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IoT and its Business Impact on Remote Monitoring of Patients with Chronic Diseases in Germany

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Dissertation written under the supervision of Gonçalo Saraiva

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Abstract

Dissertation Title: IoT and its business impact on remote monitoring of patients with chronic diseases in Germany

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Keywords: Internet of Things, Remote Monitoring, Healthcare, Digitalization

The goal of this dissertation is to determine the business impact of IoT and remote monitoring on patients with chronic diseases in Germany. Therefore, expert interviews with representatives of the four major affected stakeholder groups were conducted. These four groups consist of statutory health insurance companies, businesses, doctors and patients. The aim of these interviews was to assess the current status of IoT and remote monitoring in the German healthcare system and to find out about the main obstacles that currently keep the business impact at a low level. Although only representatives from the first three groups could be interviewed all interviewees agreed that IoT is in its early stages in Germany. The main obstacles impeding a significant growth of IoT and remote monitoring in Germany are identified as technological, regulatory, and cultural ones. Additionally, the self-governing structures of the German healthcare system and the multidisciplinary approach of already ongoing IoT projects complicate the diffusion of IoT solutions. Despite these barriers the interviewed experts are convinced that IoT and remote monitoring will prevail in Germany sooner or later.

Sumário

Título da dissertação: A Internet da Coisas e o seu impacto económico na monitorização remota de pacientes com doenças crónicas na Alemanha

Autor: Anna-Sophia Horvath

Palavras-chave: Internet das coisas, Monitorização remota, Saúde, Digitalização

O objetivo desta dissertação é determinar o impacto económico da Internet das Coisas (IoT – Internet of Things) e monitorização remota dos pacientes com doenças crónicas na Alemanha. Portanto, foram conduzidas entrevistas com representantes dos quatro maiores grupos de intervenientes afetados. Estes quatro grupos consistem em seguradoras de saúde, negócios, médicos e pacientes. O objetivo destas entrevistas foi aferir o estado atual da IoT e monitorização remota no sistema de saúde Alemão e averiguar os principais obstáculos que mantêm atualmente um baixo nível de impacto económico. Apesar de apenas os representantes dos primeiros três grupos terem sido entrevistados, todos concordaram que a IoT está na sua fase inicial na Alemanha. Os maiores obstáculos que impedem um crescimento significativo da IoT e monitorização remota na Alemanha foram identificados como sendo tecnológicos, regulatórios e culturais. Para além do mais, as estruturas autónomas do sistema de saúde Alemão e a abordagem multidisciplinar dos projetos de IoT já em curso complicam a difusão de soluções IoT. Não obstante estas barreiras, os especialistas entrevistados estão convencidos que a IoT e monitorização remota vai prevalecer na Alemanha mais tarde ou mais cedo.

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List of Abbreviations

AI	Artificial Intelligence
CAGR	Compound Annual Growth Rate
DALY	Disability-Adjusted Life Years
digilog	Digital and Analog Companions for an Aging Population
DMP	Disease Management Program
ECG	Electrocardiogram
EU	European Union
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GPS	Global Positioning System
ICT	Information and Communication Technology
IoT	Internet of Things
NCD	Noncommunicable Disease
NFC	Near Field Communication
OECD	Organization for Economic Cooperation and Development
PEST	Political – Economic – Social – Technological
PESTEL	Political – Economic – Social – Technological – Environmental – Legal
RFID	Radio-Frequency Identification
ROI	Return on Investment
SWOT	Strengths – Weaknesses – Opportunities – Threats
TAM	Technology Acceptance Model
TK	Techniker Krankenkasse
TRL	Technology Readiness Level
UMTS	Universal Mobile Telecommunication System
USD	US-Dollar
VR	Virtual Reality
WHO	World Health Organization

1 Introduction

Countries around the world are faced with rapidly ageing populations which comes along with challenges and opportunities for societies. One major challenge is noncommunicable diseases (NCDs), such as diabetes, cancer and heart diseases. They are triggered by risk factors like smoking or alcohol consumption. A recent study revealed that the risk factor causing most deaths every year worldwide is poor and unbalanced nutrition in form of high sodium consumption and low consumption of full grains and fruits (Afshin et al., 2019). In 2017, this factor was responsible for 11 million deaths worldwide and for another 255 million disability-adjusted life years (DALY) (Afshin et al., 2019). The World Health Organization (WHO) (2018) estimates, that every year 41 million people die from NCDs worldwide. The care for these people who need regular medical assistance constitutes a major cost factor for healthcare systems. The initially mentioned trend of an increasing life expectancy further reinforces this cost burden as people will live longer but in poorer health which is costly. One possibility that addresses these challenges are Internet of Things (IoT) solutions specifically designed for healthcare. As healthcare is a very vast system various solutions that focus on different areas are promising in terms of efficiency gains, cost reductions, and for a better quality of life for patients. One of these promising solutions is remote monitoring of chronically ill persons. This leads to the following problem statement and research questions (RQ).

Problem Statement: What is the potential business impact of IoT and remote monitoring of patients with chronic diseases in Germany?

RQ1: What are chronic diseases and what is the associated cost for the German healthcare system?

RQ2: How does the current state of IoT enable remote monitoring for patients with chronic diseases?

RQ3: Which German stakeholders are impacted by this business opportunity and to which extent?

The difficulties the German healthcare system faces explain why this topic is of managerial relevance. It has the potential to provide managers operating in the healthcare system with valuable insights concerning cost reductions and efficiency gains that will be needed to address future challenges caused by ageing populations for instance. Regarding academic relevance this dissertation will for the first time cover the whole ecosystem of the German healthcare system which is primarily constituted of statutory health insurance companies, companies, doctors, and patients. The focus on Germany is owed to the fact that access to these stakeholders for interviews is easiest. The combination of the points of view of all stakeholders aims at drawing insightful conclusions concerning the current state of IoT and remote monitoring in the healthcare system and recommendations on how to further promote this crucial topic. It is important to keep in mind that analyzing a single illness or patient group would not create as much value as the study of the whole ecosystem.

The literature review in chapter 2 starts with an overview of the most relevant managerial topics covered in this dissertation. This is continued by an overview of chronic diseases, a short introduction of the German healthcare system and an introduction into IoT and remote monitoring. Chapter 3 describes the applied methodology for the analysis of all involved stakeholders, companies operating in the healthcare sector, statutory health insurance companies, doctors, and patients. In chapter 4, the results of the industry analysis of the statutory healthcare system are presented in form of a SWOT analysis (Strengths – Weaknesses – Opportunities – Threats). This aims at figuring out whether IoT could be a possibility to overcome some of the system´s shortages described in chapter 2. Furthermore, additional insights derived from the interviews were structured according to the stakeholder groups. Chapter 5 shortly summarizes the main findings concerning the RQs and the problem statement and deals with the common obstacles deduced from the analysis as well as potential ways how to overcome them. Additionally, a short part on limitations and future research is added.

2 Literature Review

2.1 Relevant Management Topics

This dissertation covers mainly three relevant management areas. The first is how to look at an industry, followed by innovation in general and technological innovation. Therefore, some models structuring these areas are shortly presented. During the research it turned out that most obstacles preventing a widespread diffusion of IoT in healthcare are rooted in the system´s structure in which the key players are embedded. Consequently, this thesis will emphasize the understanding of the whole ecosystem by focusing on the area of industry assessment. Nevertheless, knowing general concepts for innovation and technological innovation is of importance as they are relevant for further analysis and future research once the system is understood. Accordingly, some mentioned concepts in this section are only briefly applied in the end without going too much in depth.

Industry Assessment

One common way to assess an industry´s degree of competition is *Porter´s Five Forces*. The five forces, bargaining power of suppliers, bargaining power of buyers, the threat of new entrants, the threat of substitute products or services, and the competitive rivalry within an industry, facilitate the assessment of the potential profit companies can achieve in the analyzed industry. The analysis and positioning of the own company in comparison to the forces enable it to better understand its strengths and weaknesses. Consequently, strategic action aiming at improving the company´s position within this industry or reaching a competitive advantage can be planned and carried out (Porter, 1979). Literature identifies numerous disadvantages of Porter´s model of which the most significant in this context is its lacking macro-economic focus (Grundy, 2006).

PEST analysis (Political – Economic – Social – Technological), however, analyses the external business environment. It allows companies to assess their individual macro-economic environment and supplies them with information that permits them to anticipate future events. Thus, a PEST analysis enables companies to react to environmental changes thereby constantly keeping the fit between their capabilities and environment. If done thoroughly enough, PEST analysis can be valuable to understand “market growth or decline, and as such the position, potential and direction for a business” (Singh, 2013, p. 42). Over the years, PEST analysis was developed to more extensive versions, like the PESTEL analysis (Political – Economic – Social – Technological – Environmental - Legal) (Singh, 2013; Yüksel, 2012). One drawback of all

forms of PEST analysis is that it is very generic without stating explicit guidelines on how to react to certain environmental changes (Singh, 2013).
A third tool is the *SWOT analysis*. The purpose of a SWOT analysis is to gather information about internal and external aspects that could have an impact on the business (Pickton & Wright, 1998). In a second step, the results of this analysis are used to formulate a strategy which usually happens by pairing an internal with an external factor to trigger a new strategic initiative (Dyson, 2004). Furthermore, decision making is based on it to ensure the survival, operational improvement and success of the business undertaking the analysis (Pickton & Wright, 1998). For the internal factors, strengths and weaknesses, a business´s resources and capabilities are analyzed and categorized accordingly. The external factors are classified according to opportunities and threats by scanning the business environment (Stacey, 2007). SWOT is highly appreciated for its simplicity and as it enables managers to focus on essential topics affecting their business (Pickton & Wright, 1998).
By means of the short descriptions of the models, the framework chosen for the subsequent industry analysis is the SWOT analysis. Given its structure which entails internal and external factors, unlike the two other proposed models, it seems to be most promising to get a holistic picture of the whole system, including flaws and strengths.

Innovation

The innovation of new products and services is considered as inevitable if a company wants to experience a sustainable growth. Some managers are even of the opinion that without innovations every company will fail sooner or later. The process of innovations within a company is often illustrated by an *innovation funnel* in which numerous ideas derived from internal and external sources are gradually reduced until one initial idea that is supposed to be most suitable at that moment gets commercialized (Cooper & Edgett, 2009).
Although innovation is seen as crucial for a company´s survival the forms innovations can take are numerous. Therefore, it is necessary to set up a framework that outlines different paths to innovation and the necessary means, ideally compatible with the company´s main capabilities, to realize it. This results in the *innovation matrix* (**appendix 1**) whose two axes are defined as the extent to which a problem is defined (well or not well) and the extent to which the domain needed for the problem´s resolution is clarified (well or not well). The resulting four options, basic research, disruptive innovation, breakthrough innovation, and sustaining innovation, and their respective tools indicate a basic strategy to start the innovation process (Satell, 2017).

Another interesting framework is the *innovator´s dilemma* by Christensen (2013). Christensen portrays various very successful and well-managed companies that failed to remain market leaders of their industries despite their good capabilities for innovation and subsequent execution. The main reason for successful companies´ failure identified by Christensen (2013) lies in their refusal to invest in disruptive innovations at an early stage unlike their competitors.

Technological Innovation

One popular model when it comes to technological innovation is the *Technology Adoption Life Cycle* developed by Rogers. The Adoption Life Cycle (**appendix 2**) categorizes parts of a population according to their innovativeness referring to the time an individual of this population adopts to new technologies. The time dimension ranges from early to late which results in five adopter categories, namely innovators, early adopters, early majority, late majority, and laggards. As the five identified categories differ in terms of socioeconomic status, personality variables, and communication behavior, distinctive strategies for each target group can be developed (Rogers, 1962).

The *Technology Acceptance Model* (TAM) developed by Davis, Bagozzi, & Warshaw (1989) aims at explaining the factors determining the user acceptance of new developed computer technology. They identify the perceived usefulness and perceived ease of use as the two most important factors for user acceptance. In addition, the person´s attitude toward using the new technology and the behavioral intention to use it are of relevance (Davis et al., 1989). Some extensions of TAM are nowadays used for information systems in healthcare, mainly in the areas of electronic health records, telemedicine, and applications (Rahimi, Nadri, Lotfnezhad Afshar, & Timpka, 2018).

