to measure and improve Key Performance Indicators (KPIs). Sensors collect statistics such as environmental conditions, energy usage, and equipment performance in real-time and allow operators to access this information from any location. Creating an environment with increased transparency to help determine product quality, bottlenecks, and other KPIs, real-time data allows operators to work more efficiently and productively (Lee & Lee, 2015; Hercko et al., 2015).
2. *Data gathering and filtering solutions are easier to implement than many people think.* Producers of I40 technologies regularly describe their products as Plug and Play, signifying that they are easy to use and install. From our literature research and interviews with representatives from companies producing and using I40 technologies, we found that implementing data management technology may not be as arduous as commonly believed. Installment time can be as short as fifteen minutes, and per our interviewees' claims the average installation time was one day.
3. *Cyber-physical systems expedite traditionally human performed processes.* From our interviews with producers and users of automation technology, we concluded that automation

and robotics improve time efficiency. From literature research, we found that augmented reality (AR) improves communication in industry across the globe, reducing response time and machine downtime (Mclennan, 2017). Inspection service companies revealed that drones help surveyors complete their work faster and more safely. Additionally, additive manufacturing producers and users showed that 3D printers increase the speed of prototyping and promote greater product customization.

Obstacles to Industry 4.0 adoption

4. *Utilization of Industry 4.0 technologies results in reallocation of personnel from unskilled to technically skilled labor.* A major concern among employees in companies implementing Industry 4.0 technologies is that technology will replace the workforce. Despite this fear, many of our interviewees do not believe Industry 4.0 technology will result in a decrease in the number of employees. Although this discussion varies on a case-by-case basis, these responses fell into two groups: (1) those who believe that positions will stay and (2) those who believe that certain positions will be eliminated, but other positions will be created.
5. *Despite affordable options, time and resource constraints prevent companies from investing in digitization.* A major concern for companies considering Industry 4.0 technology is the cost and difficulty of the implementation process. Concerned that the complexity of the product will require extensive machine downtime and capital, companies regularly overlook more reasonable options. Furthermore, concerns regarding return-on-investment hinder some companies from purchasing I40 technologies.
6. *Concerns with cybersecurity deter many companies from digitizing their processes.* A requirement for digitization, Industry 4.0 technologies connect to both each other and to the internet. While this makes data and process management easier, it also increases the fear of cyber-attacks and hackings that may result in critical information leaks. Technologies that constantly handle large volumes of information, such as Internet of Things and cloud storage, are especially subject to security concerns. We found, however, that there are existing safer options of which company management may not be aware.
7. *Many companies hesitate to change their business structure for digitization due to the experimental nature of Industry 4.0 technologies.* According to many of our interviewees, one of the barriers preventing companies from adopting digitization is uncertainty with altering an existing infrastructure. While many of the production companies from which we interviewed representatives produced Plug and Play solutions, other extensive digitization solutions often require large changes to utilize the new technology fully. Companies, especially those that are well established, are often reluctant to forgo a working business infrastructure for something

radically different, especially with a new technology not thoroughly developed (Ericsson, 2016). Mr. Dannesboe from OptiPeople believes that people do not know enough about the benefits of implementing Industry 4.0 and that educating them would encourage the change needed to digitize production further (personal communication, April 3, 2018).

From our findings, we concluded that in order to be able to implement industry 4.0, a company needs these five attributes:

- *Adequate financial resources*
- *Adequate technological infrastructure and background*
- *Strong connection between management and production personnel*
- *Solid understanding of the benefits of digitization*
- *Desire to innovate*

One of the major limitations in our research was response bias from interviewed representatives. Representatives from companies producing or using Industry 4.0 technology may have reported generalized or inaccurate data, especially because they did not always respond with numbers but rather subjective, personal opinions. We recommend those interested in Industry 4.0 to read this report with an open mind and acknowledge the potential bias obtained from our research.

Recommendations

From our findings, general observations, and conversations with interviewees and our sponsor, we determined the following recommendations for the Copenhagen School of Entrepreneurship for further development of Industry 4.0:

<u>For the Copenhagen School of Entrepreneurship</u>

- *CSE continue to treat their participant companies on a case by case basis, and advise their participants to do the same for their clients.* By treating participants on a case by case basis, companies are more likely to find solutions customized to their needs.
- *Search for companies exhibiting five key attributes by using our readiness assessment tool.* Our findings indicated that companies exhibiting the following traits are capable of implementing Industry 4.0 technologies successfully: *adequate financial resources, adequate technological infrastructure and background, strong connection between management and production personnel, solid understanding of the benefits of digitization, and desire to innovate*. By using our readiness assessment tool to find companies ready to implement Industry 4.0 technologies, DGP participants can find potential clients able to use their products successfully.

- *Focus on improving inter-company collaboration and communication.* By improving inter-company collaboration and communication, technology development speed will increase and smaller companies may more easily receive access to the benefits of I40 technologies.
- *Increase Denmark's emphasis on technical education for Danish students and manufacturing employees.* Increasing emphasis on technical education will decrease Denmark's technical labor shortage and improve current employees' skills.

<u>For future research</u>

- *Perform more interviews with representatives from companies that utilize digitized technologies and companies involved with cyber-physical systems.* We were only able to gather information from a handful of companies in these categories. By performing more interviews with these two types of companies, future researchers can verify our information from interviews and research.
- *Perform interviews with representatives from companies that considered digitization, but ultimately decided against it.* We were unable to identify any companies in this category. By performing interviews with representatives from these companies, future researchers can further verify information about the obstacles and resistances to the adoption of I40 technologies.
- *Determine possible methods of increasing awareness of Industry 4.0 benefits.* By finding methods to increase awareness of I40 benefits, future researchers can find new ways to correct misconceptions of digitization and educate companies of their benefits.

We identified both technical and social obstacles to implementing Industry 4.0 and the attributes companies should have for successful technological innovation. We understand our project is just the beginning of understanding Industry 4.0 and its role in Danish industry. In conclusion, our report is an analysis of the current position of Industry 4.0 in Danish manufacturing companies. We believe our project can help CSE participants in DGP find clients and improve Industry 4.0 adoption in Denmark.

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1.0 - Introduction

Between 2000 and 2008, Denmark's GDP rose an average of 1.8 percent annually (Denmark | Data, 2018). Over the past decade, however, Denmark's GDP has stagnated, most notably decreasing by 14.6 percent since 2014 (Denmark | Data, 2018). One major reason for such decline is Denmark's decrease in production growth after the 2008 stock market crash (Ministry of Industry, 2017). Following the crash, Denmark experienced a decline in business investment and an increase in industrial outsourcing. As a result, Denmark faced lower production growth, which continues to impair national economic success today. Thus, to stay competitive in the global market and decrease the country's dependence on foreign powers, the Danish Government emphasizes the growth of its industrial sector (Ministry of Industry, Business, and Financial Affairs, 2017).

To help address economic stagnation, Denmark's Government set goals to raise its GDP by DKK 80 billion (USD 13 billion) by 2025. Toward this goal, the Danish Government expects the industrial sector to contribute over DKK 17 billion (USD 2.8 billion). In order to achieve such goals, Denmark will have to overcome many obstacles (Ministry of Industry, 2017). One such obstacle is Denmark's dependence on Small and Medium Enterprises (SMEs). As of 2015, SMEs comprised 99.4 percent of all Danish companies and contributed almost 60 percent to Denmark's GDP (Jedynak, 2016). Evidently, SMEs possess significant financial influence in the Danish economy. Despite this influence, SMEs often have limited financial flexibility and therefore cannot make investments that boost production. Thus, this inability of SMEs to innovate and contribute sufficiently to the Danish government's goals for industrial growth may impair national economic success (De, 2014).

In an effort to advance Danish SMEs and achieve the government's goals for 2025, many organizations and universities run programs to assist SMEs in refining their business models. One such program is the Go Grow Startup Accelerator Programme (GGSAP) run by the Copenhagen School of Entrepreneurship (CSE). The GGSAP provides SME entrepreneurs access to financial expertise and connects these workers to peer networks of advanced entrepreneurs, investors, business executives, experts, and scholars. Within GGSAP is the Digital Growth Path (DGP), an acceleration path that works with innovative companies developing and utilizing digitized technology for industrial applications. Collectively known as Industry 4.0 (I40), these digitized technologies promote increased automation and data exchange among industrial machinery ("Go Grow," 2017). Ultimately, by developing this technology with peer working spaces that promote innovation and competition, the Digital Growth Path aspires to bring the benefits of Industry 4.0 to Danish companies ("Digital Growth Path," 2017).

In comparison to competitor countries, digitization has yet to be implemented extensively in the Danish industrial sector (Ericsson, 2016). Facing global market pressure to adapt and cognizant of the financial inflexibility of SMEs, Denmark's government works to assist the spread and implementation of I40 technologies. With a special focus on small Danish manufacturing companies, government and business leaders in Denmark aspire to promote the creation of disruptive I40 technologies with the creation of incubators, accelerator programs, and industry conferences. The Danish Government believes such work will promote the growth of Denmark's GDP and make it a more industrially competitive country. According to the Ministry of Industry, Business, and Financial Affairs, this growth ultimately will reinforce Denmark's position in the global market and facilitate its mission to achieve the government's economic goals (Ministry of Industry, 2017).

The goal of this project was to identify attributes that positively affect the implementation of Industry 4.0 technologies in SMEs.[1] We achieved this goal by first identifying industrial companies that develop or utilize Industry 4.0 technologies. Next, extensive research and personal interviews with company representatives provided us the data to discern the attributes of Danish industrial companies best suited to implement I40. While performing our research and interview process, we also identified some Industry 4.0 companies that satisfied the parameters in our attribute list. We recommended these identified companies to our sponsor, Claus Birkedal for participation in the Digital Growth Path. Ultimately, partnership with CSE provides these companies with the support and resources necessary to be competitive in the Industry 4.0 market. In conclusion, we believe such work will help Denmark reach its economic goals and strengthen its industrial sector.

[1] Successful implementation will be defined in greater detail later in this report, however, success is primarily determined by: ease of implementation, length of return on investment (ROI), and increased productivity within a company.

2.0 - Background

This chapter begins with an overview of Denmark's economy, industrial sector, and financial goals. Following the overview, we discuss the development and applications of a new industrial revolution, Industry 4.0 (I40). Among the many topics related to Industry 4.0, we discuss its technological significance and potential influence on business. Finally, we conclude with a detailed description of the Copenhagen School of Entrepreneurship (CSE) and its startup growth programs.

2.1 - Denmark's Economy and Industrial Sector

Two distinguishing features characterize Denmark's economy: (1) a high number of Small and Medium Enterprises (SME) and (2) a large service sector (De, 2014).[2] In 2015, Small and Medium Enterprises (SMEs) constituted 99.4 percent of all Danish enterprises and contributed almost 60 percent to the country's GDP (Jedynak, 2016). Meanwhile, Denmark's 2017 GDP Portfolio reported that the service sector created 75.2 percent of Denmark's GDP for that fiscal year ("World Factbook", 2017). Evidently dependent on SMEs and the service sector, Denmark's economy may lack business variety. Efforts to become more globally competitive and less dependent on other countries, however, may provide more balance. To achieve such goals, Denmark has sparked a new focus on its industrial sector (Tuborg Research Centre for Globalization and Firms, 2016).[3]

2.1.1 - Problems with the Danish industrial sector

In Denmark, industry constitutes 23.7 percent of the country's 2017 GDP and 18.3 percent of the country's 2017 labor force ("World Factbook", 2017).[4] Denmark's industrial sector has an increasing reliance on industrial outsourcing, decreasing domestic productivity and skilled labor (De, 2014; World Economic Forum, 2018). Therefore, Denmark seeks to expand its industrial sector to become less dependent on foreign powers (Tuborg Research Centre, 2016).[5]

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[2] There are several different variations in defining SMEs. The working definition for this paper will categorize any company with fewer than 250 employees as a Small or Medium Enterprise (De, 2014).
[3] This desire to become more globally competitive was also iterated by our sponsor contact, Claus Birkedal.
[4] Industry is defined as the "economic activity concerned with the processing of raw materials and manufacture of goods in factories" (Oxford Dictionaries).
[5] The Country Readiness for Future of Production index analyzed 100 countries in their preparedness for the future. The study used a weighted average of 59 indicators to rank the countries; Denmark came in 27th

One means of expanding the industrial sector is the use of technology. A constantly evolving field, technological advancements provide countries, especially those with emerging markets, the means necessary to influence the global financial market (World Economic Forum, 2018).[6] In order to maximize the benefits of technology, the Danish Government seeks to advance Denmark's technological infrastructure. This pursuit of economic prosperity by means of technological advancement, however, faces obstacles. Currently, some of Denmark's potential obstacles include:

- A small domestic market (De, 2014)
- A prevalence of SMEs in Danish industry (De, 2014)
- A shortage of skilled labor and engineers (Tuborg Research Centre, 2016)
- A smaller research and development (R&D) expenditure than its European peers (Tuborg Research Centre, 2016)

Due to its small domestic market, Denmark faces increased pressure to pursue international markets (De, 2014; Tuborg Research Centre, 2016; The Ministry of Foreign Affairs of Denmark, 2014). With such a high composition of SMEs, however, the Danish economy does not fully receive the benefits of global scale businesses (De, 2014; The Ministry of Foreign Affairs of Denmark, 2014). To worsen the situation, an inadequate supply of skilled workers and R&D funds exacerbate Denmark's industrial weaknesses. Consequently, SMEs frequently create low-tech products and perform minimal scientific research, fostering increased economic stagnation (De, 2014; Tuborg Research Centre, 2016).

To address some of Denmark's current problems, the report by McKinsey & Company states that Denmark should create a restructured technology policy to emphasize R&D and upper secondary level education (Tuborg Research Centre, 2016). In addition, it argues that adaption to new global market trends will help sustain current markets and entice future growing markets, reporting "that customers increasingly expect customized system solutions" (Tuborg Research Centre, 2016).

In order to satisfy these growing market trends, Denmark needs resources to be plentiful, flexible, and innovative. According to Prasanta K. De in the *South Asian Journal of Management*, Denmark should integrate the public, private, government, and academic sectors to provide SMEs the resources necessary for these trends. Ultimately, such integration will assist in rejuvenating the Danish economy to achieve its desired goals (De, 2014).

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place. A high dependence on SMEs was one of the defining features of Denmark's analysis, ultimately bringing their rank down despite other strong marks.

[6] This statement references the Country Readiness for Future of Production Index from note 3 as well as the comments from our sponsor contact Claus Birkedal (World Economic Forum, 2018).

2.1.2 - Denmark's Goals for the Industrial Sector

Concerned about the future of Denmark's industrial sector, the Danish Government launched several initiatives to promote growth. Among these initiatives, the government set a goal in 2016 to increase the national GDP by DKK 80 billion (USD 13 billion) by 2025. (Ministry of Industry, Business, and Financial Affairs, 2017). Of the DKK 80 billion goal, the Danish Smart Specialisation Strategy of 2014 projects manufacturing and industry sectors to contribute up to DKK 17 billion (USD 2.8 billion) (Larosse, 2017).

To achieve its economic goals, Denmark will require resources. Many of these resources will require investments, however, Denmark has notably low value added by investment. A phenomenon further Illustrated in Figure 2, total investment within Denmark has fallen significantly in the past decade in comparison to similar European competitors like Sweden (Ministry of Industry, 2017).

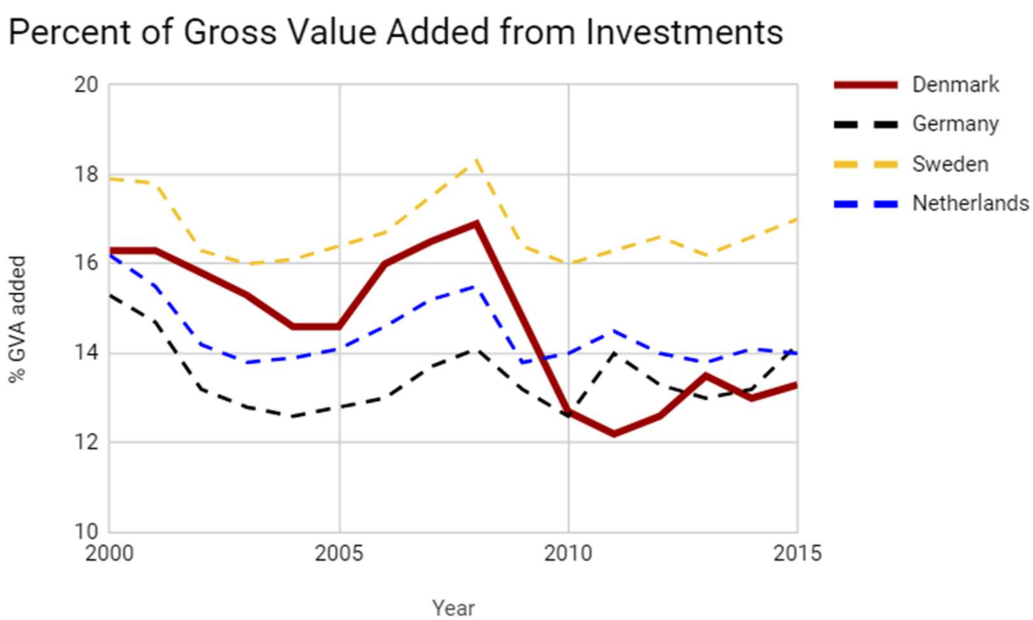

Figure 2: Business investments calculated as percentage of gross value added for the entire economy (Adapted from Ministry of Industry, 2017)

In order to help alleviate this lack of investment, the government funds several industry-boosting programs. The most prominent is the Manufacturing Academy of Denmark (MADE). MADE consists of several programs in which industry and academia work together. One of the programs, MADE Digital, aims to develop digital solutions for Danish companies, specifically SMEs. Among the many benefits of digital solutions, the Danish Government expects digitization to improve the productivity of the industrial sector and make businesses more attractive to investors. In order to achieve digitization and experience these benefits, companies implement technologies known under the umbrella, Industry 4.0 (Larosse, 2017).

2.2 - Industry 4.0

Industry 4.0 is an umbrella term that encompasses several different digitization technologies. Further described in Figure 3, Industry 4.0, also known as the "Fourth Industrial Revolution," focuses on the creation, use, and management of vast amounts of data. To simplify our project, we organized the various Industry 4.0 technologies into two categories: data management technologies and cyber-physical systems.[7]

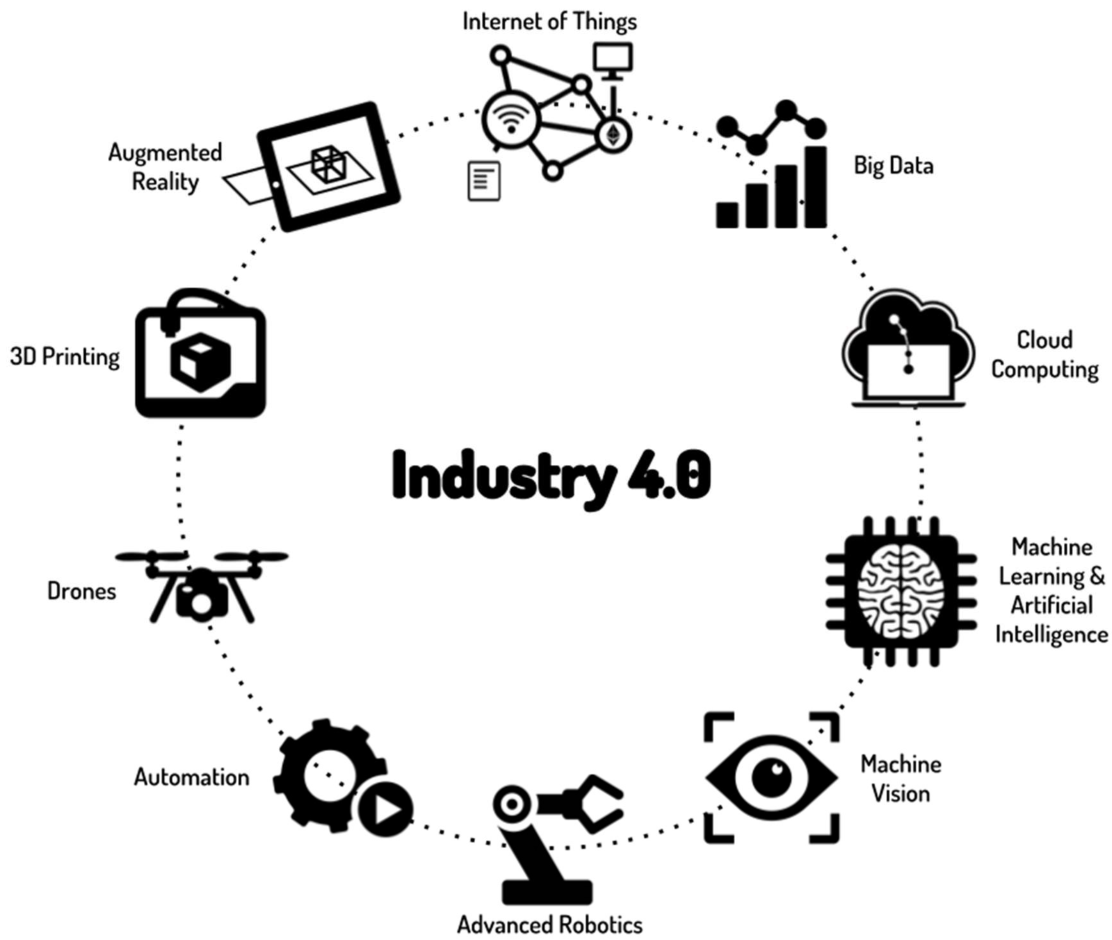

Figure 3: Industry 4.0 Digital Technologies (Adapted from: "Industry 4.0," 2015; Ahluwalia, n.d.; Holm-Hansen, n.d.; Hoogendoorn, n.d.; Icons8, 2013; Icons8, n.d.; Josh, n.d.; Mátyás, n.d.; Mátyás, n.d.; timtjtim, 2017)

[7] See Appendix A for a description of each technology.

2.2.1 - Data management technologies

One major facet of Industry 4.0 is the ability to manage and analyze large quantities of data. We classified Internet of Things (IoT), big data, cloud computing, artificial intelligence, and machine learning together as data management technologies as all of these technologies collect or analyze large amounts of data.

In general, data gathering and filtering solutions consist of several data management technologies broken into three major components: (1) a sensor network, (2) a server, and (3) an application interface (Tommy Larsen, personal communication, March 27, 2018). In a production line using data management technology, the sensor network often contains several IoT sensors. These sensors, which record data from their environment (e.g. temperature, vibrations), provide real-time information about the status of a production line. The massive quantity of data, or big data, that these sensors generate is then stored on a server, usually in a cloud on a closed internal network. Using cloud computing, algorithms organize and analyze the data depending on the application. Once analyzed, the data and the corresponding analysis reports are sent to an interface for operator interpretation. These interfaces are most often displays located on machinery or applications available to operators on portable devices. In some cases, however, these interfaces can be as simple as series of lights used to indicate machine status. Regardless of the display method, the combination of IoT, big data, cloud computing, and advanced analytics allows data to be gathered, stored, transferred, and analyzed. In this way, data management technologies work together in manufacturing lines to produce information usable by operators and engineers (Burke, et al., 2017).

2.2.2 - Cyber-physical systems

Another major facet of Industry 4.0 is the digitization of processes traditionally performed by humans. We classified automation, advanced robotics, augmented reality (AR), drones, and additive manufacturing as cyber-physical systems, as all of these technologies make traditional processes more autonomous,

Among many key features, cyber-physical systems produce precise, repeatable work that may be difficult or dangerous for humans to replicate. Unlike autonomous systems and robotics of the past, however, cyber-physical systems use artificial intelligence and other data management technologies to optimize their performances. The incorporation of data collection and analysis technology allows machines to function based on real-time conditions. This ability to behave “intelligently” with minimal human input ultimately reduces production variance and increases production efficiency. Overall, the application of data management technologies to autonomous systems creates a robotic network that enables robot-robot and robot-human collaboration. Ultimately, such cohesion creates a safer and more efficient work environment (Rodriguez, et al., 2018).

