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How can IoT improve the value-creating landscape within the Nordic life science industry?

Master's thesis in the Master Degree Program Quality and Operations Management

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Abstract

Internet of things (IoT) is currently driving a new age of digital innovations within life science by facilitating digital transformation and progressive care. However, the IoT technology is also associated with significant challenges for organizations. These challenges do pose a risk of negative impact on business, and severe complications for individuals and patients, if not understood and addressed properly.

This study is examining the value-creating landscape within the Nordic life science industry, and how it is affected by IoT as an emergent technology. Previous research on the subject demonstrates a lack of empirical studies examining the Nordic market and calls for additional empirical examinations that can help explain IoT's potential and implications on life science businesses. We conducted a qualitative study based on interviews with experts in the field, focusing on two research questions. The first research question is examining social and economic value derived from IoT within the Nordic life science market, while the second research question targets challenges associated with IoT within the Nordic life science market.

Several opportunities for IoT to create social and economic value within life science have been identified. A selection of these includes improved diagnostics, individualized care, knowledge about product usage, and decision support. Our findings do also affirm several challenges for the technology, where the main obstacles are found to be high regulatory demands and conservatism within the life science industry. Additionally, technical challenges associated with the IoT technology such as connectivity and cyber security issues are also significant.

Keywords: Internet of Things, life science, medical equipment, Nordic life science, pharmaceutical industry, digitalization, value creation

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John Randelin & Kristoffer Wallin
Gothenburg, June 2022

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Acronyms

BDA - Big Data Analysis
BLE - Bluetooth Low Energy
IoT - Internet of Things
MS Teams - Microsoft Teams
R&D - Research & Development

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Introduction

The following chapter will outline relevant background to the thesis, including technology of interest and the concerned business area. An introduction of the case company is provided, followed by the purpose of the thesis along with its research questions and limitations.

There has been a lot of interest for IoT from both industry and academia. Playing one of the key roles in digitalization and digital transformation, IoT among other emerging technologies is expected to greatly transform our current world (Esenogho et al., 2022). The global market for IoT services has been growing rapidly and is expected to reach USD 172.6B by 2025 (Kim et al., 2022). As the technology is growing and maturing, the interest from organizations to incorporate and profit of it also increases, which leads to the question of how to improve one's value proposition with this new technology.

There are several ways in which an organization can derive value from IoT. Baltuttis et al. (2022) discusses how IoT can be used to harness data for both B2C and B2B organizations. When acquiring data on how products and services actually are being used, the information can help organizations develop new and improved products. Value can further be obtained by developing new products which fulfills customers requirements. Butz and Goodstein (1996) views value creation as a consequence of a provider meeting, or exceeding, its customer´s expectations.

Despite the growing interest in IoT, Langley et al. (2021) claims that there is a lack of understanding of how the emergence of IoT will impact businesses. Previous research within this area is rather focused towards the technical aspects of IoT, looking at specific implementations of IoT aimed at a distinct use case (Hussein, 2019). Current literature indicates that there is a gap in the research field and a lack of empirical studies looking at how value is created by IoT within life science. In addition to this, we have found that the available research addressing our geographical segment of interest (i.e. the Nordic countries) is fairly limited. Also, Warner and Wäger (2019) argue that "the building of capabilities for digital transformation has received limited scholarly attention". We aim to reduce this gap in research by exploring how IoT can improve the value creating landscape within the Nordic life science industry. This will be achieved by interviewing 10-15 businesses who are knowledgeable of IoT and life science in the Nordics to see how they strive to create value, and which challenges they see for the technology. When looking at how value creation occurs within life science, several trends distinguish themselves, such as achieving tailored healthcare after each patient's individual needs and automatic drug dose adjustment, where dosages will be customized for each individual based on the stage of the illness etc. (KPMG, 2022).

Even though the individual Nordic countries (Denmark, Sweden, Finland, and Norway) are relatively small and not as densely populated as other European countries, their life science industry is globally recognised (nordic life science insight, 2021). Yet, Denmark and Sweden are especially prominent as they decided to join efforts in their national life science sectors, which led to the emergence of "Medicon Vally" (Runiewicz-Wardyn, 2020). Something that is characterizing the Nordic life science industry is the high degree of innovation, aided by the profound collaboration between industry, academia, and government incentives, known as the triple helix model (Wu and Siswanto, 2020). Due to the low population of Iceland (370 000 inhabitants in 2021 (Britannica, 2022)), the Nordic countries will only be considered as Sweden, Norway, Denmark and Finland.

1.1 Purpose and Research Questions

We aim to *describe* how IoT can improve the value-creating landscape within the Nordic life science industry. Our contribution aim to inform how current customer value can be improved by IoT, how the perception of value can be shifted due to the potential of IoT, and how new concepts of value can emerge from IoT. We define "customer" as pharmaceutical companies and manufacturers of medical devices. These are customers of the case company, rather than end customers (consumers). Hence, our perception of "customer value" is benefits towards these companies.

Firstly, we aim to identify the current state of IoT within the Nordic life science industry. Thereafter we want to identify what potential gains IoT could bring to the industry and the reasons why the IoT development has been haltered by identifying the challenges associated with IoT within life science.

As stated above, this research is limited to the Nordic countries. However, during our literature review we are researching IoT within life science globally. The purpose of this is to identify and explore new use cases and get an greater understanding for IoT applications within life science, instead of leaning on the limited research which is based on the Nordics. To meet and fulfill this purpose, the following research questions were composed:

RQ1: What social and economic value does IoT bring to the Nordic life science industry?

RQ2: What challenges does the IoT technology face within the Nordic life science industry?

When answering the research questions stated above, we draw on dynamic capability theory. The concept of "dynamic capabilities" has become one of the most profound theories within strategy management, which asserts that an organizations long term competitive advantage is dependent on its abilities to 1) *sense* opportunities (and threats), 2) *seizing* these opportunities, and to 3) *transform* resources and business models to maintain opportunities (Teece et al., 1997) & (Schilke, 2014). These competences are especially important in rapid changing market dynamics and in the context of emerging technologies (Schilke, 2014). Given the disruptive nature of digitalisation, Warner and Wäger (2019) posit that "dynamic capabilites is a powerful lens for examining the digital transformation", which is why we rely on the concept of dynamic capabilites to explore how value can derive through IoT as an emerging technology.

1.2 Case Company

The case company is a rapidly growing engineering firm, which possesses a mature ready to use IoT platform. This platform has been hardened over 8 years by almost half a million users worldwide. Further, the IoT services includes device/data, service, user and application management, to name a few. The sectors in which the platform is currently being utilized in is; diagnostication of industrial equipment and EV charging systems, vision systems, and car pooling.

However, the case company has not yet been able to integrate their successful IoT platform into their life science businesses. Still, the company is aware of the great potential of both the platform itself and the increasing digitisation trend towards life science. We are therefore interested in providing theoretical and practical insights, which may help the case company when entering new market.

1.3 Delimitations

This research will not dvel into the technical nature of IoT nor its implementations and the engineering capabilities which lies behind the technology. Instead it will focus on exploring disruptive use cases for the technology within the Nordic market and how IoT could be further utilized within life science.

The scope of this report does not incorporate the implementation of the findings and conclusions from this thesis in the case company. The geographical segment of interest is also limited to the Nordic countries. Due to the varying consensus of life science, we have chosen to only consider the business areas in which the case company is involved in (the pharmaceutical industry & manufacturing of medical devices).

Literature review

This chapter begins with an introduction and description the IoT technology, followed by an elaboration and definition of life science. Additionally, underlying theories and previous research is presented which establishes the foundation of this paper.

2.1 IoT

Rahman and Asyhari (2019) describe Internet of Things (IoT) as the role of an expert´s technical tool by empowering physical resources into smart entities through existing network infrastructures. They further propose that IoT´s primarily focus is to provide smart and seamless services at the user end, without any interruption. IoT can also be perceived as a global ecosystem connecting diverse objects to the internet. By using embedded technologies, especially sensors, these objects communicate with each other and generate and exchange data without human intervention, based on a connection through the internet (Korte et al., 2021). For this paper, we define IoT as:

> A product or machine connected to a network with the purpose of collecting real-time data which can trigger an action or serve as a basis for decision making.

Noticeably, there are several technological driving forces for IoT. Especially centralized cloud networks, which can be considered as the foundation which IoT is developed upon. Another one is the emergence of 5G which has an indispensable role to play for advancements of IoT in order to provide a mobile, reliable and low latency internet service (Liyanage et al., 2021). Chaouchi (2013) describe the hardware aspects of IoT systems as built up by both physical and digital elements, often by utilizing sensors, to perform an action based on the captured data. In combination with sensors are often circuit boards, or single-board computers, programmed to monitor the captured data. Thanks to the limited hardware requirements and energy efficiency, IoT solutions are applicable to a wide range of applications.

The growing attention regarding IoT and its impact can preferably be illustrated by the significant increase of scholarly publications addressing IoT during the last decade. Korte et al. (2021) compiled all publications in the Web of Science (WoS) with the term "Internet of Things" in their title, illustrated below.

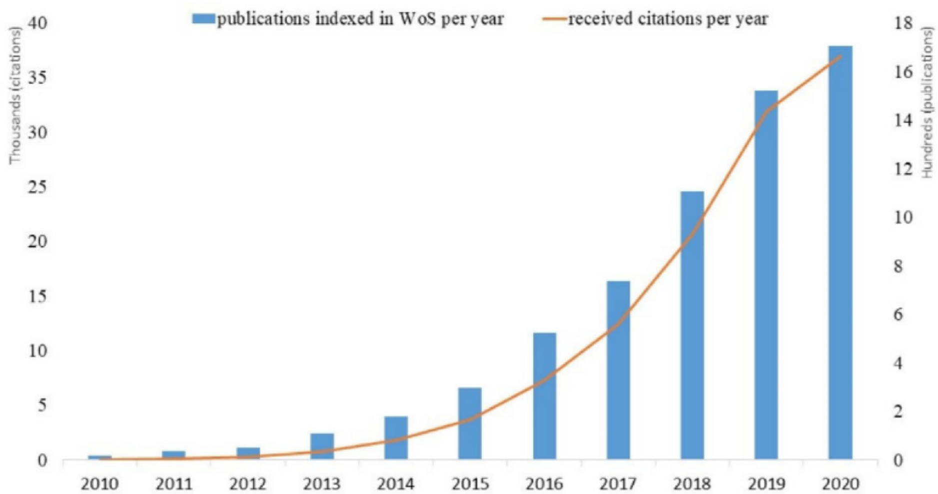

Figure 2.1: *Evolution of IoT research field.* (Korte et al., 2021)

According to Haaker et al. (2021), IoT "will fundamentally change many companies' business models as well as the way consumers interact with these companies and other stakeholders", while Langley et al. (2021) elaborate that "Businesses that succeed in adapting their extant business models to the new technological possibilities have considerable opportunities to innovate and are potentially highly competitive."Langley et al. (2021) continue by underlining the importance for organizations to understand the extent to which IoT will transform their existing business models, and as a part of this, how value creation in such service ecosystems will be affected.