One model evaluating the maturation of a certain technology is the *Technology Readiness Levels* (TRLs) originally developed by NASA for space technology. Applying TRLs to different technologies allows a coherent comparison of these technologies. NASA´s TRL system is split up into nine different TRLs which can be flexibly adopted for other processes. However, some TRLs are considered to be of great importance for any technology for which they should be applied for, such as the development of prototypes (Mankins, 1995). Armstrong (2015) shows that TRLs are meanwhile also used in other industrial areas than space technology.

2.2 Overview of Chronic Diseases

Chronic diseases should be a topic of worldwide concern given their global impact. This is not only true for humanitarian reasons but chronic diseases have severe economic consequences. Thus, the following section defines chronic diseases and their development including their caused cost burden and a short section specifically about Germany.

2.2.1 Definition

The definition of chronic diseases is not consistent as different terminologies for a similar set of diseases are used. Often, chronic diseases are referred to as lifestyle diseases or NCDs (Kim & Kim, 2018; Lee et al., 2012). The term NCD is supposed to differentiate these diseases from other, infectious ones. The difficulty with this definition is that some chronic diseases, like cervical cancer, are usually caused by an infection (WHO, 2005). Therefore, the term used here will be chronic diseases whereby the reader should be aware that NCD is commonly used.

As the word chronic implies, chronic diseases are usually of long-term duration that cannot be completely healed. Therefore, affected patients make regular use of existing healthcare systems (Robert-Koch-Institut, 2012). Chronic diseases can be traced back to various interacting factors, like the affected person´s behavior, genetic components, or the environment one is exposed to (WHO, 2005). Particularly, a person´s behavior is relevant. It can be divided into several risk factors which will be explained in-depth in the next section. The four most widespread types of chronic diseases resulting from these risk factors are cardiovascular diseases, respiratory diseases, cancers, and diabetes of which cardiovascular diseases are the most deadly ones (WHO, 2018).

According to the WHO chronic diseases are responsible for 71% of annual deaths worldwide (WHO, 2018). As most people in working age are not faced with a fatal development of their chronic disease they often have to keep on living with varying degrees of disability, sometimes for their entire remaining life (OECD/EU, 2016). The worldwide diffusion of chronic diseases becomes evident when looking at people who are at risk of suffering from them. Although there is a clear trend that low and middle income countries suffer most from chronic diseases also high income countries are highly affected by them (Lopez, Mathers, Ezzati, Jamison, & Murray, 2006). In 2016, the OECD/EU (2016) estimated that approximately 50 million EU citizens were affected by more than one chronic disease. Compared to the total number of EU citizens in the same year, 510 million, (Eurostat, 2018) this number equals 9,8%.

Contrary to widespread beliefs that mostly elderly people are affected by chronic diseases the WHO found out that “one quarter of all chronic disease deaths occurs in people under 60 years of age"(WHO, 2005, p. 12). Similar to this it cannot be said that men are affected more by chronic diseases but the distribution between both genders is almost equal (WHO, 2005).

2.2.2 Related Risk Factors

Indicators such as age, nationality, and regional affiliation do not necessarily determine the causes for chronic diseases. In fact, factors contributing to the development of chronic diseases can be looked at like a causal chain that affects people worldwide in a very similar way. At first, the political and cultural environment, developments like demographic change, globalization, and urbanization that most people would not think of in the context of chronic diseases come into play as the underlying reasons. Globalization, for instance, brings benefits in form of modern technologies that can be used for a better healthcare provision. On the downside, globalization leads to changing consumer behaviors, for example in terms of nutrition. Globally, people tend to consume more high energy meals, consisting of high degrees of salt, fat, and sugar thereby contributing to an unhealthy diet (Zimmet, 2000).

This leads to a set of factors, called 'changeable risk factors', that promote behaviors like unhealthy diet and insufficient physical activity, as well as the excessive use of alcohol and the use of tobacco in form of smoking. Even though more changeable risk factors were classified over the years, such as the increase in cardiovascular disease burden due to air pollution (Lelieveld et al., 2019), these few can be accounted for the majority of deaths caused by chronic diseases (Fine, Philogene, Gramling, Coups, & Sinha, 2004). In interaction with non-changeable risk factors like age and heredity, this bundle of risk factors causes so called 'intermediate risk factors' (WHO, 2005) such as high blood pressure and high blood glucose, overweight and obesity. Eventually, these well-known criteria cause chronic diseases like heart diseases, cancer, strokes, diabetes, asthma, and chronic respiratory diseases (WHO, 2005).

2.2.3 Cost Burden

Chronic diseases and their side effects have a significant impact on affected individuals and also influence their families, societies at large, and economies of the countries they live in.

In general, costs of chronic diseases can be separated into direct and indirect costs. Direct costs include expenses incurred in medical treatment, prevention and rehabilitation measures as well as administrative costs of healthcare systems. Therefore, these costs are carried by the healthcare sector. Indirect costs quantify the losses that chronic diseases cause in the respective economies but that cannot be directly attributed to healthcare expenditures. These costs are mostly borne by social systems and employers. Another aspect reflected in indirect costs are intangible costs consisting of the limitations affected individuals have to endure, such as depressions and pain (Statistisches Bundesamt, 2015b). As especially intangible costs are difficult to quantify the focus will lie on measurable costs instead.

One factor economic loss contains is premature death of individuals who are not yet retired. The OECD/EU (2016) estimates that indirect costs caused by premature death within the EU summed up to 115 billion euros in 2013 corresponding to approximately 0,8% of the EU´s GDP. This sum is calculated by multiplying the number of productive years lost due to premature deaths with the average annual European salary.

Another element contributing to indirect costs are changes in the employment status of workers suffering from chronic diseases. Rumball-Smith, Barthold, Nandi, & Heymann (2014) revealed that people from high-income countries suffering from diabetes were faced with a 30% increase in probability of early exit from work. This result is further supported by a study that showed that individuals having a poor self-perception of their health are more likely to leave employment due to early retirement schemes, disability or unemployment (Berg, Schuring, Avendano, Mackenbach, & Burdorf, 2010; van Rijn, Robroek, Brouwer, & Burdorf, 2014).

Finally, lower labor productivity caused by effects of chronic diseases increases the indirect cost burden. One example are part time jobs individuals with chronic diseases have to pursue despite preferring a full-time job (Saliba, Paraponaris, & Ventelou, 2007). Another indicator is the negative impact of chronic diseases on wages and hours worked for the affected individuals (Pelkowski & Berger, 2004). Also, the higher number of sick days of chronically ill employees compared to employees without chronic conditions has to be considered. The median number of sick days within the EU for employees aged 50-59 in 2013 without chronic diseases (seven days/year) differs significantly from the median number of employees suffering from one chronic disease which was at ten sick days per year, a plus of almost 43%. People having two or more chronic diseases were absent on approximately 20 days per year which reflects an increase by 186% compared to those without chronic disease (OECD/EU, 2016).

Overall, indirect costs of chronic diseases are more severe for employees with low levels of education or which can be categorized as blue-collar workers, thereby worsening existing social injustice in the labor markets (Saliba et al., 2007).

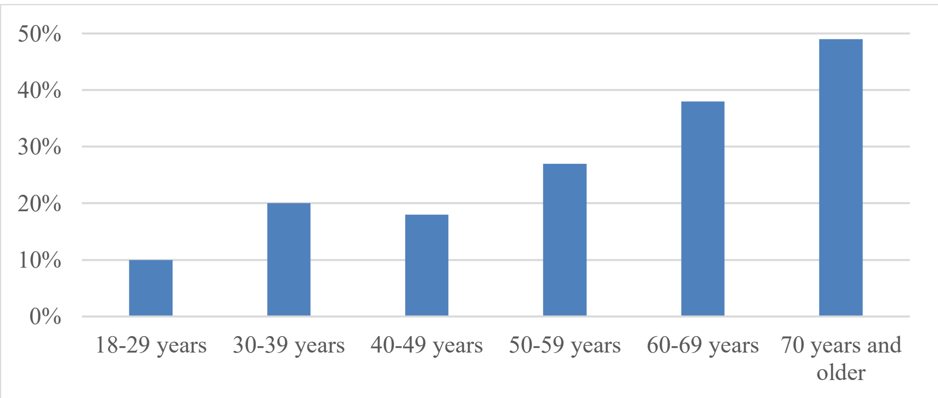
For national social systems indirect costs caused by chronic diseases represent a significant economic burden as governments need to pay out higher amounts of unemployment and sick leave benefits, early retirement payments and other monetary benefits. Generally speaking, the likelihood to be unemployed or to live in early retirement increases the higher the number of chronic diseases an individual suffers from. Within the EU, the variation of receiving early retirement or unemployment rates is very high, indicating that the reception of such benefits is more dependent on the country´s implemented social programs and the overall labor market conditions than on the individual´s state of health. These payments are problematic: Firstly, benefits governments pay due to disabilities tend to be more expensive than the support for unemployed. Secondly, as the causes and underlying roots of chronic diseases are well-known measures could be implemented to better prevent them. Consequently, investments in prevention would decrease the follow-up costs of chronic diseases (OECD/EU, 2016).

2.2.4 Chronic Conditions in Germany

2.2.4.1 Overview

A survey conducted in 2017 revealed that half of the German population (48%) suffered from chronic diseases (Kornelius, 2017). In 2012, 42% of the female and 35% of the male population indicated to have one or more chronic disease (Robert-Koch-Institut, 2012). At first, the occurrence of chronic diseases in different age groups needs to be investigated. Figure 1 confirms that chronic diseases are prevalent in younger population groups, too. Especially the age group between 30-39 years sticks out with 20%. The clear increase in people suffering from chronic diseases with increasing age, particularly from 50 years onwards, reflects the natural increase in probability to suffer from chronic diseases while ageing, as the risk factors causing them are accumulated throughout a person´s life (Strong, Mathers, Leeder, & Beaglehole, 2005). Nevertheless, it is evident that chronic diseases are widespread throughout the entire population and younger generations are increasingly affected, too.

Figure 1: *Share of patients with chronic diseases by age group in Germany (2016)*



Source: Techniker Krankenkasse (2016)

According to Kornelius (2017), the factor differentiating younger and older people suffering from chronic diseases is the type of chronic disease. In general, younger generations are mostly affected by respiratory diseases whereas elderly mainly experience cardiovascular diseases. Correspondingly, cardiovascular diseases, asthma, and diabetes are the most common chronic diseases in Germany (Kornelius, 2017).

2.2.4.2 Cost Burden

In terms of direct costs the Federal Statistical Office indicated in 2010 that one quarter of all medical expenses were due to chronic diseases (Statistisches Bundesamt, 2015a). This equals more than 70 billion euros in 2010, or 2.7% of Germany´s GDP in 2010 (Statistisches Bundesamt, 2019). Cardiovascular diseases caused the highest cost in 2015 with more than 45 billion euros (Statistisches Bundesamt, 2015b).

In 2017, the three most common causes for premature death in Germany were ischemic heart diseases, lung cancer, and strokes, all falling under the category of chronic diseases (IHME, 2017). The total of premature deaths in Germany summed up to 522.522 in 2013 (OECD/EU, 2016). Assuming an average annual salary of 37.084 € in 2013 (OECD.Stat, 2017) this corresponds to a potential economic loss of 19 billion euros per year or 0,7% of Germany´s GDP in 2013 (Statistisches Bundesamt, 2019). The indirect costs of chronic diseases are further increased by lower employment rates of people with one chronic disease (76%) or two or more chronic diseases (61%) compared to those without chronic diseases (83%) (OECD/EU, 2016). Among the employed those with chronic diseases also have more sick days compared to workers without. The share of chronically sick persons being retired early also increases with increasing number of chronic diseases. Without chronic diseases 2% of people aged 50-59 were early retired in 2013, whereas more than 7% of those with two or more chronic diseases received early retirement. For the German social system only the paid sick days in 2013 added up to 1.8% of that year's GDP (OECD/EU, 2016). This shows the significant share of indirect costs on the total sum.

2.2.5 Prevention

The EU targets a reduction of premature deaths caused by chronic diseases by 25% until 2025 (Ärzteblatt, 2016). As nowadays the different stages and respective factors that are crucial in the development of chronic diseases are well-known and modifiable, governments have numerous tools available to fight and prevent them (Barker, 2004). Ensuring better living conditions, especially for vulnerable groups like children, could happen in form of legislation that raises awareness among the population and regulates industries that are part of this causal chain (WHO, 2005).