Some cyber-physical systems, such as AR, drones, and additive manufacturing, still require human interaction. Despite this distinction, these technologies fall underneath the Industry 4.0 definition due to their digitization of processes. Among many potential applications, AR and drones allow operators to gather otherwise unattainable information about entities or locations. Additionally, AR allows companies to train employees off-site or assist in maintenance and quality control. Meanwhile, additive manufacturing, colloquially known as 3D printing, performs inexpensive and rapid prototyping and product customization. Each of the three technologies either produces or utilizes vast amounts of data which can be digitized and analyzed. Consequently, these technologies' incorporation of data management qualifies them as Industry 4.0 technologies (Rodriguez, et al., 2018).

2.2.3 - Technology and Business

Societal and political forces drive the modern business towards: (1) short product development time, (2) flexible product development, (3) decentralized internal hierarchy, and (4) resource efficiency (Baur & Wee, 2015). In order to measure these objectives and the other elements of manufacturing, companies use Key Performance Indicators (KPIs) (Cai, et al., 2009). Quantifiable measures used to evaluate the performance of a company over time, KPIs may include production rate, return on investment (ROI) or overall equipment effectiveness (OEE).[8] Across industry, companies do not have a standardized approach to using KPIs. As such, companies prioritize the monitoring of different KPIs. In order to adequately monitor KPIs, companies need to both acquire and analyze high volumes of data. With the use of cyber-physical and data management technologies, however, monitoring these parameters and creating plans for growth is possible (Cai, et al., 2009).

According to Baur and Wee, companies in the manufacturing industry who wish to stay competitive must appropriately pursue new and innovative practices. Among the many practices companies can pursue, one of the most notable is Industry 4.0. Through initiatives, incubators, and accelerators, Denmark is promoting the spread of Industry 4.0 (Baur & Wee, 2015).

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[8] Overall Equipment Effectiveness (OEE) is a tool for the manufacturing process that measures quality, availability, and performance. Appropriate weighting of these three parameters creates an OEE grade which is used to measure equipment productivity.

2.3 - Copenhagen School of Entrepreneurship

Among the several Danish academic organizations that run startup accelerator programs, one prominent organization is the Copenhagen School of Entrepreneurship (CSE). Sponsored by the Copenhagen Business School (CBS), CSE operates with the goal to teach aspiring entrepreneurs business logistics and effective marketing skills to help them find their path to success (“CSE,” 2017). To fulfill this goal, the Copenhagen School of Entrepreneurship runs programs to help entrepreneurs with innovative ideas apply these ideas in a professional, effective manner. The main program offered by CSE is the Go Grow Startup Accelerator Programme (GGSAP). Within GGSAP is a specific cluster working group, the Digital Growth Path (DGP), as visualized in Figure 4.

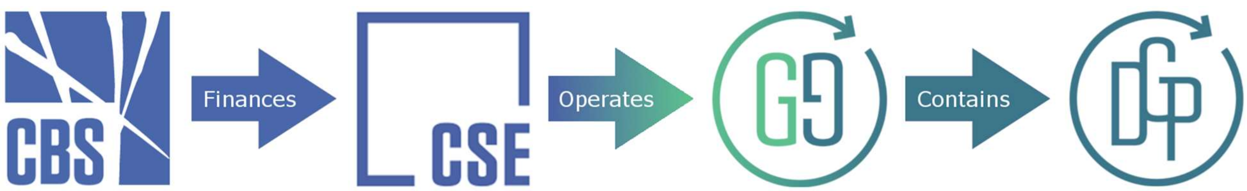

Figure 4: Program hierarchy for Digital Growth Path (Adapted from “Digital Growth Path”, 2017)

The GGSAP focuses on early stage startups that have concrete ideas and strong teams but lack business expertise. The DGP, meanwhile, focuses exclusively on companies involved with the creation of disruptive Industry 4.0 technologies (“Go Grow,” 2017; “Digital Growth Path,” 2017).[9]

2.3.1 - Go Grow Startup Accelerator Programme

Participants in this experience-based program often have technically viable ideas, but lack the business expertise to market themselves. For this reason, the program promotes educational workshops and pairs startups with business mentors to teach young entrepreneurs about the logistics of running a business (“Go Grow,” 2017). Startup companies and entrepreneurs from all sectors and markets may apply to be a part of this diverse peer network group. GGSAP offers business mentorship, corporate partnership, sponsored products and services, access to investors, and free participation to its participants (“Go Grow,” 2017).

The first feature of GGSAP is its mentors: senior executives who can provide participants with strategic overviews of their businesses and give sector-specific expertise. In general, the

[9] As described by our sponsor contact, Claus Birkedal, a disruptive technology is one that is so innovative that it could change the current infrastructure of the sector to which it pertains. These technologies are the focus of the DGP, because if successfully promoted they could positively impact Danish business and thus the Danish economy. The DGP focuses on cutting edge ideas due to their attractiveness to investors.

program mentors are the key drivers in leading participants down profitable paths ("Go Grow," 2017).

The second feature of GGSAP is its corporate partnerships. With these partnerships, participants can visit successful companies to receive hands-on experience in the corporate world. Highlighting Denmark's culture of community support, the corporate partnership feature is an opportunity for program participants to learn and network.

The third feature of GGSAP is its access to sponsored products and services, including but not limited to analytics tools, project management platforms, and market services ("Go Grow," 2017). Additionally, GGSAP provides participants with many areas of support, such as access to CBS academic scholars, intellectual property and legal advice, and marketing advice. The program also offers an alumni and peer-to-peer network. One of the fundamental purposes of GGSAP is its use of shared spaces, fostering a community and allowing participating company founders to help each other.

The fourth feature of GGSAP is its access to angel investors and venture capitalists. After months of pitch rehearsal, the program ends with a Demo Day where program participants can pitch their businesses to these investors ("Go Grow," 2017). As before noted, investment rates are low in Denmark. Among many reasons, Claus Birkedal, director of the Digital Growth Path, notes that investors have a hard time finding startups in which they want to invest. Through GGSAP, however, investors can attend the Demo Day and hear pitches from startups. Thus, the Demo Day can benefit both startups and investors alike.

At the end of this program, participants are embedded in GGSAP's peer network. Continuing to benefit from the program's features as alumni, participation in GGSAP develops business models and creates marketing skills ("Go Grow," 2017).

2.3.2 - Digital Growth Path

An innovative group within GGSAP is the Digital Growth Path (DGP), an acceleration path for companies using or developing Industry 4.0 technologies. With six participating companies in the most recently graduated class, this program serves to help Industry 4.0 participants with "understanding the scope, scale, and challenges of digital transformation within Industry 4.0" ("Digital Growth Path," 2017). To accomplish said goal, the program offers workshops, company visits, and guest speakers tailored for the participants. Additionally, it focuses on future digital trends, leadership skills, and case studies. Mentors in the program, having worked with Denmark's Digital Growth Strategy, enlighten participants to work toward the advancement of Denmark's industrial sector. Ultimately, the Digital Growth Path creates a peer working space, where Industry 4.0 startups and entrepreneurs can innovate together (“Digital Growth Path,” 2017). According to MADE, programs like DGP will help Denmark expand past the expectations of a small country with a largely SME based economy (Larosse, 2017).

2.4 - Summary

Denmark’s economy is likely to undergo dramatic structural change. Facing both domestic and international challenges due to economic stagnation and increased global competition, Denmark’s Government aims to promote its industrial sector. As a whole, Denmark’s industrial sector largely consists of limited resource Small and Medium Enterprises. Often financially inflexible but pressured to adapt, SMEs commonly struggle to advance with the new technological revolution: Industry 4.0. Aware of the spark that SMEs need to initiate change, Denmark seeks to integrate many of its available Danish resources, including its public, private, government, and academic institutions. Providing resources to SMEs in need, one specific program is the Digital Growth Path provided by the Go Grow Startup Accelerator Programme. Wishing to partner with companies that can implement Industry 4.0 technologies, the DGP aspires to promote industrial expansion and total economic success. In our attempt to aid the DGP in its search for partners, we pursued a methodology that helped us achieve our project goal: to identify attributes that indicate a company’s readiness to adopt Industry 4.0 technologies.

3.0 - Methodology

The goal of this project was to identify attributes that indicate a company's readiness to adopt Industry 4.0 technologies. Having identified these specific attributes, we created an assessment tool indicating a company's readiness for Industry 4.0 implementation. While performing our research, we also discovered companies that met the parameters for participation in the Digital Growth Path.[10] Consequently, we created a deliverable list of all of these companies to deliver to our sponsor contact, Claus Birkedal. In order to achieve our primary project goal and create our deliverable list of recommendations, we developed a strategic methodology. The steps included: identify SMEs developing or utilizing Industry 4.0 technologies; determine the applications and effectiveness of digitization from Industry 4.0 producers; discover the characteristics of companies implementing Industry 4.0 successfully; and establish the underlying commonalities between those successful companies.

3.1 - Identify SMEs Involved with Industry 4.0 Technologies

Before searching for companies, we worked with our sponsor contact, Claus Birkedal, to determine the criteria that make a company a good candidate for the Digital Growth Path (DGP). As defined by Claus Birkedal, a company suited for participation in the Digital Growth Path fit the following criteria: (1) was founded in or after 2008; (2) has an annual revenue under 10 million DKK (roughly 2 million USD); (3) employs no more than 30 people; and (4) is involved with Industry 4.0 technologies in any capacity. As our research continued, we added more restrictions to our list of criteria, but this list provided us a starting point on which to base our company searches.

For this portion of the methodology, we primarily focused on Industry 4.0 research. In an attempt to familiarize ourselves with Industry 4.0 and its effects on business, we reviewed scholarly literature and company websites. Additionally, while performing our research, we occasionally discovered companies that would be appropriate to recommend for the Digital Growth Path. As such, we remained conscious of companies within the requirements for the Digital Growth Path, even when our priorities were elsewhere.

[10] The parameters will be discussed in the following section.

3.1.1 - Map companies developing Industry 4.0 technologies

As previously stated, we first determined companies developing I40 technologies to educate ourselves more on Industry 4.0. By familiarizing ourselves with Industry 4.0 companies and more importantly, their products, we learned a lot about the applications of I40 technologies. As our project's end goal emphasized Industry 4.0 within SMEs, we primarily focused on mapping companies that fell within the aforementioned parameters. Following these parameters, we learned about Industry 4.0 from the perspective of SMEs, while also increasing our chances of locating potential DGP participants. However, as we prioritized our research for this portion of the project, we occasionally deviated from the parameters. More focused on company products as opposed to operational logistics, like company size and revenue, we were less strict on Claus' parameters for this portion of the project. Overall from our research, we gathered a well-rounded understanding of the effects of Industry 4.0 products on business.

In order to find companies that develop Industry 4.0 technologies, we used the resources provided to us by the Copenhagen School of Entrepreneurship (CSE): Orbis, a worldwide company database, Navne & Numre Erhverv, a Danish company database, and Kompass, an industrial database. In addition to these resources, our sponsor informed us of several industry conferences that take place annually in Denmark. One conference of particular interest was the Hi Industri conference. The exhibitor list from last year's Hi Industri conference contained over 600 attending companies. Of these companies, most were located outside Denmark or were seemingly unaffiliated with Industry 4.0 technologies.[11]

Using the three databases from CSE, we cross-referenced each of these identified companies with our databases to determine more specific company characteristics (revenue, size, year of incorporation, etc.). As previously stated, although our parameters were less restrictive for this information gathering process, we still prioritized companies that fell within our restrictions. Our final list contained 132 companies that met our loose parameters (Appendix A).[12]

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[11] Admittedly, our process for determining a company's affiliation with Industry 4.0 was not extensive. Our searches mostly consisted of visiting the company's webpage. Companies we selected had one or more of the following components on their webpage: a physical discussion of Industry 4.0; a physical discussion of a specific Industry 4.0 technology; a physical discussion of their specific sub-sector, which was a good target market for Industry 4.0 optimization. Although the initial round of inspection may have mistakenly eliminated potentially qualified companies, our narrowed list still consisted of a satisfactory number of eligible companies.

[12] Some companies were used that do not reflect the parameter requirements. These companies, despite being too old, prosperous or big, provided detailed information that could help us discern future companies that could be successful with Industry 4.0 implementation.

3.1.2 - Map companies utilizing Industry 4.0 technologies

In order to validate our research, we wanted to gain another perspective. Up until this point, our data came from scholarly articles and research on the producers of Industry 4.0 technologies. Aware of this potential bias, we researched the users of Industry 4.0 technologies to give us more broadened insight.

Throughout the duration of our project, Claus Birkedal occasionally provided us with companies implementing I40 technologies. To supplement these references, we performed research of our own. In order to identify companies using Industry 4.0 technologies, we used the same databases as previously mentioned (Orbis, Navne & Numre Erhverv, Kompass). Unfortunately, the databases did not provide us with enough detailed information to determine whether or not potential companies actually used Industry 4.0 technologies. As a result, we developed a new method for locating Industry 4.0 users.

Having already identified Industry 4.0 producers, we utilized their data to locate users. On many company websites, Industry 4.0 producers listed some of their partners and clientele. Thus, these identified companies provided us with a fairly extensive list of Industry 4.0 users. This method was not consistent from company to company; however, it provided us with a foundation on which to base our future research. To supplement this strategy, we also used our interviews as a means of identifying Industry 4.0 users.[13] As we interviewed many representatives of Industry 4.0 producers, we had numerous resources to expand our list of Industry 4.0 users.

Overall, we struggled much more in mapping Industry 4.0 users than we did in mapping Industry 4.0 producers. In part, this may be due to marketing. As a whole, companies seem far more likely to advertise their product rather than advertise the methods they used to create such a product. Using such logic, we had greater ease locating Industry 4.0 producers than Industry 4.0 users. Unquestionably, we made mistakes of our own. Primarily, we should have placed a bigger distinction between Industry 4.0 producers and Industry 4.0 users earlier in the project. For much of our research, we did not take into account the different perspectives that users and creators would have. As such, we lost pivotal time that could have been used to create a more strategic approach for locating I40 users.[14]

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[13] Company interviews will be discussed in a later section of the methodology. For this portion of the paper, none of the specifics of the interviews need to be made known to the reader.

[14] The same criteria as used in mapping companies producing I40 technology were used in the mapping of I40 consumers. Due to the increased difficulty in locating these companies, however, we were less restrictive on the criteria.

3.1.3 - Establish connections with companies

Until this point, we had gathered our research via scholarly reports and internet research. As such, we emphasized the need to expand our research and record "less scripted" perspectives. In order to gather this primary source information, we began to schedule interviews with representatives of companies both creating and using Industry 4.0 technologies.

From our originally narrowed list of 132 companies, we had determined that some companies fit our criteria more than others. As time was our biggest obstacle and it would be improbable to interview representatives from 132 companies, we narrowed the list down to 44 (This list grew throughout the project. The final total of contacted companies was 60, Appendix D).[15] We based our selection of companies on our own opinions of their relevance to our project. Aware that this method had bias, we selected these companies based on how well they fit into the DGP criteria and how connected they seemed to Industry 4.0.

In order to mitigate our unintentional bias, we had Claus Birkedal review the list. As he provided more business insight and familiarity with Industry 4.0, we greatly appreciated his insight on the matter. In addition to gaining Mr. Birkedal's insight, we also needed his approval before formally contacting companies. Although we only wished to interview representatives of these companies to learn more about Industry 4.0, our sponsor wanted to ensure that we did not interfere with any potential DGP partnerships. Of those companies for which Mr. Birkedal particularly sought for participation in the Digital Growth Path, Mr. Birkedal told us to withhold contact until further notice.[16]

Having provided several companies of interest to CSE, we contacted representatives of the remaining companies on our list via email. Given the concise timeline of our project, we tried to schedule interviews as quickly as possible. In order to increase the chances of scheduling interviews for the near future, we carefully chose the content and recipients of our emails. In regard to our content, we used very concise, descriptive language to describe our project and its goals (Appendix C). In an effort to better our chances of conducting an interview, we also leveraged the Copenhagen School of Entrepreneurship's name. In regard to the email recipient, we did not standardize our process; the recipient could be anyone in a management position. Using our sponsor for advice, we normally emailed the CEO or founder(s) of the company when contacting startups. For larger companies, especially those with multiple locations, however, the

[15] As either a user or producer, these companies were much more related to Industry 4.0 technology than the others. The selection process was often aided by the company websites, which commonly made reference to Industry 4.0.

[16] Companies of interest (both participants and partners) were first contacted by our sponsor contact Claus Birkedal. His granting us approval to later contact the companies was dependent on the success of his initial contact.

selection process was much more circumstantial. Usually, we tried to email a high-ranking engineer or technician located in the closest branch. For most other instances, we either had to contact the generic company email or a personal contact provided to us by Claus Birkedal. In the end, nineteen companies were willing to have a representative interview with us. More specifically, fourteen of these companies were I40 producers and five of these companies were I40 consumers.[17]

3.2 - Determine the Applications and Effectiveness of Digitization from Industry 4.0 Producers

We interviewed representatives from companies producing Industry 4.0 technologies in order to understand its applications and impacts from primary sources. Providing us advanced insight on both I40 technologies and their effects on business, this knowledge helped us achieve our project goal: to identify attributes that indicate a company's readiness to adopt Industry 4.0 technologies.

3.2.1 - Acquire product attributes and statements from company representatives

From our list of contacted companies (Appendix D), we interviewed seventeen representatives from the fourteen companies that develop Industry 4.0 products (refer to Appendix F for more information on each company). Of the companies whose representatives we interviewed, twelve developed data management products and two developed cyber-physical products (refer to Appendix F). As opposed to our scholarly research performed prior to this point, interviews gave us legitimate, primary source case studies. Aware of the importance of these interviews, we carefully phrased our questions. Using the expertise of CSE representatives, we designed our questions to mainly elicit responses pertaining to: (1) the application of the company's product; (2) the cost of the product; (3) the benefits of the product as reported by the company's clients, (4) specific company clients, and (5) the obstacles of product implementation (see Appendix H).[18]

When creating our questions, we made sure that our content was both clear and concise. Aware that these companies were providing us a great service with no financial upside for them,

[17] Admittedly, we interviewed far more Industry 4.0 producers than we did Industry 4.0 users. This imbalance is addressed later in the report.
[18] Asking interviewees for company clients allowed us to locate Industry 4.0 users. These data were incredibly valuable given the difficulty of locating I40 users with our databases.

we emphasized the need to keep the questions structured and prioritized. Keeping these points of emphasis in mind, we planned our interviews to last approximately 30 minutes.

In order to comply with CSE requirements and the WPI IRB standards for human subjects, we created a non-disclosure agreement (NDA) for every interviewee. This written agreement made clear to the interviewee three points: (1) it asked for consent in our data recording methods; (2) it communicated our project goals, and (3) it informed the interviewee of his or her ability to have us disregard and destroy any and all information from the interview at his or her discretion. For interviews via Skype or phone, we emailed the NDA via an online form to the interviewee (Appendix G). Stated by both WPI and CSE, ethics are an integral part of every research project. As such, this NDA provided the interviewees with full reassurance of our professionalism before interviews commenced.

While performing our interviews, one of our biggest concerns was the potential improper recording of data. In an attempt to mitigate uncertainties or miscommunication with the interviewees, we recorded the interviews using a smartphone audio recording app. For interviewees unwilling to provide audio recording consent, we alternatively took notes reflecting the conversation as accurately as possible.[19] This method, however, was not ideal as note-taking often involves a lot of interpretation. Aware that we might misinterpret the context of our data regardless of our data collection method, we also regularly repeated viewpoints made by the interviewee to verify the accuracy of our interpretation. This means of clarification helped us prevent ambiguity from clouding our line of questioning.

While we took precautions to mitigate our own bias during our retrieval of information, workplace bias may have skewed our data. Interviewed employees may have appeared to share the opinion of their superiors, however, they may have hidden their actual opinions as they were unfavorable or out of line with their company's mission. The fact that we were working with SMEs may have intensified such an issue, as their small size increases employee-superior interaction. In our attempt to avoid workplace bias, we provided the interviewee full control over what data, if any, we could use. Ultimately, as a final precaution, we also destroyed all interview data after the conclusion of the project. We clearly wrote these points in our aforementioned NDA.

Aside from consent and bias in interview data, we did not have other major ethical concerns. To avoid leading or incentivizing the interviewee, we restrained from reacting to any answers that we might have found interesting or unexpected. Ultimately, we did not experience any difficulty with this concern though, as the line of questioning carried limited social or cultural

[19] Fortunately, all interviewees provided consent to record the interviews. Despite this, at least one team member took notes during every interview to track the key topics addressed by the interviewee.

implications. We focused the conversation on digital technology that assists business operation, and with this professional mentality, we had no ethical concerns.

3.2.2 - Determine applications and effectiveness of products

We performed these interviews to collect data that could help us determine the applications and effectiveness of Industry 4.0 products. With such data, we subsequently aspired to create an Industry 4.0 readiness assessment tool. As we performed several weeks of data collection, we continually updated and modified the assessment tool. In the end, our analysis of Industry 4.0 producers emphasized three main pillars: Financial and Legal Concerns, Technical Concerns, and Cultural and Societal Concerns.

Before conducting our first interview, we had already assumed that financial and legal concerns would be important considerations in the implementation of Industry 4.0. Verified by our interviews and scholarly research data, the financial and legal aspect of implementing Industry 4.0 is very important. Consequently, our analysis of our interviews placed a specific emphasis on all financial and legal data.

When analyzing our data, we looked for common themes. Particularly interested in the physical cost of implementation of the company's product and the financial standing of their clientele (annual revenue, capital, etc.), we searched for data reflecting the ease of product implementation. With respect to legal concerns, we took a similar approach. Highlighting common themes cited by our interviewees, we also paid particular attention to legal risk.

In regard to our technical concerns, we had a less structured data analysis. Because common technical concerns vary from technology to technology, we had difficulty creating a standardized approach. As a result, we had to rely on our own judgment with the help of CSE representatives. Similar to our approach with the financial and legal concerns, we looked for common themes among our interviews. We particularly sought data reflecting a company's existing infrastructure and the ease of implementation of the I40 product.

Our final pillar was cultural and societal concerns. Prior to our interviews, we had not acknowledged a need for this pillar. From the data we collected in our interviews, however, this pillar became very important. Similar to our methods for the other two pillars, we searched for common themes among our interviews with respect to Industry 4.0's cultural and societal aspects. Some examples of these common themes were a fear of hacking and a desire to collaborate across industry.

Ultimately, this method of analyzing our data varied over time. Prior to accumulating data from many interviews, we did not know what data to seek. At that time, we had valuable information, but without an adequate number of case studies to which to compare our data, we were left with speculations and questions. As we continued to perform more interviews though, our points of emphasis became more specific. Ultimately with our data, we created three concrete pillars, each with increasingly common themes found throughout our interviews.

Admittedly, this method of analysis lacked structure. An unstandardized and biased approach, we based our method of analysis on themes we perceived to be common amongst our interviews. Alternatively though, we saw no other way of performing such analysis. We ultimately created an assessment tool from our own perspective. We used a plethora of scholarly resources to make our tool and analyses more valid; however, inevitably, our perspective will not be universally perceived as correct. As such, we can only make our assessment tool as realistic as the data presented to us allows.[20]

3.3 - Evaluate Characteristics of Companies Using Industry 4.0

To supplement our data from companies producing Industry 4.0 technologies, we also analyzed the characteristics of companies already using Industry 4.0 technologies. From our interviews with representatives from these companies, we collected data identifying the benefits, costs, obstacles, and overall effectiveness of I40 implementation. These data ultimately helped us determine the business attributes necessary for the successful implementation of Industry 4.0 technologies in companies.