This view on IoT and how it can benefit the organizations which succeed in implementing it is shared between the academia as well as the industry. Deloitte (2020) identifies IoT as one of the big technologies which will provide the bedrock for connecting organizations, generating data and managing more intelligent operations. While many industries are curious about what IoT can bring to their business operations, the life science industry has traditionally been slow, partially due to regulations and a conservative approach to innovation. But this approach is changing, the COVID-19 pandemic brought an urgent change which will ultimately transform the life science industry (Cognizant, 2021).

2.2 Life Science

"Life science" is a broad term that lacks a common and established definition. Rise, the Swedish government funded research institute, describe life science as "an interdisciplinary concept that gathers companies and research whose goal is improved health" RISE (2022). North Carolina Biotechnology Center on the other hand, writes that "The simplest way to define life sciences is the study of living organisms and life processes." (NCBC, 2022). For this study however, life science will be considered as the pharmaceutical industry and the medical devices sector. These are two business areas in which the case company is active within.

2.2.1 The Pharmaceutical Industry

"The pharmaceutical industry can be viewed as a complex system of processes, operations, and organizations involved in the discovery, development, and manufacturing of drugs" (Moniz et al., 2015). The global pharmaceutical industry is a trillion dollar business and steadily increasing (Statista, 2022). According to the European Federation of Pharmaceuticals Industries and Associations (efpia), the pharmaceutical biotechnology sector tops the list of R&D intensity industries. In 2019, 15,4% of net sales revenues was invested in R&D, compared to 11,8% of the second highest R&D intensity sector (software & computer services) (efpia, 2021).

The pharmaceutical industry is inherently characterised by information asymmetry, which means that pharmaceutical companies possess more information regarding their drugs than any other party do (Malerba and Orsenigo, 2015). To ensure the quality of drugs, and in extension the safety of consumers, the European Medicines Agency (EMA) has constructed legislations that all parties within the pharmaceutical value chain have to comply with. Further, all actors have to prove their ability to validate the quality of their processes and products towards the required legislation to hold a certification and that is necessary in order to operate within the European Union.

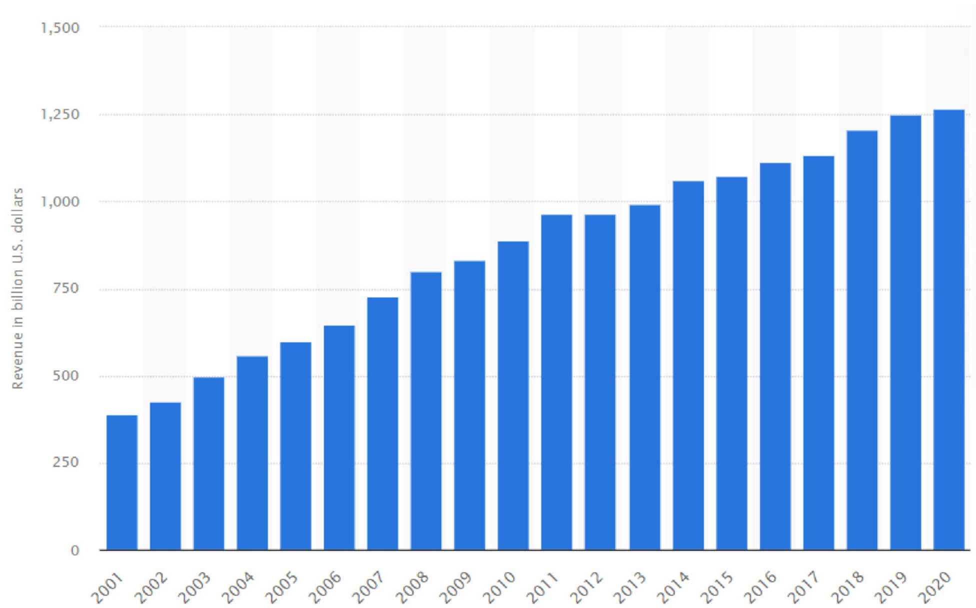

Figure 2.2: *Annual pharmaceutical revenues (global).* (Statista, 2022)

National authorities conduct inspections to ensure that the pharmaceutical actors comply accordingly. (EMA, 2020)

One of the most significant trends we are currently witnessing within the pharmaceutical industry is the emergence of 4P medicine (Alonso et al., 2019), (Lee and Lee, 2015), (Dimitrov, 2016), (Armgarth et al., 2021). P4 medicine entails a focus on systems that include predictive, personalized, preventive, and participative aspects, and proposes an integration of numerous points of biological data to better define the health and wellbeing of the individual person. Personalized models made possible by data analysis can thereby predict transitions to illness and orient medical interventions (Alonso et al., 2019). Further, connected portable devices and software systems are a necessity in this transformation, which IoT can facilitate.

Another practical example of IoT utilization concerns the identification of adverse drug reactions. By combining the pharmaceutical information system (composed of a database with drug descriptions, active ingredients, side effects etc.) with a patient's digital health profile, potential adverse drug reactions can be analyzed and avoided. This system has been implemented in Japan and Spain (Jara et al., 2010). IoT and digital health profiles are also expected to play a significant role in clinical trials. Poor recruitment has been reported to be the most critical reason for clinical trial delays, consequently delaying access to new treatments and increasing drug development costs (Laaksonen et al., 2021). IoT could thereby provide the digital infrastructure to connect participants with desirable profiles to clinical trials with certain prerequisites.

The supply chain logistics of pharmaceuticals is another area in which Pachayappan et al. (2016) call for IoT solutions. Presented issues relates to maintaining accurate temperatures, monitoring mitigation and risk factors during transportation and storing. These problems have become evident considering vaccines during the COVID-19 pandemic, where IoT can aid by providing real-time visibility, traceability, and diagnostics.

Again, this study aims at evaluating IoT within the Nordic life science industry. Yet, the Nordic region is not entirely homogeneous, but consist of multiple counties with different prerequisites. So how does each Nordic country's pharmaceutical industry compare, IoT set aside? By examining the net trade balance (export vs import of pharmaceutical products), one can get a general comprehension of how devoted each county are to their national pharmaceutical industry. Based on the Standard International Trade Classification (SITC) data, efpia has estimated these numbers which are displayed in table 2.1. The figures do also align with the estimates of Statista (2022).

Country	**Net trade balance (€ million)**
Denmark	12,800
Sweden	5,500
Norway	600
Finland	-1,300

Table 2.1: Net trade balance of pharmaceuticals (efpia, 2021)

Clearly, Denmark is very progressive within the pharmaceutical industry, exporting significantly more than they are importing. Moreover, Denmark is exceeding all other counties in terms of production worth, employments, and investments in R&D (efpia, 2021).

2.2.2 Medical devices

World Health Organization (WHO) defines medical devices as "An article, instrument, apparatus or machine that is used in the prevention, diagnosis or treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose" (WHO, 2020). The medical device industry is particularly heterogeneous and overlaps with other fields of healthcare, as medical devices cover a wide range of application areas such as patient diagnostics, surgery, home care, and monitoring (Maci and Marešová, 2022).

In 2020, the global medical devices market size was about $ 430 billion and is expected to grow to $ 650 billion in 2028 (FortuneBusinessInsight, 2022) & (Analytica, 2021). Considering the increasing life expectancy and decreasing fertility rates, the global population is ageing. This phenomenon along with the opportunities that technological advancements are enabling provides a solid market lookout for the medical devices industry.

IoT is one example of a technological advancement that has become a milestone in the digital healthcare domain, thanks to the evolution of high-speed networking technologies and the increasing adoption of wearable devices, smartphones, and other mobile platforms in healthcare (Mavrogiorgou et al., 2019). There are several ways in which IoT is finding its way into the medical device sector, KPMG (2022) states that in the new and digitized life science ecosystem, the patient will take the center stage, and products within healthcare will be customized to each patient's unique prerequisites. This trend is evident in several developments, such as connected sensor wearables for Parkinson's disease and sclerosis patients which provide medication management. In addition, existing medical device products such as inhalers and insulin pens can be connected to gather data for further care analytics, and even personalized therapy Dimitrov (2016).

To ensure the quality and validity of medical devices, the European Medicines Agency (EMA) has constructed the "Medical Device Regulation" (MDR) that all actors within the value chain have to comply with. Further, all parties have to prove their ability to validate the quality of their processes and products towards MDR to hold a certification. This certification is necessary in order to operate within the European Union. EMA is also responsible for inspections to ensure that the pharmaceutical actors comply accordingly

(EMA, 2022).

As outlined previously, the Nordic region is not entirely homogeneous. Thus, we have been examining the net trade balance (export vs import of medical devices) to get a general understanding of how devoted each county are to their national medical devices industry. Based on the International Trade Centre data, MedTech Europe has estimated these numbers which are displayed in table 2.2.

Country	**Net trade balance (€ million)**
Finland	700
Denmark	340
Sweden	-301
Norway	-886

Table 2.2: Net trade balance of medical devices (MedTechEurope, 2021)

Noticeably, Denmark and Sweden are not as progressive within medical devices as in pharmaceutical products. Instead, Finland exports medical devices to the greatest net worth, while their net trade balance for pharmaceuticals is the lowest of the Nordic counties. Additionally, the Nordic medical devices industry is not as big as the pharmaceutical.

2.3 IoT within life science

The global market for IoT and wearable IoT devices is accelerating rapidly, with an annual growth rate of over 65% (Tehrani and Jin, 2018), it is one of the fastest growing technologies. Despite the flexibility of IoT a majority of the devices used today are related to fitness and sports wearables, while the devices aimed for medical use are either in early development stage or haltered by clinical trials (Tehrani and Jin, 2018). Life science, and especially the pharmaceutical and medical device sector are characterized by being highly innovative, R&D dependent and resource intensive (Gbadegeshin, 2019). These characteristics have hampered the digitization trend in these areas compared to others. Despite these obstacles, life science is currently under a digitization trend, fueled by the advancements in sensor technologies and IoT.

2.4 Value Creation

To understand how IoT can affect the value creating ability of a firm and what effect the increased value creation can have for the firm, it is suitable to begin by looking at what value creation is, and how it can be defined. Grönroos (2013) refers to value creation as a process which increases the customer's well being and renders the end user better off in some way. This concept has gained importance in recent years, Chiarello et al. (2021) states that besides pursuing the promise of an emerging technology, firms also have to understand and address the specific challenges that technology may present. This is necessary to better direct their value creation efforts.