An investment in prevention has several positive effects. It potentially delays or even prevents the development of chronic diseases and softens its consequences. This would allow elderly to stay more self-determined despite suffering from chronic diseases (Saß, Wurm, & Scheidt-Nave, 2010; Wurm & Tesch-Römer, 2009). All this reduces direct and indirect expenses of chronic diseases through better labor market outcomes as the overall population would become healthier. Therefore, governments should allocate a greater share of health expenditure for prevention and think more thoroughly about the implementation of certain regulation policies.

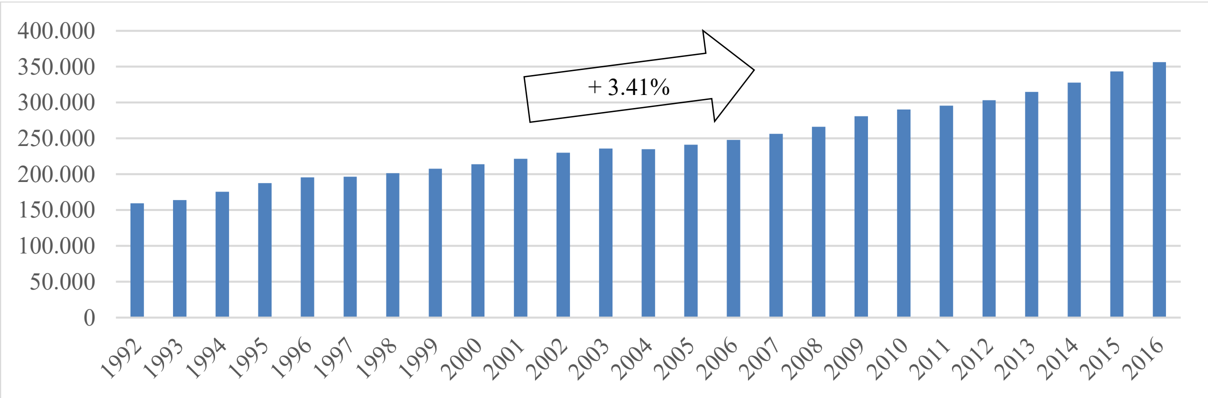
2.3 Overview of Total German Healthcare System

Based on this information the question is which industry has the potential to change these conditions. For Germany it is the healthcare system as it establishes the rules and boundaries for most players in this field. Therefore, the next part provides some information needed to grasp the most crucial concepts.

The German healthcare system is basically divided into two subsystems, the statutory healthcare system and the private one (Busse, Riesberg, & WHO, 2004). Since 2009, German law requires a compulsory health insurance for people with a regular residence in Germany (Kalis, 2015). This implies that every person earning more than 400 € per month and not more than the threshold for the private healthcare system has to be insured in a statutory sickness fund. They have to accept new members regardless of their personal state of health (Bundesgesundheitsministerium, 2018). Employees earning more than 60.750 € per year as of 2019 are entitled to switch from the mandatory statutory healthcare to the private system whereby private sickness funds can reject applicants due to their age or health status. Self-employed persons, civil servants, freelancers, and students are entitled to choose between both system regardless of any prerequisites (Bundesgesundheitsministerium, 2018; PKV, 2019a). In 2018, 10,7% of all health insured persons in Germany were privately insured (Bundesgesundheitsministerium, 2019; PKV, 2019b). The private health insurance companies define their membership fees according to an individual´s health status (OECD/European Observatory on Health Systems and Policies, 2017). Compared to that, statutory sickness funds receive membership fees depending on an individual´s earning. Since 2015, the fees for health insurance are 14.6% of a person´s monthly salary which is equally divided and paid by the insured person and its employer. On top of that, insurance companies charge their members contributions that differ between 0.3% and 1.8% (Busse, Blümel, Knieps, & Bärnighausen, 2017). In total, the necessary contributions are very similar throughout all 109 statutory health insurance funds (Gesundheitsberichterstattung des Bundes, 2019). The money collected by the funds, except for the additional contributions, are merged in a national health fund and subsequently distributed to the sickness funds according to a risk equalization scheme. The statutory health insurance covers a broad range of services which also includes dental treatment. If insured persons wish to be insured for services not included in the basic version, they need to take out additional private insurances. Regardless of the system in which someone is insured, everyone can choose the preferred doctor freely which implies that no separate infrastructure for privately insured persons exists (OECD/European Observatory on Health Systems and Policies, 2017).

The total expenses of the German healthcare system have been steadily increasing since the 1990s. In 2016, they reached more than 356 billion euros.

Figure 2*: Annual health expenditure in Germany (in million euros) including CAGR*



Source: Statistisches Bundesamt (2019)

In relation to Germany´s GDP in 2015 (3.048 billion euros), the total healthcare expenditure represented 11.3% of Germany´s GDP which is above the European average (9.9%) that year (OECD/EU, 2016; Statistisches Bundesamt, 2019). Comparing the share of health expenditure measured against GDP in 1992 and 2015, we see an increase from 9.4% to 11.3% (Statistisches Bundesamt, 2019) which indicates that the real share of health expenditure grew. In 2015, the German health expenditure per capita was at 4.180 € the second highest in the EU suggesting that the system is quite expensive (OECD/EU, 2016; Statistisches Bundesamt, 2019). Given the previous description of the system it is obvious that the major part of health expenditure (78%) is financed with compulsory health insurance. Only 7% of financing happens by government schemes (OECD/EU, 2016). The major part of health expenditure occurs in outpatient facilities, followed by hospitals and pharmacies (Statistisches Bundesamt, 2019). This is due to outpatient facilities being the first point of contact for most patients as hospitals are only frequented with a referral by a doctor except for emergencies (OECD/European Observatory on Health Systems and Policies, 2017).

2.4 IoT

Picking up on the so far mentioned difficulties the German healthcare system faces the next section focuses on a new technology, IoT. It tries to determine whether and to which extent IoT might be a valuable upfront investment that increases the resilience and efficiency of the existing healthcare system and enables it to better meet growing demands.

2.4.1 Overview

In 1991, Mark Weiser (1991) presented his idea of IoT that he back then called 'ubiquitous computing'. He was of the opinion that "the most profound technologies are those that disappear" (Weiser, 1991, p. 94). That is why he and his colleagues were "trying to conceive a new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background" (Weiser, 1991, p. 94). The term IoT was firstly taken into public by Kevin Ashton who said that "we need an Internet of Things, a standardized way for computers to understand the real world" (Schoenberger, 2002, paragraph 6).

But what exactly is IoT? IoT is a network consisting of physical interconnected devices equipped with sensors, processors and communications technology which operate either within a local data network or the Internet. Hence, it represents the connection between the physical and digital world. With the help of sensors, IoT enabled devices collect information which is then accumulated with the information of other smart devices in the network. Based on this collected and analyzed information either immediate actions can be taken or the information is saved for long-term purposes. Interestingly, the last two stages link IoT with other emerging technologies such as big data, artificial intelligence (AI), and deep learning (De Cremer, Nguyen, & Simkin, 2017; Sullivan, 2018).

When thinking of IoT it has to be clear that IoT is not a precisely defined technology but refers to a combination of technological functionalities that eventually creates value based on the functionalities´ interactions. This is why IoT systems are individually designed for each purpose and range from simple to very complex systems. In the following, the most important technical components for a well-functioning IoT system are described whereby often few of them are sufficient for a working system illustrating the great flexibility of IoT. Smart objects must have the possibility to communicate and cooperate with other devices in the system. Usually, this happens based on wireless technology like UMTS, Wi-Fi, or Bluetooth. For users to be able to control smart devices remotely, devices need to be addressable. Relevant in that context is the equipment of these devices with effectors. Another important component is the clear identification of the devices most commonly realized with barcodes, RFID, or NFC. Sensor technology is required to collect and transmit information. Processors and storage capacity are needed to give smart objects the opportunity to process gathered information. Some application areas of IoT presuppose the localization of the used objects. Employed techniques encompass for example GPS or the mobile network. If desired, IoT systems can interact with human beings. The technical solution for this is a user interface, for example a smartphone (Mattern & Flörkemeier, 2010).

Why is IoT a current trend everyone talks about when some visionaries had thought about it already 30 years ago? At the time Weiser published his article he was aware that the time for widespread commercial IoT had not yet come. He identified primarily chip performance, energy consumption, and high prices as the main obstacles for implementation (Weiser, 1991). In the meantime, Mattern & Flörkemeier (2010) identified progress in Information and Communication Technology (ICT) and microelectronics as the main drivers for the rapidly growing IoT portfolio. The progress in these domains is responsible for miniaturization, decreasing prices, increasing capacity, and lower energy consumption of various components. However, even nowadays IoT is at the beginning as technology still needs to further improve to become less costly and more easily accessible for a broader range of industries (Mattern & Flörkemeier, 2010). The benefits of IoT are based on the system´s capability to collect and interpret data which consequently favors businesses, societies, and individuals. The advantages of businesses are the optimization of processes like resource management that ultimately causes an increase in efficiency and productivity what in turn decreases costs (De Cremer et al., 2017; Sullivan, 2018). Especially logistics has gained lots of IoT experience, mostly based on RFID technology as this allows "asset tracking and inventory control, security, tracking of shipping, location and energy conservation, as well as building profiles of customers and suppliers" (De Cremer et al., 2017, p. 146). The implications of IoT for society as a whole arise in sectors such as infrastructure and healthcare that similar to those services affecting individuals, for instance smart home, aim at improving quality of life while, for the first case, simultaneously fighting societal threats (Manyika et al., 2013; Mattern & Flörkemeier, 2010).

A report published by IHS in 2016 counted 17.68 billion installed IoT devices worldwide. According to IHS, this number is expected to increase by more than 300% until 2025 to 75.44 billion installed devices (Lucero, 2016). McKinsey estimates the potential economic value IoT could create until 2025 to range from 3.9 to 11.1 trillion USD whereby IoT is seen as most promising for factories, cities and the human body (McKinsey & Company, 2018). Bain & Company (2018) forecasts the market volume of IoT to more than double from 2017 to 2021, from 235 billion USD to 520 billion USD. These figures, even if they turn out to be not entirely correct, illustrate for one part that IoT is still in its initial stage and the enormous future potential IoT has.

According to a survey conducted by Bain, the major obstacles that hinder a widespread implementation of IoT are security concerns, difficulties in the integration of new IoT devices in already existing systems, and an unclear ROI (Bain & Company, 2018). McKinsey adds technical and regulatory concerns that need to be fixed to make a widespread acceptance of IoT possible (Manyika et al., 2013).

2.4.2 IoT and Remote Monitoring in Healthcare

Similar to the general idea of IoT, IoT in healthcare offers a wide range of different applications that can be flexibly tailored to an individual´s needs and that cover a broad field of health areas. That is why it is important to differentiate telemedicine from IoT. IoT is often mentioned together with telemedicine, which can be correct, but telemedicine also works without specific IoT connections. A very common IoT product are wearables, like Apple Watch or Nike´s Fuel band with their health applications. Although most of these products are relatively basic Apple Watch Series 4 already includes the possibility of an electrocardiogram (ECG) (Apple, 2019). The German sickness fund Techniker Krankenkasse (TK) offers members bonus points which can be exchanged to money if they participate in a fitness program. One part of this program is the documentation of the number of steps walked over a predetermined time period with the help of wearables (Techniker Krankenkasse, 2018).

The solutions created with IoT in healthcare also include services that are supposed to facilitate chronic disease management. Normally, they are more complex than the single use of wearables and include, in contrast to wearables, medical services such as diagnosis or treatment, too (Kim & Kim, 2018). Usually, monitoring systems in healthcare include vital sign sensors that can be part of wearables or smart mobile devices that gather relevant information from the environment and its user (Mora, Gil, Terol, Azorín, & Szymanski, 2017). In a first step, this collected information is transferred to smartphones. According to Mattern & Flörkemeier

(2010) smartphones are very likely to become increasingly important as they provide additional information like the current location and as their usage is faster and more convenient for users. As soon as a smartphone received the information, the device can either process, store and display the analyzed data or send it to a cloud which basically does the same. People with authorized access to this cloud, e.g. physicians, are then able to monitor the incoming data and intervene if necessary (Mora et al., 2017).