3.3.1 - Verify opinions about digitization from Industry 4.0 technology users

Using the company list generated by the methods outlined in section 3.1.2, we interviewed five representatives from companies using Industry 4.0 technologies.[21] Of these companies, one only used cyber-physical systems, one only used data management, and three used both categories of technologies (Appendix I contains the list and brief description of these companies. Appendix J contains the interview question script for these companies). With the help of CSE, we designed the question sets to elicit responses pertaining to the company's characteristics, such as their technological infrastructure, and the benefits and drawbacks of Industry 4.0 technologies observed by the company.

[20] The assessment tool can be found in section 3.4.1.
[21] As first stated in section 3.1.2, these companies were often found via the interviews we performed in section 3.2.

Finally, we followed the same interview procedure as discussed in section 3.2.1 to mitigate bias and miscommunication. Additionally, we utilized the same non-disclosure agreement (NDA) as in section 3.2.1 (see Appendix G).

3.3.2 - Determine the attributes needed for digitization

We followed the same process as in section 3.2.2 to determine the attributes needed for digitization within a SME. Similar to our analysis for data acquired from the producers, we regularly updated this process throughout the project. As such, its lack of structure indicates the same concerns as aforementioned.

One additional concern with this analysis, however, is the sample size. As addressed in section 3.1.2, we had much more difficulty mapping companies that use Industry 4.0 technologies than those who create Industry 4.0 technologies. A theme that carried over to our interviews, our sample size of representatives interviewed from I40 users was significantly smaller than that of I40 producers. Consequently, such sampling bias created legitimate concerns regarding the accuracy of our data. Although we tried to address this lack of perspective by performing more scholarly research, the sampling bias still created a gap in our research. Using the perspective of Industry 4.0 users, we wanted to clarify any potentially questionable remarks made by Industry 4.0 creators. Unfortunately, our lack of depth in primary source data made it difficult to validate any concerns.

Admittedly, as addressed in section 3.1.2, we should have done more to locate Industry 4.0 users earlier in the project. A pivotal component in our research not distinguished early enough, Industry 4.0 users did not receive appropriate consideration as a result of our limited time and the difficulty of the project.

3.4 - Determine a Method of Assessing Industry 4.0 Readiness in Companies

Using the analysis of our interviews from sections 3.2.1 and 3.3.1, we created an Industry 4.0 readiness assessment tool. Emphasizing three main pillars (Financial and Legal Concerns, Technical Concerns, and Cultural and Societal Concerns) as described in section 3.2.2, our assessment tool helps provide insight into a company's readiness to implement I40 technology. Ultimately, we submitted this tool, along with our list of potential DGP participants, recommendations, and our attribute list, to our sponsor as our deliverables.

3.4.1 - Creation of an Industry 4.0 Readiness Assessment Tool

Using the data collected from our interviews, we created an Industry 4.0 Readiness Assessment Tool. The tool has three different categories, each of which we found to be vitally important in the implementation of Industry 4.0 technology. The three categories are: (1) Financial and Legal Concerns; (2) Technical Concerns; and (3) Cultural and Societal Concerns.

We created this customizable assessment tool to help companies determine their individual readiness for Industry 4.0 implementation. The tool does not account for all Industry 4.0 related indicators; however, it emphasizes the indicators that we found most important. Naturally, bias may have influenced the chosen indicators for the tool, but we tried to mitigate such bias with scholarly research. From our perspective, this tool has two potential uses.

The first is to use it as a tool for self-assessment. The first time companies use this tool, they may have trouble selecting answers. As the tool is only a rating scale from one to four, companies might struggle to determine which specific value best reflects their position. After performing their first readiness assessment, companies can resume normal operations. At a future time, companies can then return to the tool and use it again. With this technique, the company can determine their progression in Industry 4.0 implementation over time. Specifically, they can determine whether or not the steps they took in between uses of the tool benefitted their pursuit of Industry 4.0.

The second use is for business experts, such as those at the Copenhagen School of Entrepreneurship. By using their specialized business insight, experts can apply tangible metrics to the rating scale. As a result, business experts, such as those at the DGP, can customize the assessment tool to help DGP participants locate potential clientele.

As previously mentioned, the base version of the readiness assessment tool does not provide concrete values. With this lack of specificity, companies and business experts can customize the tool to better represent their parameters and restrictions. Additionally, companies can give certain parameters or categories (i.e. Financial and Legal, Technical, Societal and Cultural) specific weights. As a whole, the readiness assessment tool can provide companies Industry 4.0 guidance, however, in order to maximize its potential it must also be customized.

In conclusion, this tool does not provide answers. Instead, it helps companies evaluate their readiness for implementing Industry 4.0 technologies. As Industry 4.0 technologies continually optimize and adapt, this tool provides companies a means to monitor their continuously changing progress.

3.4.2 - How to use the tool

As seen in Appendix K, the assessment tool consists of three separate readiness tables. The three tables are Financial and Legal Readiness, Technical Readiness, and Cultural and Societal Readiness. Each table has a list of indicators describing parameters of interest within each assessment category. On a rating scale of one to four, the user of the tool indicates his or her perception as to his or her company's score with respect to each parameter. After addressing each parameter, the user finds his or her average score for that table. After performing this process on each of the three tables, the user has the company averages with respect to each of the three categories. With these three averages, the user can then find a total Industry 4.0 readiness average based on the respective weights given to each category. Ultimately, for more elaborate descriptions of each parameter refer to Appendix K.[22]

3.4.3 - Inspiration of the tool

During our research, we encountered several Industry 4.0 Readiness Assessment tools that helped inspire the creation of our tool. Commonly created by universities and consultancies, we found Industry 4.0 readiness assessments made by entities such as the University of Warwick and PricewaterhouseCoopers. Each tool had its own distinguishing features, however, they commonly had multiple weighted categories and rating scale scoring. Consequently, we modeled our assessment tool so that it possessed these two qualities.

Although each assessment tool provided us valued insight, we had particular interest in the University of Warwick tool. Working in collaboration with Crimson&Co, a global management consultancy, and Pinsent Masons, an international law firm, the University of Warwick created a self-assessment tool that companies can use to monitor their Industry 4.0 readiness.

The tool consisted of 6 “core” dimensions. These dimensions were: (1) products and services; (2) manufacturing and operations; (3) strategy and organization; (4) supply chain; (5) business model; (6) and legal considerations. Each “core” dimension began with a brief description of the specific dimension. After the description, the tool showed a readiness table for the specific dimension. Each dimension then had a list of sub-dimensions to further categorize a company's readiness for Industry 4.0. In the products and services dimension for example, the table had a sub-dimension for product customization. To score the sub-dimension, the table used a rating scale with four options. The levels ranged from beginner to intermediate to experienced to expert. As a company progresses through the levels, the company becomes better suited to

[22] This version of the tool has equal weights on all parameters. However, the tool can be customized based on the user's expertise.

handle Industry 4.0. For each level, the tool had loose restrictions. For example, a beginner level of product customization reads as the following: “Product allows for no individualization, standardized mass production.” Ultimately, each level had its own restrictions.

After the table, each “core” dimension discussed some of the tangible metrics found amongst the 53 companies the University of Warwick interviewed. Following, these values helped them create a baseline readiness level using the average value from each sub-dimension. These data were then reflected on a radar graph to help visualize the company’s readiness. Finally after each radar graph, the report quickly discussed ways in which the dimension could be improved.

The entire report contained six iterations of this outline. With modeled data for each “core” dimension, the report culminated with a total readiness average. Illustrated with a radar graph, this overall readiness helps company management determine the company’s weaknesses in implementing Industry 4.0.

The 37 sub-dimensions used in the report were very helpful when creating our own assessment tool. Although we had created many of the sub-dimensions prior to discovering this tool, its similarities with our existing parameters gave us confidence that we were creating a reasonable tool. Additionally, the use of radar charts and the rating scale were particularly inspiring to us.

Overall, our assessment tool is the product of our own research. Although it shares commonalities with many tools, these tools were strictly used for inspiration and clarification. In regard to sub-dimensions, there is overlap in parameters between all of the tools. This overlap, however, has to do with the general themes regarding Industry 4.0 that are prevalent in all business. Our tool may not ultimately be as precise as that of PricewaterhouseCoopers, however, it fully indicates the points of emphasis found within our research.

The bibliography contains the citations for each assessment tool used as inspiration.[23]

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PricewaterhouseCoopers. (2015). *Industry 4.0 - Self Assessment*. Retrieved from https://i40-self-assessment.pwc.de/i40/landing/

3.5 - Summary

Following the methods outlined in this chapter, we primarily collected and analyzed data acquired from scholarly research and interviews. With this data, we created a list of SME attributes that positively affect the implementation of Industry 4.0 technologies. Having identified these attributes, we created a deliverable assessment tool that helps measure a company's readiness for Industry 4.0 innovation. While following our methods, we also located companies that appropriately fit the parameters for participation in the Digital Growth Path. Ultimately, we delivered a complete list of these companies to our sponsor contact, Claus Birkedal. Overall, our methods gave us the structure to satisfy our project goal, while also giving us the flexibility to provide our sponsor with useful deliverables.

4.0 - Findings and Analysis

We begin this chapter with a section in which we analyze the data gathered from our interviews. The first two findings relate to interviews with representatives of companies producing or using data management technology. The third finding relates to interviews with representatives of companies producing or using cyber-physical technology. After examining the applications and benefits of I40 technologies, we discuss the obstacles impeding the implementation of Industry 4.0. In conclusion, we finish with an acknowledgement of our research limitations.[24] Ultimately, we used this work to make recommendations for successful Industry 4.0 implementation.[25]

4.1 - Analysis of Industry 4.0 technologies

From our interviews with representatives of companies producing or using Industry 4.0 technologies, we generated the following findings.

Finding 1: Coordinated data management technologies improve business operations.

As mentioned in section 2.2.1, our first category of Industry 4.0 technologies is data management technology. This category includes the Internet of Things (IoT), big data management, cloud computing, artificial intelligence (AI), machine learning, and machine vision. Data management technology revolves around the collection and manipulation of data. Our sponsor contact, Claus Birkedal, describes data management technology as “technology [that] analyzes large amounts of data that humans would not otherwise be able to handle” (Personal Communication, April 10, 2018).

As discussed in section 2.3.1, companies observe Key Performance Indicators (KPIs) to gauge their success. Although specific KPIs vary from company to company, monitoring them usually requires a large amount of data consumption and computation. Consequently, companies often rely on data management technologies to collect, process, and analyze large amounts of data.

From our research and interviews, most of the data management technologies about which we learned affected different KPIs. As a result, we struggled to compare individual products. For example, Blackbird’s product, Factbird, measures and improves production in terms

[24] These findings are subject to bias, sampling size, and other research limitations which we discuss at the end of the chapter.
[25] Refer to Appendix L for a table describing the companies from which we interviewed representatives and their respective technologies.

of machine availability, while Aqubiq's product, DripView, measures and improves production based on decreased water usage. As these parameters vary based on the I40 producer's target market, we struggled to keep all data management technologies together. Aware of this lack of uniformity with our indicators, we subsequently created Table 1 to provide a means of collecting all performance-driven parameters together.

Table 1: Performance of data management products in term of target KPI[26]

Company	Key Performance Indicator	Value
Aqubiq	Water Consumption	Decrease by 15%
Blackbird	Machine Availability	Increase by 10-15%
Emplate	Customer Traffic	Increase by 7%
E-Shoptimizer	Data Comparison Speed[27]	Increase by 85-90%
FreeSense	Batch Variance	Decrease by couple percent[28]
Haarslev	Labor Costs, Parts Costs	Decrease by 15%, Decrease by 40%
Hexastate	Costs	Decrease by 5-40%
Inniti	Volumetric Capabilities Labor Costs	Increase by 300% Decrease by 70%
Novo Nordisk[29]	Performance	Increase by 10%
Operator Systems	Overall Equipment Effectiveness (OEE) and Availability	Increase by 5%
OptiPeople	Machine Availability	Increase by 10-15%

[26] FrontIoT and MM Technology did not disclose any product operation values.
[27] Data comparison speed measures the variation in speed between a human and a computer in performing online price matching (Jonathan, Personal Interview, March 22, 2018).
[28] FreeSense has not performed enough tests to determine accurate levels of improvement in batch variance. These values are predictions based on normal batch variations and the potential of their product (Niels Jensen, Personal Communication, April 12, 2018).
[29] Novo Nordisk uses many data management technologies, one being Factbird by Blackbird (Morten Lungren, Personal Interview, April 17, 2018).

Table 1 shows specialized metrics reflective of each company's respective areas of focus. Despite the clear variation in the measured indicators, the values show that these data management solutions improve business operations.

It is significant to note that Table 1 consists mostly of companies producing Industry 4.0 technologies. As these companies create and sell a product, they may have made exaggerated claims as to the effectiveness of their devices. Thus, in order to verify the legitimacy of their claims, we included data from users in Table 1 as well. From Haarslev and Novo Nordisk, we helped verify some of the speculation as to the effectiveness of data management technologies. Specifically, as Novo Nordisk is a client of Blackbird, we compared Blackbird's statistics with Novo Nordisk's and found the values to be quite similar. This comparison was a good example, however, our analysis was imperfect. As we did not pursue a sufficient number of companies using the technology, we had less authority in asserting the benefits of data management technologies.

The key to success for the companies listed in Table 1 is their use of data. As their devices collect more data and companies seek further optimization, I40 product usefulness continues to increase. Finn Hunneche of Blackbird summarized the importance of data intelligence as: "In the fourth industrial revolution, it's not steam, but it's information that is the catalyst in the process. So whoever is able to add information to the processes will outcompete the other ones" (personal communication, April 4, 2018). This growing trend to have readily available data has two major benefits: (1) continuous, real-time monitoring of data and (2) historical data analysis.

Real-time data monitoring allows operators to view machine operating parameters without delay. By providing immediate access to machine data, real-time data monitoring decreases the need for human operators to constantly monitor machines. Prior to the installation of smart sensors, machine monitoring was only effective if there was an operator reading the data. Capable of providing real-time data and analysis, smart sensors now allow operators to allocate their time better. These sensors collect statistics such as environmental conditions, energy usage, and equipment performance in real-time and allow operators to access this information from any location. Creating an environment with increased transparency to help determine product quality, bottlenecks, and other key production features, the presence of real-time data allows operators to work more efficiently and productively (Lee & Lee, 2015; Hercko et al., 2015).[30]

[30] Transcom conferences are international gatherings organized by the University of Zilina in Slovakia to discuss technological matters. At the Transcom 2015 conference, Hercko et al. (2015) reported that

Historical data analysis is the other major benefit of Industry 4.0 data management technologies. By tracking and storing historical data, companies can monitor progression or regression over time. A tool often accompanied by machine learning, statistical process control (SPC), or some other analytical algorithm, historical data analysis enables operators to perform tasks like predictive maintenance. This ability to predict failure ultimately reduces machine downtime, which, according to Anders Meister from CIM.AS, is "the most costly problem in the industry; if you cannot produce, you cannot sell anything" (personal communication, April 12, 2018).

Asger Damtoft from Hexastate, a company producing predictive maintenance devices and software, claimed that the application of such products can reduce maintenance costs by up to 50 percent (personal communication, March 22, 2018). Mads Mikkelsen from MM Technology additionally reported that the analysis of historical data gathered from their device allows operators to predict machine failures in advance (personal communication, April 6, 2018). Independent reports support such claims; in *An Introduction to Predictive Maintenance*, R. Keith Mobley reports that predictive maintenance decreases unexpected machine failures by 55 percent and average time to repair by 60 percent (Mobley, 2002).

Furthermore, Microsoft presents a case study, performed in conjunction with Tetra Pak that demonstrates more of the benefits of data management technologies. In 2016, packaging giant Tetra Pak began an Industry 4.0 trial period with Microsoft. For Tetra Pak, Microsoft created a tailored IoT, big data, and cloud solution. Following the creation, Tetra Pak implemented the solution in eleven of their clients' production lines. Over a six month period, the clients claim that each line saved up to 48 hours in machine downtime, equal to DDK ~220,000 (USD ~37,000). As such, there is evidence to suggest that predictive maintenance enhances productivity and saves time and money (Mclennan, 2017).

Finding 2: Data gathering and filtering solutions are easier to implement than many people think.

According to Finn Hunneche, CEO of Blackbird, the public commonly perceives the notion that increasingly complex technology coincides with increasingly difficult product implementation. Specifically, Mr. Hunneche describes this perception as the following: "[The public] think[s] that … technology becomes more and more complicated … and then they conclude right away that it has to be very difficult and very expensive" (personal communication, April 4, 2018). Mr. Hunneche's

implementing data management technologies increases transparency in manufacturing by tracking performance and output.

statement, although a single interpretation and a generalization of the public, was a perception found throughout our research. According to producers of I40 technologies though, their products are easy to install and use; so easy that they call them Plug and Play.[31]

Blackbird is an example of a company that has adopted the Plug and Play label. In the description for installing their product, Factbird, they write: “Plug and play - Factbird can be installed in less than one hour on a production line. Installation only requires an AC power outlet and a connected sensor” (Blackbird, Website, 2018). Indicative of a simple installation procedure, Aqubiq, FrontIoT, and MM Technology also label their products as Plug and Play solutions (Peter Nørtoft, Personal Communication, April 5, 2018; Charlotte Grønvold, Personal Communication, April 9, 2018; Mads Mikkelsen, Personal Communication, April 6, 2018).[32]

In order to describe the installation times of each product more concisely, we created a table in Appendix M. As seen in the table, I40 users, often with the help of the producers, claim to install data management solutions within a few business days. In all, the data may not represent the entire data management technology sector, but the data do indicate the ease and swiftness with which companies can implement data management technologies.

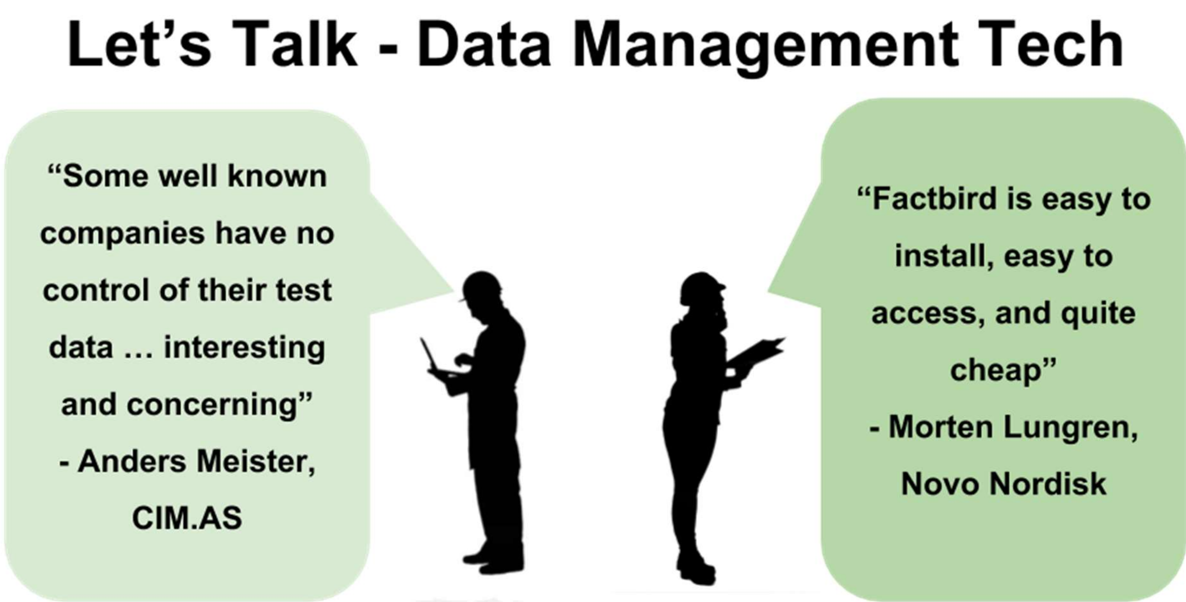

Figure 5: Let’s Talk - Data Management Tech (Adapted from: “Silhouette Young engineer woman,” n.d.; “Silhouette Attractive,” n.d.; Anders Meister, personal communication, April 12, 2018; Morten Lungren, personal communication, April 17, 2018).

[31] Producers of data management technologies are stakeholders. Thus, they carry bias when describing their products. This bias will be addressed later in the chapter.

[32] The description Plug and Play was either explicitly used by the company representative during our interview or was written on the company website.

Finding 3: Cyber-physical technologies expedite traditionally human performed processes.

The second category of Industry 4.0 technologies is cyber-physical systems. To reiterate, this section includes system automation, advanced robotics, augmented reality (AR), drones, and 3D printing. Cyber-physical technologies have a variety of applications and uses; however, companies implement these technologies all for the same reason: to expedite processes. As discussed in section 2.2.2, these technologies usually stand alone. Consequently, we discuss them individually in our analysis.

Automation allows operators to perform repetitive processes for extended periods of time without worrying about human induced error. Inniti, a startup working out of the Copenhagen School of Entrepreneurship, creates a solution for automating test benches for R&D and wet lab procedures. Specifically, their solution automates experiments and performs data collection, thereby decreasing human error and saving time. Malthe Muff, one of Inniti's three co-founders, claimed that Inniti's solution increases the volumetric capabilities of a test bench by 300 percent and saves 70 percent on labor costs (Malthe Muff, personal communication, April 5, 2018).[33][34]

A second example of system automation is Company B, an anonymous company creating semi-autonomous 3D printers. According to the interviewed representative of Company B, the additive manufacturing sector has yet to digitize fully and develop a "click and print" solution. Currently, additive manufacturing requires operators to be highly involved with the process, often refilling machines and continually checking on prints. Inspired by this technological gap, Company B works to automate some of the more tedious manual tasks associated with additive manufacturing. With their product, operators no longer need to replace resin continuously, exchange build planes, or store finished parts. The printer promotes unobstructed, non-stop operation, thus working 24/7 (Interviewee B, personal communication, [date redacted]).

Robotics were a core component of the third industrial revolution. With the application of data management technologies such as artificial intelligence and machine vision, now advanced robotics are part of Industry 4.0. At Haarslev Industries, operators use welding robots to assemble large machinery. Among their many benefits, these robots improve product quality and reduce labor costs by 15 percent. Advanced robotics also affect efficiency: working significantly faster

[33] Inniti has not yet brought their solution to market and has only tested it during its development stage. For this reason the benefits could only be backed up by the tests performed by Inniti in conjunction with their partner company.

[34] Building and monitoring experiments are tedious routine tasks for researchers. The employees using these products are PhDs or PhD candidate level employees. As such, their skill set could be better used doing less trivial tasks. To be clear, this product does not replace the job of a highly skilled employee, but frees up their time to do more cost effective work - thus reducing labor costs. Researchers have confirmed this opinion.

and with more precision than human personnel, the use of robotics for highly specialized, tedious tasks allows human personnel to be reallocated to other tasks. Paired with machine vision, Haarslev's robots can inspect 100 to 256 welding holes that must be held within very tight tolerances in assembling the product. Cost-effective and precise, David Coen claims, "no human could do what those robots do today." Mr. Coen claims that the implementation of advanced robotics in their production line has made Haarslev competitive with Chinese production prices (David Coen, personal communication, April 20, 2018). Søren Peter Johanson, the Technology Manager at Danish Technological Institute (DTI), discussed the use of mobile robots at Elos Medtech Vinol. Mr. Johanson states that their robots use raw data to find errors and execute predictive maintenance (Søren Peter Johanson, personal communication, April 16, 2018). This integration of data management and cyber-physical technologies advance the use of robotics in Industry 4.0.