This paper distinguishes between two types of value, social and economic. Social value emerges, i.e., from positive experiences and pleasant encounters (Dann et al., 2020), and can be evident in the positive experiences gained when implementing IoT, from reduced workload or more reliable collected data. Mehera and Ordonez-Ponce (2021) views social value as a positive change affecting both individuals and communities. We define social value as:

Improvements in quality of life for individuals or society, e.g. reduced stress.

On the other hand, economic value can be derived from cost savings, reliability or utility value (Dann et al., 2020). This definition of economic value is similar to Investopedia (2022), where economic value is defined as the value placed on a good or service, based on the benefits obtained from it. For this paper, economic value is defined as:

The economic advantages IoT can bring to an organization, i.e. increased savings or reduced cost.

Ormiston and Seymour (2011) describes that "new value creation occurs through the process of innovation and technological advancement, with the economy as a whole benefitting from new firms supplanting older, less innovative, firms". The success of creating, delivering, and sustaining value, is dependent of the dynamic capabilities of the value provider.

2.5 Dynamic Capabilities

The theory of dynamic capabilities has emerged as one of the most profound frameworks within strategic management, studying competitive advantage in environmental conditions characterized by high dynamism (Schilke, 2014). Traditionally, competitive advantage can be gained *at a point in time* from ownership of scarce, relevant, and difficult-to-imitate assets, especially know-how. Yet, *sustaining* a competitive advantage in a global and fast-moving business environment requires adapting to changing customer needs and technological opportunities (Teece et al., 1997).

Since Teece et al. (1997) first defined the theory of dynamic capabilities, there has been a number of interpretations and variations of its utilization. While some highlight the underlying nature of dynamic capabilities as an ability, others conceptualize dynamic capabilities as a process that is more or less repeatable, identifiable and stable (Steininger et al., 2022). Due to the immense and heterogeneous application areas of IoT, we do not find it entirely applicable to address the concept of dynamic capabilities as an stable and repeatable process. We are therefore considering dynamic capabilities as it was originally designed, as an ability.

Dynamic capabilities are especially important in rapidly changing market dynamics and in the context of emerging technologies (Schilke, 2014). Given the disruptive nature of digitalisation, Warner and Wäger (2019) posit that "dynamic capabilities is a powerful lens for examining the digital transformation". In big data analytics (BDA), which IoT very much entails, dynamic capabilities represent a suitable approach for value creation as BDA systems may support an organization in adapting an existing resource base to address changing environments (Rialti et al., 2019). Digital transformation can also support an organisation's development of its internal dynamic capabilities. For instance, digital transformation allows companies to build direct emotional relationships with their customers, which enhances their sensing capabilities. This customer understanding, facilitated by digital means, is also beneficial in terms of transformation capabilities (Matarazzo et al., 2021).

The concept of dynamic capabilities lies on three principles, or practices, namely *sensing, seizing & transforming*. In the increasingly global competitive market with rapid technological advancements, consumer needs and competitor activities are constantly in a state of flux. Hence, "sensing new opportunities is very much a scanning, creation, learning, and interpretive activity" (Teece, 2007). As a new (technological or market) opportunity is identified, it must be addressed through new products, processes, or services. Additionally, a particular business model that aligns with the commercialization strategy must also be selected. These aspects relate to an organization's capabilities of seizing. Ultimately, as an opportunity is seized and a sufficient business model is put in place, the organization need to transform its tangible and intangible assets to maintain competitive advantage (Teece, 2007). Activities that supports a firms dynamic capabilities could be; Internal cross-functional workshops (sensing), business collaborations (seizing), and continuous SWOT analysis (transformning).

To examine how organizational dynamic capabilities influence at an industry level, the framework of industry capabilities can be considered. Lampel and Shamsie (2003) describe industry capabilities as systemic properties that result from the behaviour of firms acting to improve their position within their industry by searching for new practices and routines, consequently benefitting the consolidated industry. Lampel and Shamsie (2003) further analyzed industrial capabilities by adopting a dynamic capabilities perspective, which resulted in the key assertion that the evolution of industry capabilities is linked to the evolution of the relationship between a firm and industry structure.

When firms in an industry remobilize activities, due to organizational dynamic capabilities, the externalization of internal resources that often accompanies this shift changes the industry's competitive dynamics. The immediate effect is an acceleration of the innovation–imitation cycle. For example, new best-practice routines and products are observed and become a source of inspiration for competitors within the industry. This scenario reinforces the evolution of industry capabilities by increasing shared routines and practices at the expense of specific firms (Lampel and Shamsie, 2003).

Method

The following chapter outlines how the research was conducted, the selected research design and the chosen approach.

3.1 Research Strategy and Design

When selecting a suitable research strategy it is common to distinguish between two conventional approaches, qualitative and quantitative (Bell et al., 2019). The quantitative research strategy emphasizes on quantification in the collection and analysis of numerical data. This entails testing and validating a theory based on large amounts of merely numerical data. On the other hand, a qualitative research strategy focuses on words, rather than the collection and analysis of large datasets (Bell et al., 2019). Blaikie and Priest (2019) continue this explanation by stating how a qualitative strategy is used to describe and explore a social situation or context by using words. This study has a descriptive purpose and will both explore and identify challenges as well as the potential of IoT, therefore a qualitative research strategy was chosen as the most suitable for fulfilling the research aim and answering the selected research questions.

Blaikie and Priest (2019) differentiate between four different research designs, inductive, deductive, retroductive and abductive, and explains how the selected research design must be based on choices which are suitable to the posed research questions and the selected topic. The inductive approach is appropriate for descriptive or explorative purposes. The abductive approach is also fitting for descriptive purposes, but unlike inductive, is suitable for theory generation. The deductive approach aims at testing and validating a proposed theory based on some existing literature. Lastly, the retroductive approach is described by Bell et al. (2019) as involving working backwards from an observed social or economic phenomenon with the aim of finding the cause of it. As outlined earlier, this study has a descriptive purpose aiming to both explore and identify key challenges and opportunities for IoT within life science. Moreover, this study includes data collection related to these concepts and searches for patterns and similarities within the collected data set. With this in mind, the inductive research approach was selected as the most suitable.

Bell et al. (2019) describe the case study design as an intensive and in-depth examination of a single organization, location, event, etc. Andrade (2009) continues this discussion by bringing up the advantages of the interpretive case study design, since it provides an opportunity to get a deep insight into the problem under study. Interpretive research makes it possible to present the researcher's own constructions as well as the respondents (Andrade, 2009). This study is a case study in the sense that it focuses on a single case company, but will however be based on interviews with customers from various organizations, acquired from our contacts at the case company. Therefore, this study can further be viewed as an interpretive case study, since it will also identify what the customers of the IoT platform think of it, and how they value it.

3.2 Data collection

This thesis consists of both primary and secondary data. Primary data is build up by interviews with people relevant to the thesis aim. The secondary data consists of our literature review combined with documents and presentations provided by the case company.

3.2.1 Literature review

According to Bell et al. (2019), the literature review is an important step in the process of conducting research and serves to link the research questions to existing literature. During the literature review, existing literature on the topic was read. The literature provided the researchers with a greater understanding of what is already known in the selected research field, and strengthened the credibility of this study. For this purpose, Google Scholar and Chalmers library database was used as the main way of finding reliable sources, and the reference's credibility was assessed by the number of citations. When searching for relevant literature, the following keywords were used:

Key words:
IoT, Internet of Things, Life Science, Medical Devices, Pharmaceutical industry, Value Creation, Social value, economic value

3.2.2 Interviews (Primary Data)

There are a variety of methods for data collection in qualitative research, including observations, textual or visual analysis, and interviews (Gill et al., 2008). Moreover, qualitative interviewing is a powerful method to capture the ways people make meaning of their experiences (Rabionet, 2011). As this study aims to identify value and challenges, which are subjects of personal perceptions, interviews were chosen as a suitable data collection method. Additionally, this study has a descriptive purpose, thereby making interviews sufficient due to its descriptive nature. Interviews were held with employees at the case company who operates within the life science industry, as well as the manager of the IoT platform. External specialists within IoT and its various business applications were also interviewed. A summary of all informants is depicted in table 3.1.

Depending on the interviewee´s experience with IoT and life science, two types of interviews were held, unstructured and semi-structured. The unstructured interviews were held when the researchers had limited information about the respondent and needed a format that permitted the authors to talk freely around a few questions. If the person was found relevant, another semi-structured interview was scheduled. In other cases, when it was obvious the respondent was knowledgeable about IoT and life science, only a semi-structured interview was conducted. This approach was preferable since life science is a broad field and it was not always known before the interview if the respondents expertise would be in line with this study´s definition or not.

The unstructured round of interviews was open in the sense that few questions were prepared in advance and a general discussion considering life science and IoT was encouraged. Bell et al. (2019) state that this approach is preferred when the researcher wants to see things the way the participant sees them. The semi-structured method was chosen due to the broad consensus and varying perspectives of both life science and IoT, which demand a certain degree of flexibility that the semi-structured format provides. As semi-structured interviews aim to provide clarity in a predefined area of interest, an interview guide should be arranged in beforehand. The interview guide covers the main topics of the study and offers a focused structure for the discussion, but should not be followed strictly. Instead, the idea is to explore the research area by collecting similar types of information from each participant by providing them with guidance on what to talk about (Kallio et al., 2016). The interview guide was designed by first outlining the aim and purpose of the study, followed by questions regarding the participant´s experience of IoT and the organisation itself. Thereafter, questions were designed to identify the participant´s perspective of social and economic value as well as challenges regarding IoT within life science, with follow up questions to examine underlying reasons to the participants point of view. The interview guide can be found in appendix A.

The participants of the semi-structured interviews were also provided some topics that the interview was orientated around beforehand. This was to provide the best conditions for contribution by sharing the context pre-interview and to strengthen the dependability of the research (Bell et al., 2019). Matters of confidentiality were also discussed before the interview took place. The interviews were recorded if agreed to and lasted about 30-90 minutes. Afterwards, the interviews were transcribed and sent to the interviewee to ensure consent and trustworthiness.

In terms of sampling strategies, purposive sampling followed by snowball sampling was used in this study. In purposive sampling, people are selected in a strategic way because of their relevance to the research questions being posed (Bell et al., 2019). The purposive sample was initially based to utilize the existing knowledge in life science and IoT from the employees of the case company. Thereafter, the researchers established contact with others that were recommended from the purposive sampling, so-called snowball sampling (Bell et al., 2019). The criteria set for sampling was several years' experience of working with digitalization within life science, preferably with IoT integrated solutions. Company representatives, as well as regional business developers (specialized in digitalization within life science), were interviewed. While company representatives were sufficient in providing practical, specific, and empirical insights, regional business developers were a great complement in including macro perspectives considering IoT within life science.