Although exact figures determining the value of IoT in healthcare vary from source to source, the general indicated trend is the same. Experts and analysists expect the economic value of IoT in healthcare to be very high and strongly growing. According to McKinsey, IoT in healthcare is one of the three most promising IoT business segments. Their report from 2018 assessed the potential economic value of IoT in healthcare to vary between 0.2 to 1.6 trillion USD until 2025 (McKinsey & Company, 2018). Interestingly, these figures were revised downwards compared to those from 2013 where McKinsey assumed the economic impact of IoT in healthcare to range from 1.1 to 2.5 trillions USD per year until 2025 (Manyika et al., 2013). One possible explanation is that companies have not yet reached the stage in which the technology would be fully deployed across the industry. Another analysis revealed that this difficulty is not limited to the healthcare sector but affects all business segments IoT aims at. Specific solutions were found for all sectors and their respective concepts tested. However, companies eventually hesitate to scale up which could justify the downwards revision (McKinsey & Company, 2018). The major reasons for this hesitation could be investors not seeing a clear economic benefit of available solutions yet and lacking customer or patient acceptance (Bain & Company, 2018; Kim & Kim, 2018).

Regardless of all economic evaluations of IoT in healthcare, one must be aware that effective IoT solutions in healthcare cause a win-win situation for all involved parties. Companies providing these solutions make money, governments and healthcare systems offering IoT services save money and patients benefit from it due to a better quality of life, a higher mobility, and a better healthcare provision (Hassan, El Desouky, Elghamrawy, & Sarhan, 2019; Manyika et al., 2013).

The idea of monitoring patients remotely via IoT systems poses own challenges. Transferring the concerns Mora et al. (2017) expressed to another setting, one difficulty could be the overuse of the system´s computing capabilities if many patients are monitored and “the streaming of data collected by many sensors deployed across the body”. Another identified drawback of remote monitoring systems is if relevant data for further diagnosis or intervention by physicians is lost (Bilagi, Pavithra S. M. C., Ramya R., Renuka, & Sindhuja S. R., 2018). Furthermore, significant disadvantage occurs in case of a broken data connection, either within the local network or in form of internet disturbances that can prevent necessary medical intervention in case of an emergency (Hassan, El Desouky, Elghamrawy, & Sarhan, 2018).

One project that combines IoT and remote monitoring is the development of Digital and Analog Companions for an Aging Population (digilog). Digilog aims at extending a person´s life and saving lives by collecting relevant data like an ECG with the help of fitness trackers and small wearable sensors. The particularity is that it allows data to be collected over a very long time which facilitates a timely detection and treatment of irregularities. Without disturbing the patient´s life the sensors transmit the gathered data to a cloud where it is analyzed by physicians. Digilog also enables its users to independently determine access rights to their files and to designate a person that should be informed in case of an emergency. One selection criterion for the cloud was its compatibility with other technologies to ensure an easy integration of differing systems. Digilog´s initiators hope to save more lives, strive to decrease healthcare costs and address sociopolitical problems by providing affordable healthcare in rural and less developed regions (Microsoft, 2017).

3 Methodology

The applied methodology is split into primary and secondary research which is due to the fact that it allows a more holistic understanding of the defined RQs (Valentine, 2005). For the first part of the analysis, the SWOT analysis of the German healthcare system, secondary data in form of academic literature was collected. As the points discussed in the SWOT analysis cover diverse topics with varying backgrounds primary data collection for these would have been too time-consuming given the overall available time for the dissertation. Additionally, high-quality secondary data for most discussed topics is available (Bell, Bryman, Harley, & Bryman, 2018). The majority of the used sources are journal articles combined with information that was published on websites of federal institutions. Moreover, few reports of the OECD and consulting companies were referred to given some very recent topics for which no academic literature exists so far.

The second part of the analysis is based on primary research, namely expert interviews. The focus on primary research for this part of the analysis is due to the fact that the current diffusion of IoT and remote monitoring in the German healthcare system taking into account all points of view is tried to be assessed. Academic literature that combines all these aspects does not exist so far. Although it was tried to get at least one interviewee from each of the four parties (companies, doctors, statutory health insurance companies, and patients), data security reasons prevented an interview with a patient. In total, four interview partners were found of which three wanted to exercise their legitimate right to remain anonymous (Whiting, 2008). Two are employees from the same German company operating in the medical healthcare market, one interviewee works for a large German statutory health insurance company, and Prof. Dr. Dr. Kurt J.G. Schmailzl initiated the project digilog described before. As for all impacted stakeholders except for the group of patients an interview partner was found the patient´s point of view was tried to be covered with relevant insights derived from the other interviews.

The interview type chosen for the expert interviews was semi-structured. The advantage of this approach is the flexibility for the interviewer to change, add, or skip questions. Therefore, it was possible to dig deeper into upcoming topics and gain more relevant insights than it would have been with a structured interview. This is of particular importance as the expert interviews strive to compare the different perspectives of the stakeholders regarding the research topic (Longhurst, 2010; Rager, Oestmann, Werner, Schreier, & Groeben, 1999).

Before the interviews took place rough frameworks of questions were developed which varied depending on the stakeholder (**appendix 3**). As all interviewees were located in Germany, the one-on-one interviews were conducted via telephone with a duration of 30-60 minutes each.

The interviews themselves were recorded with prior acceptance of the interviewees and afterwards translated to English (**appendix 4-7**). In some cases not all parts of the interview were written down for the sake of clarity (Rager et al., 1999).

4 Results´ Analysis

4.1 SWOT Analysis: German Statutory Healthcare System

The analysis of the German healthcare system is done by means of a SWOT analysis that provides a short overview of the most relevant points whereby it does not strive for completeness. Therefore, the focus lies on a simpler SWOT analysis although more advanced forms have been developed, see Pickton & Wright (1998). The analysis itself will be mostly focused on the statutory healthcare system and aims at clarifying whether IoT could be a good approach to overcome some of the system´s shortcomings.

4.1.1 Strengths

4.1.1.1 History

The German statutory health insurance system was founded in 1883 by Chancellor Otto von Bismarck and is considered to be the first modern health insurance system worldwide. It is based on three major principles which are solidarity, the participation of employers, and self-governing structures. Solidarity refers to the fact that all insured persons contribute a percentage of their salary to the insurance funds regardless of their health status. Consequently, they are entitled to benefit from it irrespective of "their socioeconomic situation, ability to pay, or geographical location" (Busse et al., 2017, p. 882). The participation of employers refers to the 50% share employers have to pay of the 14.6% contribution for every person insured in the statutory healthcare system. The third principle, self-governing structures, will be explained in more detail in section 4.1.2.2. The reason why the more than 136 years old statutory healthcare system is considered a strength is that "it survived, with key principles intact, different forms of government (an empire, republics, and dictatorships), two world wars, hyperinflation, and the division and subsequent reunification of Germany" (Busse et al., 2017, p. 882). This resilience is the basic requirement for the system to be able to deal with future challenges.

4.1.1.2 Disease Management Programs

One example for the system´s adaptability is the introduction of Disease Management Programs (DMP) in 2002. They were a response to quality problems within the statutory healthcare system especially affecting chronically ill patients (Busse et al., 2017). The aim of the DMPs was to improve the healthcare for the mentioned patient group whose deficits were caused by the strong division of the system in inpatient and outpatient facilities and to reduce the number of unnecessary referrals to hospitals (OECD/European Observatory on Health Systems and Policies, 2017). The different DMPs are focused on one specific disease and entail precise instructions according to which the medical staff has to treat enrolled patients (Linder, Ahrens, Köppel, Heilmann, & Verheyen, 2011). Although the number of participating patients increased to 6.6 million in 2015, the success of DMPs is discussed controversially (Busse et al., 2017). Despite the increase in participating patients the number of unnecessary referrals to hospitals remained stable (OECD/European Observatory on Health Systems and Policies, 2017). Linder et al. (2011) studied the success of DMPs on basis of the DMP conceptualized for diabetes mellitus type II and concluded that a benefit from participating in that program cannot be clearly established. They find a slightly lower number of emergency admission and lower hospital costs. These benefits are outweighed by higher expenses due to more prescriptions and more consultations of physicians. Therefore, they recommended to stop the current form of very bureaucratical and expensive DMPs (1.1 billion euros in 2009) (Linder et al., 2011). Nevertheless, the relative early implementation of DMPs in Germany can be considered a strength as it reflects the system´s flexibility and existing awareness concerning chronic diseases.

4.1.1.3 High Degree of Coverage

The population share covered by statutory health insurance increased since its foundation in 1883. In 2009, welfare recipients were included in the compulsory health insurance, too, which lead to a coverage of almost 100% including those being insured in the private system (Busse et al., 2017). However, in 2015 it was estimated that approximately 0.1% of the population does not have health insurance. The reasons for this are mostly administrative barriers or an individual´s inability to pay the membership fees, especially in case of self-employed people with very low earnings. Another population group frequently not covered by compulsory health insurance are migrants without valid identification documents. Although being entitled for health insurance they often do not apply for it due to communication difficulties and their fear of legal consequences (OECD/European Observatory on Health Systems and Policies, 2017). In 2018, 89.3% of all insured people were insured within the statutory healthcare system which represents an increase of 0.7% compared to the 88.6% in 2012 (Bundesgesundheitsministerium, 2019; PKV, 2019b). The strength resulting from high coverage can be seen in reforms that address the challenges caused by chronic diseases. Due to the high coverage reforms are quite likely to be very effective if they are implemented well.

4.1.2 Weaknesses

4.1.2.1 Cost Effectiveness

Looking at the expenses and their development one would expect the healthcare system to offer high quality services. However, there are two characteristics that negatively affect the system´s efficiency. Firstly, Germany has a very extended inpatient sector with 813 beds per 100.000 citizens which is the highest European bed capacity. This ensures a very good availability of medical treatment throughout the country. Additionally, the infrastructure has lots of technical and human capabilities. Despite the high number of doctors and nursing staff, the doctor/bed and the nurse/bed ratio are very low and a high quality supply of technical equipment and specialists cannot be guaranteed in all numerous existing hospitals (Busse et al., 2017; OECD/European Observatory on Health Systems and Policies, 2017). Secondly, Germany is characterized by a strong separation of inpatient and outpatient services. In both sectors, the number of patients receiving treatment is very high, also compared to the EU. This strong and lasting separation causes inefficiencies in the provision of healthcare especially regarding the efficient use of available resources (OECD/European Observatory on Health Systems and Policies, 2017). Considering these two points, it is not surprising that the different indicators assessing a healthcare system´s quality are mediocre (KPMG, 2014).

Good results were achieved in terms of technical efficiency in the inpatient sector as well as the costs per contact with a doctor in the outpatient sector. However, it must be kept in mind that a high degree of technical efficiency certainly indicates high utilization but does not give any information about the treatment´s necessity (Busse et al., 2017; KPMG, 2014). Other positive areas are, for instance, the early detection of cervical cancer, the relatively low additional private payments for dental care, or the relative low death toll of released patients who received stroke treatment. Significantly worse results are achieved in the death toll of released patients suffering a myocardial infarction who received treatment or the death toll of cervical and breast cancer per 100.000 citizens (KPMG, 2014). Regardless of the system´s positive contribution that avoided preventable deaths thanks to a timely and effective treatment, an additional 10% of deaths could have been avoided with an improved system in 2014 (OECD/European Observatory on Health Systems and Policies, 2017).

Summarizing, this means that despite the high and increasing health expenditure for the German healthcare system, its quality is not the best that could be achieved with the respective amount of expenses (KPMG, 2014). Therefore, a concentration of the current available human and technical resources as well as a consolidation of hospitals in combination with a better collaboration of the inpatient and outpatient sector are needed to improve the overall quality of the system and to be prepared for future challenges (Busse et al., 2017).

4.1.2.2 Principle: Self-Governing Structure

The third principle introduced in 1883 were self-governing structures. Self-governing structures mean that the government has only limited control over the implementation of reforms that are determined by the legislation at the federal level. Responsible for the implementation is the federal joint committee, composed of representatives of several medical associations and some independent representatives which have the required competencies for the necessary reorganizations in the system. The advantage of this structure is that the representatives of the committee, unlike politicians, make decisions while having in-depth knowledge about the healthcare system. The major disadvantage is that members of the committee do not necessarily act in the best interest of patients or society as a whole and that institutions which initially caused the quality deficits and structural problems are being held responsible for resolving them. This, in combination with a continuous rivalry over competences between the federal and the federal state level often effectively prevents the implementation of reforms striving for quality and efficiency improvements (Busse et al., 2017; OECD/European Observatory on Health Systems and Policies, 2017).

In order to equip the statutory healthcare system with better tools to obtain improved quality at the current expenditure level the principle of self-governing structures should be reassessed.