Augmented Reality allows operators to superimpose computer generated images onto their view of a real-world environment. Tetra Pak, the aforementioned packaging company, uses Microsoft HoloLens to help global specialists perform maintenance tasks. Capable of overlaying digital projections to the user's physical surroundings, the HoloLens provides a convenient projection of real-time instructions. Among its many benefits, one of the true values of this technology lies in its influence in machine service. In the case of Tetra Pak, company engineers can communicate with servicing operators by means of the HoloLens. Using a "digital twin," augmented reality (AR) allows the engineer to see both the machine of interest and the on-site service member as he or she works to perform a maintenance task. Ultimately, the use of the Microsoft HoloLens reduces response time to downed machines and improves communication between engineer specialists and on-site service members (Mclennan, 2017).

Drones are typically small aircraft, piloted remotely by operators, used as a tool for humans to complete tasks too "dull, dirty, or dangerous" for humans (Tice, 1991). Employees at Dansk Drone Kompagni (DDK), a full-service inspection and surveying company, fly drones around specified customer locations and take photographs of areas of interest. Using their own software tool, DDK then organizes the images into an interactive map, known as a 'mosaic.' Hans Hansen of DDK stated that drones are a Plug and Play technology that require only batteries and a controlling device to use. Additionally, he noted that the operation speed of drones allows human workers to survey an area of interest very quickly, often within thirty minutes. Aside from expediting the speed of human surveyors, drones can also survey dangerous areas more cheaply, more quickly, and with higher quality than traditional methods like helicopter flyovers. Often used on flooded areas, swamps, construction sites, and chimneys, drones provide surveyors with the time to perform other tasks (Hans Hansen, personal communication, April 9, 2018).

Despite increased flexibility and speed, however, there are some drawbacks associated with drone technology. As stated by Hans Hansen, in Denmark, drones cannot legally fly above 120 meters or out of direct line of sight without the proper permits. In addition, the local government must also be notified 24 hours in advance of all flights. The capabilities of drone technology provide tremendous value to industry, but current legislation hinders some of the potential of drones (Hans Hansen, personal communication, April 9, 2018). This legislation, however, does have good reason for its existence. Drones can reach remote areas and take high quality images with little effort. For this reason, it is very important to have laws to protect the general public from invasion of privacy. Ultimately though, these potential misconducts have generated laws that add an additional barrier for companies that use drones.

3D Printing fulfills a niche in today's market; a growing pressure to combine individual customization with large production volume. A principle known as mass customization, the desire to satisfy individual needs on a large scale depends largely on flexibility and modularity (Interviewee B, personal communication, [date redacted]). 3D printing, more formally known as additive manufacturing, is a key to such flexibility and modularity. The process of building layer by layer, additive manufacturing creates more intricate designs in less time and with fewer resources than more traditional methods such as Computer Numerical Control (Brettel, et al., 2014).[35]

Damvig is a 3D printing service company that prints orders for clients in the private and industrial sectors. Using Damvig's services, small-scale orders and prototypes, which constitute 75 to 80 percent of Damvig's operations, usually have a turnaround time of one day. Due to the speed of 3D printing, this turnaround is significantly faster than traditional methods would allow. In addition to prototypes and small-scale orders though, Damvig also receives high-volume orders from large corporations, such as pharmaceutical companies. For these orders, Damvig prints and delivers batches of products on a bi-weekly basis, minimizing the need for large storage facilities.

Despite such potential to quickly satisfy customer needs, 3D printing does have flaws. According to Jesper Damvig of Damvig, 3D printers have poor data feedback systems and a lack of machine collaboration by means of IoT. Therefore, the additive manufacturing process currently cannot optimize fully (personal communication, April 11, 2018). Interviewee B from Company B further noted that 3D printing is primarily suited to augment other technologies, rather than be a standalone technology. While 3D printing is optimal for prototyping and small orders, the process

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[35] Computer Numerical Control (CNC) is a means of subtractive manufacturing. Instead of adding layers to create a part, CNC starts with a solid workpiece and removes material until the end product is produced.

is not cost effective for mass production. (Jesper Damvig, personal communication, April 11, 2018; Interviewee B, personal communication, [date redacted]).

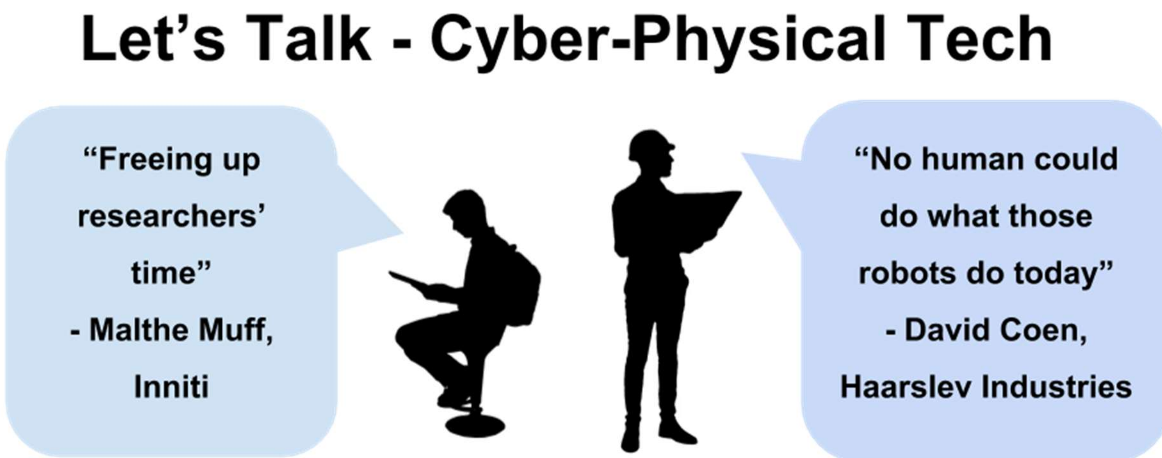

Figure 6: Let's Talk - Cyber-Physical Tech (Adapted from: "University student," n.d.; "Silhouette Young engineer in helmet," n.d.; Malthe Muff, personal communication, April 5, 2018; David Coen, personal communication, April 20, 2018).

4.2 - Industry 4.0 Obstacles

While identifying the applications of Industry 4.0 technology, we also discovered many obstacles to Industry 4.0 implementation. These obstacles form from legitimate concerns; however, this section uses our findings to help address misconceptions society may have about Industry 4.0. From our research, we regularly encountered data reflecting the lack of awareness that people have of Industry 4.0 and its implementation. Despite the frequency though, it was impossible for us to label this lack of awareness as a common perception among the public. The frequency with which we heard data reflecting the public's uncertainties of Industry 4.0, however, did indicate to us that the public was not optimally informed.

Finding 4: Utilization of Industry 4.0 technologies results in reallocation of personnel from unskilled to technically skilled labor.

A major concern among employees in companies implementing Industry 4.0 technologies is that technology will replace the workforce. Despite this fear, many of our interviewees do not believe Industry 4.0 technology will result in a decrease in the number of employees. Although this discussion varies on a case-by-case basis, these responses typically fell into two groups: (1) those that believe that current employees will stay and (2) those that believe that certain employees will be replaced with more skilled workers.

Asger Damtoft and Steffan Nielson from Hexastate asserted that their product is not a replacement for an employee, but rather a tool to increase the speed and efficiency at which the employee can work (personal communication, March 22, 2018). Additionally, Mr. Larsen from Operator Systems claimed that implementation of their software encourages increased human resource specification, wherein employees are reallocated to other priorities instead of being laid off (personal communication, March 27, 2018). In a similar sense, Mr. Muff from Inniti stated that implementation of their automation system allows PhD level employees to spend less time monitoring experiments and more time on other, more important, tasks (personal communication, April 5, 2018).

Ole Feddersen from Novo Nordisk, a user of many I40 technologies, agreed with Mr. Larsen and Mr. Muff. Specifically, Mr. Feddersen stated that digitization both allows operators to move to other tasks and enables new production lines to be opened. Mr. Feddersen expects Novo Nordisk's revenue to grow by 5 percent annually using such technologies. As a result, Mr. Feddersen claimed that management has no plans to lay off employees. Instead, Novo Nordisk would rather train operators and relocate them appropriately. Additionally, because Novo Nordisk uses fairly modern machinery and their operators already understand Industry 4.0, digitization for Novo Nordisk is an "evolution based on what [they] already have," according to Mr. Feddersen (personal communication, April 17, 2018).

Similar to Mr. Feddersen of Novo Nordisk, David Coen from Haarslev Industries stated that Haarslev reallocates workers displaced by new technologies. When Haarslev first adopted welding robots, the robots "displaced dozens of workers" according to Mr. Coen. This, however, provided Haarslev the opportunity to expand faster than they had in the past. Consequently, instead of releasing quality workers, Haarslev reallocated displaced employees to new positions to accommodate the new growth of Haarslev Industries (David Coen, personal communication, April 20, 2018).

Alternatively, some of our interviewees believed Industry 4.0 will cause layoffs; however, these layoffs will be balanced with additional hirings in other positions. As a whole, these interviewees believed that companies will release low skilled employees in favor of technically skilled workers. Hans Hansen of Dansk Drone Kompagni and Anders Meister of CIM.AS both believed that manual labor would be cut as a result of their products and services (Hans Hansen, personal communication, April 9, 2018; Anders Meister, personal communication, April 12, 2018). While on-the-ground surveyors are still important to land surveying, they are less necessary when paired with drone surveyors. Mr. Hansen believed that when drones become autonomous, the human pilots will be replaced with coders (personal communication, April 9, 2018).

A study performed by the Boston Consulting Group supports these assertions. In their survey of over 500 Danish manufacturers, over 90 percent of respondent companies did not expect a decrease in employment within their businesses and over 50 percent actually expected to hire more employees as a result of Industry 4.0. Furthermore, most companies expected skill demand to shift from manual processing to technical roles such as engineering. These results support many of our interviewees' claims that digitization leads to a reallocation of manpower instead of replacement.

This shift in skill set and increase in employment, however, may not result from reallocation of existing employees in most Danish companies. In the same Boston Consulting Group study, 62 percent of Danish companies expected to hire technically skilled employees, instead of expanding the skillsets of current employees.[36] This indicates that while employment might increase, technically skilled workers will replace low skilled employees (Colotla & Hoengaard, 2016). Mr. Feddersen and Mr. Coen both reported that employees expressed concern about their job security, suggesting that fears of replacement by machines are prevalent in industry (Ole Feddersen, personal communication, April 16, 2018; David Coen, personal communication, April 20,2018). Although Mr. Feddersen's and Mr. Coen's claimed that they would not replace employees, Mr. Coen claimed that this employee resistance was the most significant obstacle in implementing digitized technology.

Overall from these two perspectives, our data supports the prediction that Industry 4.0 will not decrease employment in Denmark. The difference between these perspectives, however, is that some data indicate job replacement, while other data indicate employee retraining. As a whole, our interviewees tended to believe that employee retraining would occur, while our scholarly literature tended to emphasize employee replacement. One possible reason for this inconsistency could be the current state of labor in Denmark. A study by Human Capital Analytics Group found that there is a growing shortage of technically skilled labor in Denmark. Involving 789 Børsen companies, and stated that scientists and engineers are the employees most needed, followed by IT and IT-related workers, and lastly skilled production workers (Human Capital Analytics Group, 2016).[37] This shortage in skilled technicians and engineers may encourage companies to retain and train current employees for operating new technologies. Ultimately

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[36] In comparison, the survey indicated that 25 percent of companies in the United States and 20 percent of companies in Germany will search for new hires instead of expanding the skillsets of existing employees (Colotla & Hoengaard, 2016).
[37] *Dagbladet Børsen* is a prestigious Danish economic newspaper, comparable to the *New York Times* and the *Wall Street Journal* of America.

though, while retraining benefits current employees, companies may have difficulty finding qualified personnel in the future, possibly leading to more industrial outsourcing.

Finding 5: Despite affordable options, time and resource constraints prevent companies from investing in digitization.

A major concern for companies considering Industry 4.0 technology is the cost and difficulty of the implementation process. Concerned that the complexity of the product will require extensive machine downtime and capital, companies regularly overlook more reasonable options. Furthermore, concerns regarding return-on-investment (ROI) prevent some companies from purchasing technologies.

Mr. Hunneche and Mr. Dannesboe, from Blackbird and OptiPeople respectively, both reported that their customers commonly think the implementation process will take several years (Finn Hunneche, personal communication, April 4, 2018; Kim Dannesboe, personal communication, April 3, 2018). However, many technology production companies claim that operators can install their data management solutions within a day with minimal to no machine downtime (see Finding 1). Typically, more of an addition rather than a replacement, the implementation of sensors and software connected via WiFi or cellular network to a cloud is fast and customizable.

One of the foremost concerns people have with implementation, despite the Plug and Play nature of data management technology, is the process of interconnecting the machinery in a production line. As companies have their own proprietary information, many believe that elaborate modifications must be made to customize the data management software for a company-specific platform. This fear is further exacerbated when companies utilize machinery from different producers that are incompatible with one another (Mads Mikkelsen, personal communication, April 6, 2018).

According to Dr. Christian Schröder, connecting machinery with differing protocols traditionally requires retrofitting the machines with automation software to achieve compatibility.[38] This process can be lengthy and expensive, cutting into production time and taking man hours away from other tasks. The lack of IT specialists among SMEs worsens this problem, as managers or other employees without appropriate experience or knowledge often must perform the digitizing processes (Schröder, 2016). To address these problems, which are especially prevalent in SMEs, companies such as MM Technology produce equipment that acts as a protocol translator and an intelligent data logger. By using products like those from MM

[38] Dr. Christian Schröder is head of Orrick's IP/IT & Data Privacy Practice Group in Düsseldorf

Technology, SMEs can benefit from digitization without having to retrofit their current machinery. Although the task seems daunting, the speed at which operators can implement digitized solutions is still far greater than companies imagine (Mads Mikkelsen, personal communication, April 6, 2018).

As discussed in section 2.1, financial constraints are also a major concern for companies, especially SMEs, seeking technological innovation. Out of the fourteen companies from which we interviewed representatives, seven charged DKK 100,000 (USD ~16,000) or more for the upfront cost alone. A high upfront cost, most SMEs would probably struggle to make such a payment. In addition to some high upfront costs, twelve companies implemented a subscription-based business model. Thus, the scheduled payments may make it difficult for companies to get a return-on-investment as quickly as desired. Due to these constraints, 67 percent of respondents to a study conducted by the Boston Consulting Group expressed a need for external funding before beginning investment in digitization (Colotla & Hoengaard, 2016).

The prevalence of expensive digitization services often deters companies from researching further into Industry 4.0 technologies. As a result, companies potentially disheartened by expensive products are often unaware of recent price drops that make digitization much more affordable. For example, a study done by Ericsson shows that the cost of Internet of Things sensors has decreased by almost 80 percent within the last decade (Ericsson, 2016).[39] We compared companies with similar solutions to understand the pricing market. One of the companies from which we interviewed representatives, Company D, claimed to cater towards SMEs with affordable prices; Company D charged only DKK 2,000 (USD ~300) per line and less than DKK 1,000 (USD ~160) per month as a subscription fee (Interviewee D, personal communication, [date redacted]).[40] In comparison to the companies charging over DKK 100,000 (USD ~16,000) for the installation fee alone though, Company D's product is much more affordable and can help a small company more easily transition to digitization.

Another theme we encountered in our interviews that offsets the financial investment required for digitization is the quick return-on-investment (ROI) that many companies achieve. Due to the steep prices of large Industry 4.0 products, companies with smaller production volumes are unlikely to make ROIs within a financially viable time period ("Industry 4.0: What is it," n.d.). However, as a result of companies producing data management technologies that cater to SMEs, SMEs can achieve ROIs in a financially manageable time period. Similarly, ROIs for cyber-

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[39] Ericsson is a Swedish multinational networking and telecommunications company

[40] Company D did not want to reveal their product pricing to the public, so while referred to by name in the rest of the paper, in this Finding there are referred to by a randomized letter.

physical systems impact their adoption. Sigurd Villumsen of Velux researched the placement of advanced robots on Velux's production line. He stated that the return on investment for an advanced robotic unit is five to seven years. Velux and other companies' management believe that a one to two-year ROI is more reasonable. Thus, advanced robotics implementation is often hindered by this financial situation (Sigurd Villumsen, personal communication, April 23, 2018). Meanwhile, Haarslev invested in several robots and AI technologies. Despite their steep prices of over DKK 350,000 (USD 60,000) each, David Coen claims that the ROI for the robots was under two years. Out of the nineteen companies, representatives from eight reported that they or their clients typically have ROIs of under two years. This finding agrees with a survey conducted by PricewaterhouseCooper, wherein over half of the companies expected ROIs of under two years after implementing Industry 4.0 technologies (Geissbauer, Vedso, & Schrauf, 2016).[41] Overall, Asger Damtoft argues that the main factor for the ROI of a product is the frequency that a product is used; commonly used devices will pay themselves more quickly than rarely used devices (personal communication, March 22, 2018).

Finding 6: Concerns with cybersecurity deter many companies from digitizing their processes.

A requirement for digitization, Industry 4.0 technologies connect to both each other and to the internet. While this makes data and process management easier, it also increases the fear of cyberattacks and hackings that may result in critical information leaks or unwanted process alterations. Technologies that constantly handle large volumes of information, such as Internet of Things and cloud storage, are especially subject to scrutiny. Finn Hunneche from Blackbird revealed that one of the biggest concerns potential customers voiced is data security (personal communication, April 4, 2018). Charlotte Groenvold from FrontIoT, an Internet of Things sensor production company, acknowledged the same concern (personal communication, April 9, 2018).

In a study of Industry 4.0 implementation published by Mieschke Hofmann und Partner, over 95 percent of the company responses indicated that data protection and security is becoming increasingly problematic with increased digitization.[42] Independent of company size, revenue, industry, and respondent's position in the company, these responses demonstrated that data security is a ubiquitous concern (Kelkar, Heger, & Dao, 2014). A study published by the Pierre Audoin Consultants further demonstrated the data security concern. In the report, 75 percent of

[41] PricewaterhouseCoopers is a multinational professional services company, focusing on assurance, tax, and advisory services. They are the second largest audit network in the world (CITE PWC).
[42] Mieschke Hofmann und Partner is a German IT and process consulting company for the automotive and manufacturing sectors

the interviewees cited data security as the major hindering factor in implementing cloud services. As a result, 40 percent of these companies did not utilize cloud computing (Freudenberg IT, 2014).

Many Industry 4.0 producers take steps to alleviate data security concerns. One of the more common methods is to utilize the cloud services of well known companies as a foundation for their cloud computation services. Cloud services from companies such as Google or Microsoft are extremely secure and constantly updated with new security measures (Malthe Muff, personal communication, April 5, 2018); according to Mr. Hunneche, companies commonly use these services in Europe (personal communication, April 4, 2018). Another method used by FrontIoT is the application of Sigfox for data transmission.[43] According to Ms. Groenvold of FrontIoT, the combination of Sigfox and the small CPUs in FrontIoT's product makes device hacking unfeasible. She did, however, note that the servers, where sensors send data, are a point of vulnerability, so therefore FrontIoT focuses their security measures on their servers (personal communication, April 9, 2018).

While it is unfortunately unfeasible to create a completely secure network, security measures can alleviate some of the fears involved with cybersecurity in Industry 4.0. For example, according to Henning Kagermann, incorporating security measures directly into Internet of Things and data management solutions from the outset makes these solutions Secure by Design.[44,45] For added security, these applications and other “smart” devices should be updated regularly with the most recent security measures (Kagermann, 2014). By taking steps to increase data security, lowering the risk of cyberattacks could reduce unease companies have with regards to digitization.

Finding 7: Many companies hesitate to change their business structure for digitization due to the experimental nature of Industry 4.0 technologies.

According to many of our company interviewees, one of the barriers preventing companies from adopting digitization is uncertainty about altering an existing infrastructure. While many of the production companies from which we interviewed representatives claimed to produce Plug and

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[43] Sigfox is a company that offers a data transmission service. Using low frequency radio waves for data transmission, SigFox sells bandwidth to its customers for a small fee. Sigfox is convenient because as long a Sigfox device is within their coverage areas, there is zero setup required to configure a device for data transmission.

[44] Henning Kagermann is a former chairman of the Executive Board and Chief Executive Officer of SAP SE, a multinational company that makes software to manage business operations

[45] Secure by Design is a computer engineering term that refers to software that has been designed from the ground up to be secure, instead of having security measures implemented as an add-on

Play digital solutions, other extensive digitization solutions often require elaborate modifications to utilize the new technology fully. Companies, especially those that are well established, are often reluctant to forgo a working business infrastructure for something radically different, especially with a new technology not thoroughly developed (Ericsson, 2016). Mr. Dannesboe from OptiPeople believes that people do not know enough about the benefits of implementing Industry 4.0 and that educating them would encourage the change needed to further digitize production (personal communication, April 3, 2018).

A study performed by Ericsson supports this finding. One of the reasons reported in the study was the reluctance to recreate a production line that took years to develop. The study also found that due to the recent inception of Industry 4.0, management can see investment in digitization as risky. Because there is little known data on successful Industry 4.0 business plans, decisions need to be based on concurrent data; such as from customer feedback, instead of past case studies (Ericsson, 2016). This situation may be partially due to the fact that many of the benefits of Industry 4.0 are not quantitative, such as increased flexibility and faster prototyping times. This results in a lack of convincing business cases, leaving many companies to prefer the "tried-and-true" business operation (Colotla & Hoengaard, 2016). Without a developed business case, investing in digitization is a "leap of faith", as described by Ole Feddersen of Novo Nordisk (personal communication, April 4, 2018).

Additionally, some company management personnel do not know how to utilize Industry technology in their business. Because there are so many types and applications of I40 tech, companies may need case studies or task force teams to find suitable uses for them. Ole Feddersen, Søren Peter Johansson, and David Coen expressed these concerns during their interviews in regards to their products (Ole Feddersen, personal communication, April 17, 2018; Søren Johansson, personal communication, April 16, 2018; David Coen, personal communication, April 20, 2018). Finn Hunneche, Ander Meister, and Niels Jensen also expressed these concerns when mentioning data usage (Finn Hunneche, personal communication, April 4, 2018; Anders Meister, personal communication, April 12, 2018; Niels Jensen, personal communication, April 12, 2018).

This pattern with new technology adoption has been seen before. *MIS Quarterly* published a research project by Karahanna, Straub, & Chervany (1999) written during the internet boom.[46] The goal of the project was to study the differences between pre-adoption and post-adoption attitudes and beliefs towards innovation. Karahanna et al. looked closely at the perceived

[46] *MIS Quarterly* is a peer reviewed information technology journal

attributes of an innovation that directly affect attitude and behavior. From their research they identified seven categories:

- Perceived Usefulness - degree to which the technology is perceived as better than previous options
- Image - degree to which the technology increases one's social image or status
- Compatibility - degree to which the technology is compatible with existing solutions
- Complexity - degree to which the technology is easy to operate
- Trialability - degree to which the technology is easy to experiment with before fully committing to the solution
- Visibility - degree to which the technology is visible in the organization (this relates to social image and status)
- Result Demonstrability - the degree to which the results of using the innovation are observable and communicable to others

Each of these categories is perceived, meaning they have no concrete support. Our experience with interviewing company representatives follows the same patterns observed by Karahanna et al. Regardless of the technological breakthroughs and industrial innovation, decisions within an organization are made by individuals with opinions. Opinions are an integral part of the decision-making process for an organization, especially those external to the organization considering the technology adoption (Karahanna et al., 1999).

According to a study by Lutz Sommer, the readiness of a company to implement Industry 4.0 is strongly dependent on the company's size, with larger companies likely more prepared.[47] Therefore, even with Industry 4.0 products that appear favorable for SMEs, smaller companies need to take extreme precautions before implementing revolutionary technology (Sommer, 2016).