Easterby-Smith et al. (2021) highlight *precision* and *representativeness* as two aspects that should be reflected upon in the sampling process. Precision considers the credibility of the results gained from the sample, while representativeness acknowledges the accuracy of the sample´s description of a larger population. Thanks to the purposive sampling being based on different stakeholders of IoT integration within life science, the researchers consider matters of precision and representativeness to be met. However, when using snowball sampling there is a potential bias risk that the recommended person shares very similar views as the previous person (Bell et al., 2019). This risk has been addressed by analyzing primary data gotten from interviews with secondary data, as well as existing literature when feasible. This method is called triangulation, where the result of one data collection method is cross-checked against other data sources (Bell et al., 2019). Also, interviews were conducted until theoretical saturation was reached. Theoretical saturation implies the state when further interviews do not contribute to new findings or additional data (Bell et al., 2019).

<table>
<tr><th>Internal/External</th><th>Participant</th><th>Role</th><th>Topic Covered</th><th>Duration (min)</th><th>Format</th><th>Type</th></tr>
<tr><td rowspan="4">Internal</td><td rowspan="2">A</td><td rowspan="2">Manager of IoT</td><td rowspan="2">IoT - Platform</td><td>60</td><td>MS Teams</td><td>Unstructured</td></tr>
<tr><td>90</td><td>In person</td><td>Semi-structured</td></tr>
<tr><td>E</td><td>Projekt manager</td><td>Regulations within life science</td><td>60</td><td>In person</td><td>Unstructured</td></tr>
<tr><td>J</td><td>Department manager</td><td>IoT within life science</td><td>60</td><td>In person</td><td>Unstructured</td></tr>
<tr><td rowspan="12">External</td><td rowspan="2">B</td><td rowspan="2">Board member</td><td rowspan="2">IoT within life science</td><td>60</td><td>MS Teams</td><td>Unstructured</td></tr>
<tr><td>90</td><td>MS Teams</td><td>Semi-structured</td></tr>
<tr><td rowspan="2">C</td><td rowspan="2">Department head</td><td rowspan="2">IoT and medical devices</td><td>60</td><td>In Person</td><td>Unstructured</td></tr>
<tr><td>45</td><td>MS Teams</td><td>Semi-structured</td></tr>
<tr><td>D</td><td>Project leader</td><td>IoT within life science</td><td>40</td><td>Telephone</td><td>Unstructured</td></tr>
<tr><td>K</td><td>Business advisor</td><td>Regulations within life science</td><td>60</td><td>MS Teams</td><td>Unstructured</td></tr>
<tr><td>L</td><td>Project leader</td><td>IoT within life science</td><td>60</td><td>In person</td><td>Unstructured</td></tr>
<tr><td>M</td><td>Legal advisor</td><td>Regulations within life science</td><td>60</td><td>MS Teams</td><td>Unstructured</td></tr>
<tr><td>F</td><td>Department head</td><td>IoT within life science</td><td>45</td><td>MS Teams</td><td>Semi-structured</td></tr>
<tr><td>G</td><td>Researcher</td><td>IoT within life science</td><td>90</td><td>MS Teams</td><td>Semi-structured</td></tr>
<tr><td>H</td><td>Department head</td><td>IoT within medtech</td><td>30</td><td>MS Teams</td><td>Semi-structured</td></tr>
<tr><td>I</td><td>Business advisor</td><td>IoT within life science</td><td>30</td><td>MS Teams</td><td>Semi-structured</td></tr>
<tr><td>Total</td><td>13 Participants</td><td></td><td></td><td>15 hours and 40 minutes</td><td></td><td></td></tr>
</table>

Table 3.1: Internal and external interviews.

Table 3.1 is structured by first presenting the internal respondents, all employed by the case company. Their respective role at the company together with the duration and format of the interview is also presented. Bellow the internal interviews the external experts which were interviewed are presented with the same structure. In total 16 interviews where held and 13 different respondents were interviewed.

3.2.3 Internal Documentation (Secondary Data)

The researchers gained access to internal reports and PowerPoint presentations from contacts at the case company. These documents supported the understanding of the IoT platform´s utilization and provided an illustration of the different components within the platform. The internal documents also provided insights into how the case company works with standards and regulations within the medical device and pharmaceutical sectors. These internal documents were a good addition to our literature review and interviews since they complemented the gathered literature in relation to the case company. A summary of the secondary data sources is depicted in table 3.2.

Document	Length	Description
Presentation A	16 Slides	Customer presentation of the IoT platform
Presentation B	19 Slides	Presentation of case company and IoT
Presentation C	38 Slides	Regulations within life science
Document D	118 Pages	Regulations for medical devices.
Document E	52 Pages	Standards and regulations for life science
Document F	28 Pages	Digitalization within life science
Total	73 Slides and 198 Pages	

Table 3.2: Secondary data sources obtained from the case company.

The primary data presented in table 3.1 was gathered and analyzed in order to answer the stated research questions. The secondary data instead served the purpose of helping the researchers understand the case company context and their established IoT platform better. The secondary data further provided insights on how the platform is marketed to customers, and presentation about regulations for life science.

3.3 Data Analysis

A thematic analysis was pursued in the process of organizing and analysing the collected qualitative data from interviews. As described by Braun and Clarke (2006), thematic analysis is a method for discovering and analysing patterns within a data set through a systematic and replicable process. Further, Bell et al. (2019) state that thematic analysis in qualitative research is a suitable method for reaching an in-depth consensus on the field of interest. As this study aimed to provide knowledge and insights by describing challenges associated with IoT within life science and IoT´s potential to create value, this methodology was seen as beneficial.

The thematic analysis was conducted according to the methodology proposed by Braun and Clarke (2006), starting with manually transcribing the acquired interview data. Afterwards, key features within the data set which appeared interesting to the research questions were extracted, so-called codes. To contextualize, several interviewees mentioned elderly care as an area with great potential to create and deliver customer value through IoT. Since this commonality was observed across multiple informants, the researchers arrived at a "IoT enabling improved elderly care" code that contains similar aspects. Afterwards, all codes were subsequently organized and combined, based on their similarities, into first-order themes. For example, the previously mentioned code regarding elderly care was merged with other codes orientated towards social value into the theme "Patient-centred values derived from IoT". Second-order themes were later created from the first-order themes, hence continuously consolidating data from codes into overarching second-order themes. The first level theme considering patient-centred values was thereby merged with organisational-centred values into the second-level and final theme "Social and economic value derived from IoT".

Braun and Clarke (2006) describe that a thematic analysis can be conducted in two ways, either by an inductive or a theoretical approach. What distinguishes them is the interpretation of data and in extension the essence of themes. The inductive approach requires themes to be strongly linked to the data itself and should not be driven by the researcher´s theoretical interest in the area. In contrast, the coding in a theoretical thematic analysis should be strongly linked to the posed research questions and be driven by the researcher´s theoretical interest in the topic. Since the aim of this study was well defined with a clear theoretical context linked to value creation, a theoretical thematic analysis was pursued.

The gathered interviews were transcribed and then discussed between the researchers to make sure the respondent had been correctly understood. In cases where the authors were unsure what the interviewee meant, the section was discussed again with the respondent. The interviews were further continuously coded by carefully reading through the transcribed data and making notes and highlighting quotes and sections which were repetitive or relevant to the study. When all the transcribed interviews had been summarized and initially coded, all codes were moved from Google Docs to Google Spreadsheet. The citations were then grouped based on similarity and common elements. Bell et al. (2019) explains how it is important to reflect on the initial codes to gain a sense of continuity and linkages between them. Since the purpose of this research is to identify and explore the value of IoT within life science, and the potential challenges for the technology, codes relevant for this purpose were categorized and grouped together. Following this, the researchers discussed how the codes should be further combined into themes. Braun and Clarke (2006) states that a theme should capture something important about the data in relation to the research questions. With this in mind, the first-order themes were derived from groups of codes with similar meanings and implications. Finally, the first-order themes were categorized into second-order themes based on the type of value or challenge the first-order theme identified.

Codes (32)	*1-level themes (9)*	*2-level themes (4)*
IoT enabling improved elderly care	**Patient-centred values derived from IoT**	**Social and economic value derived from IoT**
Using IoT to monitor vitals on humans		
IoT driving predictive, preventive, personalized and participatory (4P) medicine		
IoT providing increased knowledge regarding patients medicine usage		
IoT supporting diabetic patients		
IoT acting as a decision support	**Organisational-centred values derived from IoT**	
IoT as a component in digital simulation		
IoT providing information and knowledge about product usage		
IoT facilitating improved diagnostics		
Remote control of medical procedures made posible by IoT		
Reducing costs and increasing revenues by IoT		
IoT providing possibilities for extended ownership over value chains	**The potential of IoT to transform life science businesses and their delivery of customer value**	**Challenging and benifitial implications of digital transformation within life science**
IoT enabling different business models		
IoT enabling faster R&D output	**Implications on internal operations management following IoT implementation**	
IoT facilitating speed and efficiency gains in production		
Conservatism regarding new technologies and IoT		
Life science as a conservative and slow-moving industry	**The Nordic life science industry**	**The Nordic life science market and industry**
Life science regulations as a challenge		
Public and private care associated challenges	**The Nordic life science market**	
IoT as an asset in reaching and understanding customers		
Market related considerations when scaling IoT		
Battery and hardware challenges for IoT	**Technical concerns and issues of the prerequisites necessary for IoT**	**Technical opportunities and challenges of data management and IoT integration**
Connectivity related challenges		
Environmental sustainability concerns		
The need for reliable IoT solutions		
Issues of competability in different data formats	**Data related challenges with IoT utilization**	
Rights to ownership and usage of collected data		
Integrity issues of sensitive personal data		
Data storage and sharing challenges		
Cyber security challenges for sensitive data		
Access and sharing of data promotes value creation and delivery of IoT services	**Technical opportunities to create value by IoT**	
Posibilities when consolidating AI and IoT		

Figure 3.1: *Thematic analysis.*

Eventually, the second-level themes were formulated as

-*Social and economic value derived from IoT*

-*Challenging and beneficial implications of digital transformation within life science*

-*The Nordic life science market and industry*

-*Technical opportunities and challenges of data management and IoT integration*

By not analyzing the challenges and values separately, the authors hoped to provide a more nuanced result. A complete representation of all codes and themes can be seen in table 3.1 above.

3.4 Research Quality

Trustworthiness has been an important aspect of this research, and a concept that has been carefully considered through the process of writing this thesis. Bell et al. (2019) describes how trustworthiness is made up of four criteria: credibility, transferability, dependability, and confirmability.

Credibility is described by Bell et al. (2019) as making sure the research follows good practice and submitting the findings to a member of the studied social world. For ensuring credibility, the research steps have been carefully documented and outlined in the study, and all transcribed interviews were sent to the respondents for verification that it has been correctly understood. To further increase the research credibility, triangulation in the data collection was used. Triangulation involves gathering data from multiple sources, such as interviews, literature reviews, and internal documents from the case company.