4.1.2.3 Private Healthcare System

The existence of the private healthcare system next to the statutory one fuels debates. One matter often being disputed is the higher remuneration physicians receive for treating privately insured persons. This makes privately insured patients more appealing to doctors and increases the waiting time for patients in the statutory system (OECD/European Observatory on Health Systems and Policies, 2017).

A second issue is the pure existence of the private healthcare system as it contradicts the principle of solidarity. High earners receive the option to switch from the statutory healthcare system to the private one in which they often have to pay less membership fees. This is due to their general better health status which is a result of their often higher level of education. The statutory healthcare system being based on solidarity lacks top earners which would contribute a higher share while simultaneously being of better health and therefore less costly. This questions the sustainability of the statutory sickness funds. In order to fight this they were enabled to offer members different plans according to an individual´s needs which is supposed to attract and keep more people in the statutory system (Busse et al., 2017; OECD/European Observatory on Health Systems and Policies, 2017). Looking at the share of people insured in the private healthcare system since 2012, a reduction from 11.4% to 10.7% in 2018 can be observed (Bundesgesundheitsministerium, 2019; PKV, 2019b). The exact reasons for this trend cannot be clearly assessed. However, the lost revenue of top earners in the statutory system will complicate the system´s situation when it comes to complex future challenges.

4.1.3 Opportunities

4.1.3.1 Digitalization

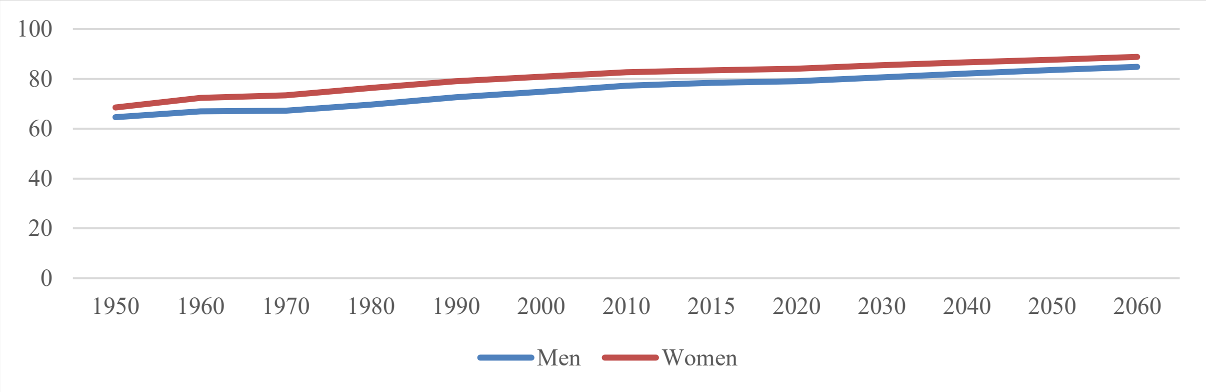
A report published by McKinsey in 2018 states that the German healthcare system could have saved up to 34 billion euros in 2018 if it was digitalized. This amount corresponds to 12% of the total expenses. The three categories promising most saving potentials are paperless data (9 billion euros), online interactions (8.9 billion euros), and result transparency (6.1 billion euros). The savings potential for self-management of chronically ill people is estimated to be 2 billion euros. The two most promising technologies are the electronic medical record and the electronic prescription. The advantages of a digitalized healthcare system would be direct efficiency gains accompanied by indirect efficiency gains three times as high as the direct ones. Additionally, digitalization would diminish demand as unnecessary double treatments caused by the separation of the inpatient and outpatient sector could be avoided. Increased service quality would reduce future treatments, too. The inpatient and outpatient sector are the two areas which would benefit most from a digitalization (McKinsey, 2018). All categories described potentially include applications that work with IoT, big data, or AI. Murdoch & Detsky (2013) identify four aspects of big data that could increase efficiency and quality in healthcare. The generation and diffusion of new knowledge and the empowerment of patients by providing them their individual health records are among them (Murdoch & Detsky, 2013). Also other institutions see the potential of new technologies. The vbw (2018) requests to scale digital projects that were already tested successfully Germany-wide in order to ensure a quick economic return.

4.1.4 Threats

4.1.4.1 Demographic Change

Demographic change is influenced by three factors: life expectancy, birthrate, and migration. Life expectancy at birth in Germany has been increasing over the last 65 years for both genders. In 2015, women had a life expectancy of 83.4 years compared to 68.5 years when born in 1950, a plus of 15 years. A similar picture can be drawn for men whose life expectancy rose from 64.6 years in 1950 to 78.4 years in 2015. For the following decades, the life expectancy at birth is estimated to further increase to 88.8 years for women born in 2060 and to 84.8 years for men born in the same year (Statistisches Bundesamt, 2019). The reasons for this increase are among other things healthier lifestyles as well as better medical availability and treatment (OECD/EU, 2016).

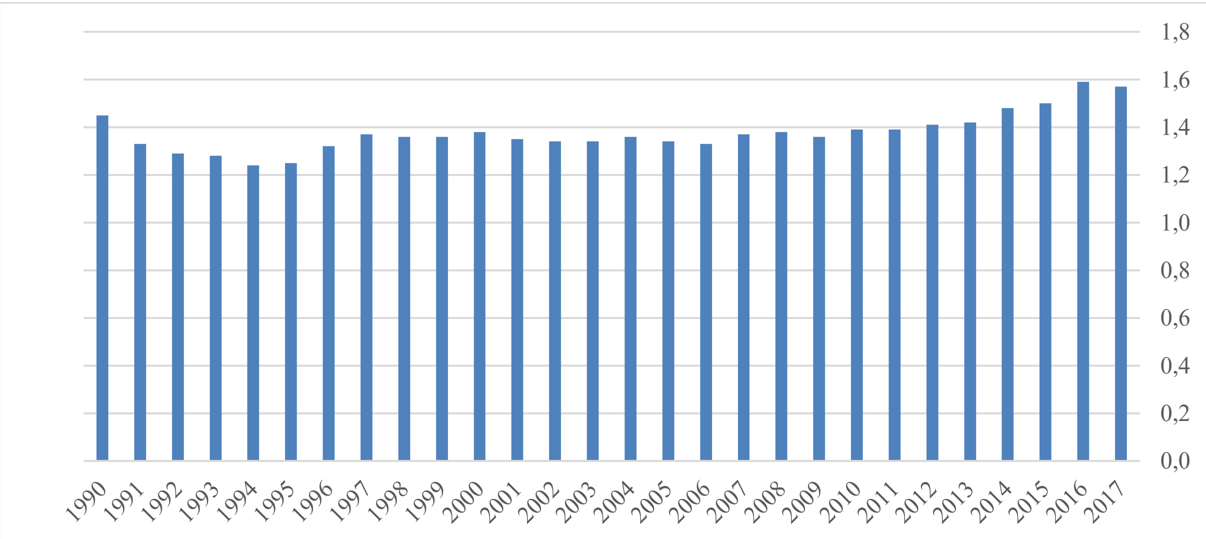
Figure 3: Life expectancy at birth by gender in Germany



Source: Statistisches Bundesamt (2019)

In terms of the second factor, fertility rate, figure 4 shows that it is relatively low in Germany. Since 2010, it has been slightly increasing, nevertheless the ratio is still too low for a sustainable development of the population (Statistisches Bundesamt, 2019).

Figure 4: *Fertility rate in Germany*



Source: Statistisches Bundesamt (2019)

Despite emigrants leaving Germany the balance of migration is positive as more immigrants are incoming than emigrants leaving. On average, immigrants are younger than the average population which can have positive effects on a country´s demographic development (Nowossadeck, 2012).

Despite the positive migration balance the high and increasing life expectancy at birth in combination with the relatively low fertility rate mean that Germany will be increasingly faced with an ageing population. Currently, approximately one fifth of the German population is older than 65 (Nowossadeck, 2012). This share will increase in the future and pose major challenges for the healthcare system and the pension funds as simultaneously the share of people working will decrease (OECD/EU, 2016). Although ageing does not necessarily imply suffering from diseases, the risk of getting ill significantly increases with age. For the German healthcare system this means that it needs to prepare to deal with a rising number of multimorbidity and elderly who are in need for care. Therefore, the share of health expenditure on GDP is very likely to increase over the coming years.

4.1.4.2 Increase in chronic diseases

As seen in section 2.1.4, chronic diseases are prevalent throughout all age groups in German society. Although younger people (< 65 years) are less affected by chronic diseases (currently one fifth of the population) the share is expected to increase over the following years, causing a rising cost burden on social systems. Moreover, the combination of the above described demographic change and the increased risk of suffering from diseases while ageing leads to an increasing rate of people suffering from chronic diseases, too. Already nowadays, more than 50% of the population being 65 years or older have to deal with one or more chronic disease. Also this portion is expected to increase and, hence, cause higher costs (Nowossadeck, 2012).

4.1.5 Conclusion

This SWOT analysis revealed that the opportunity of digitalization and technical progress, e.g. using IoT for remote monitoring, could be a valuable concept to overcome the system´s weakness of inefficiencies particularly caused by the fragmentation of the inpatient and outpatient sector. This combination is especially interesting in case of a successful implementation as it entails the possibility to fight the threat of demographic change and a worsening chronic disease burden successfully. Nevertheless, this is just one possibility out of many which does not guarantee the resolution of all problems

4.2 Insights Obtained by Expert Interviews

Now, the most important insights from the interviews regarding their significance for the evaluation and the underlying reasons of the current state of IoT and remote monitoring in the German healthcare system are presented. As the most relevant players are companies operating in the healthcare sector, statutory health insurance companies, doctors, and patients, the gained insights will be bundled and aggregated for each group resulting in four subcategories equivalent to the main market participants.

4.2.1 Companies

Companies divide the healthcare market into two segments, the consumer healthcare market and the medical one. To the consumer market belong mostly wearables such as the Apple watch or general fitness trackers. For IoT and remote monitoring the medical healthcare market is of relevance and characterized by products offering a high medical benefit that target a patient group whose high level of suffering requires these products.

In terms of the hype surrounding IoT companies have the impression that it increased over the last couple of years, also putting them under pressure to connect every single device. However, for IoT solutions to create value they need to fulfill a medical unmet need which is mostly the case for patients with high psychological stress as they have to handle these products on a daily basis.

Although companies do not consider technology itself as a major burden for IoT a significant obstacle is represented by the acceptance of innovations in the medical profession and the overall healthcare system. As firstly the medical and economic benefit of innovations have to be proven with studies companies have to invest lot of money and time as it takes decades until innovations reach standard care. Therefore, companies hold physicians accountable for a quicker implementation of innovations. A different problem in the same area are doctors themselves who perceive IoT solutions as time consuming and entailing additional effort which is interfering with their goal to treat patients as quickly as possible. Furthermore, their daily workload does not allow them to monitor patients remotely. Additional resistance of doctors arises from their perceived inviolability of their profession, their fear of lost control and liability and a missing business model that would guarantee a remuneration for treatments done remotely. Theoretically, compensation for these services is included in the statutory healthcare system. Nevertheless, restraints and requirements along with a very limited number of applications make this compensation basically ineffective.

Another factor companies identify as essential for a sustainable IoT and remote monitoring development is the assurance of the solutions´ interoperability within an ecosystem which is opposite to the often existing isolated solutions.

Other than this, companies see first positive developments aiming at overcoming the previous mentioned obstacles in some doctors who are engaged in the topic and try to exceed existing boundaries. This comes along with an increasing willingness to cooperate, share tasks, and be open for interdisciplinary work. Their raised interest in this subject reflects their recognition of the relevance of data transfer which takes increasingly place between practices and medical associations. Overall, companies are convinced that the entire healthcare system needs to surpass the point where all essential structures and data highways are set up to promote recognizable growth in digitalization and IoT solutions. As soon as this happens, companies see significant business potential in IoT solutions for the future and think of them as a win-win situation for the whole system that is inevitable due to its annually rising costs.

The two most promising future trends predicted by companies are a technological and a political one. The technological trend is seen in a central data base that gathers all data concerning one patient regardless whether it was captured by physicians or the patient himself. The latter option would logically include a widespread diffusion of IoT and remote monitoring. The political trend relates to an ageing German medical profession. As one third of all general practitioners will retire within the next few years and the government promotes regional care centers the overall healthcare structure will change tremendously. To keep up the supply in all areas more initiatives that promote telemedicine and therefore IoT solutions will be needed.