[47] Lutz Sommer is an engineering and economics professor at Albstadt-Sigmaringen University of Applied Sciences

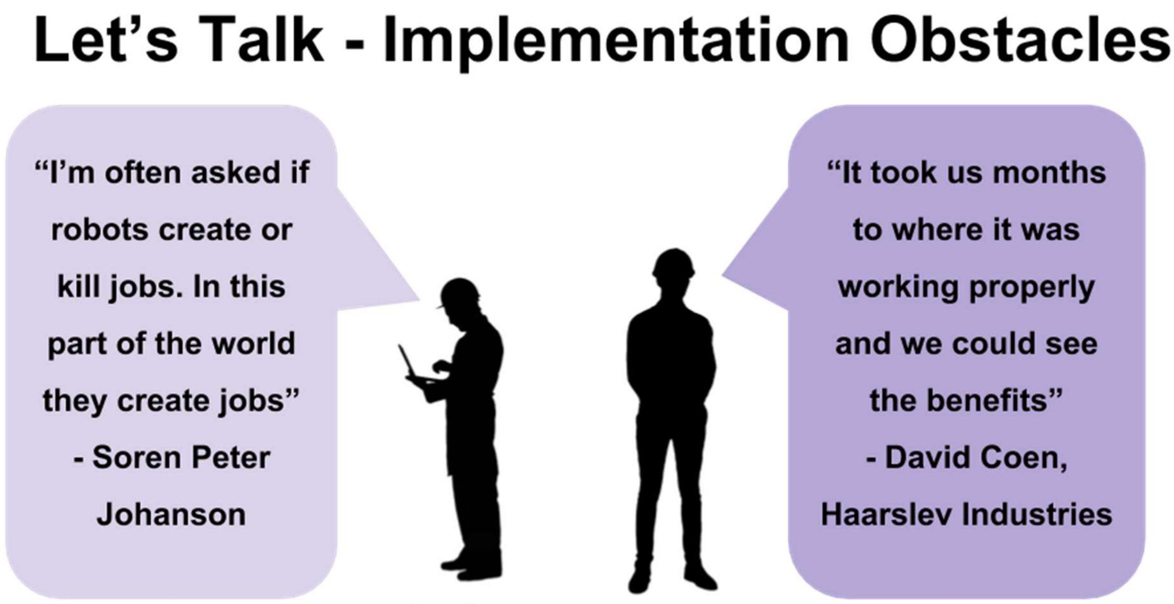

Figure 7: Let’s Talk - Implementation Obstacles (Adapted from: “Silhouette Attractive,” n.d.; “Silhouette Happy,” n.d.; Soren Johansen, personal communication, April 16, 2018; David Coen, personal communication, April 20, 2018).

These findings overall showed five majors attributes that are important in Industry 4.0 implementation. These attributes are adequate financial resources, adequate technological infrastructure and background, strong connection between management and manufacturing staff, solid understanding of the benefits of digitization, and the desire to innovate. In the recommendations, we will describe these attributes further.

4.3 - Research Limitations

One of the major limitations in our research was response bias from interviewed representatives. Representatives from companies producing Industry 4.0 technology may have tried to exaggerate the benefits or downplay the costs of their product. Representatives from companies utilizing Industry 4.0 technologies may have also exaggerated the effectiveness of digitization, especially because they did not always respond with numbers but rather subjective, personal opinions. Consequently, the information that we received during the interviews may not be completely accurate.

Another limitation for our project was sampling bias. Participation in our research study was voluntary, meaning only representatives of companies capable and interested in participating in our research responded to our outreach. As such, we often encountered companies turning down the opportunity to participate in an interview because they had more significant business priorities. Consequently, the information that we obtained during our interviews may not be an accurate representation of the Industry 4.0 sector as a whole, thus our data cannot be conclusive for all of Denmark.

Additionally, we interviewed mostly representatives from companies producing I40 technology, and only talked to 5 representatives from companies utilizing I40 technology. This adds to the sampling bias, for the producers may not have been able to provide a full perspective on the technology. From the producers, we learned a lot about their clients; however, we do not have enough data from the users' perspectives to validate the content provided by the producers. Consequently, we do not have a full analysis on the effects of implementing I40 technology into a business.

We also encountered sampling bias due to geographical location. Due to our time constraints and travel expenses, we favored interviewing representatives from companies in greater Copenhagen. We were generally able to conduct local interviews in person. Meanwhile, for most interviews outside our desired location, we conducted them via Skype or phone call. This variation in interview type also related to what kinds of companies we interviewed. As stated in section 2.1, a vast majority of manufacturing and industrial companies are located in Jutland while most technical companies are found in Zealand. Therefore, the number of Internet of Things or big data management companies was proportionally larger on Zealand than the number of robotic or other manufacturing companies. Consequently, the variety of interview types between the technologies was disproportionate.

During our company sampling, we may have also experienced some survivorship bias, a form of selection bias. Throughout this project, one of our major goals was to find attributes of companies that may increase the chance of successful Industry 4.0 implementation. In our research, we only interviewed representatives from companies currently in business, as opposed to companies that attempted to digitize their processes and failed. These companies would be useful in determining company traits that make Industry 4.0 implementation undesirable, but were nearly impossible to find. Consequently, we cannot definitively determine whether companies with failed Industry 4.0 implementation possessed our positive or negative attributes, rendering our attribute list possibly inconclusive.

5.0 - Conclusions and Recommendations

The final chapter reiterates and applies our findings. Having performed extensive analysis on the data received via interviews and literature research, we now apply those data to making our recommendations and addressing our project goal: identification of attributes that indicate a company's readiness to adopt Industry 4.0 technologies.

5.1 - Summary of Key Findings

This section begins with a reiteration of the findings discovered from the previous chapter. From our work, we identified the benefits and drawbacks of data management and cyber-physical technologies. Our data informed us that Industry 4.0 technologies improve business operations and expedite traditionally manual processes. Additionally, our data also helped us identify obstacles to the implementation of Industry 4.0 technology, most notably its societal and cultural effects.

Industry 4.0 technologies positively affect company performance

We first researched Industry 4.0 companies producing or using data management technologies. As defined by our sponsor contact, Claus Birkedal, data management technologies "analyze large amounts of data that humans would not otherwise be able to handle" (personal communication, April 10, 2018). Our research revealed that data management technologies improve business operations. Although target indicators vary from company to company, many digital companies use data management technologies to measure Key Performance Indicators (KPIs). From our literature research and interviews with representatives from companies producing and using I40 technologies, we found that implementing data management technology may not be as arduous as commonly believed. The results outlined in Appendix A help indicate that data gathering and filtering solutions are easier to implement than many people think.

Additionally, we learned that cyber-physical technology "reduces man hours spent on menial tasks and increases resource efficiency" (Claus Birkedal, Personal Communication, April 9, 2018). From interviews with automation technology producers and users, we concluded that automation and robotics free up skilled workers' time, thus improving time efficiency. Through literature research, we found that augmented reality (AR) can be used to improve communication in industry across the globe reducing response time and machine downtime (Mclennan, 2017). Inspection service companies revealed that drones help surveyors complete their work faster and more safely. Additionally, additive manufacturing producers and users showed that 3D printers increase the speed of prototyping and allow for greater product customization. Overall, our results showed that these specific tools expedite traditionally manual processes.

Cultural and societal externalities directly affect the implementation of Industry 4.0

While attempting to understand the aspects of industry that directly affect the implementation of Industry 4.0, we learned that there are many fears regarding these new technologies. We began to consider some of the obstacles and elements that impede Industry 4.0 innovation. Although impossible for us to conclude the public's perception on Industry 4.0, we frequently found from literature research and interviews — from representatives of I40 technology producer and user companies — that there is a lack of awareness around the subject. During our research, we found some of these fears to be security, employment, and cost concerns.

Our results showed that despite concerns, many producers and users of Industry 4.0 technologies do not see jobs being destroyed as a result of their products. Instead, these companies see Industry 4.0 technologies as tools for not only the employees of companies but the company as a whole. Our results showed that time and resource constraints prevent companies from investing in digitization despite affordable options. Company management are often skeptical to implement an unknown technological solution, assuming the time to implement and the cost of the product can be large. In addition to resource usage, management are often concerned with cybersecurity. While "connecting your machines to the internet" raises potential security concerns, our results showed that IoT solutions are more secure than companies' own servers. Many management personnel are skeptical about the benefits of digitization due to the new and experimental nature of Industry 4.0 technologies, and thus are hesitant to change their business structures. Our results suggest that once management realizes the benefits of Industry 4.0, this obstacle will be less difficult to overcome.

5.2 - Recommendations

With these findings, we created recommendations to help increase the adoption of Industry 4.0 technology across Denmark. Our deliverables to CSE are listed in Appendix O.

5.2.1 - Recommendations for the Digital Growth Path

Claus Birkedal, director of the Digital Growth Path, seeks innovative Industry 4.0 startups for participation in the Copenhagen School of Entrepreneurship acceleration program. We have created the following recommendations to help Mr. Birkedal and participants of the DGP determine what types of companies can successfully utilize Industry 4.0.

We recommend that companies interested in implementing Industry 4.0 be treated on a case-by-case basis.

Industry 4.0 is an umbrella term covering many technologies. As each technology has a vast number of applications and potential customizations, no two companies will utilize Industry 4.0 technologies in the same manner. Consequently, we recommend that each company of interest be studied in detail. The DGP should emphasize financial and technical parameters, but the DGP must also evaluate the characteristics of the company's management. To harvest all of the potential of Industry 4.0 technologies, company management must be patient with the technology and be open to learn. This technology works in collaboration with humans, thus to maximize its success, individuals must be dedicated as well. In the graphic below, we explain the stages of implementation for a business using I40 technologies. We recommend that the DGP management keep these obstacles in mind when educating participants of the DGP.

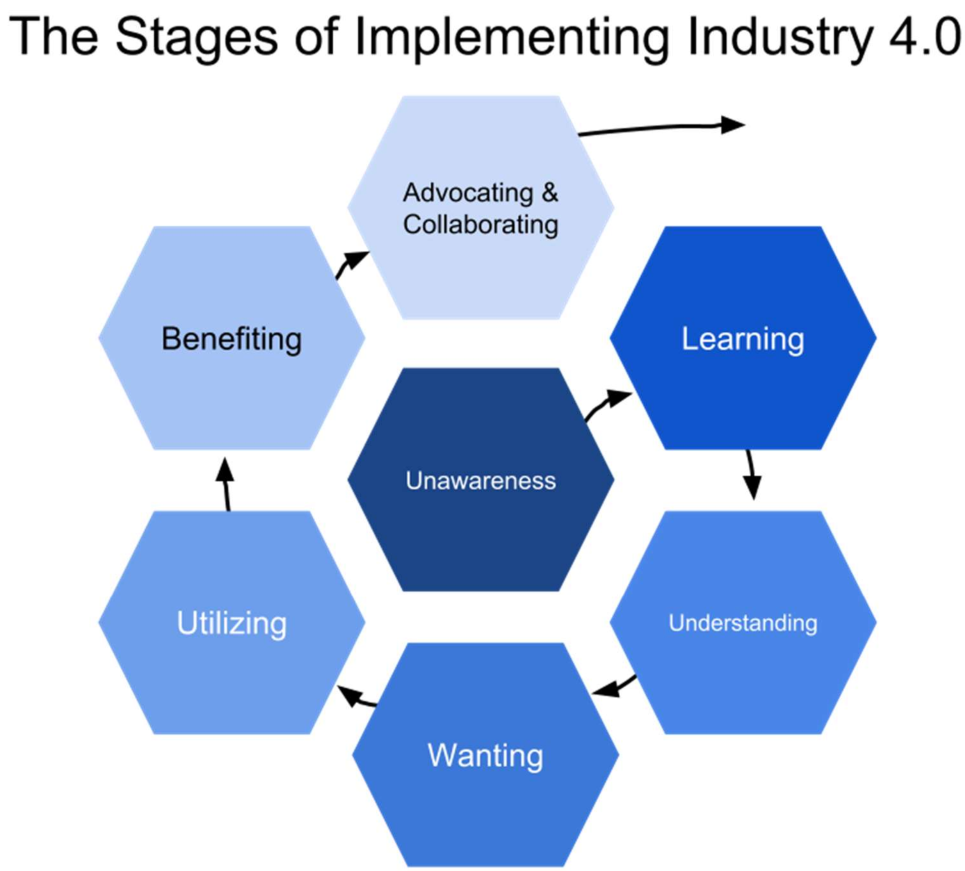

Figure 8: The stages of implementing Industry 4.0 in a business

Figure 8 above is a visual representation of the stages of implementation for a business. In each stage, business management needs to overcome obstacles before proceeding to the following stage. During the unawareness period, business management first need to hear about Industry 4.0. Next during the learning period, businesses need to take the initiative to learn about the technologies that constitute Industry 4.0 and their benefits. In the understanding period, the business individuals begin to understand how Industry 4.0 applies to them. For the wanting period, business management weighs the costs and benefits of innovation — they have to want to take risks and reap the benefits. Once a business has completed these four stages, they can begin to utilize Industry 4.0. In the next period, the business sees the benefits of Industry 4.0 in their company including increased productivity. Ultimately, this success leads to good publicity for Industry 4.0. In the final step, advocating for Industry 4.0 and collaboration with other companies allows Industry 4.0 to spread.

We recommend that companies exhibit five key attributes before attempting implementation of Industry 4.0 technologies

From our research and conversations with business professionals, we created a set of attributes, reflected in the assessment tool, that a company should possess to successfully implement Industry 4.0. We created this list of attributes to help participants of the DGP make more informed business decisions not only for their own operations, but also to identify potential clientele.

Despite our best efforts, we note that our list of attributes does not account for every company or every circumstance. Additionally, due to the biases associated with this form of research, we wish to clarify that the list of attributes is neither exclusive nor requisite. Thus, companies may exhibit different attributes or not have some attributes altogether, and still be well positioned to implement Industry 4.0 technologies. We discuss each attribute below in great detail: adequate financial resources, adequate technological infrastructure and background, strong connection between management and manufacturing staff, solid understanding of the benefits of digitization, and the desire to innovate.

Attribute 1: Adequate financial resources

In order for a company to take on an Industry 4.0 innovation it must have the ability to either purchase an existing solution or develop its own. No solutions are free of charge and all require some amount of time and resource allocation to configure. As available resources and necessities vary across companies, it is speculative to give concrete financial thresholds for companies. However, companies should prioritize the appropriate allocation of funds prior to investing in Industry 4.0 technology.

Attribute 2: Adequate technological infrastructure and expertise

Although many Industry 4.0 producers regularly describe their products as Plug and Play, there is an extensive learning process to optimizing an I40 system. As such, these complex, young technologies often require highly educated personnel not only to configure the systems but also to analyze and use the information gathered.[48]

Aside from requiring a strong technological background, companies best optimize I40 when it is integrated with a strong existing infrastructure. This is due to the fact that data management technologies producers often design their products to augment and interface with existing processes or devices. In manufacturing, for example, we found that IoT solutions can

[48] This was said by interviewees from CIM.AS, Blackbird, and Company B.

achieve predictive maintenance and determine overall equipment effectiveness on existing machinery. However, this application is very specific and applies to data management technologies, which focus on gathering data from an environment. For this reason, companies require an established technological infrastructure for many data management installments.

For cyber-physical installments, this is not necessarily the case; cyber-physical systems are the machinery. Because of this, implementing a highly complex and advanced device into a business requires machine operating skills and the ability to handle the new capabilities that come with the solution. For this reason, companies also will require technically skilled workers to interpret the information gathered by the machine.

Attribute 3: Strong connection between management and operator

Many companies have a hierarchy in their workforce; upper management and machine operators often do not communicate regularly. From our research with company producers and users, management and operators often see business from different perspectives. In Novo Nordisk, the acceptance of Industry 4.0 technologies by workers, as a positive addition to the company, was highly dependent on employee position. For data management technologies, the acquisition of large amounts of data can be daunting and overwhelming for someone in management. However, these new data might be incredibly helpful for a machine operator. Consequently, any lack of clarity and communication between members of the business hierarchy should be addressed. For Industry 4.0 technology to be most successfully implemented, transparency across the business hierarchy is pivotal.

Attribute 4: Solid understanding of the benefits of digitization

One attribute that we encountered while interviewing I40 producers is that companies whose managers already understand the benefits of digitalization are far more likely to implement Industry 4.0 solutions. In the case of data management technology, this attribute holds significant weight. Our research indicates that data management solutions are far less tangible than cyber-physical systems and, for this reason, it can be difficult for potential buyers to evaluate their effectiveness. BlackBird's CEO and the director of sales at OptiPeople echoed this point as well. According to interviewees from both companies, the implementation of their products in companies that already perform rudimentary data collection is more successful than companies that do not.

While this may not be the most important attribute, it does however increase the chances of a more successful implementation for many Industry 4.0 solutions. Successful implementations are ones that are completed in a timely fashion, yield positive results, and are well managed by the customer. The first two parts of a successfully implementation are straightforward; completion of the installation from the time of purchase to final installation and the yield of positive results are indicative of success. The third part, proper consumer management, is less obvious and highly solution specific. When a customer has a solid understanding of the technology and the benefits it can offer, he or she can then make the internal changes necessary to adequately receive the benefits of the new installation.

Attribute 5: Desire to innovate

Throughout our interviews we encountered interviewees stating that what truly hinders the implementation of I40 is not the technology, but rather the people behind the companies. Kim Dannesboe of OptiPeople stated that in his experience, introducing Industry 4.0 is more about the people implementing it, rather than the technology (personal communication, April 3, 2018). Finn Hunneche of BlackBird, Tommy Larsen of Operator Systems, Anders Meister of CIM, and Peter Nørtoft of Aqubiq all echoed this same concept as well, pointing out that people are the reason for a dampened I40 implementation and not the technology. As discussed in our findings, Karahanna et al. closely observed how perceptions of an innovation directly affect one's attitude and behavior regarding a new innovation even if they are misguided beliefs. Therefore, a strong desire to innovate positively influences the implementation of Industry 4.0 technologies.

5.2.2 - Recommendations for Encouraging Industry 4.0 Adoption in Denmark

In addition to the recommendations to the Copenhagen School of Entrepreneurship, we also have recommendations for Danish industry in general to expedite spreading Industry 4.0. These recommendations should be shared by CSE to their company participants and to the public through their actions and media.

We recommend that CSE encourages improving inter-company collaboration and communication.

Interviewees claimed that communication between companies is lacking and inter-company collaboration would improve Denmark's industry sector. Hans Hansen believes his company, and the business of drone services, would benefit from inter-company collaboration and communication. Xenia Obel of Aarhus University believes that Denmark needs "one ecosystem" within the industrial sector. According to her, SMEs will not stay competitive with larger corporations if they continue to work on their own. Open synergy between SMEs can help them stay competitive and share ideas. For example, Danish patents are expensive, and a young startup would not have the capital for one without taking out a loan. One ecosystem would spread risk and resources across many companies, together helping each other advance in business.

These ideas are shared by the CSE. Peer networking has always been a pillar for CSE and the Go Grow program; we recommend this ecosystem be nurtured, and remain an important part of the Digital Growth Path.

We recommend that CSE encourages increasing Denmark's emphasis on technical education for Danish students and manufacturing employees by reaching out to educational organizations, such as the Technical University of Denmark.

During our interviews and literature research, we noticed a shift in skill from manual to technical focus. However, as noted in the background and Finding 4, Denmark suffers from a lack of technically skilled workers. Jesper Damvig claimed there is a need for education on technology, supporting youth education, and in order to counteract a shortage of skilled labor and prepare for the future, educational institutions across Denmark should emphasize technical programs for students and current manufacturing employees. The programs for students would help companies find qualified employees out of school and help students find employment in areas where more manpower is needed.

Additionally, companies can start programs for educating their own employees. As discussed in Finding 4, Danish companies are more likely to find replacements for unqualified employees instead of educating current employees. The programs for current manufacturing employees would encourage companies to invest in training their current employees as an alternative to finding replacements. With emphasis on educating these two demographics, companies would not have shortages of skilled labor and existing employees would not have to worry about their job security.

5.2.3 - Recommendations for Future Research

In addition to the recommendations above, we recommend that CSE representatives continue our research on Industry 4.0 in Denmark and verify the results obtained from this project.

We recommend performing more interviews with representatives from companies that utilize digitized technologies and from companies involved with cyber-physical systems.

As explained in chapter 4.2, we believe our research was limited by a few constraints. We performed fewer interviews than desired with representatives from companies utilizing I40 technology, and the geographical constraints of Denmark and our time frame lowered the number of cyber-physical technology companies involved. Both of these company demographics are underrepresented in our research and therefore our analysis may not reflect them accurately. By conducting more interviews with representatives from these companies, another team could perform a more precise evaluation of these companies and validate previously gathered information.

Perform interviews with representatives from companies that considered digitization, but ultimately decided against it.

Interviews with representatives from these companies would provide valuable information about the obstacles faced by companies attempting to digitize their processes. They would also provide insight on the costs of Industry 4.0 technologies that outweigh benefits in the eyes of specific companies. Companies that develop this technology may not know the details about these obstacles, and companies that have successfully digitized their processes may not have run into these issues. Therefore, these interviews would shed light on the most significant challenges faced by certain companies and the attributes of the companies that prevented success. While these companies would be extremely difficult to find, it may be possible to get this information from Industry 4.0 producers by asking if they had any potential clients who pulled out of purchasing their solution or any former clients who no longer digitize their processes.

Determine possible methods of increasing awareness of Industry 4.0 benefits.

Throughout our interviews, we noticed that the overarching problem with Denmark's adoption of Industry 4.0 was the lack of awareness of Industry 4.0 technologies' benefits. In order to educate the public, future projects should investigate methods of spreading awareness. Whether awareness is spread in school curricula or through inter-company collaboration, there must be efforts made to inform the industrial community of Denmark.

5.3 - A Global Perspective: Technology and Society

Through our time in Denmark, we encountered many experiences that we did not anticipate. From these experiences, we learned several lessons that helped shape our project.

Be wary of your bias towards technology, especially after performing preliminary research.

When we researched Industry 4.0 technologies in preparation for our project, we quickly determined that the benefits of Industry 4.0 technologies far outweigh the costs. Therefore, we assumed that financial constraints were the primary reason for the lack of digitization in Danish companies. From our perspective, Small and Medium Enterprises were financially inflexible and comprised the overwhelming majority of the business population in Denmark. Thus, we believed Denmark's lack of digitization was primarily due to the inability of SMEs to adapt. However, once we began interviewing company representatives and researching from a different perspective, we quickly realized that there was more to Denmark's situation than just finances. Ultimately from our research, the true limiting factor in Denmark was not money, but knowledge.

Do not assume that you will find "the solution" you expected to a problem. The answer may come in a different form and there will probably be multiple correct solutions.

We thought there would be a clear yes or no answer to our big questions. In reality, our interviewees and research articles had a variety of opinions; the results could relate closely or contradict dramatically, making analysis difficult. Beginning the project, we believed we could get solid quantitative data on ROI, implementation time, pricing, and productivity. Our results, however, mostly came back qualitative. Thus, there is no one "solution" to a problem. In conclusion, although this finding directly relates to our project, it is a lifelong lesson.

Take advantage of sponsor resources for getting information or contact with potential interviewees.

One of our biggest concerns coming to Denmark was finding companies from which to interview representatives. In the United States, we found very few Danish companies appropriate for our project. Once we arrived in Denmark, however, Erik Sonne, the librarian, was extremely helpful. The databases Mr. Sonne provided were incredibly useful in allowing us to filter our search of Danish companies to those most appropriate. In addition to the databases, Claus Birkedal utilized his contacts with companies to help set up interviews and find company lists. With these two resources alone, we easily found over one hundred appropriate companies within the first week of starting the project. Ultimately, we recommend using all resources at your disposal.

Be aware that your project is not your sponsor's biggest priority. Be respectful of their time and wishes.

When performing an IQP project, students must acknowledge that their school work might differ from their work for their sponsor. As this balance of priorities will be essential in the business world, it is important to learn from this experience. Always be respectful to your superiors and do your best to satisfy their needs.