Transferability involves whether the research findings will apply in another context than what is covered in the research (Bell et al., 2019). For ensuring transferability throughout the research, the authors have given a detailed description of each interview, and the total number of transcribed pages. Furthermore, interviews were held until theoretical saturation was reached to make sure as many perspectives as possible were included in the thesis.

Dependability is described by Bell et al. (2019) by the adoption of an auditing approach, where it would be possible for peers to take part in all data from all phases of the research process. For maintaining dependability a detailed description of how the steps in the research have been carried out has been documented. This includes a literature guide, transcribed interviews, and the analysis of the gathered data. The final report will also undergo a peer review before publication.

The final criterion of trustworthiness is confirmability which is concerned with ensuring objectivity and avoiding the researcher's own personal values affecting the results of the study (Bell et al., 2019). Bell et al. (2019) argues that it is impossible to achieve complete objectivity in qualitative research. To ensure confirmability in the research the transcribed interviews and selected quotes were discussed with the respondents to make sure they were correctly understood and not interpreted by the authors.

3.5 Ethical Considerations

According to Bell et al. (2019), research ethics can be divided into four aspects: whether or not there has been- harm to participants, lack of informed consent, invasion of privacy, or deception. Bell et al. (2019) also state that issues of confidentiality and anonymity can be especially challenging in qualitative research.

These considerations have been addressed by informing all interviewees about the research and its purpose, their role in it, and their rights of not being obligated to answer any questions. Further, permission to record the interview was always asked. Afterwards, the transcription of the interview was offered to the interviewee if wanted. Based on the intention and purpose of this study, no additional value would be gained from information about specific participants, nor the case company. Therefore, all names have been kept anonymous to ensure confidentiality. The case company has also been provided with this report before publishing to reach a mutual agreement on its content. Quotes from interviews being used in this report have been sent to the respective interviewee to ensure consent.

Empirical findings

In this chapter, we present the empirical findings derived from the interviews. Moreover, these findings represent what different stakeholders of IoT implementation within the Nordic life science industry did acknowledge as challenging or beneficial. This chapter is organized according to the result of the thematic analysis. The four second-order themes constitute the headlines, which are further elaborated on based on the first-order themes they emerged from.

4.1 Social and economic value derived from IoT

During the interviews, several respondents brought up different aspects of both economic and social values that could be derived from implementing IoT. All organizations strive to increase their profitability, which was identified as a driving force behind IoT implementations. The economic values which were identified mainly involved using IoT as a way to reduce the operational costs or utilizing it for increasing the revenue streams. The social values brought up mainly included an increased sense of security and relieving stress which could be experienced by connecting certain objects to the internet. The following sections 4.1.1 - 4.1.2 describe in more detail which benefits IoT may bring to both patients and organizations.

4.1.1 Patient-centred values derived from IoT

The opportunities for IoT within life science are many, according to a majority of the respondents. Some of the most recurrent opportunities mentioned were within elderly care and medicine manufacturing and treatment. Respondent B states:

"Elderly people are generally a population which will benefit a lot from remote care since they often have difficulties getting to a hospital for treatment. IoT

plays an enormous role when it comes to providing efficient and accurate remote care."

Several respondents brought up the value of learning more about your customers and how the products are used. For a pharmaceutical company, which has a focus on R&D, learning more about how the developed medicine is being used by gathering real-time data can shorten the lead time for development. This also applies to manufacturing companies, which develop equipment targeting patients. Respondents gave examples of how an increased knowledge about product usage can help companies develop new equipment that better suits each patient's needs. Respondent A exemplifies:

"It is frightening to see how little companies know about how their products are being used. By connecting machines and having them send real-time data which can then further be used as input to research and development of new products which better fulfill the customer requirements. This is far better than sending out surveys, hoping to get valuable insights. IoT can be a huge help here."

"If you have an IoT device that tells you the sugar rating on a real-time basis, then you will be able to manage that disease more effectively, not only for yourself but also for your near ones. If you have a kid that has diabetes, you can actually not be so worried because you are tracking your kid on a real-time basis."

All respondents acknowledged some benefits for patients that IoT could bring with a focus on gathering real-time data which could be used to increase knowledge about patients health status or increase the quality of life for sick patients.

4.1.2 Organisational-centred values derived from IoT

A majority of the respondents discussed and gave examples of how IoT can be utilized within organizations, to both provide better care and streamline operations. Values discussed during the interviews ranged from improved diagnostics and decision support for hospitals and physicians to using gathered data as a basis for the education of healthcare professionals. To understand how IoT can transform and provide value for organizations acting in life science, respondent I states:

"The potential for increasing reliability of a doctor's decision is huge. If IoT could capture enough data, and subsequently learn to act and take decisions based on that data, it could serve as decision support for doctors, as a second opinion."

This idea was lifted by several respondents, who believe the healthcare system as it functions today faces several challenges, which could be reduced or solved by a more connected organization. Respondent C continues:

"The biggest weakness of today's healthcare is subjective decisions made, to instead take more data-driven decisions based on data captured for each individual patient, we could see a lot of improvements in this area."

Respondents further made a case that this captured data from real patients could be used in the education of physicians, by providing them with a simulation of a real medical procedure. Respondent D states:

"I believe digital simulations, based on data captured by connected medical devices, will be used for training of surgeons and doctors. Let's say if you want to be an eye surgeon, you would have to have passed several simulated tests for various procedures before you get your license. This is an area I believe will only be growing."

Interviewees argue that the implementation of IoT within life science organizations will have the possibility to capture an abundance of data, which then can be analyzed and used for several purposes, from educational use to decision support.

As stated above, the prospect of increasing the organization's profitability can be a driving force to IoT and a more connected and digital operation. This was clear from several respondents who talked about the various possibilities to both increase an organization's revenues and decrease costs. Respondent B gave an example of this:

"When IoT gives you the possibility to reach the patient online, and provide better care, you can reduce your operational cost."

This was also supported by respondent A, who states:

"If we can learn how our internal operations work, by gathering and analyzing data, we can then optimize and streamline these operations, which in the long run will save us both time and resources."

Several respondents also lifted the possibility of increasing revenues with IoT. Respondent C states:

"IoT helps us to improve our customer offerings. When we learn how our customers are using and interacting with our products, we can tailor them to better suit each customer better. This is helping us to sell more products"

During all interviews, some aspects of financial benefits were mentioned, both within the companies that were actively working with digitalization and IoT and those who were planning to start within the foreseeable future.

Several respondents discussed the challenges for skilled surgeons having to be present with the patients for all medical procedures. This was discussed as having a limited effect since surgeons could be more time-effective if they could do their operations remotely. This was further an area interviewees suggested there is an advantage for IoT and a more connected health care. Interviewee B exemplifies:

"IoT will also give the possibility to drive efficiency by doing certain things remotely. Without a digitalized health system this is not possible, and skilled surgeons will spend half their time traveling between sick patients."

During the interviews, respondents brought up how digitalization and especially IoT can transform an entire industry, by providing possibilities for servitization and facilitating monitoring of a product's value chain. This is presented in the next section.

4.2 Challenging and beneficial implications of digital transformation within life science

Disruptive technologies bring both challenges and opportunities for companies, not least in conservative sectors such as life science. This became obvious during the interviews when respondents brought up several major opportunities the technology could bring, but how challenging it could become for an organization trying to implement them in a slow-moving industry. The following sections, 4.2.1 - 4.2.2 will give some examples from the gathered data of challenges and opportunities for IoT.

4.2.1 The potential of IoT to transform life science businesses and their delivery of customer value

Respondents frequently brought up the benefits of getting "closer" to your customers and being able to monitor and gather data continuously as the product is being used. The possibility to take control of a larger section of the value chain for a product was discussed frequently. Respondents referred to the possibility to bypass middle hands if the manufacturer of a medical device also can get insights into how the product is being used, rather than trying to collect information from hospitals and health centers. Respondent B states:

"Using IoT to gather data is a powerful tool for manufacturers of medical equipment. You can shorten that entire lead cycle which in many cases was not possible before digitalization. Now you have direct access to information, which shortens the lead time for getting that information."

Another aspect brought up by the respondents was the possibility to transform your organization's business model. IoT enables companies to solve problems in new ways, which in turn makes new business models possible. Gathering data from customers using the products makes it possible to sell additional services. Several respondents discussed how IoT within health care often requires additional products to be sold, e.g. batteries to power the device. Respondents believed there is a possibility to sell subscription models of batteries or other services and components needed for the device to function as intended. Interviewee A states:

"IoT helps companies transform their entire business model. They can be much more effective and direct when making data-driven decisions by collecting and utilizing real-time data."

The idea that IoT can open up new possibilities for organizations wanting to change business models is also supported by respondent B:

"When companies are directly connected to their products, and therefore their customers, they can create disruptive business models and increase their revenues. "

4.2.2 Implications on internal operations management following IoT implementation

All respondents, in one way or another, discussed the immense impact the collected data can have on an organization. This opportunity may be even bigger for organizations that are R&D intensive, such as pharmaceutical developers and manufacturers. Collecting data in real-time from patients in a test group for new drug development can drastically shorten the time to market. This was discussed in detail with respondent F:

"You can use the data from IoT as feedback in drug development. Pharma and life science businesses always rely heavily on your ability to do research. This is a very research-intensive industry. This can reduce the risk of failure in drug development."

Respondents discussed the time it takes for traditional companies to gather information and data on how a drug is affecting the patient, connecting the patient would enable much faster feedback. This was discussed as extra relevant in vaccine development when time is of the essence. Several respondents further discussed the advantages IoT can bring to the production of pharmaceuticals. Respondent F gave an example of this:

"In the pharma industry, you always have to test your developments before you can put them into production. This requires clinical trials. With digital solutions like IoT, you can monitor the patients that are in the trials and get better and faster results."

Interviewees often referred to life science as a conservative and slow-moving industry, which potentially could prove to be a challenge for IoT and digitalization. Many respondents considered IoT as a new technology, and although seeing potential, they were skeptical to the willingness to adapt it to life science. Respondent D states:

"The life science market is really conservative, and for a technology to be successful the market needs to be mature. If it is not mature you will have a huge challenge to reach your customers."

Despite the characteristics of life science, a few intervieewes believed certain geographical markets could be more willing and ready to adopt new technologies than others. Respondent E believes the Swedish market may be more open and willing to adapt to new technologies than the other Nordic countries.

"In my experience, the Swedish market is relatively open for new technologies, and could therefore be a good place to start implementing IoT.

4.3 The Nordic life science market and industry

This section outlines the prerequisites and particularizes of operating in the Nordic life science business. Firstly, details and interesting characteristics regarding the industry itself are outlined. One of them being the high degree of necessary regulatory compliance. Secondly, market dynamics will be covered including differences between public and private actors. Finally, benefits gained from IoT in reaching and understanding end-customers (consumers and patients) are elaborated upon including a practical example.