4.2.2 Statutory Health Insurance Companies

The market of sickness funds is differentiated into two segments depending on the positioning of the single company. Health insurance companies whose target group is mostly elderly people are more cautious with the introduction of new digital solutions whereas those focusing on younger clients try to foster digitalization. They perceive new technologies as an investment for the future and consider the healthcare system´s digitalization as a necessity. Therefore, they constantly try to set new standards for existing innovation limits by investing a considerable amount of money, time, and other resources, and by acting as an advisor within the political system to open it from this side, too.

Statutory health insurance companies see the added value of IoT projects split up between patients, physicians and themselves, therefore, being it a win-win situation. However, sickness funds witness that the same digital solution is more interesting for some players than for others.

These deviating motivations and interests are additionally boosted by the dominating self-governing structures and make all players benefit in different ways.
Similar to companies, sickness funds put emphasis on the interoperability of developed solutions with an external system as only this way the essential value creation can take place.
However, sickness funds have to overcome several obstacles before digital solutions are established in standard care. The first relates to legitimate data regulations imposed in Germany and the EU which make timely implementations difficult and often cause start-ups in this sector to fail given their lack of resources to deal with this issue. In a second step, the social security framework limits the scope of product development significantly. Sickness funds require creativity to find solutions within these regulations. Certain positive developments in this direction can be observed in the current government. If the first two obstacles are overcome, the launch of a product to standard care is further complicated given mandatory small scale tests with a restricted number of test persons and a long duration. The resulting lack in scalability additionally impedes the development of start-ups whose business models usually rely on this.
The reasons why sickness funds nevertheless engage in the development of digital solutions are twofold. Their primary motivation is the sustainable improvement of care quality for policy holders. This is often accompanied with efficiency gains for them. The second major motivation is caused by the pressure they are exposed to from tech companies. Some sickness funds firmly believe that sooner or later some players will seize the opportunity of digitalization in the German healthcare market. They are unwilling to simply leave the market to external players such as tech companies but want to actively shape the future even though this involves high financial commitments.
In their opinion, the growth potential of IoT solutions highly depends on the pressure exerted by digital savvy people to the system as for instance politicians. Although a general euphoric mood regarding digitalization is prevailing particularly the healthcare sector struggles to catch up due to its highly regulated environment.

4.2.3 Doctors

The interview conducted with Prof. Dr. Dr. Schmailzl exactly represents a case required by companies in which engaged physicians try to foster IoT solutions. He recognized that some German regions are characterized by a poor healthcare provision illustrated by a high number of small hospitals that have to shut down, the difficulty of finding successors for practices in rural areas, and an insufficient public transport that barely allows the access of remaining supply points. As a response the project digilog was founded aiming at the delivery of medical technology to patients.

The project itself successfully surpassed the test phase and developed itself since then into a brand encompassing several services. The brand digilog is of particular sociopolitical interest as with the help of investments it is tried to develop it to an alternative for a region that faces a severe structural change.

One major barrier to surpass the test phase was technological issues that are in general relatively easy to solve. However, for small companies also these solvable problems represent mentionable obstacles. Additionally, legal affairs in form of data transfer and data storage needed to be resolved which was eventually done with servers that are located in Germany. The initiators of digilog experienced that people in Western Europe do not want health related data to be processed via US servers. The third considerable complication was caused by the project´s multidisciplinary setup. Digilog entails a total of 37 consortium partners from varying backgrounds which complicated internal cooperation. Nevertheless, they managed to make it a successful project.

The main success factors are seen in the used sensor technology that is very user friendly and does not intervene in a person´s daily life. Secondly, the global approach of the project´s concept is decisive for its success. Digilog does not aim at solving one isolated problem but focuses on the delivery of numerous parameters thereby representing a portable hospital.

Similar to the representatives of companies and the statutory health insurance companies, Prof. Dr. Dr. Schmailzl considers the general prevalence of IoT solutions in Germany to be in its initial phase where only a few excited doctors try to push it forward. The main reason for this is the mistrust and the lacking willingness to invest in new technologies that prevail in Germany. Specialists see differences in other countries.

In order to change this situation and foster a quicker and successful implementation of IoT solutions doctors need to be convinced that these solutions are not competing with their services and that they will receive a remuneration for it. As soon as they are on board and recognize the advantage of innovations things are likely to change substantially. Regardless of this, digitalization of the healthcare system which is the precondition for IoT solutions and other new technologies is an imperative, will be successful and change the whole medicine sooner or later.

4.2.4 Patients

Although no interviews with patients could have been conducted the other interviews revealed some insights regarding patients. One shared concern are data security concerns that affect data transfer and data storage. Apart from the applicable European General Data Protection Regulation (GDPR) that needs to be complied to providers of IoT solutions are confronted with the public unwillingness to have health-related data running over serves located in the USA. Another topic that all users have in common is the used technology, mainly the sensor technology. Sensor technology needs to be very user friendly, without any manuals that need to be consulted before the usage and they must not interfere with the user´s daily life. If these two points are not fulfilled doctors doubt the acceptance of patients for IoT solutions. Furthermore, solutions designed for elderly should be simple and convenient with an error potential as low as possible. Based on their experience, companies think that the product design is secondary as long as the product is beneficial for the attending doctor and patient. Given the user pattern of already developed products by health insurance companies digital natives are not considered as having troubles accepting IoT solutions as they are already interested in the mostly preventative existing solutions. Elderly people seem to be willing to accept IoT solutions if their psychological stress is high enough. This equals the second peak of the user pattern. Furthermore, persons of trust seem to be of high relevance for them. Older people who cannot grasp the benefits of such solutions are willing to accept them if their doctor takes advantage out of them.

5 Main Conclusions and Future Research

This section shortly summarizes the findings for each RQ and the problem statement. Chronic diseases stand out with a worldwide occurrence. They are also prevalent throughout all age groups of German society affecting nearly 50% of the overall population (Kornelius, 2017). Even though the total sum of the direct and indirect cost burden of chronic diseases is difficult to assess it becomes evident that its size is enormous as only the direct costs are estimated to sum up to one quarter of all healthcare expenditures (Statistisches Bundesamt, 2015a).

Although further development potential of IoT and remote monitoring is seen the current state of technology definitely enables remote monitoring for chronically ill patients. A very good example for this is the portrayed project digilog.

Interestingly, all interviewed experts agree that all stakeholder groups in the German healthcare system are impacted by IoT and remote monitoring. However, the given structures, especially the self-governing ones, cause different players to be impacted in different ways.

As a conclusion, again all interviewees agree that the current business impact of this opportunity is relatively small due to the fact that it is still in its initial phase. Applying this to the Technology Adoption Life Cycle, users would be categorized as innovators that might have already proceeded to the boundary of early adopters. Nevertheless, most experts do not only see a huge business potential of it in the coming years but think of it as an unavoidable development that has to happen to meet current challenges.

The crucial question is what hinders IoT and remote monitoring from a wide diffusion in Germany. Therefore, the identified obstacles and potential ways to overcome them derived from the expert interviews are described in the following (please refer to **appendix 8** for a detailed overview).

Technological Obstacles

In general, technology for IoT solutions is not considered as a major implementation barrier. Of course, there are some minor difficulties but they can be solved. However, for small companies also minor problems might be challenges that first need to be solved. Another technological challenge is the compatibility of different IoT solutions in a large ecosystem. Often, their technical set-up hinders a quick connection with each other. One example are the different versions of the electronic health record that exist in Germany so far. Additionally, technology needs to ensure existing structures and data highways throughout Germany before IoT innovations can become successful nationwide.

Regulatory Obstacles

The last two topics touched upon in the section of technological obstacles, the compatibility of solutions to an external ecosystem and the assurance of structures and data highways, partially belong to regulatory obstacles, too, as governmental regulations could facilitate the resolution of these problems. Another regulatory issue is data security regarding data transfer and storage. This is highly regulated in the GDPR which came into force in May 2018 (European Commission, 2018) as well as the German Social Security Framework. Furthermore, the existing remunerations for digital medical services are barely meaningful as high barriers and prerequisites need to be overcome first to make use of them. The very narrow scope of applications additionally impedes the implementation of new IoT solutions.

Cultural Obstacles

A cultural problem complicating the growth of IoT solutions is the prevailing mistrust of digital solutions in Germany which comes along with an unwillingness to invest necessary amounts in digital solutions. Moreover, the medical profession is characterized by several traits hindering IoT solutions. Some of these are the physicians´ fear of liability and of lost control, and their perceived inviolability of the medical profession. Their doubts regarding a rising digital competition including a lacking remuneration combined with their already high work load leads to a lacking but necessary push of most physicians to promote digital solutions. This situation is further exacerbated by the long time evidence for and acceptance of new innovations in medicine takes.

Self-Governing Structures

Another barrier are the prevailing self-governing structures in the German healthcare system. Digital innovations are of different interest for single players. Due to this system, these players try to promote or prevent their implementation according to their own motivations and based on varying incentives without thinking of the best for society.

Multidisciplinary Approach

The last obstacle is the multidisciplinary approach that particularly more complex IoT projects require at least at the beginning. One example for this is the project digilog with its 37 consortium partners. Although the different backgrounds of the partners complicate the development of digital innovations to a certain degree, some advantages can be drawn from this variety as well.

The five obstacles described are responsible for the fact the remote monitoring via IoT and digital solutions are at the very beginning in Germany. They significantly limit their growth potential as it currently takes lots of resources, money, and time to overcome them. This is a particularly serious problem when it comes to small companies and start-ups that have promising ideas but simply cannot afford the necessary resources to deal with the given conditions. To change this situation permanently these obstacles should be overcome one way or another. Roughly speaking, the strategies to overcome these obstacles can be divided into three different ones. For many of the barriers described such as a more flexible Social Security Framework or standards for the compatibility of digital solutions in an external ecosystem a sustainable solution would be the intervention of the legislator. Especially for the section of cultural obstacles often only a cultural change can improve the situation for the system´s players. The dominant mistrust of digital solutions in Germany could be changed by increasing the sensibility of the advantages of these solutions in society for instance. The last strategy might not be a desired one but some obstacles are very unlikely to change and therefore hard to overcome. This implies that players operating in this environment will have to adapt. One example for this is data security that was just recently strengthened by the European Commission with the GDPR. Apart from that companies, also smaller initiatives, have proven that they can deal with obstacles relatively well and learn much by doing.

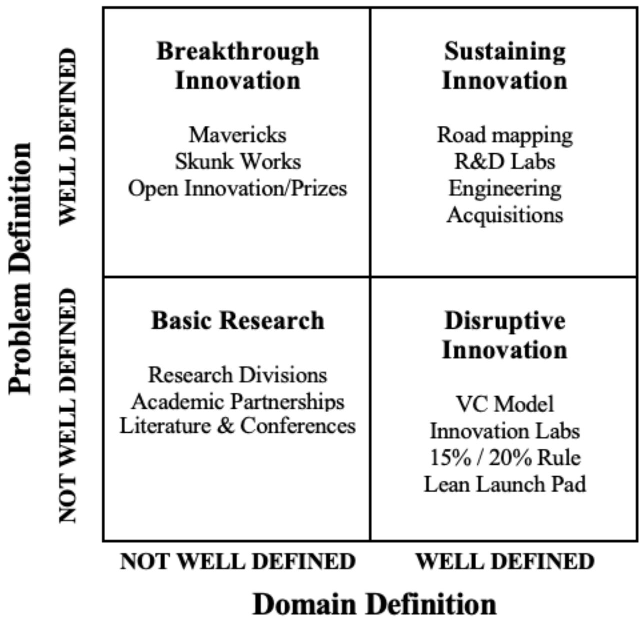
There is also positive news. Some changes facilitating the implementation of IoT solutions have already been happening or are currently occurring. The professional legalization of nationwide telemedicine could take place in the near future. This is said to be one prerequisite to help IoT solutions grow more rapidly. Also, the responsible federal institution announced a standardized electronic health record for whole Germany until 2021 latest (Gematik, 2018). A happening cultural change in the medical profession can be seen in those doctors already working on IoT and digital solutions despite the current obstacles. The combination of the increasing interest of physicians in this topic, the increasing external pressure from companies not belonging to the traditional German healthcare market, and the pressure exercised by digital natives who want to actively shape the future make some people believe that the system has reached a changing point at the moment. Relating this to the innovation matrix IoT and remote monitoring can be categorized as ‘breakthrough innovation’ given the well-defined problem and the so far not well-defined domain. Digilog’s multidisciplinary approach exactly followed the strategy of skunk works that is one proposed for this type of innovation. This successful project indicates that some players are on the right way to develop the full potential of this business opportunity. Whether it is taken and significantly promoted will be seen within the coming years. However, experts are convinced that digitalization and IoT will prevail sooner or later to handle the challenges of the German society.