5.4 - Closing Notes

In conclusion, our report is an analysis of the current position of Industry 4.0 in Danish manufacturing companies. Within our work, we identified the obstacles to implementing Industry 4.0 and the attributes companies should have for successful technological innovation. Ultimately, we believe if we interviewed more companies utilizing these technologies, our analysis would be more representative.

Completing an Interactive Quality Project is not an easy task. It takes time, dedication, wisdom, and humility. We recommend those interested in Industry 4.0 to read this report with an open mind and acknowledge the potential bias obtained from our research. We understand our project is just the beginning of understanding Industry 4.0 and its role in Danish industry.

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Appendix A: Industry 4.0 Technologies

In this appendix we describe the major technologies encompassed under the umbrella of Industry 4.0 in more detail. The benefits and drawbacks as well as key points about the technology and their applications are discussed. This information is intended to be supplemental to the information in the report.

Section 1: 3D Printing
Section 2: Advanced Analytics
Section 3: Advanced Robotics
Section 4: Artificial Intelligence/ Machine Learning
Section 5: Augmented Reality
Section 6: Big Data
Section 7: Cloud Computing
Section 8: Drones
Section 9: Internet of Things
Section 10: Machine Vision

Section 1: 3D Printing

3D printing, also known as additive manufacturing, is the process of creating a three dimensional object from a digital file. Building the object ‘layer by layer’, 3D printing is a unique alternative to more traditional methods such as subtractive manufacturing. Although there are many forms of 3D printing, it usually begins with a 3D model created in a software program such as CAD (Computer Aided Design). From there, the file is sent to a slicer, which takes the file and cuts it horizontally into several hundred (can be more). The ‘slices’ are then sent to the printer and the object begins to form.

Two of the most common forms of 3D printing are FDM and SLA. FDM, or Fused Deposition Modeling, is one of the cheapest forms of 3D printing. It works by a process known as material extrusion, where a heated thermoplastic filament is sprayed out of a nozzle. The melted filament is placed ‘layer by layer’ by the nozzle which is programmed to move into the correct geometric coordinates. As the filament cools, it solidifies and creates a solid layer for further building. SLA, or Stereolithography, is a form of material curing known as vat polymerization. Using a vat of photopolymer resin, a point laser cures (solidifies) specific portions of the resin depending on the digital file. As each layer is created, the vat rises so as to allow the next layer of resin to be cured.

Benefits:

- Create complicated, intricate parts quickly
- Less waste
- Less material cost
- Rapid prototyping

Drawbacks:

- More of a supplementary technology than a standalone technology
- Currently only good for low volume production

Current Applications:

- Automotive industry
- Medical industry

Notes:

3D printers are a tool for companies that wish to prototype new designs and products as a proof of concept. They not only speed up the prototyping process but they also enable companies to do more in house development.

Section 2: Advanced Analytics

Advanced Analytics is the autonomous or semi-autonomous examination of data using sophisticated techniques and tools, typically beyond those of traditional business analytics, to discover deeper insights, make predictions, or generate recommendations. Advanced analytic techniques include: data/text mining, machine learning, pattern matching, forecasting, visualization, network and cluster analysis, graph analysis, simulation, and complex event processing.

While the traditional analytical tools that comprise basic business analytics examine historical data, tools for advanced analytics focus on forecasting future events and behaviors, enabling businesses to simulate new scenarios to predict the effects of potential changes.

Benefits:

- High volume data analysis provides answers
- Predictive maintenance
- Predicting consumer habits

Drawbacks:

- Overwhelming volumes of data
- Requires other technologies and resources

Current Applications:

- Banking industry
- Discrete Manufacturing industry

Our Take:

Advanced analytics are a great tool for companies to operate intelligently and make strategic decisions for the future. Companies that already collect large amounts of data can benefit the most from applying advanced analytics to the collected data. Doing so allows them to simulate new scenarios and predict events like machine failures as well as outcomes of possible changes.

Section 3: Advanced Robotics

Advanced robotics in an Industry 4.0 setting take two forms: collaborative robotics and fully autonomous robots. Collaborative robots physically interact with humans in a shared workspace. These devices make complex tasks easier for workers to complete as well as increase the efficiency of their work. Designed to work with people these devices greatly improve the industrial workplace. In contrast, fully autonomous advanced robotics are machines that act autonomously, that interact physically with people or their environment, and that are capable of making decisions based on sensor data. Prior to advanced robotics assembly line robots were not very intelligent devices, they could only complete one task and no more, now I40 autonomous robots make changes based on sensor data and they are aware of people in their environment.

Benefits:
- Highly precise
- Fast production rate
- Continuous operation

Drawbacks:
- Cost
- Fear of hacking
- Fear of unemployment
- Increase in skills gap
- Safety concern of working with robots

Current Applications:
- Automotive industry
- Pharmaceutical industry
- Retail industry

Our Take:

Advanced robotics enable production companies to do more complicated tasks opening up the opportunity for the creation of new and better products. In addition these devices increase safety within a production facility by taking over potentially dangerous tasks like heavy lifting and welding. Overall, companies that focus on manufacturing benefit the most from applying advanced robotics.

Section 4: Artificial Intelligence/Machine Learning

Artificial intelligence is the theory and development of computer systems capable of performing tasks that would otherwise require human intelligence. Visual perception, speech recognition, decision-making, and translation between languages are some examples artificial intelligence. In an Industry 4.0 setting, artificial intelligence enables manufacturing systems to intelligently respond to their environment. What makes artificially intelligent systems so revolutionary is their ability to remember outcomes from previous decisions and modify future actions to improve their abilities. As opposed to hard-coded systems, AI systems learn by example to optimize performance.

Benefits:

- Require little input
- Automatically optimize performance

Drawbacks:

- Skepticism from people
- Legal concerns
- Ethical concerns

Current Applications:

- Discrete Manufacturing

Our Take:

Artificial intelligence has many applications in an industrial setting however there is a large amount of fear surrounding the concept. At the root of the technology there is decision making programmed in by a designer and this coupled with security concerns created fear about the technology. As development and awareness of AI increases, applications will increase and skepticism may be replaced with a more complete understanding.

Section 5: Augmented Reality

Augmented Reality (AR) is a technology that superimposes images on a users environment. That is to say that AR alters one's perception of a real world environment. Through sensory stimulation AR allows for users to more easily visualize concepts and ideas before creation.

Benefits:

- Fast visualization of ideas and concepts

Drawbacks:

- Requires a large number of sensors and computing power

Current Applications:

Our Take:

Augmented Reality in an industrial setting allows for companies to communicate information internally between operators and engineers. Engineers can use Augmented Reality technology to superimpose a machine that an operator is working on to help workers make better decisions fasters.

Section 6: Big Data

Big data is the handling of large volumes of complex data that traditional data-processing methods are not adequate for. Big Data encompasses the collection, transfer, storage, and analysis of these data. Sensors on assembly lines, environment condition sensors, and imaging from manufacturing lines are just some of the many sensors that collect data in Industry today. With the addition of many new sensors in industry, engineers can apply Big Data practices to adequately handle and understand the vast quantity of data collected.

Benefits:

- Highly capable
- Suitable for many applications

Drawbacks:

- Requires configuration
- Can be difficult to understand

Current Applications:

- Pharmaceutical Industry
- Automotive Industry
- Food industry

Our Take:

Using Big Data companies achieve more than previously imagined by analyzing data. Big Data requires data collection and for this reason integrates well in businesses that collect large amounts of data. One of the major benefits of Big Data in the manufacturing industry is the ability to predict machine failures before they happen. By intelligently analyzing data collected from machinery abnormal conditions can be detected enabling businesses to act before a failure occurs.

Section 7: Cloud Computing

Cloud Computing is the concept of outsourcing computing from local devices to a more powerful remote device. When there are many devices collecting data, it becomes very costly to enable all of those devices to do computations on that data. Cloud Computing solves this problem by enabling many inexpensive sensors to only collect and transfer data which computations are then performed using another more powerful device. To summarize, using a cloud of inexpensive devices and more powerful computers, Cloud Computing makes collecting data from multiple locations and doing computations on that data cheaper and simpler.

Benefits:

- Inexpensive way of computing on collected data

Drawbacks:

- Configuring many separate devices is complex

Current Applications:

- Research and Development

Our Take:

Cloud computing enables companies to pool resources (i.e. inexpensive sensor systems and powerful computers) and increase their computational power with little modification to the data collection systems. This concept integrates well with Big Data and Advanced Analytics due to the large amount of data as well as the computational power available.

Section 8: Drones

Drones as discussed in this report are devices that produce thrust, typically using propellers, enabling the device to fly stably. These devices are fitted with cameras, radios, and Global Positioning System (GPS) allowing for image and data collection from locations that were previously inaccessible. For this reason drones are used by surveying and inspection companies to quickly take photographs for further analysis.

Benefits:
- Quick data acquisition
- Previously unattainable data

Drawbacks:
- Require skill to operate
- Expensive to replace
- Legal restrictions

Current Applications:
- Surveying Companies
- Inspection Companies

Our Take:

Drones fitted with cameras and GPSs make quality control and maintenance tasks on large equipment like power lines, wind turbines, and cell phone towers much easier and quicker. Using drones, operators inspect the point of interest prior to sending workers out saving time and increasing accuracy.

Section 9: Internet of Things

Internet of things (IoT) is the concept of connecting many inexpensive devices with little computational power to each other, facilities, fleets and people, effectively creating an internet of devices or *things*. The main focus of IoT is data collection using sensors connected to the internet. This technology has developed significantly in industry and, in the case of manufacturing companies, is used to monitor and collect data on processes.

Benefits:

- Sensors are relatively expensive
- Require no human input to operate

Drawbacks:

- Fears of Hacking
- Somewhat difficult to determine good use applications

Current Applications:

- Automotive Industry
- Aircraft industry

Our Take:

In an industrial future-focused application IoT requires more than just data collection. Applying advanced analytics and using Big Data practices make this technology meaningful and for this reason there tends to be confusion regarding the benefits of the IoT. As a standalone concept IoT encompasses the data collection, only once analytics and Big Data practices are applied does it become significant.

Section 10: Machine Vision

Machine Vision is the idea of fitting machinery with optical sensors and analytical software so that machinery can gather information from their environment. These sensors take images and, using image processing, these machines can collect information like serial numbers as well as determine the quality of production units. Machine Vision is applied in process control, robot guidance, as well as automatic inspection.

Benefits:

- Greatly improve quality control
- Faster data collection
- Autonomous operation

Drawbacks:

- Requires expensive machinery
- Highly application specific

Current Applications:

- Many applications in the manufacturing industry
- Food Industry
- Automotive Industry

Our Take:

Machine vision when applied in an industrial setting has the potential to greatly increase automation in quality control. Machine vision provides real time analysis of production units and allows for machines to remove items from the production line that don’t meet quality control specifications. Real time analysis and immediate response from the machine vision data makes this technology significant in an industrial application.

Appendix B - List of Researched Companies

This list contains all of the companies that we researched or were referred to by our contacts. The companies in this list produce or utilize one or more types of Industry 4.0 technologies or produce technology that our sponsor described as “cutting edge” and wished to pursue. These companies do not necessarily fit the requirements to be considered a startup company by our sponsor; many of these companies were researched for our own research benefit.

Name	**Technology Type**	**Reported Revenue or Total Assets (millions DKK)**[49]	**Number of Employees**	**Year of Incorporation**
3D Printhuset	3D printing	5.3		2014
3D Systems	3D printing			
3dprinted	3D printing	0.6	3	2013
AccessIOT	Water, Electricity, heating IoT sensors	0.145		2016
Addifab	3D printing	7.62	5	2014
Agfa inks	ink integration in manufacturing	5.7	15	2011
Aqua Robur	IoT	0.96	2	2015
Aqubiq	Water waste sensors + cloud = IoT	0.156	26	2016
bagger-nielsen	cable housing; robotics		8	2005
Balluf	automation; sensors		7	2005
Baumer A/S	Sensors		55	2000
bengtssons-maskin	automation hydraulics	66	25	1938
Bernstein	IoT sensor (for safety, mainly doors)		6	1996
bihl + wiedemann	Automation, IoT		3	2010
Blackbird	IoT for any			

[49] Companies are not required to reveal their annual revenue, so total assets were used when applicable and available.

	manufacturing process			
Blue Line	automation		16	2004
Blue Ocean Robotics	robotics,		29	2012
Blue Workforce	robotics for prod. line		4	2012
Bossard	mentioned IoT on page	0.304	87	1951
BotSupply	AI; robotics		1	2016
Cadsys Scandinavia ApS	3D printers	1.6	3	2008
CheckPoint software technologies	cloud security software	0.026	15	2002
Cim.as	Machine vision, big data	7.2	4	1999
CloudWorkers A/S	Cloud	3.5	16	2001
Cloudx IVS	Cloud		3	2017
Cluedin	Cloud integration	5.9	4	2015
Conpleks Robotech ApS	Robotics, Cloud software	1.1		2016
CPH Cloud	Cloud	0.234	9	2010
Creative Drone Media	Drone inspection worked for General Electric	0.042		2015
Damvig	3D printing for customers in Industry			2007
Danrobotics	Manufacturing Robots		12	2013
Dansk Drone Kompagni ApS	drone inspection	0.35		2003
Data respons	R&D Services for IoT/Drone/automatio n in manufacturing Solutions and more			1999
Davinci 3D	Sell HP 3D Printers		3	2000
Dencker	nano plastics		29	1996
Diatom	Chemicals		21	1970
DIRA	Danish Network of Robotics for Automation			

Docospot	(digital management) Sensors or processes management and quality assurance			2013
DroneInspektion ApS	drone inspection	0.025	1	2016
E-shoptimizer	Big data management			
Easy Locker	IoT		2	2015
EasyRobotics ApS	Robotics	1.1	1	2014
EffiMat	Robotics	15.6	17	2011
Efuture	Drones			2016
ElastiSense	IoT sensors		3	2016
Element Logic	Robotics, Cloud software	2.7		2006
Emplate	IoT for foot traffic			
Exato	Cloud, cybersecurity	1.5	4	2008
Flowtool ApS	IoT			
Fluidan ApS	sensor (rheostream)	0.864	3	2014
FreeSense	IoT for pharmaceutical bioreactors			
Fron-Tech	3D printers	1.7	1	1998
FrontIoT ApS	IoT	0.9	4	2006
GasDetect	IoT, Sensors	4.4	8	2010
Geodata	big data; automation; in geo surveying	0.025	16	2011
Green City Solutions GmbH	IoT	1.7	8	2014
Hannemann Engineering ApS	Robotics	3.75	7	2007
Harting ApS	IoT	8.5	7	2005
Hexastate	IoT for predictive maintenance			
IFM Electronics	IoT predictive maintenance	7.8	10	1998
Igus ApS	3D printers	1.4	3	1999
Ingemann Maskinfabrik A/S	CNC	1.1	7	1988

Inniti	IoT and automation for chemistry testing			
IoT Denmark A/S	IoT	13	8	2015
IoTkompagniet	IoT			2017
JustBring	IoT	0.21		2015
Kjaerful Pedersen A/S	Environmental sensors, cloud = IoT	17.8	24	2004
Konduto ApS/SaniNudge	washing sensor, cloud	0.066		2016
KP Automation	automation, robotics	11.7	14	2015
Kuka	All I40	67.7	30	2010
Kvejborg ApS	3D scanning	2.6	5	2013
Leap Technology ApS	Actuators/Sensors = Cloud	0.83	2	2013
Leapcraft ApS	IoT sensors	3.84	7	2013
Lexit Group Denmark ApS	Digital integration	10	7	2009
LogIt Rocks	Data management			2016
LT Automation	robotics; automation	2.76	3	2011
MM Technolgy	IOT for manufacturing			2016
Mobile Industrial Robots ApS	robotics	15	20	2013
ModelMe3D	Simulations, augmented reality			2017
MotionTag GmbH	IoT, big data		8	2015
Nano River Technologies	nano (ICs)	0.336		2010
Nextwork	big data; help organizations adapt to the digital transformation and new technologies; marketing	0.086	15	2016
Nordsense	IoT	0.144		2015
NorthQ	IoT	10.3	7	2007
Numeric ApS	Cloud	2.87	4	2016
Octavic	automation			
Odense Robotics	robotics; automation			
Omron	automation; sensors		37	1989

On Robot ApS	modular robotic arms	7.8	15	2015
Operator Systems	IoT			
OptiPeople	digitization; interface tech?	2.9	3	2010
Panpac Engineering A/S	robotics	0.41	28	2003
Pehama Productions A/S	Automation, robotics	14.3	31	1997
Penstable	IoT, AI		1	2017
Pepperl + Fuchs ApS	Predictive Maintenance	10.3	8	1989
Phoenix Contact A/S	Clouds (ask about Proficloud product - uses IoT as well)	53	33	1983
Pilz Skandinavien	Automation, robotics	26.9	31	1996
Pitney Bowes Denmark	Big Data	103	29	1987
PLM Group 3-D Printing	3D printing for prototypes and testing	5.4	2	2014
Profibus Denmark	robotics, sensors, etc			2000
Protech	3D printing	4.6	5	2004
Reeft	Data management	19.2	14	2014
Regal A/S	Sensor data; IoT	5.6	9	1980
Roboman	robotics	0.001	3	2015
Robotcenter (Yaskawa Motoman)	Assembly Robots	18	6	2011
Robotize ApS	Robots	2.6	2	2015
Robotool A/S	Robots	10	15	2001
Roeq ApS	Robots			2017
Saxe Group	Automation food, pharmaceuticals	4.2	13	2008
Scoptio	Drone Imaging		3	2014
Sensohive	data sensors	0.92	4	2014
Sensomind	AI manufacturing solutions		4	2017
Sensorist	data sensors	1.94	4	2012
Sick	IoT sensors	9	7513	1946

Solar Turbines	gas turbine engine manufacturing	3.6	15	2002
Specshell	3d printing	1	11	2014
Spektral Experience ApS	augmented reality	13.2	11	2011
Staubli Tec-Systems GmbH	robotics		300	1986
Taarnby Forsyning (Turnover Supply)	IoT sensor for water lines (finds broken lines/low water pressure)	0.02	30	2010
Teccluster A/S	3D printing	0.01	15	2003
Tosibox	IoT	15	14	2011
Trusted A/S	supply chain management tech (blockchain?); gps	1.3	5	2016
Unitechnology	3D printing		15	1984
Universal Robots	collaborative robotics	0.65	365	2005
Urban Water ApS	IoT	2.7	3	2011
Virtual Reality - Denmark	Augmented/ virtual reality	0.6		2015
Visblue	sustainable batteries for renewable energy; "IoT"		1	2014
Vision Automation	"Robot Vision", automated robot inspection of production tools	49.5	12	1992
We-teco	IoT, big data			2017
Werosys	IoT printing machine for monitoring production		8	2013
Xillia	IoT in pharmaceuticals manufacturing	1.2	466	1959
Xtel	IoT		15	2016

Appendix C - Emails to Companies

In order to contact companies to arrange interviews, we created an email template for initial communication. A total of four email templates were constructed based on recommendations and advice from our sponsor to make a professional and positive first impression.

Section 1: Initial contact email for potential Digital Growth Path clients or partners
Section 2: Initial contact email for other companies
Section 3: Email to restate interest in interview for non-respondents
Section 4: Follow up thank you email after interviews

Section 1: Initial contact email for potential Digital Growth Path clients or partners

Subject: Request for Interview on Industry 4.0 Topics

Hello NAME OF CONTACT,

Background
We are a team of American engineering students from Boston who are serving as ambassadors for the Copenhagen School of Entrepreneurship with Claus Birkedal. We are working with the CSE to identify companies that are producing or utilizing some variation of technology within the Industry 4.0 umbrella (IoT, AI, drone, robotics, 3D printing, etc). Ultimately our work has two main goals:

1. Locate potential clientele/companies that could benefit from membership in CSE's Go Grow Startup Accelerator Programme: Digital Growth Path. This program takes small, startup businesses involved with digitization and it promotes their increased growth by providing a wide means of business resources for free.
2. Locate established Industry 4.0 companies to provide business insight and potentially become partners for future CSE events and programs.

Request and purpose of interview
COMPANY NAME current involvement with KIND OF TECHNOLOGY indicates a strong presence of Industry 4.0 within your business infrastructure. If possible, we would like to set up interviews with one or two company representatives on DATE/TIME. We could conduct an in person or Skype interview, to your preference.
From the interview, we hope to learn more about the benefits and drawbacks of Industry 4.0 on a business. Additionally, we will inform you of the work CSE is doing in this sector to promote the growth of Industry 4.0 startups.

Ultimately, your expertise will help us discern the attributes necessary for a company to appropriately integrate Industry 4.0 into their business model.

Thank you for your time and we look forward to your response,

Ryan Darnley, Matt DiPlacido, Michelle Kerns, Alexander Kim
industry4-d18@wpi.edu

Section 2: Initial contact email for other companies

Subject: Request for Interview on Industry 4.0 Topics

Hello NAME OF CONTACT,

Background

We are a team of American engineering students from Boston who are serving as ambassadors for the Copenhagen School of Entrepreneurship with Claus Birkedal. We are working with the CSE to identify companies that are producing or utilizing some variation of technology within the Industry 4.0 umbrella (IoT, AI, drone, robotics, 3D printing, etc). Ultimately our work has two main goals:

1. Learn about the sectors of Danish industry using Industry 4.0 and how it is successfully implemented in companies.
2. Locate established Industry 4.0 companies to provide business insight and potentially become partners for future CSE events and programs.

Request and purpose of interview

COMPANY NAME's current involvement with KIND OF TECHNOLOGY indicates a strong presence of Industry 4.0 within your business infrastructure. If possible, we would like to set up interviews with one or two company representatives on DATE/TIME. We could conduct a 30-45 minute in person or Skype interview, to your preference.

From the interview, we hope to learn more about the benefits and drawbacks of Industry 4.0 on a business. Additionally, we will inform you of the work CSE is doing in this sector to promote the growth of Industry 4.0 startups.

Ultimately, your expertise will help us discern the attributes necessary for a company to appropriately integrate Industry 4.0 into their business model.

Thank you for your time and we look forward to your response,

Ryan Darnley, Matt DiPlacido, Michelle Kerns, Alexander Kim
industry4-d18@wpi.edu

Section 3: Email to restate interest in interview for non-respondents

Hello NAME OF CONTACT,

On DATE, my team tried to contact you to schedule an interview for our school research project. We would just like to restate our interest in talking with representatives from COMPANY NAME. With an emphasis on Industry 4.0, we have a great amount of interest in your implementation of KIND OF TECHNOLOGY. We realize that many people have hectic schedules around this upcoming holiday break. As a result, we would still love to arrange an interview with you some time after DATE.

Thank you again for your time and have a happy holiday,

Ryan Darnley, Matt DiPlacido, Michelle Kerns, Alexander Kim
industry4-d18@wpi.edu

Section 4: Follow up thank you email after interviews

Subject: Thank you for the interview

Hello NAME OF CONTACT,

Thank you so much for taking the time to talk to us on DATE. We thoroughly enjoyed talking to you and learning more about COMPANY NAME. The interview helped us better understand the benefits and usages of KIND OF TECHNOLOGY and will help us understand the applications and possibility of Industry 4.0 technologies as a whole.

As you requested, we will send you a copy of our final report in the beginning of May.[50] If you have any follow up questions or concerns, please feel free to contact us at any time. We wish you success in the development of your company.

Thank you,

Ryan, Matt, Michelle, and Alex
industry4-d18@wpi.edu

[50] This line was included for companies that requested a copy of our final report upon completion of our project.