4.3.1 The Nordic life science industry

The Nordic life science industry is, by multiple interviewees, a very conservative sector which can make it challenging to achieve acceptability for any new technology. Respondent B describes:

"Life science is an industry that is a bit slow in the adaptation of such technology (IoT). For good reasons, because you don´t want to just try here. An additional responsibility is also associated with this industry of being extremely sensitive. I mean, it can be a matter of life and death, really"

The perception of the industry being conservative, for better or worse, is shared by respondent D, saying:

"The med tech and pharma sectors are more conservative than most others. There is a precautionary principle in the industry that fundamentally is positive in some way, but I think it is very much based on being worried about what you can actually do in terms of not violating any regulatory compliance"

When asked why the life science industry is specifically conservative, several interviewees highlighted the risk of severe complications for individuals if products do not fulfil their intended use. Consequently, that potential risk demands high levels of quality assurance which is directed by regulations.

Following these regulations is, according to multiple interviewees, an expensive and time-consuming necessity and a significant challenge for adopting IoT. Respondent E states:

"To sell something as a medical device, you must comply with MDR. Also, for more advanced products you must have independent bodies that review and control that you meet all the requirements. In MDR, it is clearly stated that you must meet these different standards, must do a risk analysis according to ISO 14971, must have a quality system, et.c. Before 2021, this has been more of a recommendation and not specified.

So as a med-tech company you must now be able to follow a backlog where you can show the data and how you have reasoned. This includes proof that the product is safe, documentation supporting the risk analyses, and so on. You must show that you have thought about everything that can happen and possibly go wrong. So the very small companies now suddenly need a quality program, with responsibilities and positions, it is very difficult for them. It costs a lot too."

Hence, changes in existing compliant processes and products cause immense complications for life science companies. According to several interviewees, these circumstances require significant tangible gains when integrating IoT into manufacturing processes or products. As respondent G put it, *"then the question is whether the IoT solution that you are providing me is better than the solution I already have"*

Several interviewees also pinpoint the extensive lead times for research and development of new products as another aspect that aggregates life science as a slow-moving industry. Respondent B exemplifies:

"The big problem is this whole time to market. R&D lead times for drugs or vaccines can range from several years to a decade and during that time technology evolves a lot. So, it takes a lot of investment to get anything new into that industry."

When asked about how prerequisites of managing life science operations differ depending on geographical areas and countries, many respondents outlined that regulatory requirements differ between countries even though EMA seek a consolidated European market. In relation to the global life science market, respondent C saying:

"I think you have to adapt, differentiate and compete with high quality when we have a Western- European industry where we cannot compete with mass production and cheaper technologies. Then we must work with the latest instead."

4.3.2 The Nordic life science market

The Nordic life science market, which is considered as the customers of pharmaceutical products and medical devices as well as patients and end-consumers, is according to several interviewees quite unique. The most noticed trait however is the divergence of stakeholders, which ranges from institutions and agencies, regions and municipalities, private and public health care providers, patients and consumers. A challenge for IoT in public care is described by person H as:

"When working towards public care, the digital transition takes a very long time because the public environment is very organized according to a certain type of care. So, from a Nordic perspective, it is organizational changes that need to be directed for these products (IoT) to be able to function operationally"

Another difference between the public and private domain is raised by respondent D, saying:

"In public environments, it's not okay to make mistakes since your operations and documentation need to be publicly available. Mistakes become public and you get exposed. This is especially critical when it considers individuals' health and well-being. I think people are more careful then."

Respondent G also stresses the complexity of operating in the Nordic life science market, saying:

"When you try to work with digital health, the processes and the ways of doing it differ because the responsibilities are not in the same institutions and agencies."

Noticeably, there are challenges associated with IoT integration within the complex Nordic health care system. However, as health providers aim to facilitate be best possible care for patients, how can IoT promote this task in creating and delivering social value? An opportunity mentioned in multiple interviews is by utilizing IoT to reach and understand consumers or patients more efficiently. Respondent B contextualizes:

"When utilizing IoT you have a possibility to reach the customer or the patient directly. That provides an ability to do many things if you understand if the customer is liking the service or product or not. That understanding provides insights that enable value addition, which could be more services to the end-user. You also understand if the service or product is being positioned to the right patient or not."

One practical example of how IoT can be utilized to generate knowledge of patient behaviour was provided by respondent C who participated in the development of an IoT diaper. He explains that:

"The project really initiated from the fact that we needed to differentiate ourselves from our competitors. We thought that if we learned how people at retirement homes use our diapers, we would have a good base to enhance their experiences of using them."

By integrating reusable and connected sensors at the diaper´s utter surface, two major problems could be eliminated. Firstly, people no longer needed to wear used diapers longer than necessary, as an alarm was triggered when it was time to change. Secondly, as legislation mandate that used diapers cannot be worn for more than two hours, regular checks need to be done. These are certainly intrusive and do also disturb sleep patterns at night. Thanks to the IoT solution these regular checks every two hours could be avoided, instead only changing diaper when needed.

In addition to the improved efficiency IoT enables in reaching and understanding customers or patients, it is also sufficient in scaling value delivery to new markets. Respondent B explains:

"So, thanks to IoT the reach is much faster, scalability is much faster. Companies can quickly reflect the market needs and do the adoption, do whatever minimal adoption is to be done for a same similar model to work in a different country or region.

Still, there's always challenges of what has worked in one country, will it work in the other country? It always takes time to understand a new market and understand what needs to be done and changed to adapt to the new market."

4.4 Technical opportunities and challenges of data management and IoT integration

This section treats the technical aspects of IoT, both from a challenging and value creating standpoint. Reliability considerations is discussed, followed by connectivity and hardware associated challenges. Organisational unwillingness to share data is covered, as well as the value creating potential if that opinion is changed. Cyber security issues and management of personal data is also elaborated upon. How that relates to matters of interobility is later discussed, followed by the potential of AI integration within IoT services.

4.4.1 Technical concerns and issues of the prerequisites necessary for IoT

To create and deliver value through IoT, several interviewees stress the importance of reliable services. As life science products ultimately affect people's health and well-being an error or breakdown may result in life-threatening events, which makes reliability extremely critical. That is especially crucial when the consumer is dependent on the product or service to always be operational and trustworthy, as for example pacemakers and diabetic equipment. As interviewee B put it:

"And then there is an aspect of reliability, which is very high and almost non-negotiable in the life science industry. So, it does make it a bit difficult of course. Also, once you get used to something that basically gives you real-time information all the time and that service gets disrupted, then you will immediately be very dissatisfied as a customer."

However, reliability is not only a concern for products directly used by patients or customers. Speaking to the IoT platform manager at the case company, person A, manufacturing is another important area in terms of reliability which needs to be managed effectively.

"If the customer wants IoT in a production environment, then you must deliver a high degree of reliability and functioning support. Some requirements so that the service is available, alternatively that our platform is integrated with something they already have in their production environment."

As IoT involves centralized cloud-based architectures and a connected network of devices, there is also a potential risk of severe complications if that digital infrastructure is compromised. Respondent F explains:

"If you have such a general system where everything is connected in the same way, IoT related, and someone happens to do some minor error in the code in the cloud function, it will be wrong everywhere. It's not just your instrument that goes wrong, it's going wrong for everyone."

A necessary component for IoT, which also compose a significant factor affecting reliability, is connectivity technology of some sort. Interviewees have proposed numerous solutions of it including 4/5G, WiFi and Bluetooth Low Energy (BLE), each of them suited for different situations and circumstances. What has become evident from interviews is that hardware limitations and remote locations can pose a challenge in terms of establishing reliable connectivity. Respondents A describes:

"Connectivity issues can also arise because the connection possibilities differ. Obviously, connectivity is much worse in Alaska than in central London. So geographically communication can be a challenging thing. There are also lots of other challenges like some devices are not even built to communicate, then you must go there and build yourself. Also, to what extent does the product need to be connected? You cannot get data every second if the product is not connected all the time. That is also a price issue."

Sensors and devices facilitating IoT do also need some sort of power supply, which according to interviewees often consist of a battery. Several participants underlined the cost reduction of hardware such as batteries, sensors and connectivity technology over the last decade as a driving force for IoT. Still, hardware requirements can pose a challenge for IoT. Respondent B describes:

"And especially for pharma type industries which often require sensors with limited form factors. But then you need to put it on a device which has a battery, which has a connecting module, and all of that. So getting everything integrated can be tricky. Because you have more and more intelligence on the device, which requires computing power and computing power means that it's using more battery. Especially when you have these devices that don't have a power supply, right. Then you need a battery that can last long."

As the trend of hardware associated costs decreases, multiple interviewees shared their concerns about sustainability implications. Respondent C saying:

“Cheaper sensors and batteries may lead to wear and tear. So if there is no tangible benefit from the IoT solution, it will be an environmental burden with electronic waste.”

4.4.2 Data related challenges with IoT utilization

After analyzing the obtained data from interviews, many obstacles for IoT within life science seem to originate from issues of data management. Firstly, data need to be stored and shared for IoT to function. Several interviewees witnessed a widespread conservatism regarding these aspects, especially within life science. Respondent D describes:

“But some companies do not want any data to leave the internal servers at all, thereby minimizing the risk of exposure. They can say that “of course we can do it (integrating IoT services), but then the data must be locally stored and not come out in any way”. And then suddenly it becomes a different cost for them. Because if you can use a shared server, it’s a completely different thing.”

Respondent F shares the same view, saying:

“Many life science companies are quite reserved and do not dare to share data at all in case something connected is leaked. So, a big limitation has been that you only possess the data you have been able to generate yourself. You do not share it with anyone else, nor do you get it from anyone else.”

This fear of getting exposed calls for investments in cyber security, which has been a regular occurrent theme in interviews. Several interviewees stress that cyber security must always be considered when working with IoT but is even more important when the data treats personal information. Also, they claim that the consensus regarding cyber security´s importance has increased over the years by both individuals and organizations. Respondent B describes:

“Privacy and data security is another big area. especially in the life science industry, because it’s often about your private information and private data, and how do you secure it? So that becomes a very big issue a big responsibility for the companies to make sure that the data is secure.”

However, some interviewees have proposed anonymization as a measure to increase the protection of personal data. By not coupling the personal data with any information that may reveal the individual, matters of personal integrity could be strengthened. Respondent D elaborates:

"Look at how far the banks have come in their solutions targeting cyber security, it should not really be an obstacle with sensitive and personal information. For example, you can share an ECG but you do not need to know to who it belongs. It can be said that it is a lady of 60 years, a newborn or something like that. It does not have to be tied to a person."

Respondent H also advocates anonymization of data as an effort to shield personal data.

"I know that companies look at anonymization solutions. This is definitely a viable path, but even here you will fall back on the structuring of data. But there is a possibility here.