Limitations and Future Research

The major limitation of this dissertation is its focus on qualitative research only as it might cause a restricted objectivity concerning the research topic and potentially limits its representativeness. Furthermore, the fact that no patient could be found for an interview limits the significance of the analysis for patients. This is why future research should not only aim at including interviews conducted with patients but also interviews that cover a broader range of representatives of the system´s key players. This could include start-ups operating within this field or doctors that are not part of a project striving towards the implementation of an IoT solution. Furthermore, future research could focus on a comparison between Germany and at least one other country that is one step further in terms of digitalization and IoT in healthcare. In this context, the inclusion of healthcare systems that originated from a completely different background, for instance the USA, could yield valuable insights, too. Another aspect future research could include is the potential IoT solutions have for preventing chronic diseases. Literature recognizes the high potential of prevention but none of the interviewed experts mentioned it. To overcome the limitations emerging from the focus on qualitative research future research could include quantitative tools. Additionally, it could address the obstacles rooted in innovation and technological innovation.

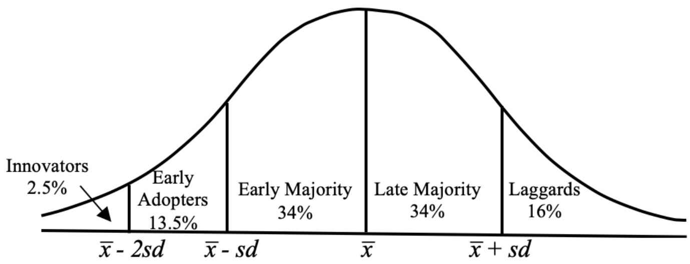
6 Appendices

Appendix 1: Innovation Matrix



Source: Adopted from Satell (2017)

Appendix 2: Technology Adoption Life Cycle



Source: Adapted from Rogers (1962)

Appendix 3: Interview Frameworks

<u>Company</u>

- In which area are you working and what are your main responsibilities?
- Do you offer a product that is specifically designed for chronically ill persons?
- Is there any target group which has a high potential in terms of IoT and remote monitoring?
    - Time: now vs. future
    - Course of disease: prevention, follow-up treatment
    - Disease: Diabetes, asthma, cancer, cardiovascular disease
    - Age: young vs. old patients
- How were your experiences with the products already on the market?
    - Acceptance of products
    - Current conditions
    - Obstacles
    - Opportunities
- What are the success factors a company operating in this environment needs?
- How do you assess the current state of technology of IoT and remote monitoring of patients with chronic conditions?
    - Does it create an added value?
    - If not, why not?
- How do you assess the potential of IoT and remote monitoring in five to ten years?
- Have you perceived a change in the hype surrounding IoT within the last ten years?
- In your opinion, what is the most promising trend regarding digitalization and healthcare in Germany?
- Do you think of IoT and remote monitoring of patients with chronic conditions as a win-win situation for the whole healthcare system?

Statutory Health Insurance Company

- In which area are you working and what are your main responsibilities?
- How do you assess the current situation of IoT and remote monitoring in Germany?
- Does the current state of technology of IoT and remote monitoring of patients with chronic condition create an added value?
- How were your experiences with the products already on the market?
    - Acceptance of products
    - Current conditions
    - Obstacles
    - Opportunities
- In your opinion, how do statutory health insurance companies deal with the topic IoT and digitalization?
- Do you pursue a digital strategy or do you develop new digital solutions without a specific concept?
- How do you assess the potential of IoT and remote monitoring in five to ten years?
- What has to be changed in order to promote IoT and remote monitoring? What is the role of statutory health insurance companies in this context?
- Have you perceived a change in the hype surrounding IoT within the last ten years?
- In your opinion, what is the most promising trend regarding digitalization and healthcare in Germany?
- Do you think of IoT and remote monitoring of patients with chronic conditions as a win-win situation for the whole healthcare system?

Doctor

- Can you shortly describe what your project is about?
- How do you assess the current state of technology of IoT and remote monitoring of patients with chronic conditions?
    - Does it create an added value?
    - If not, why not?
- How were your experiences with the products already on the market?
    - Acceptance of products
    - Current conditions
    - Obstacles
    - Opportunities
- What are the success factors of your project?
- How widespread are IoT solutions in medicine so far?
- Do you think that IoT innovations will be successful in the long-run or remain a niche product?
- Are you of the opinion that IoT innovations are most successful when they are pushed by physicians?
- What needs to be changed in order to trigger this change?
- In your opinion, what is the most promising trend regarding digitalization and healthcare in Germany?
- Do you think of IoT and remote monitoring of patients with chronic conditions as a win-win situation for the whole healthcare system?

Appendix 4: Interview I: Company

Which are your most promising target groups?

In our area we cluster products into those which promise a high medical benefit and those for patients with tremendous pain who have a high necessity for such products. These are the two major target groups that, of course, also need to fit into the reimbursement. If we have a product but no payer in the healthcare system we need to find a client base which is willing to bear the costs. This client base are usually groups with a high level of suffering or those that are very solvent.

Which groups are characterized by a high level of suffering?

They are usually persons with a chronic disease that causes high pain, reduces their quality of life, and potentially disturbs their patterns of sleep. Overall, it’s a group of persons that is restricted and not able to take an active part in everyday life. Another very important group are relatives, especially parents of children. In this case the level of suffering of the whole family is very high which triggers a high willingness to pay and a higher probability of reimbursement within the healthcare system.

Do primarily parents bear the costs are do you see a higher willingness of the sickness funds to incur the costs in this case?

The essential question in this context is how high the medical benefit is and how well it is proven. If the medical benefit of a treatment is proven sickness funds are required to incur the costs.

Which products and solutions that are designed to address the needs of chronically sick people do you already offer?

We have a breath analysis device that aims at measuring the inflammation values of allergic asthma patients. Thereby, it strives to offer the patient support for an improved calibration of medication and provides the opportunity for the doctor to determine how well the current therapy works and whether it needs to be adjusted to the patient´s needs.

Is the breath analysis device connected to the doctor via IoT?

Currently we offer two different devices. One is for the physician who carries out the measurement in the practice without the possibility for the patient to take it home. The second one we will launch soon is a home measuring device for the patient. The patient will have this device at home and will be able to use it regularly. This device offers the patient the opportunity to bring a print of the measurements to the responsible doctor. The doctor will then be able to see how the inflammatory markers have changed over time, how medication was taken etc.. We have also included the option to send the collected data to the physician by e-mail. However, we got the feedback from the pulmonologists with which we developed that device that they would not want to read out devices (connected by IoT) in their practice as it is comes along with a big effort. For them it is essential to treat patients quickly and everything that is time-consuming is counterproductive for them. Another statement was that doctors do not have the time to monitor patients remotely during their daily routine and most are not willing to do so during the evening hours.

Do you have products that entail a specific IoT component?

We have a back end that collects mostly data from users, the user behavior and technical data but we do not use it to actively control the user. We have an IoT strategy. We are trying to connect every device with an application that sends data back to us but as said before this data is not used to actively control the users but to further improve our products.

What do your experiences with the products already on the market look like? What were the main obstacles and where do you perceive opportunities?

The topic of networks and interconnectedness is a major problem. The software used by physicians in their practices are very different and integrating devices in order to guarantee an automatic data flow is quite difficult which often requires a technician for the installation. Additionally, as most software producers use different connectivities they need to be configured individually which is very cumbersome.

How are the user reports of your products?

They are good. We are currently developing reports for the usage of our application. Nowadays, smart solutions on a smartphone have a chance as the generation 60+ has more and more phone users that know how to use smartphones. Important for this group is to offer simple solutions such as specific codes that only need to be scanned or an automatic connection. Other relevant points that ensure that no patients are lost are to keep the error potential as low as possible and provide convenient solutions.

What are the success factors for a company in that environment?

A product needs to deliver an added value. It should not be another app just for the sake of an app. Products need to be easy to integrate, in the best case in one system that manages all data flows so that not several different systems that require a different handling coexist simultaneously. Apart from added value products should provide a certain fun factor without focusing too much on technology and illness.

Do you consider the fact that your products are part of a prestigious German company to be an advantage?

Absolutely! People trust in our capability to deliver excellent technology and do not need to be afraid of the usage of their data. Our company has some roots in the medical area in which patients as well as physicians made positive experiences. Our business area still benefits from these past experiences.

Does your product portfolio focus mostly on doctors or on patients?

At the moment, we only address doctors but in the future we will have products for patients as well. The current difficulty is that due to the costly production our product for patients is high priced which means that only a small patient group with a high necessity is able to afford it. Unlike a fitness tracker we are in a range of a smartphone which implies that patients need to have a certain level of physical stress to buy it.

Have you perceived a change in the hype surrounding IoT within the last ten years?

It has been increasing. It already was a hype ten years ago but on a different level. Back then we started in the area of telemedicine and assumed that everything would be in the market within the next five years. The hype particularly increased from a technical point of view as nowadays it is demanded to connect every single device. Today we have more possibilities but it is still a hype just with a different name. In the past it was called connectivity, now it is IoT. We will see how it is called in five years.

In your opinion, what was the reason why IoT was not as far as you expected it to be after five years?

Many isolated technical solutions as well as the lacking pull of the users, the physicians. A lot of projects and small pilots were started but nothing significant. Also, the infrastructure was not as far developed as needed. After ten years I realize a change in the sense that doctors are pushing more and more their own solutions and that the topic of data transfer becomes more relevant. Nevertheless, fax machines and telephones are still considered to be very important communication tools. But now we have reached a point at which we can ask ourselves whether we are over the worst. I see a lot of progress in the exchange of data between responsible associations and practices. Some professional federations try to get back data from their physicians in order to be able to set up a real supply. We need to exceed the point that ensures that necessary structures and data highways exist, so that we can work with the available data. The difficulty still is the interface of physicians and the data that is sent and received by patients due to data security. In my opinion this needs to be resolved properly. Also Vivy is a central topic for me. As soon as this is implemented appropriately we have a data base for every single patient for which only the patient has access and decides what to share with whom. This is an essential step to promote telemedicine and IoT solutions. We must not offer our own solutions but have to build something where all data flows to and can be read out. In my opinion we can observe the contrary direction in smart home appliances. Most of them are isolated solutions of which some might be better than others on the market but not integrable with other solutions. In the long-run they will not survive.

Do you know of initiatives that go away from isolated solutions and focus on more compatibility?
Some tenders require comparability and in the case of doctors pushing their own solutions they focus on solutions that enables participants with different software solutions to participate. Another example is the electronic health record for which all data needs to be of the same standard. However, across national borders we observe significant differences. It is an area where we still have a bit of way to go.

What were the reasons why doctors resisted IoT solutions?
That was mostly due to doctors who did not want to be controlled as well as their perceived image of the inviolability of the medical profession. This also undergoes a change at the moment. Doctors increasingly prefer to work in co-operations, task sharing is more and more emphasized, interdisciplinary work gains more relevance, and doctors are more willing to integrate their patients and the data they collect on their own. I think doctors start preferring to have lots of measurement points collected by patients although they are of lower quality than fewer top quality measurement points gathered in a doctor´s practice as they better indicate the

course of a disease. This trend is also reflected in regular surveys conducted by the German Medical Assembly. They show that such projects are given an increasing chance by doctors.

If I understood you correctly, the potential of IoT and remote monitoring largely remained unused so far. How do you assess this potential in five to ten years?
I do not want to give any exact figures but the potential is huge. Especially the unused potential. The difficulty is the financing which is not very well implemented yet. It needs to be clearly specified that physicians get a remuneration for patients they look after remotely. Formally it is already included in the statutory healthcare system, however, in reality it is barley used as it is linked with high barriers and prerequisites. Furthermore, it is limited to very few applications which basically makes it unusable. In order to change this, the legislator needs to generate stimuli and drive change.

In your opinion, what is the most promising trend regarding digitalization and healthcare in Germany?
On the one hand a central data base that collects all data of patients including the data gathered with the help of home measuring devices in combination with tools that look for abnormalities and inform a patient if necessary. The second approach, the usage of AI, goes into a similar direction and especially sickness funds are actively involved in it at the moment. Health insurance companies have a lot of data of their clients. With the help of AI they are looking for abnormalities. As soon as they realize that a specific medical history causes a higher probability of for instance hospitalization etc., sickness funds plan to offer affected persons individually tailored solutions. If applied correctly, this combination can achieve a great deal.