Appendix D - Industry 4.0 Companies Contacted

This appendix lists all of the companies that representatives from were contacted requesting interviews. Companies that produce as well as companies that use Industry 4.0 technologies are included in this lis

1. ABP Food Group
2. AccessIOT
3. Addifab
4. Alfa Laval
5. Aqua Robur
6. Aqubiq
7. Balluf
8. Blackbird
9. CheckPoint Software Technologies
10. CIM.AS
11. Clued-In
12. CPH Cloud
13. Creative Drone Media
14. Damvig
15. Dansk Drone Kompagni ApS
16. Data Respons
17. Dencker
18. DevTech PET
19. Docospot
20. Element Logic
21. Exhausto
22. Freesense
23. FrontIoT ApS
24. Geodata
25. Haarslev
26. Hydrema
27. IFM Electronics
28. IoT Denmark
29. KP Automation
30. LT Automation
31. MM Tech
32. Napatech
33. Nordsense
34. Novo Nordisk
35. Omron
36. OptiPeople
37. Pehama Productions A/S
38. Pepperl & Fuchs ApS
39. Pilz Skandinavien
40. Roboman
41. Saxe Group
42. Scopito
43. Siemens
44. Sensorist
45. SpecShell
46. Swedish Match
47. Taarnbly Forsyning
48. Teknologisk Institut
49. Trelleborg Industri AB
50. Trusted A/S
51. Universal Robots
52. Urban Water
53. Velux
54. Vision Automation
55. Walki
56. Werosys
57. We-Teco
58. Wision Tool AG
59. Xellia
60. Xtel

Appendix E - Interview Protocol

We created an interview protocol to streamline the process of scheduling and avoid distractions and tangents during interviews. This protocol also served to remind us to perform every part of the interview process and keep interviews consistent. Based on recommendations from our sponsor and our advisors we created the following procedure for contacting, interviewing, and following up with companies of interest to create a meaningful relationship.

General Interview Protocol

- Arranging interview
    - Have CSE representatives initiate contact
    - Once we have permission, contact company through email
        - See Appendix C
    - Decide who is going if company is far away
- Send email with background questions to prepare interviewee
- Assign roles (main interviewer, main recorder, main note taker, etc.)
- Introductions
    - Reintroduce names and project goals
    - Have interviewee sign NDA
    - Ask permission to record and use information
    - Begin recording
- Main interview Questions
    - See Appendix H for questions for producers of I40 and Appendix J for questions for users of I40
- Conclusions
    - Ask if there is anything they would like to add
    - Gratitude for time and interview
    - Ask if they want a copy of our final report
    - Ask for any clarifying questions
    - Ask for permission to contact them in the future if needed
    - End recording
- Follow up
    - Send ‘thank you’ email
        - See Appendix C
    - Remind them to contact us if they have something to add or if they want us to omit portions of their interview
- Send final report once completed

Appendix F: Interviewed Industry 4.0 Producers

In this appendix we describe each Industry 4.0 technology producer whose representatives we interviewed. A brief description of the company products and what makes them an Industry 4.0 technology, the company's target customers, as well as general company information regarding number of employees and founding year are shown for the following companies.

Section 1: Anonymous

Interviewee: Anonymous

Main I40 Tech: Producer of **3D printing**

Company Focus:

Anonymous builds autonomous 3D printers that refill their resin/plastics reservoirs and move parts on their own from the printer on their own. These devices are capable of working overnight with no human input, collecting prints, and correcting errors without operator intervention greatly improving output.

Target Customers:

Hearing Aid industry, Companies that use printers or will be providing a 3D printing service

Reason for Creation:

The inspiration for these printers was to improve the production of hearing aids, these devices are capable of producing intricate shapes in a relatively quick and inexpensive manner.

Other Important Information:

Size:	redacted for anonymity
Year of Incorporation:	redacted for anonymity
Set-up Time:	redacted for anonymity
Extra:	Interviewee wished to stay anonymous

Section 2: Aqubiq

Date of Interview: 4/6/2018
Interviewee: Peter Nørtoft

Main I40 Tech: **IoT sensor, Cloud Computing, Advanced Analytics**
Company Focus:

Aqubiq creates a smart water sensor that helps people understand water consumption and subsequently reduce their water consumption. This is a hardware solution that attaches to a specific brand of water meter, that once connect automatically connects to a GSM network. Using cloud computing water consumption data is stored and analyzed to determine patterns. In addition to pattern detection, Aqubiq's solution can determine when, how much, and what devices are using water with just one sensor. This system interfaces with a cell phone application that is available on iOS and Android so users can monitor water consumption anywhere.

Target Customer:

Private homes/businesses are the target. They have begun to sell to the water company that owns the water meters so that they can use the device to determine leaks in for customers

Reason for Creation:

To be economically friendly - the average european person uses 100 liters a water per day

Other Important Information:

Size:	2 full time employees
Year of Incorporation:	2016
Set-up time:	15 minutes

Section 3: Blackbird

Date of Interview: 4/4/2018
Interviewee: Finn Hunneche

Main I40 Tech: **IoT Sensors, Cloud**
Company Focus:

Manufacturing sensors that measure overall equipment efficiency and machine availability to better understand bottlenecks in a production facility. Using optical, laser, temperature, and various other sensors to collect information about production machinery, Factbird provides management and operators with specific information about bottlenecks in a production line.

Target Customers:

Manufacturing companies

Reason for Creation:

BlackBird was created as a spin-off of a parent manufacturing company that focused ad difficulty determining issues with the production line. Differing opinions in the company made it difficult to determine the root cause so a device was created to monitor and provide more concrete evidence about the reasons for bottlenecks/

Other Important Information:
Size: 17 employees
Year of Incorporation: 2012
Set-up time: 1 hour

Section 4: CIM.AS

Date of Interview: 4/12/2018
Interviewee: Anders Meister

Main I40 Tech: Producer of **Machine vision**
Company Focus:

CIM.AS creates tailor made machine vision solutions for companies looking to integrate this technology. The differentiation between them and other integrators is that they provide a full service as well as technical support throughout the entire development period. CIM.AS is hired to build a solution for a company looking to integrate machine vision for quality control, process optimization, surface measurements, and part validation.

Target Customers:

Manufacturing customers, pharma, Grundfos, and Airtame

Reason for Creation:

CIM.AS wanted to create a full service that enables them to take on all of the complicated development work and still allow for manufacturing companies to implement powerful quality control and data management for optimization.

Other Important Information:
Size: 40 employees
Year of Incorporation: 1998
Set-up Time: 2 hours for Facts product, 1 day for machine vision product

Section 5: EM Plate

Date of Interview: 3/22
Interviewee: Christoffer Hauthorn, Søren Gregersen

Main I40 Tech: Producer of **IoT sensors, big data**

Company Focus:

Emplate creates an IoT based system for malls that keeps track of customer paths and provides mall goers with rebates and special offers as they pass by stores. In addition their application lets customers follow stores to receive deals when away from the mall. This incentivizes customer loyalty and has proven to increase mall foot traffic in every mall it was installed in. Using a prebuilt hardware solution, Bluetooth is used to detect proximity to the hardware solutions which are placed strategically in malls which in turn quantify foot traffic in malls.

Target Customers:

Malls that wish to increase foot traffic

Reason for Creation:

This device was originally intended to be used in museums however the creators received little support for this application. The idea was that when in a museum as one approaches an exhibit they would receive a notification that would link them to a detailed explanation of what they are looking at. This idea was adapted to malls so that when walking by a store rebates and deals are displayed incentivizing store visits.

Other Important Information:

Size: 6 co-founders
Year of Incorporation: 2015
Set-up Time: 1 day
Notes: Monitored malls have 3 percent increase with digitization in traffic, compared to the industry average of 4 percent decrease

Section 6: E-Shoptimizer

Date of Interview:	3/22
Interviewee:	Jonathan Hanson

Main I40 Tech: Producer of **Big Data**

Company Focus:

Big Data Management tool for real-time price comparison. Customers with online stores pay E-Shoptimizer to compare their prices with those of their competitors and to adjust them accordingly. This software tool uses big data to store and analyze information to allow for competitive pricing without the time consuming task of comparing prices and adjusting manually.

Target Consumers:

Companies that sell products online and wish to price competitively

Reason for Creation:

Price comparison was previously a very time consuming task and E-Shoptimizer's employees saw a gap in the market for which they wanted to find a solution.

Other Important Information:

Size:	3 co-founders, over last 6 months 3 interns and 1 volunteer
Year of Incorporation:	2016
Set-up Time:	30 minutes
Extra:	Member of Aalborg Incubator

Section 7: FreeSense

Date of Interview: 4/12/2018
Interviewee: Niels Jensen

Main I40 Tech: Producer of **IoT sensor**
Company Focus:

FreeSense creates an IoT sensors for bioreactors that collects mass amounts of data. Their product is a small ball shaped sensor device that is placed in large reactors and, as it moves around the reactor with the materials inside, collects data that has never been collected before. Internal tank flow characteristics as well as depth specific information like temperature and pH are some of the several data points that were previously unattainable.

Target Customers:

Biotech companies, pharmaceutical companies

Reason for Creation:

This device was created in collaboration with a local university as a PHD research project that received interest from industry. The idea was continued and turned into a business that now provides a data collection service for biotech companies to optimize quality and fully understand reactions on a very large scale.

Other Important Information:

Size:	11-12 employees
Year of Incorporation:	2016
Set-up Time:	Currently, 3 months (company is still a startup)

Section 8: Front IoT

Date of Interview: 4/10/2018
Interviewee: Charlotte Groenvold, Klaus Berthelsens, Johan Broddfelt

Main I40 Tech: Producer of **IoT devices**
Company Focus:

Front IoT is a consulting company that provides services for companies from many industries. They tested one IoT device in hospitals that determined whether lights were turned on or off. This device was originally used to determine energy consumption however it managed to gather more information than anticipated like the nature of hospital staff. Front IoT is currently developing another IoT device that will help companies monitor their utilities consumption. Designed for industrial setting this device will interface with the industry standard communication bus for utilities and will collect consumption data for industries to understand their consumption.

Target Customers:

Any company that uses utilities, Utilities providers

Reason for Creation:

This device was created after the success of the light sensor in the hospital application. Front IoT employees recognized that there was the possibility of industrial applications.

Other Important Information:

Size:	5 employees
Year of Incorporation:	2006
Set-up Time:	1 hour

Section 9: Hexastate

Date of Interview: 3/22/2018
Interviewee: Asger Damtoft and Steffan Nielson

Main I40 Tech: Producer of **IoT sensors & predictive maintenance**
Company Focus:

Hexastate develops technology that enables businesses to achieve condition based maintenance (CBM). This means that maintenance is performed on a need basis rather than a schedule basis. In industrial setting maintenance is performed after a set period of time as described by the manufacturer of the machine, however with CBM solutions that perfect time to replace a part can be determined. Using vibrations sensors and software algorithms machine failures can be predicted saving businesses time and money. Additionally, Hexastate created a simple user interface that illuminates one of three lights, a green, yellow, or red light, to indicate the status of the machine (i.e operational, repair soon, or needs immediate attention).

Target Customers:

Mainly medium/large companies with multiple pieces of machinery

Reason for the Creation:

Hexastate employees started to create this device during their time at university. It started as an idea and quickly turned into a viable business idea. Hexastate employees realized that conditions based maintenance is highly desirable in industry and their solution was capable of achieving it.

Other Important Information:

Size:	3 employees
Year of Incorporation:	2018
Set-up Time:	1 day
Extra:	Member of Aalborg Incubator

Section 10: Inniti

Date of Interview: 4/5/2018
Interviewee: Malthe Muff

Main I40 Tech: Producer of **Automation**
Company Focus:

Inniti creates an automated test bench for research in wet labs. Using pumps, valves, and sensors Inniti created a flexible testbench that brings the flexibility benefits of a manual set up and combines those with the benefits of a dedicated solution. Like a dedicated solution Inniti's product is capable of recording data during tests with our human input as well as modifying the test automatically to accommodate for changes in the test.

Target Customers:

Industrial companies doing research and development in wet labs, Institutional research labs.

Reason for Creation:

This solution was created to reduce the amount of time spent laboring over a test in a lab. Often times PhD students and researchers spend several hours configuring test benches and performing tests only to stand next to the test to record information, Inniti's founders decided there must be a better solution to save time for researchers.

Other Important Information:
Size: 5 employees
Year of Incorporation: 2017
Set-up Time: 2 to 6 hours

Section 11: MM Technology

Date of Interview: 4/6/2018
Interviewee: Mads Mikkelsen

Main I40 Tech: Producer of **Big Data, Cloud, IoT**

Company Focus:

MM Technology creates data loggers for industrial manufacturing equipment. In today's world there are many different producers of assembly line machines that store data in a proprietary format. MM Technology's product, known as SIA, bridges the gap between proprietary data formats. SIA collects data from multiple different machines in different formats and then performs desired statistical analysis on this information to gather details about machine effectiveness.

Target Customers:

Manufacturing companies, Producers of manufacturing equipment

Reason for Creation:

The founder of MM Technology prior to creating his company worked with data loggers however he noticed that there was nothing flexible enough that was available as a ready-made solution. For this reason, the founder decided to create his own and it eventually developed into the SIA platform.

Other Important Information:

Size:	2 Employees
Year of Incorporation:	2016
Set-up Time:	3-5 days

Section 12: Operator Systems

Date of Interview: 3/27
Interviewee: Tommy Larsen

Main I40 Tech: Producer of **IoT sensors/PLC**

Company Focus:

Operator Systems produces a software solution that improves businesses through data analysis. This software tool communicates with Open Platform Communication devices (OPCs) to gather data from production machinery. This data is then analyzed in their software solution and enables Operator systems to measure OEE (Overall Equipment Effectiveness), perform SPC (Statistical Process Control), and monitor Quality Control. Operator System's delivers a fast, flexible, and standardized solution focused on solving challenges specific to manufacturing companies

Some of Operator Systems customers include: Continental Tire, IKEA, Amcor, OSTP, Anglo Beef, and C&D Food.

Reason for Creation:

This tool is designed for business optimization, it monitors overall equipment effectiveness and reports abnormal statistics on which business executives can make better educated decisions.

Other Important Information:

Size:	100 Employees
Year of Incorporation:	2004
Set-up Time:	Few days to a month (depending on solution purchased)
Extra:	Participate of 2017-18 Digital Growth Path Batch

Section 13: OptiPeople

Date of Interview: 4/3/2018
Interviewee: Kim Dannesboe

Main I40 Tech: Producer of **IoT sensor, big data**
Company Focus:

A small piece of hardware, known as a data logger, monitors machine parameters, calculations are then performed to determine overall equipment effectiveness. Using a simple web interface operators and management can view the status of the machinery in their facilities and are immediately notified when an error occurs. OptiPeople's solution has the ability to only monitor availability, instead of monitoring complete operational statistics. This is because many companies do not know what to do with all of the statistics regarding their machinery when all they really care about is if the machine is operating or not. This helps ease company management and operators into the digital age.

Reason for Creation:

Business Optimization by monitoring overall equipment effectiveness (OEE) for tracking business specific KPIs (Key Performance Indicators)

Other Important Information:
Size: 2 in Denmark, 5 developers in Thailand
Year of Incorporation: 2015
Set-up Time: 1 day

Section 14: Scopito

Date of Interview: 4/15/2018
Interviewee: Ken Falk

Main I40 Tech: Producer of **Big Data**

Company Focus:

Scopito creates a software tool for processing large quantities of images collected during inspections of large equipment. They typically focus on utilities industries that have large power lines, wind turbines, or electrical boxes that need regular inspection. Using GPS data along with statistical analysis vast quantities of images can be reduced by up to 95 percent to focus only on areas of interest. This software tool can be applied to any company that wishes to filter large quantities of photographs for analysis.

Target Customers:

Utilities Companies

Reason for Creation:

Drones fitted with cameras are a great means of surveying and inspecting equipment from vantage points that were previously inaccessible. Scopito originally was founded on the vision that drones would be used to take images and then their software tool would filter the images once a point of interest was found. This however changed once Scopito decided that their software tool would have other applications as well.

Other Important Information:

Size: 9 Employees
Year of Incorporation: 2014

Appendix G - Non-Disclosure Agreement Consent Forms

Interviewees were asked to sign this non-disclosure form, which informed them of their rights in regard to our interview. They had the option to allow us to record the interview with a phone app and/or through note taking and also gave the interviewee the right to choose what information we use in the report and analysis. The form also records the logistics of the interview, such as the date, the location of the interview, the roles of each group member in attendance, and the details of the interviewee. For each interview, two copies of the form were printed out and both were filled out and signed by the interviewers and interviewee. One copy of the form was left with the interviewee to remind them of their rights to which they agreed. The second copy stayed with us for our own bookkeeping and reminded us of what the interviewee allowed us to do with the information they provided. Company representatives interviewed over Skype or phone call were sent a Google form to fill out that contained the same information as the physical NDA.

Written Consent Form

Interview Consent Form

_______________________________________(name of interviewee(s)), ____________________ __________________________ (employment title(s)) at _______________________(company) do agree to have Ryan Darnley, Matt DiPlacido, Michelle Kerns, and Alexander Kim interview me for research for their Worcester Polytechnic Institute project, in partnership with the Copenhagen Business School. I am comfortable with the interview being done in the English language, and will address my opinions with this in mind.

I agree to the WPI students:

- ☐ Recording notes during this interview
- ☐ Recording the interview with a phone recording app
- ☐ Reporting data and responses from this interview in their report
- ☐ Reporting individual quotes from interview, that do not pertain specifically to my company

☐ **I do not agree to the recording or usage of information during my interview**

If I do not want my interview used in the WPI report, I will notify the WPI students by email [industry4-d18@wpi.edu], and the notes, recording, and information gathered from me will be destroyed. The WPI students may contact me or my company at ____ (personal or company email).

☐ I would like a copy of the final report emailed to the above address

Date of Interview: _____/_____/_______

Interview format ☐ In person at _________________________

☐ Other _________________________

WPI Student in charge of Interview questions: ___________________________

WPI Student in charge of written notes: ___________________________

___________________________ Employee Name (printed)

___________________________ Employee Name (signature)

___________________________ Employee Name (printed)

___________________________ Employee Name (signature)

____
Interviewer (signature)

____
Notetaker (signature)

Online Consent Form

Interview Consent Form

The form was made to the requirements of the Ethics Board of Worcester Polytechnic Institute for ethical practices in interviews and protection of the interviewee and their company.

*Obligatoire

What is your name and employment title? *

Votre réponse

What is the name of the company that you work for? *

Votre réponse

Do you agree to have Ryan Darnley, Matt DiPlacido, Michelle Kerns, and Alexander Kim interview you for research for their Worcester Polytechnic Institute (WPI) project, in partnership with the Copenhagen School of Entrepreneurship? *

- ◯ Yes
- ◯ No

Are you comfortable with the interview being done in the English language, and will address your opinions with this in mind? *

- ◯ Yes
- ◯ No

Do you agree to the WPI students (check all that apply):

- ☐ Recording notes during this interview
- ☐ Recording the interview with a phone recording app
- ☐ Reporting data and responses from this interview in their report
- ☐ Reporting individual quotes from interview, that do not pertain specifically to my company

OR

- ◯ I do not agree to the recording or usage of information during my interview

If you do not want your interview used in the WPI report, you will notify the WPI students by email [industry4-d18@wpi.edu], and the notes, recording, and information gathered from you will be destroyed. The WPI students may contact you or your company at _______. *

Personal or company email address

Votre réponse

Would you like a copy of the final report emailed to the above address? *

- ◯ Yes
- ◯ No

By signing here, you agree to your answers above. *

Type your name

Votre réponse

ENVOYER

N'envoyez jamais de mots de passe via Google Forms.

Appendix H - Industry 4.0 Producer Interview Script

This script was created to make our interviews with Industry 4.0 producers natural and conversational as well as provide consistency between interviews. Although this template provided structure to our interviews it did not restrict questions to those only included in the template.

Question Script I40 producers

1. Thank you for taking the time to speak with us, we understand schedules can be busy so we don't want to take up too much of your time and will keep this under 30 minutes.
2. Explain why we are talking: American engineering students doing research, we want to understand Industry 4.0, our goal is to create a list of attributes that indicate ease of implementing Industry 4.0, ultimately we have a report due May 2nd
3. Ask for consent to record and sign Non Disclosure Agreement
4. We've looked into Company and our understanding is that company creates/develops technology. **Could you elaborate on this and explain the product a little more *and tell us about your role in Company*?**
    a. What type of solution is this (i.e. software, hardware, both)?[51]
    b. What inspired the creation of this product?[52]
    c. How big is Company? How many employees? When was Company created?
5. Who do you primarily sell your product to?
    a. How big are these companies in terms of revenue? Number of employees?
    b. Are there specific criteria that You/Company look(s) for when finding customers?[53]
6. What is the implementation process for your product like in these companies?
    a. How long does that take (implementing the solution)?
    b. What slows this down (legal/paperwork maybe)?
7. How much does implementing this cost your customers?[54]
    a. Subscription fee, Hardware/software upfront cost
    b. Is there training needed?
8. What is the biggest obstacle in implementing Company product?[55]

[51] Distinguishing the type of solution is vital because different solutions have different costs, implementation times, and effects on a business. Specifying whether the solution is primarily hardware, software or both is integral in filtering information gathered from interviews.

[52] Understanding the reason for the creation of this technology provides more insight into the benefits it can provide

[53] We are trying to determine the attributes of companies that can easily implement Industry 4.0 and this is elaborated further during the interview at this point. Restating our objective here and explicitly asking the creators of Industry 4.0 what they look for when choosing customers is critical.

[54] Understanding the business models of the companies we interview enabled us to understand the viability of these solutions in the eyes of the customer. Knowing the business model and the return on investment time for the customer provides great insight into the value of Industry 4.0.

    a. What changes could speed this process up?

9. Our project is about understanding I40 and promoting its spread so we want to know if you have any insight on that aspect of industry?[56]
    a. Uncertainty or unawareness of benefits, unwillingness to change business structure and infrastructure
    b. Financial costs, employment concerns, security concerns
10. Have you ever heard of any incubators for Industry 4.0 startups and SMEs (like CSE)?[57]
    a. Have you ever considered joining/partnering?
11. Are there any lingering questions?
12. Thank you for your time

---

[55] Because the goal of this project is to understand the obstacles that impede the spread of Industry 4.0, this question is relatively ambiguous and leaves the answer up to the interviewee. This question yielded many great and elaborate responses that significantly helped the project.

[56] This question is a follow up to the previous question that explains why we asked the previous question as well as inquiries about further insight about the obstacles impeding I40 implementation.

[57] This question was requested by our sponsor to gather further insight into the awareness of programs like the Go Grow Startup Accelerator Program offered by the Copenhagen School of Entrepreneurship.

Appendix I: Interviewed Industry 4.0 Users

In this appendix we describe each company using Industry 4.0 technology whose representatives we interviewed. A brief description of what the company does, how it uses Industry 4.0, their target customers, as well as general company information regarding number of employees and founding year are shown for the following companies.

Section 1: Damvig
Section 2: Dansk Drone Kompagni
Section 3: Haarslev Industries
Section 4: Novo Nordisk
Section 5: Velux

Section 1: Damvig

Date of Interview: 4/11/2018
Interviewee: Jesper Damvig

Main I40 Tech: User of **3D printing**
Company Focus:

Damvig is a producer user of 3D Printers that provides there printing abilities as a service. Customers pay Damvig to print their designs in a fast and cost-effective manner. Doing so enables companies to prototype faster and save money if they only need to print in small batches. Damvig is capable of same day or next day delivery of printed parts.

Target Customers:

Customers are from all sorts of industries, using Damvig for prototyping or large industrial orders.

Inspiration for Service:

The inspiration for providing this service was to offer a 3D printing service with a large amount of customization and quick delivery time

Other Important Information:
Size: 14 employees
Year of Incorporation: 1995

Section 2: Dansk Drone Kompagni

Date of Interview: 4/11/2018
Interviewee: Hans Hansen

Main I40 Tech: User of **Drones**
Company Focus:

Dansk Drone Kompagni (DDK) flies drones to provide a surveying or inspection service for its customers. DDK has the knowledge of all rules and regulations in the local jurisdictions as well as the skills to fly drone for data collection. DDK employees are capable of completing surveying and inspection tasks in just under 30 minutes, which using traditional methods would take significantly longer.