So you must be able to handle the data in a structured and orderly way. Here, healthcare faces a major challenge in standardizing documentation of all possible clinical data in a structured way. How well the data is structured has big implications on the usability in the process step"

As Respondent H touches upon, structuring and interoperability of data is another consideration which has been communicated by interviewees. Thus, gathered data needs to be compatible with the IoT infrastructure to have use of it. Respondent G explains:

"Because first data needs to be clean, organized and extracted from many different systems that usually operate differently. So you have all those questions related to interoperability which needs to work in order for the data to flow"

Another discussion raised during interviews entails ownership and responsibility of data. Questions like -Who owns the rights of the data? Who are obliged to secure it? And who should be able to capitalize on it? Respondent G describes:

"And right now, people are talking about, even though we are not there yet, who owns the data and who has the right to kind of get paid for the data? Many patients are lobbying for that they should have the right to you know, is somebody using the data for something? Why should not they be paid for

it? And then all the ethical aspects and the consent who can have access to the data."

4.4.3 Technical opportunities to create value by IoT

The conservative position many organizations take in sharing data has already been elaborated upon in chapter 4.4.2. Yet, if that standpoint would change, which is an outlook many interviewees believe in, significant economic and social value could be gained. Respondent D exemplifies:

"This is where I think the future incentives will aim at. I think it will be possible to be more open with data and it will be possible to find AI solutions to better diagnose X-rays or ECG data for example. Previously, organizations did not really dare to develop solutions that are based on the cloud. I think that will change in the long run."

The emergence of big data analysis supported by AI could also aid in more equal care. Patients that due to social-economic factors cannot access thorough care can be benefitted from this trend. Respondent A explains:

"If you share data at a common channel, then you don´t have to rely on that doctor with 38 years of experience in cancer, because that knowledge is already in the cloud. So, the doctor in Somalia with 1 year of experience can use that knowledge of other doctors to support conclusions. I think that would be really valuable from a social perspective."

Like the previously mentioned interviewees D and A, several other interviewees stressed the potential synergies between IoT and AI. As IoT act as a collector and distributor of data, AI can be a sufficient complement in processing that data. Ultimately, the result of a data processed diagnosis may be more reliable than a trained professional. Respondent B elaborates:

"Once you have that data, then you have the possibility to apply machine learning. That might result in some of the jobs within healthcare and life science getting redundant, like radiologists. But it also means that all jobs can be more efficiently performed"

Discussion

This chapter relates and analyses the emiprical findings to the academic literature and selected research questions. The chapter is divided by this study´s two research questions.

5.1 What social and economic value does IoT bring to the Nordic life science industry?

The empirical findings show that IoT has the potential to bring both economic and social value to life science actors. Further, the findings indicate that economic value often steems social value and vice versa. Due to the descriptive nature of this study, no quantification of the perceived value has been made.

Social value, as defined by Mehera and Ordonez-Ponce (2021), and the definition used in this study refers to a positive change that affects both individuals and communities. From the results, it is clear that there are several positive effects for patients and actors within the life science domain that can be gained from implementing IoT. Digitalizing care and monitoring patients remotely enable new opportunities to provide better diagnoses and provide more patient-centric care. This could be achieved by collecting patient-specific data from various wearable devices, and using that data as a basis for monitoring and analyzing patients in real-time. This falls in line with KPMG (2022) that in the digitalized health care the patient will enter the center stage and treatment and pharmaceuticals will be prescribed on an individual level. Personalized care improves the quality of life for patients and makes it possible to save valuable resources for health care providers, e.g. prescribing the right pharmaceutical in the appropriate doses. Personalized care also brings aspects of social value to the recipients, and is discussed in the literature as 4P medicine, i.e. predictive, personalized, preventive, and participative care. Alonso et al. (2019) makes the case that preventive models can be made by analyzing data and predicting transitions to illnesses. This could have significant implications for patients, who could potentially avoid getting sick at all.

As discussed in earlier chapters, value creation can be defined as a process that increases the customer's well-being and renders the end-user better off in some way (Grönroos, 2013). This type of value creation was evident from the previous chapter and gave examples of benefits directed to patients and physicians. Mavrogiorgou et al. (2019) describe the introduction of IoT as a milestone in the digital health care domain, providing possibilities for gathering data that were not previously possible. This outlook for IoT as a revolutionary technology was a common theme in the previous chapter. Especially interesting was the possibilities to R&D input that collected data can provide within life science. For many actors in drug development and manufacturing of medical equipment, research is a major driver of cost. By connecting patients and machines to the internet, the possibility to gather data in real-time can be a way of reducing the cost of development. Collecting data can be achieved by monitoring machines while they are being used, or by having a patient wear a device with the purpose of monitoring vitals. This reasoning falls in line with Gbadegeshin (2019) and Dimitrov (2016), who identify life science as an R&D-dependent sector and see the potential for a cost-effective way of gathering data from equipment with IoT.

Several codes further touched upon the value of using the collected data as a way to monitor how products are being used by customers. This would enable ways to get instant feedback on product usage and use that input in the development of new and improved products. To capture feedback today is often a lengthy and expensive process, and often done by sending our surveys, etc. IoT has the potential to make this process most cost-effective and reliable.

A frequent area of interest for IoT was the possibilities it enables in elderly care e.g. using it to monitor the elderly which would relieve stress and create a sense of security both for the elderly as well as relatives. The positive aspects for patients brought by improved diagnostics and more reliable measurements enabled by IoT are also aspects of social value. Improved and more accurate diagnostics will benefit the patients in several ways, such as getting the right treatment faster and more personalized care.

From the empirical findings, it further stands clear there is a potential for economic value which can be derived from IoT. The definition of economic value used in this report is similar to the one presented by Dann et al.

(2020), that economic value stems from cost savings, reliability, and utility value. The results show that respondents see a clear potential for reduced costs by implementing IoT and using it to e.g. monitor patients remotely which could be a way of streamlining the operation and reducing its cost. Aspects of reliability benefits were also evident from the findings as IoT would provide health care with more reliable data over time. As suggested in the consultancy report from Deloitte (2020) it is clear that the potential for creating economic benefits by utilizing IoT within life science is growing rapidly. From the findings, an area where this is visible is the possibility of remote control over specific medical procedures by IoT which would make health care more effective and save resources otherwise spent on traveling.

The benefits of shortening the value chain can be seen as both economic and social value and is an area discussed both in the findings and academic literature. Pachayappan et al. (2016) call for IoT solutions to be implemented, especially in the pharma value chain as a way to monitor and control the pharmaceuticals during transportation and use. This would provide economic benefits since it would be possible to make sure all pharmaceuticals reach the standards of quality for use, e.g. by monitoring temperature during transportation. By digitalizing the value chain and production, respondents saw further possibilities to increase revenue within life science by identifying problems in the production of pharmaceuticals and medical equipment.

Our findings suggest that IoT utilization is also positive in terms of developing the underlying principles of internal dynamic capabilities. As data generating products and big data analysis tools are big assets in customer knowledge and business intelligence, the basis for valuable insights should strengthen a company´s internal dynamic capabilities and consequently its ability to achieve competitive advantage. Real-time data gathered from connected devices in an IoT infrastructure do also promote instant feedback from products or services, which support business strategy decisions related to the principles of dynamic capabilities.

5.2 What challenges does the IoT technology face within the Nordic life science industry?

When analyzing the empirical findings, it became clear that the widespread conservatism and traditional culture within life science companies is a major challenge for IoT adoption. Lengthy lead times and significant investments are required to comply with regulations and quality assurance during all phases of development, production, and distribution. Therefore, any new technology such as IoT is perceived with extreme caution if there is a risk of it interfering with the existing, compliant, and established processes and products. The description of life science as a conservative and R&D intensive industry is also expressed in previous research presented in chapter 2 (efpia, 2021), (Gbadegeshin, 2019) & (Cognizant, 2021).

The regulatory environment in life science can thereby be recognized as a cause of conservatism, but also as a challenge alone. As mentioned in chapter 2, regulations can be locally divergent and country-specific making it challenging to scale IoT solutions as adjustments are constantly required to meet market and customer requirements. This is a time consuming and expensive task as documentation and risk assessments are enforced for each process step in every individual market, which makes it tough to achieve profitability. Also, a specific person who is legally responsible for complying with the specific regulations needs to be appointed at the company. Relevant academic education and prior experiences within the field are required. That skill set is very hard to come by, especially in the IT domain.

However, our results are contradictory to some extent. While most interviewees are perceiving life science regulations as a challenge for IoT for the above-mentioned reasons, others had a different perspective. As life science regulations mainly entail risk assessments, thorough documentation, verification and validation, etc., IoT could act as a driving force since its application areas can support these matters. For example, process documentation could be cloud-based and standardized through IoT, thereby making it easier to access and manage. As IoT can provide a higher degree of visualization e.g. in manufacturing or distribution, errors can also be discovered faster and more accurate. Cold chain logistics of drugs and vaccines mentioned by

Pachayappan et al. (2016) in chapter 2 is one example of IoT being utilized as a real-time diagnostic tool aimed at discovering potential failures affecting quality. As for verification and validation, the data obtained from connected units provides information about their usage that is hard to obtain traditionally. All these aspects are viable and beneficial in terms of quality, which should be encouraged from a regulatory perspective.

One way of approaching IoT in relation to life science regulations is to avoid a direct link between IoT and a medical use. Instead, utilizing the technology as a supportive technology e.g., data insights manufacturing visualization. In these circumstances, regulatory complications are kept minimal, yet application areas are fewer which limits a company´s possibilities to create value.

As Rahman and Asyhari (2019) described in chapter 2, the primary focus of IoT is to provide smart and seamless services without any interruptions. Thus, IoT services need to be reliable to create and deliver value. The importance of reliability is also supported by the empirical observations where it is expressed as a challenge. Since IoT is based on centralized cloud services a potential error may result in extensive breakdowns with severe consequences for individuals, patients, or operations.

We like to think of IoT as a facilitator of data value streams. It starts with the capturing of data, followed by some sort of processing, and is finalized by a distribution to the appropriate receiver. During all phases, there are challenges, some even more critical or apparent in a life science context. As presented in chapter 4, life science organizations are unwilling to share their collected data even though our findings deem that trend to change. So, in capturing data each organization needs to create routines addressing ethical aspects of data protection. For example, who could possibly access the data and how can the individual/ patient ensure the consent of his/her data being shared? Navigating through these circumstances and being compliant with existing data protection legislation and life science specific regulations has been expressed as a major challenge for IoT transition. Interestingly, individuals do not seem to share organizations' unwillingness to share data. According to the Swedish Institute for Opinion Polls (SIFO), 93% of the Swedish population is positive about sharing their health data anonymously (SIFO, 2021). Nevertheless, the great potential of collected data is not utilized, which ultimately affects patients.