Target Customers:

Construction companies, Utilities companies, Surveying companies

Inspiration for Offering Service:

DDK noticed a gap in the inspection and surveying industry that could be solved with the application of camera equipped drones.

Other Important Information:
Size: 5 employees
Year of Incorporation: 2013
Set-up Time: 20-30 minutes

Section 3: Haarslev Industries

Date of Interview: 4/20/2018
Interviewee: David Coen

Main I40 Tech: User of **Robotics, machine vision**
Company Focus:

Haarslev Industries produces machinery for handling waste in the food industry. One of their main products is an industrial dryer that separates food was into its core components and materials with a 99 percent yield. These dryers are very large in scale and require large scale machinery to construct. Recently Haarslev Industries installed 3 welding robots for the construction of the dryers as well as machine vision on these robots to check the quality of the welds and make the necessary changes. These robots have enabled Haarslev Industries to compete with the production rates of China and have even have reduced the amount of outsourcing done by Haarslev Industries.

Reason for Implementation:

Robotics complete tasks faster and better than humans could and this is the only way that Haarslev can compete with the low costs of outsourcing to China.

Other Important Information:
Size: 1,100 employees
Year of Incorporation: 1973

Section 4: Novo Nordisk

Date of Interview: 4/17/2018
Interviewee: Ole Feddersen, Morten Lungren, Thomas Bach Nielson

Main I40 Tech: User of **IoT sensors (Blackbird), big data, 3D printing, robotics, etc**

Company Focus:

Novo Nordisk is the largest biotech company in Denmark. looking for optimization and understanding the production line at a data level. Novo Nordisk manufactures and markets pharmaceutical products and services. Some of their main products include diabetes care medications and devices. Novo Nordisk is also involved with hemostasis management, growth hormone therapy and hormone replacement therapy.

Novo Nordisk is using IoT/OPC sensors (specifically BlackBird's Factbird) on packaging production lines to collect data about the packaging process. Additionally, Novo Nordisk implements big data practices to manage the large volumes of data collected by these and other IoT device. 3D printers and robotics are also used for prototyping and simple tasks. The implementation process of these industry 4.0 technologies was not quick, Ole Feddersen noted that the process was gradually and took several years.

Reason for Implementation:

Novo Nordisk looked into implementing Industry 4.0 technologies for the purpose of saving costs and staying competitive.

Other Important Information:
Size: Over 41,000 employees
Year of Incorporation: 1923

Section 5: Velux

Date of Interview: 4/23/2018
Interviewee: Sigurd Villumsen

Main I40 Tech: Potential user of **robotics, data management tech**
Company Focus:

Velux is a leader in the design and manufacturing of windows for both business and residential use. Because of their focus on manufacturing Velux is considering the implementation of Industry 4.0 practices to stay competitive and reduce costs.

Other Important Information:
Size: ~10,000 Employees
Year of Incorporation: 1941

Appendix J - Industry 4.0 User Interview Script

This script was created to make our interviews with Industry 4.0 users natural and conversational as well as provide consistency between interviews. Although this template provided structure to our interviews it did not restrict questions to those only included in the template.

Question Script I40 users

1. Thank you for taking the time to speak with us, we understand schedules can be busy so we don't want to take up too much of your time and will keep this under 30 minutes.
2. Explain why we are talking: American engineering students doing research, we want to understand Industry 4.0, our goal is to create a list of attributes that indicate ease of implementing Industry 4.0, ultimately we have a report due May 2nd
3. Ask for consent to record and sign Non-Disclosure Agreement
4. We've looked into Company and our understanding is that company implements/is considering to implement technology. **Could you elaborate on what Company does, explain the applications of Industry 4.0 a little more, and tell us about your role in Company?**
    a. What kind of solutions do you implement/wish to implement?
    b. What was/is the desired goal of using this/these product(s)?[58]
    c. How big is Company? How many employees? When was Company created?
5. What changes have you seen in your company since implementing technology?
    a. Change in productivity?
    b. What is the estimated Return on Investment?
6. What was the implementation process like for technology?
    a. How long did this take?
    b. Did anything slow down this process or make it take more time than it could have?
7. How much did implementing this technology cost?[59]
    a. Subscription fee, Hardware/software upfront cost?[60]
    b. Was there training needed?
8. What was the biggest obstacle in implementing technology?
    a. What changes could have sped this process up?

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[58] Understanding the intentions for implementing or considering to implement I40 provided insight into the capabilities of I40. Additionally, this provided us with and understanding of the perceptions of Industry 4.0.
[59] Understanding the business models of the companies we interview enabled us to understand the viability of these solutions in the eyes of the customer. Knowing the business model and the return on investment time for the customer provides great insight into the value of Industry 4.0.
[60] Understanding the business models of the producers as well as the opinions of the users on these business models is important for Industry 4.0 technology producers. If users and potential users voice opinions that particular business models are unattractive or others are more attractive this will provide us with more attributes and information for our sponsor.

    b. Were there internal struggles (e.g. management resistance, operator resistance, shareholder etc)

9. Obviously our project is about understanding I40 and promoting its spread so we would like to know if you have any insight on that aspect of industry?[61]
    a. Uncertainty or unawareness of benefits, unwillingness to change business structure and infrastructure
    b. Financial costs, employment concerns, security concerns
10. Are there any lingering questions?
11. Thank you for your time

[61] This is an elaboration on the previous question that restates our goal and elaborates on why we asked the previous question. Understanding the criteria that affect the implementation of I40 is an integral part of our project and this question seeks further information on this aspect of industry.

Appendix K - Industry 4.0 Readiness Assessment

This appendix describes the assessment tool that we created to gauge the overall readiness of a company looking to implement industry 4.0 technologies.

How to use the tool?

The three tables are Financial and Legal Readiness, Technical Readiness, and Cultural and Societal Readiness. Each table has a list of indicators describing a parameter of interest within each assessment category. On a rating scale of one to four, the user of the tool indicates his or her perception as to their company's position with respect to each parameter. After addressing each parameter, the user finds their average score for that table. After performing this process on each of the three tables, the user has their company averages with respect to each of the three categories.

Financial and Legal Readiness Table

Financial and Legal Readiness				
Parameters	Score			
Available Company Capital	1	2	3	4
Cost of Industry 4.0 product	1	2	3	4
Predicted ROI (Return on Investment)	1	2	3	4
Financial Risk	1	2	3	4
Legal Risk	1	2	3	4

Explanation of Parameters:

Available Company Capital: This parameter reflects a company's available assets. A score of 1 would indicate that the company has minimal to no capital that can be used for Industry 4.0 innovation. Meanwhile, a score of 4 indicates that the company has no financial concerns in providing the appropriate resources to implement an Industry 4.0 technology. The level of capital necessary for implementation will vary across each Industry 4.0 technology.
Cost of Industry 4.0 product: This parameter reflects the physical cost of implementing the Industry 4.0 technology. This cost takes into account machine downtime, employment and salary effects, as well as the physical cost of the product. A score of 1 indicates that the costs will

significantly affect business operations, while a score of 4 indicates that the costs carry little effect to business operations.

Predicted Return on Investment: This parameter reflects the length of time it will take to achieve a positive return on investment. A score of 4 indicates a fast ROI while a score of 1 indicates a very long, or even never attained ROI.

Financial Risk: This parameter weighs the potential benefits of Industry 4.0 implementation with its potential financial costs. A score of 1 indicates little to no advantage for implementation, while a score of 4 indicates complete confidence in implementation.

Legal Risk: This parameter weighs the potential benefits of Industry 4.0 implementation with its potential legal costs. Legal costs include, data ownership, updated regulation, and more. A score of 1 indicates little to no advantage for implementation, while a score of 4 indicates complete confidence in implementation.

Technical Readiness Table

Technical Readiness				
Parameters	Score			
Existing Infrastructure	1	2	3	4
Adaptability of Existing Infrastructure	1	2	3	4
Complexity of Product Integration With Existing Infrastructure	1	2	3	4
Current Level of Data Gathering	1	2	3	4
Current Level of Data Usage	1	2	3	4
Current Level of Cybersecurity Protection	1	2	3	4
Level of Applicability Product Has in Solving a Company Problem	1	2	3	4

Explanation of Parameters:

Existing Infrastructure: This parameter indicates the current level of modernization in the existing company infrastructure. A score of 1 indicates that the machinery lacks digitization and modernization. A score of 4 indicates that the machinery is technologically advanced and likely to be easily compatible with digitization.
Adaptability of Existing Infrastructure: This parameter indicates the ease with which the existing infrastructure can be modified to properly integrate with the desired Industry 4.0 technology. A score of 1 indicates that the existing infrastructure is very rigid and difficult to modify. A score of 4 indicates that the existing infrastructure is very flexible and adaptable. This indicator is subject to change based on the technology and the specific application.
Complexity of Product With Existing Infrastructure: This parameter indicates the complexity of the installation with the existing infrastructure. This parameter is highly dependent on the adaptability of the existing infrastructure. A score of 1 indicates that the implementation will be a long, rigorous process. A score of 4 indicates that the implementation will be akin to Plug and Play. This indicator is subject to change based on the technology and the specific application.
Current Level of Data Gathering: This parameter indicates the current level of data gathering used in company operations. A score of 1 indicates little to no data collection, while a score of 4 indicates high volume data collection. For clarification, a score of 3 might indicate high volume data collection, however, the process is done manually as opposed to electronically.
Current Level of Data Usage: This parameter indicates the current level of data application in company operations. A score of 1 indicates little to no data application, while a score of 4 indicates high volumes of data application.

Current Level of Cybersecurity Protection: This parameter indicates a company's protection against potential hacking or cybersecurity threats. As Industry 4.0 corresponds to increasingly high quantities of data, there is an increased emphasis on IT protection. A score of 1 indicates little to no IT protection. Meanwhile, a score of 4 indicates high levels of IT protection in every existing department of a business.

Level of Applicability Product Has in Solving a Company Problem: This parameter indicates the relevance of a product with the company's problem. Due to the hype of Industry 4.0, companies frequently feel a need to adopt the technology, even if they do not have any applications for it. As such, a score of 1 indicates little to no need of application, while a score of 4 indicates that the product perfectly solves an existing company problem.

Cultural and Societal Readiness Table

Cultural and Societal Readiness				
Parameters	Score			
Current Level of Awareness of the Benefits and Applications of Industry 4.0 Technologies	1	2	3	4
Current Level of Traditionalism or Contentedness	1	2	3	4
Current Fear of Hacking	1	2	3	4
Current Fear of Unemployment Due to Increased Development of Technology	1	2	3	4
Current Level of Desire to Innovate	1	2	3	4
Current Level of Collaboration Across Industry	1	2	3	4
Current Level of Vertical Integration	1	2	3	4
Current Level of Horizontal Integration	1	2	3	4

Explanation of Parameters:

Current Level of Awareness of the Benefits and Applications of Industry 4.0 Technologies: This parameter indicates a company management's awareness to the potential of Industry 4.0 technologies. A score of 1 indicates that the company management has little to no understanding of the technology and its use in business. A score of 4 indicates that the applicability of the technology is fully understood.
Current Level of Traditionalism or Contentedness: This parameter indicates a company management's level of traditionalism. A phenomenon known as "organizational inertia," this parameter measures how willing a company's management is to adopt new processes for future business operations. A score of 1 indicates a company's management that has little to no ambition in changing its existing business plan. A score of 4 indicates a company's management that wishes to quickly jump into Industry 4.0 technology.
Current Fear of Hacking: This parameter indicates a company's management's fear of hacking. As Industry 4.0 creates high volumes of data, there is a growing fear that data leaks or system failures could occur as a result of hacking. A score of 1 indicates high levels of concern with hacking, while a score of 4 indicates little to no concern.
Current Fear of Unemployment Due to Increased Development of Technology: This parameter indicates a company's management's fear of technology replacing jobs. A common theme with Industry 4.0 technologies, this fear is especially prevalent among unskilled labor employees. A score of 1 indicates high levels of fear regarding the replacement of jobs with technology, while a score of 4 indicates little to no fear.
Current Level of Desire to Innovate: This parameter indicates a company's desire to innovate. The implementation of Industry 4.0 technology often requires an entirely new business restructuring. As the steps needed to implement Industry 4.0 can be numerous, a major

requirement for its success is the desire among companies to implement it. Thus, a score of 1 indicates little to no desire to implement Industry 4.0 technologies. Meanwhile, a score of 4 indicates a great level of desire for innovation.

Current Level of Collaboration Across Industry: This parameter indicates a company's current level of collaboration with other companies, universities, and organizations across its industry. The application of Industry 4.0 technology can be a risk. As such, company management should encourage the pooling of resources in order to attain higher performance technologies and mitigate potential risks. A score of 1 indicates little to no collaboration across Industry, while a score of 4 indicates a large amount of business partners and collaborators.

Current Level of Vertical Integration: This parameter indicates a company's management's current level of vertical integration. Vertical integration is defined as "the merger of companies at different stages of production and/or distribution in the same industry." Vertical integration often expedites the manufacturing process, while also cutting costs. A score of 1 indicates little to no vertical integration within the company, while a score of 4 indicates high levels of integration.

Current Level of Horizontal Integration: This parameter indicates a company's management's current level of horizontal integration. Horizontal integration is defined as "the merger of companies at the same stage of production in the same or different industries." A score of 1 indicates little to no horizontal integration within the company, while a score of 4 indicates high levels of integration.

Sources that inspired the creation of this tool:

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Appendix L: Company List and Product Description

Included in this table is a brief description of the product(s) offered by as well as the business models of the companies from which we interviewed representatives.

Company Name	Business Model	Product Description
Anonymous	Purchase fee	Automation products for 3D printers. Allows continuous operation of printers by autonomously refilling resin, collecting prints, correcting errors without operator intervention, and more.
Aqubiq	Initial implementation cost with subscription based service	Internet of Things sensors to attach to water meters for private clients that reads information off of the meter to track water usage and decrease waste.
Blackbird	Initial implementation cost with subscription based service	Hardware solution that manages data from Internet of Things sensors to calculate KPIs and a software solution that visualizes the information to increase productivity.
CIM.AS	Purchase fee	Customized solutions for machine vision in manufacturing settings. Used for quality control, surface measurements, part validation with customizable operator interface.
Damvig	Service fee	3D printing service for creating prototypes or cheaply mass producing devices. Prints objects in various materials for almost all industrial applications.
Dansk Drone Kompagni	Service fee	Drone service for inspections and software for processing photographs into easy-to-manage mosaic. Uses GPS to track path of drone and create image map.
E-Shoptimizer	Initial implementation cost with subscription based service	Software solution that manages from e-shop competition to perform real-time price comparison and ues artificial intelligence to match products from different e-shops with +90 percent accuracy.
Emplate	Initial implementation cost with	Software solution that receives data from sensors in malls to monitor traffic. Manages data to increase customer loyalty though incentives such as coupons.

	subscription based service	
FreeSense	Initial implementation cost with subscription based service	Sensor devices that track mixture attributes in bioreactors at varying locations. Manages and analyzes data to calculate modifications to procedures for optimizing output.
FrontIoT	Initial implementation cost with subscription based service	Many products; current one collects data from meter-buses in old buildings and transmits information to a database. Machine learning used to detect resource usage in case of abnormalities.
Hexastate	Initial implementation cost with subscription based service	Vibration sensors that use cellular data to send data to a centralized server and a data analysis service that detects abnormal vibrations to determine optimal repair schedule.
Inniti	Initial implementation cost with subscription based service	Modular automated pump systems with the flexibility of manual setups. Performs iterations and collects data autonomously, storing it in a cloud with machine learning.
MM Technology	Purchase fee or project support fee	Cloud solution that collects data from several sensors with a universal data logger, allows communication between standard, alternative, and emerging equipment, and reacts based on the data collected.
Operator Systems	Initial implementation cost with subscription based service	Software solution that receives data from Internet of Things sensors on production lines. Manages and analyzes data to calculate Key Performance Indicators (KPIs) to monitor process efficiency.
OptiPeople	Initial implementation cost with subscription based service	Cloud solution that takes information from production line sensors and data loggers to calculate KPIs and optimize process efficiency.

Appendix M - Product Installation Procedure and Duration

This table contains information about the average duration of the implementation process for the products offered by the companies from which we interviewed representatives.

Table AA: Product Installation Procedure and Duration from Producers' Perspective[62][63]

Company	Brief Description of Product Implementation	Average Duration
Aqubiq	-Install a single data transfer device on an existing water meter -Supply power -Link phone application with account/device	15 minutes
Blackbird	-Install sensor and Factbird to production line and connect Factbird to 100V/240V AC power -Create profile on app.blackbird.online	1 hour
CIM.AS	Flex Solution -IT employee from customer company works with CIM.AS to create an SQL database -Software solution is then configured	Two Hours
	Machine Vision Solution -Work with the customer to design a machine vision solution -using their existing frameworks they integrate a solution in to their manufacturing line	Max one week

[62] The descriptions of the product implementation and the average duration of installation were either posted on the company webpage or stated by the interviewed company representative.
[63] Although producers potentially carry bias with their product, the duration of product installation can be interpreted as truthful. For most of the installations, the producers physically helped implement the product into the customer's existing infrastructure. Consequently, their presence throughout the whole installation and training period indicates an accurate timeline.

	-Data collected is now accessed by the customer	
Emplate	-Install sensors to pathways (entrances and exits) of retail stores -Connect sensors to server	One day
E-Shoptimizer	-Install desired website plugins	30 minutes
FreeSense	-up to 5 FreeSense sensors are placed in bioreactor -data collection is configured -Support for the service is provided during entire implementation period	One Day[64]
FrontIoT	-connect device to industrial building water/heat/electricity Controller Area Network bus -Connection is automatically established with no intervention	One hour[65]
Hexastate	-Install sensors onto machines of interest	One day
Inniti	-Product package installation and building -Install server station -Education on how to use system software	2 to 6 hours
MM Tech	-Install data logger onto production line -Connect to data user interface -Installation and operation are simple and clearly described in the instruction set	3 to 5 days
Operator Systems	-Identification of current infrastructure -Identification of necessary modifications	Few days to a month (Time varies

[64] A FreeSense employee noted that although the physical installation of the device is rather simple the service they provide requires them to be highly involved throughout the entire process. This business model coupled with the innovations solution’s ability to gather data that has never been captured before can make the entire involvement with the customer take up to 1 year, from time of sales pitch to sufficient data collection.

[65] FrontIoT is a consulting group that is working to create their own product capable of monitoring utilities for industry. FrontIoT does not have a finished product yet so the information provided is based on their aspirations around which they are designing the product.

	-Configuration of hardware with software network -Pilot testing	based on package purchased)
OptiPeople	-Electrician must find appropriate location for sensor placement -Sensor must be installed to existing infrastructure -Installed sensor must be connected to cloud network -Access analyzed data via user interface	One day

Appendix N - Industry 4.0 Technology Involvement

This table describes the involvement with Industry 4.0 of the companies from which we interviewed representatives. In many cases the companies researched produce a solution using multiple I40 technologies. Alternately some companies produce a solution that offers many I40 technologies.

Table Legend:

P - Produces this Industry 4.0 technology
U - Uses this Industry 4.0 technology

	Data Management					Cyber-physical			
Name	**IoT**	**Big Data**	**Cloud**	**Machine learning**	**Machine vision**	**Robotics**	**Automation**	**Drones**	**3D Printing**
Anonymous							**P**		**P**
Aqubiq	**P**	**P**	**U**	**P**					
Blackbird	**P**	**U**	**U**						
CIM.AS		**P**	**U**	**P**	**P**				
Damvig									**U**
Dansk Drone Kompagni		**U**						**U**	
Emplate	**U**		**U**						
E-shoptimizer				**P**					
FreeSense	**P**	**P**							
FrontIoT	**P**	**U**	**U**						
Haarslev				**U**	**U**	**U**			
Hexastate	**P**	**P**							
Inniti	**P**		**U**				**P**		
MM Technology	**P**	**P**	**U**	**U**					
Novo Nordisk	**U**	**U**	**U**			**U**	**U**		**U**
Operator Systems	**U**	**P**	**P**						

OptiPeople	**U**	**P**	**P**						
Scopito		**U**	**U**						
Velux		**X**				**X**			

Appendix O - CSE Deliverables

Described below are the deliverables for the Copenhagen School of Entrepreneurship, our sponsor. These lists and recommendations are to be used by Claus Birkedal, Britta Ravn Bjerglund, and other CSE employees.

Companies we recommended for the Digital Growth Path:

- 3dprinted
- Addifab (Claus was in contact with)
- Agfa inks
- Aqua Robur
- Aqubiq (Claus was in contact with)
- Blackbird (Claus was in contact with)
- Cadsys Scandinavia ApS
- Cluedin
- CPH Cloud
- EasyRobotics ApS (Claus was in contact with)
- Exato
- Fluidan ApS
- GasDetect
- Geodata
- Green City Solutions GmbH
- KP Automation
- Kvejborg ApS
- Leap Technology ApS
- Leapcraft ApS (Claus was in contact with)
- Lexit Group Denmark ApS
- LT Automation
- MM Technology (Claus was in contact with)
- Nextwork
- Numeric ApS
- On Robot ApS (Claus was in contact with)
- OptiPeople (Claus was in contact with)
- PLM Group 3D Printing
- Roboman
- Robotize ApS (Claus was in contact with)
- SaniNudge (Claus was in contact with)
- Saxe Group
- Scopito
- Sensohive (Claus was in contact with)
- Sensomind (Claus was in contact with)
- Sensorist
- Specshell

- Taarnby Forsyning
- Trusted A/S
- Urban Water ApS
- Werosys
- Xillia

Companies Claus interviewed for / accepted into the program:

- Drivi (driving school portal)
- Saninudge (IoT for hospital staff)
- Radisurf (super adhesive nano-coating)
- 21Risk (factory risk management portal)
- Obital (eye-tracking for disabled people)

Places/Institutions where more companies could be found:

- DTU
    - FreeSense was started here and Malthe Muff mentioned his professors here were fond of I40 innovation.
- c/o COBIS, Ole Maaløes Vej 3, 2200 København N
    - A University of Copenhagen employee told us that it houses a lot of startups.
- Scale Up Denmark
    - Malthe Muff told us about this program.

Synopsis of our recommendations from our report:

Recommendations for Digital Growth Path (Claus and participants)

- The following recommendations are intended to help Claus Birkedal, and the DGP participants, determine what types of companies can successfully utilize Industry 4.0.
    - We recommend that customer companies be treated on a case-by-case basis.
        - This is visualized in Figure 8, showing the stages of I40 implementation in a business.
    - We recommend that when searching for companies that can successfully take on Industry 4.0 technologies one should look for five key attributes.
        - Attribute 1: Adequate financial resources
        - Attribute 2: Adequate technological infrastructure and background
        - Attribute 3: Strong connection between management and operator
        - Attribute 4: Solid understanding of the benefits of digitization
        - Attribute 5: Desire to innovate

Recommendations for Encouraging Industry 4.0 Adoption in Denmark

- These recommendations would be shared by CSE to their company participants and to the public through their actions and media.
  - We recommend that CSE focus on improving inter-company collaboration and communication.
  - We recommend increasing emphasis on technical education for Danish students and manufacturing employees.

Recommendations for Future Research

- In addition to the recommendations above, we recommend that CSE representatives continue our research on Industry 4.0 in Danish industry and verify the results obtained from this project.
  - We recommend performing more interviews with representatives from companies that utilize digitized technologies and from companies involved with cyber-physical systems.
  - Perform interviews with representatives from companies that considered digitization, but ultimately decided against it.
  - Determine possible methods of increasing awareness of Industry 4.0 benefits.