In terms of processing, the most emphasized challenge relates to interoperability. As Korte et al. (2021) in chapter 2 describe IoT as an ecosystem connecting diverse objects to the internet, the diversity of objects causes heterogeneity of data. According to our empirical observations, this fact is even more apparent in life science since the healthcare systems in the Nordic, which constitute the major market for life science companies, are very much decentralized. That means a great deal of variation in operations and data structuring, which is a challenge that needs to be addressed for IoT to work efficiently.

The challenges associated with data distribution generally entail matters of reliability and cyber security. As presented in chapter 4, individuals and patients need to rely on an IoT based service to provide trustworthy information at the right time. For example, a person suffering from diabetes still requires personal sugar level information even though connectivity possibilities might be poor. As for cyber security, the data distribution channels need to be protected from external threats and cyber-attacks. What makes measures targeting reliability and cyber security specifically challenging is the abundance and complexity of potential faults which all need to be addressed.

The last major challenge for IoT within life science is related to organizational culture and technical maturity. This observation also correlates with Langley et al. (2021) (chapter 2), who stresses the importance for organizations to understand the extent to which IoT will transform their existing business models. Like Langley, our findings demonstrate a lack of knowledge regarding digital products compared to traditional ones, which is a challenge for IoT within life science. This seems to be true both internally and externally, e.g. salesmen and customers.

On a similar note, Haaker et al. (2021) claims that IoT IoT "will fundamentally change many companies' business models as well as the way consumers interact with these companies and other stakeholders", while Langley et al. (2021) elaborate that "Businesses that succeed in adapting their extant business models to the new technological possibilities have considerable opportunities to innovate and are potentially highly competitive". Our findings are pointing in the same direction, even though life science may be slower in its embrace of IoT services compared to other industries due to previously mentioned reasons. Still, we have been introduced to practical IoT solutions that have reconstructed existing business models and how customers interact with the traditional offering, the IoT diaper being one of them. The identified success factors for these companies had been to embrace the IoT transition slowly, have a very clear use case, and secure alignment at all corporate levels.

Notably, the challenges for IoT within life science are numerous and naturally different. Yet, as Chiarello et al. (2021) describes in chapter 2, firms have to understand and address the specific challenges that the technology may present.

5.3 Limitations and Future Research

In this study, various social and economic values derived from IoT within the Nordic life science industry have been presented. Additionally, challenges associated with IoT utilization within the sector are outlined. As the collection of primary data has exclusively addressed companies and organizations' operations within the Nordic countries, we assume the results to be representative for the entire region. Yet, as the Nordic life science market is argued to be at the forefront of digital transformation, the market segmentation could limit generalizability outside the Nordic countries. Future studies could thereby examine other markets and geographical areas, preferably outside Europe as regulatory circumstances are different to a greater extent compared to markets within the European Union.

The aim of this study was to describe the potential for value creation and the associated challenges for IoT within life science, hence no recommendations for IoT use/business cases are posed. Practical implementations of IoT within the Nordic life science industry are consequently outside the scope of this study.

Apart from multiple interviewees from the case company, the primary data was collected through interviews with only one representative from each organization. Hence, future studies could target one particular company/organization to capture the utilization of IoT in greater detail. Since this study had a descriptive purpose, no attempt has been made to grade or measure the presented social and economic value. Quantification could therefore also be a matter of interest for future studies.

As stated in chapter 1, this study defines "customers" as pharmaceutical companies and manufacturers of medical devices. Hence, the perception of "customer value" is benefits towards these companies. Still, as social value in this study is defined as "improvements in quality of life for individuals or society", it would be interesting to interview consumers and patients directly to expand the understanding of social value within life science and to validate this study´s findings. Yet, this study does not include data from patients or potential recipients of the social value derived from IoT, instead it relies on the opinions of experts within the field. Future studies could therefore adopt a more end-customer orientated analysis of value creation generated from IoT. If so, IoT needs to be presented in a consequently and accessible manner since these interviewees may not know the technology in beforehand.

Since our findings suggest life science regulations as a major challenge as compliance is perceived as complex to manage regardless of IoT, an interesting topic for future research could also be regulatory complications when integrating IoT in existing or innovative products or processes.

Conclusions

The following chapter presents the main findings and theoretical and practical contributions of this study. This chapter is divided into two sections, discussing the two research questions separately before submitting the research contributions of this study.

The purpose of this research has been to examine how IoT can affect the value-creating landscape within the Nordic life science industry. With the aim of fulfilling this purpose, a qualitative research design and an inductive strategy were chosen as the most appropriate. During the process of this study, 16 experts within life science and IoT actively working within the Nordic countries have been interviewed. The answers from the interviews were coded using the framework of thematic analysis and presented as the empirical findings. Two research questions were selected to meet the selected purpose.

RQ1: What social and economic value does IoT bring to the Nordic life science industry?

Our findings are broadly consistent with the academic literature on the subject, and a variety of social and economic benefits can be expected for actors within life science by digitalizing and implementing IoT. This study defines social value as "Improvements in quality of life for individuals or society, e.g. reduced stress". Examples of social value which can stem from IoT are reduced stress within health- and elderly care, increased reliability of collected data, and faster and more accurate diagnosis. IoT makes it possible to monitor patients in real-time which provides comfort to not only the people suffering from a disease, but also to their relatives who do not need to worry. Findings also indicate values by discovering abnormalities of an individuals health earlier by monitoring vitals such as EKG, which would traditionally be overlooked.

The other type of value used in this study is economic value, which consequently is defined as "The economic advantages IoT can bring to an organization, e.g. increased savings or reduced cost". Economic value is therefore strongly correlated to the profitability of the organization, and IoT needs to have a positive economic impact for it to be a viable option in the future. The findings suggest several ways in which IoT can bring economic value to an organization, such as taking remote control over medical procedures and enabling surgeons to be more time-effective. Since life science is a research intensive domain, and R&D is associated with high cost, there is potential for IoT to significantly drive cost reductions by gathering data in a cost effective way. Economic value can further come from increased revenue streams, which IoT can enable.

RQ2: What challenges does the IoT technology face within the Nordic life science industry?

Our study reveals that the challenges include regulatory compliance, conservatism regarding digital transformation, technical prerequisites for IoT, and data management. However, our findings suggest that these challenges can inhabit opportunities if dealt with accordingly. For example, regulatory compliance is demanding for numerous reasons outlined in chapter 4, yet IoT could be an asset in quality assurance risk assessment as discussed in the previous chapter.

According to both literature and our findings, digital transformation is inevitable in life science as patients are now entering the center stage, demanding more customized and efficient care on their own terms. Precision medicine and 4P medicine described in chapter 2 are two considerable trends derived from this patient-centred trend. Doctors, nurses, and other healthcare professionals who in general (according to our empirical observations) are reluctant to change in combination with the conservative and traditional healthcare systems in the Nordic, which this study acknowledges as a challenge, may therefore be subject to change onwards, benefitting digital solutions and IoT based services.

The challenges regarding technical prerequisites for IoT are very much valid, but most not specifically linked to life science. As the IoT technology is relatively new, several driving forces are still under development such as 5G, BLE and sensor technology. Hence, we are perceiving the identified challenges related to battery and hardware, connectivity, and reliability as legitimate but less of a concern onwards.

There are multiple challenges associated with data management, such as interoperability, cyber security, data ownership, and integrity issues. These challenges are very conditional, depending on the specific use case for IoT e.g., in manufacturing processes or medical products. Thus, a sensible strategy is required to address these challenges while being compliant with requirements for storage of personal data (GDPR for instance) and life science regulations.

6.1 Research Contribution

This study contributes to the existing research on IoT within life science by presenting social and economic value as well as different types of associated challenges. As outlined in chapter 1, current literature addressing this study´s geographical segment of interest i.e., the Nordic countries is limited. As the Nordic countries are globally recognized for various areas within life science as well as technical innovation, we found this gap in research particularly relevant to bridge. Previous research is also more focused on the technical aspects of IoT, as underlined by Hussein (2019) in chapter 1, while this study´s contribution aims to provide a more holistic representation of IoT integration within a specific life science market. We also hope that our findings can aid organizations in their efforts to apply IoT in the life science domain by displaying potential pitfalls which should be addressed, and the potential for organizational and individual benefits.

As the title of this study implies, our research aims at providing insights related to the Nordic life science industry in general. In doing so, we have been interviewing a diverse set of stakeholders of IoT within the Nordic life science industry. Further, the purposive sampling for interviewees has been based on their ability to provide knowledge related to benefits and challenges associated with IoT integration within life science. As this thesis have been conducted in collaboration with the case company, a provider of IoT solutions, the research has been designed to provide learnings for the case company itself and naturally other organisations in similar positions.

Some interviewees have therefore been customers of the case company, thus life science companies, which is the type of organisations that we define as customers in this study. The theoretical implications are therefore inclined to shed light on the potential for IoT offerings, as well as challenges that should be addressed in the process of initiating IoT within the Nordic life science industry.

By this approach, we hope and believe that this research can tell something about how IoT can improve the value creating landscape within the Nordic life science industry, bridge the identified gap in previous research, as well as providing insights to the case company in its IoT related exploration phase within life science.

Additionally, this study contributes to knowledge regarding how IoT can enhance the underlying principles of dynamic capabilities and how dynamic capabilities can drive IoT. As developments in firm specific dynamic capabilities also drives industry capabilities as outlined in chapter 2, we assert the utilized theoretical framework to be of relevance within the context of the wider life science industry.

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Appendix A

To the context:

- How many employees are you?
  - In the Nordic? Globally?

- In what geographical areas are you active?
  - What do you do differently in each market? - *Why?*

- How familiar are you with IoT?
  - To what extent are you working with IoT?
    - In which areas? -*Why*?

- Is there anything that distinguish the Nordic life science sector compared to other markets? -*Why?*

RQ1 What social and economic value does IoT bring to the Nordic life science industry?

- Why do you think IoT is interesting for your business?
  - How does IoT increase your revenues? -*How?*
  - Can IoT help you decrease your operational costs? -*How?*
  - How is your IoT solutions received from your customers?

- Do you have anyone specifically working within IoT within your organization?

- How did IoT emerged within your business? What has been the driving forces?

- Have your work/operations been changed somehow due to IoT integration?

- What´s your general view on the digitalization trend within life science?

- How do you identify possible use cases for IoT?
  - How have you been able to capitalize on them?

RQ2 What challenges does the IoT technology face within the Nordic life science industry?

- What was challenging for you when implementing IoT? -*Why?*
  - Is there a bottleneck?

- How would you like to further integrate IoT in your business? -*Why?*
  - What is challenging for it? -*Why?*

- Does IoT related challenges differ, depending on the geographical areas? -*Why?*
  - Or of any other reasons?

Figure 7.1: *Interview guide*

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