Do you think of IoT and remote monitoring of patients with chronic conditions as a win-win situation for the whole healthcare system?
Yes, it's a win-win situation for the whole system. As soon as we have the possibility of early detection it benefits the patient and the total population. The potential to prevent a disease, a chronic disease, or any other event is great. It will enable us to live in better health and cause less costs. Actually, there is no other option to that. The healthcare system gets more expensive from year to year and we have an increasing number of possibilities that do not get cheaper. We live longer but not in better health but often with an increasing disease burden. If we then have the opportunity to live more years in better health this is very good.

Appendix 5: Interview II: Company

What is your opinion of IoT in healthcare?

I am critically opposed to the use of IoT in healthcare. There are many studies in this direction and if it is done correctly it can be of use but we have to look carefully at it.

Why are you critically opposed to IoT in healthcare?

There are many solutions in the market but the psychological stress of patients needs to be very high in order for them to take something out of these solutions. We have thousands of diabetes apps nobody uses. On the other side we have examples such as Medtronic which integrated an interface for pacemakers and defibrillators in order to allow physicians to evaluate gathered data. Practicing physicians are barely interested in these solutions as they do not want to be liable for it. Remote monitoring is not accepted by most doctors as no business model exists for it and even if a new solution of remote monitoring was launched doctors would be unwilling to accept it as they have already enough work. For patients their psychological stress needs to be very high in order to engage daily or on a permanent base with one´s health. The situation is different for patients who have vital monitoring and are released from hospital but in this case the number of patients is not as high anymore. These are larger integrated solutions and not necessarily IoT solutions. Another segments deals more with quantified health such as fitness trackers that mostly covers the consumer healthcare market but not the medical healthcare market. The boundaries between both markets are sometimes crossed but not to a great extent.

What are the preconditions that ensure that an IoT solution creates real value?

The business case, the medical unmet need, needs to be well thought through in order for it to work. Technology is less of a problem.

Do you see future technological development potential?

I do see development potential provided that the interconnectedness will be improved. I participated in an IoT training two weeks ago in which the relay of smartphones was much discussed. For me, this is an interim solution. Right now a user still has to do many things like installing an app to connect different items. In my point of view it will become successfully as soon as data is collected automatically and all data security concerns are solved. Google or Apple monitor our motion profile the whole day without us having a real problem with it. As soon as someone would like to collected health related data though no one is willing to give away their data. Actually, Google and Apple can already analyze how we move and which activity profile we have. Exactly this is one of the best long-term predictors for health and even one of the best predictors for mortality.

In the future, do you see Google and Apple as the companies to provide this data or would you prefer another service provider for such data?

It should definitely be another service provider than Google or Apple. It is an issue but so far none of the both companies does very well in the healthcare market. It is more about how technology would need to look like. For me, technology needs to be more in the background and that´s the development potential for IoT I see.

Is your company thinking or already working in this direction? Which are the most promising players in the market taking into account this topic?

We are only marginal players in that field as we touch on existing infrastructure. In terms of the infrastructure we use we are for sure not the driver of innovation as we originated from the consumer area. The effort to design products in an unobtrusive way is too high also taking into account that we do not have the necessary quantity for it.

In your opinion, what are the success factors for a company in this business area?

Market knowledge and B2B customer understanding. The absolute key factor is the understanding of the end user´s business model, the medical use, and how their reimbursement works. In our case the business model of doctors, the hospitals or the laboratories. For patients I need to understand the patient´s problems and the difficulties these clients are exposed to as well as for which patient groups my product would be relevant. In both cases a well understanding of medicine and the business models of the service providers is essential. A successful model finds the right solutions for a business model and a problem statement. Whether a product is nicely designed or not is secondary. As long as the doctor and the patient benefit from it everything else is secondary.

Is there a reason why your company has focused on products for service providers so far?

Yes. Medical innovations do always break through research findings and spread through specialists to general practitioners. In general, it takes 20-25 years for a finding to get to a specialist and up to another five years to reach general practitioners provided that the finding is suitable for them. Examples for this are blood glucose meters or oxygen saturation. As soon as these values are accepted by physicians they can be established at patients. But you cannot let

the patient become more knowledgeable than the doctor. The reason for this is that the physician is responsible for the diagnosis and the therapy of an patient and will remain responsible for it. Therefore, the doctors needs to be convinced first.
In terms of business model it is much easier to enter a market as a me-too vendor of a product that already exists. It is basically a displacement market in which we try to replace an existing competitor by expanding the areas of applications. In a second step we launch the product for the patient as ultimately the doctor has to prescribe it or explain the usage of it. The responsibility of the treatment remains with the doctor and cannot be taken by the producer.

In your opinion, are physicians responsible to promote an increased use of solutions that entail IoT components?
It depends. In the consumer healthcare market the driver was the consumer market itself. Similar to fitness tracker that went up and down again we will see more applications that come through the consumer market. When it comes to relevant medical applications it will always be the physicians to promote it.

What are the main obstacles you are confronted with when launching your products?
So far, we have difficulties stabilizing the technology. This is mostly due to us being a very young company and as we are operating in a very ambitious measurement range. Another obstacle is the acceptance of the medical profession and the overall medical care system. Acceptance and empirical evidence are the two barriers as they take a very long time.

Do you know why there is a lack of acceptance?
It´s because sales in medicine works the way it works, namely based on studies. If we want to sell something we have to conduct a study which shows the medical use of our product. As soon as the medical use of a product is shown the next step is to show the economic use of the product which eventually guarantees the reimbursement. This does not only cost lot of money but takes a very long time to establish.

How long does this take on average?
We have evidences for our product since 1993 but the reimbursement in Germany started around 2005 limited for privately insured patients. The broad medical acceptance has been increasing over the last five years. Some products, especially in the operative area, do not take that much time but classical diagnostic procedures take longer. The 20 years are due to the high

number of studies that need to be conducted and which need to be financed. After this, approximately 15 years are left until patent protection expires. These years need to be sufficient to bring a return and cover the expenses that occurred for the development.

Have you perceived a change in the hype surrounding IoT within the last ten years?
Yes. In many areas we have not been able to develop more than funny gadgets. There is nothing we really need. Nowadays, we have more critical voices after an initial period of euphoria. On the other hand some really interesting solutions are developed from very different areas. Most of them are for the consumer healthcare market but not for the medical healthcare market. I have the impression that currently the trend is the development of really useful solutions.

Do you think the potential IoT has in the healthcare sector is larger in the consumer healthcare market than in the medical healthcare market?
Yes! IoT needs to be differentiated. Maintenance or software updates that happen with IoT is remote maintenance which exists in other industries for already 30 years. For IoT that creates value for its users the consumer healthcare market is more promising in my eyes.

How do you quantitively assess the potential of IoT in healthcare in five to ten years?
I have not been looking at business figures recently. That´s why I cannot say anything about it.

In your opinion, what is the most promising trend regarding digitalization and healthcare in Germany?
The dominating trend will be the over aging of the medical profession. That’s the trend that will change everything within the next ten years. Within the next five years approximately one third of all general practitioners will retire. On top of that politics is basically working against general practitioners by promoting the dominance of hospitals. This causes the medical care centers which were propagated ten years ago to proliferate and will change the supply structure significantly. This in turn means that the ban on remote treatment will be revoked and that supply across the country will not exist anymore but will be concentrated in regional centers. It´s a political not a technical trend.

Appendix 6: Interview III: Statutory Health Insurance Company

How do you assess the current situation of IoT and remote monitoring in Germany?

IoT is based on a variety of technologies that can be employed for different purposes in the overall care setting. Currently a lot of projects with IoT are undertaken in Germany. Specific in the area of chronically ill patients I do not know a specific case. This is also due to the strong regulations of telemedicine in Germany. The professional legalization, meaning that physicians are allowed to engage in telemedicine, was in may 2018. For that reason Germany lags behind compared to other countries.

Does the current state of technology of IoT and remote monitoring of patients with chronic condition create added value?

The added value of remote monitoring, IoT and all technologies that belong to it covers several areas. On one hand, it causes relief to patients as they are no longer forced to be on site. Especially for elderly and chronically ill patients this takes less of their time and increases their convenience. Remote monitoring enables physicians to concentrate their efforts on more acute and severe illnesses in their practice and allows them to guarantee a better care quality. At the moment, particularly follow-up treatments and the screening of certain values, for example of diabetics, can be done very well remotely. Especially for statutory health insurance companies this provides an opportunity to significantly improve care quality. Remote monitoring also enables more frequent regular appointments that will be made. Therefore, we try to foster these products more and more. Cost savings for sickness funds heavily depend on the agreed contracts with the different service providers. Generally speaking, services provided through remote monitoring tend to be cheaper than the physical patient visits in a doctor´s practice.

How is the acceptance of the digital products you have already launched in the market?

The different solutions have a very varying number of users. Some have a very high number of users, whereas other products have only a couple of hundred users. As we mostly target a very young population group that is relatively small compared to the total population these products represent an investment for the future. We perceive our digital solutions as cases of success that required a very high initial investment with lots of resources to make it to the standard care.

Who uses your digital products?

The number of users and the acceptance rate of our solutions show two peaks. The first peak is in the age group of 20-30 years old users. After that age group, the curve flattens. The second peak can be observed in the age group of 50-60 years old users. We do not have specific data available but we assume that the first peak represents digital natives. The second peak are chronically ill people who are increasingly dependent on digital solutions due to their high burden of suffering as these solutions improve their care quality.

What are currently the main obstacles in the implementation of digital solutions?

The first major obstacle is data security in Germany as well as in the EU. Data security is a legitimate concern and important to address, however, it complicates and prevents a quick implementation of digital solutions. Statutory health insurance companies have to design their process cycles according to certain legislation. The compliance with laws on data protection makes these processes very time-consuming. Often, this causes co-operations with start-ups that provide new digital solutions to fail as most start-ups do not have the needed human resources.

Secondly, the social security framework which is defined in the Code of Social Law V contains a lot of clauses such as paragraph 63 or paragraph 140 that significantly limit the scope in which statutory health insurance companies can develop their products for the German healthcare market. This requires a great degree of creativity from the sickness funds to develop suitable products within this limitations. The current government contributes to a positive development by reducing the strict regulations to a certain degree.

As soon as the first two major obstacles are overcome the sickness funds are faced with a third challenge, launching the developed products in the standard care. Although the added value of a developed digital product might have been proven by some studies most solutions first have to be tested at small scale with a limited number of test persons and over a multiple year period. The resulting lack in scalability restricts the possibilities of start-ups to a great extent as they are usually based on a different business model. Consequently, some start-ups move to foreign healthcare markets that promise an easier and broader market access such as the US or the Chinese market.

What is the role of statutory health insurance companies in terms of promoting IoT or digitalization in general in the German healthcare system?

The health insurance company I am working for recognizes the necessity of digitalizing the German healthcare system. Therefore, we constantly try to set new standards for the existing innovation limits. In order to do so, we act as an advisor in health politics with the goal to open the system for digitalization. One success that has been made is reflected by the 'E-Health-

Law' that among other things means to strengthen the competitive position of start-ups in the German healthcare system. Additionally, my employer provides a lot of money and resources to drive digitalization forward.

In your opinion, how do other statutory health insurance companies deal with the topic IoT and digitalization?

Altogether, the positioning of the single sickness fund determines how it deals with digitalization. Health insurance companies that primarily target young people increasingly try to promote digitalization and adapt their digital product portfolio accordingly. This is why in that case digital solutions are more designed to address prevention whereas sickness funds whose insured persons have a higher average age are more cautious with their offered digital products. This age group is less susceptible to digital solutions compared to younger persons who are often classified as digital natives.

Which are your preferred companies that your partner with for the development of digital solutions?

It all comes down to the mixture. On the one hand we cooperate with start-ups that operate industry-independent and have an open perspective when solving problems. For this purpose we created a special program that seeks to better prepare start-ups for the German healthcare market. On the other hand we also have partnerships with large established companies such as IBM which was highly involved in the development of the electronic health record.

Do you pursue a digital strategy or do you develop new digital solutions without a specific concept?

Initially, the focus was on developing something digital. In the meantime we follow a clear digital strategy we developed approximately 2.5 years ago which aims at transferring all solutions to a digital ecosystem in which they can work together interdependently. Additionally, we want to develop solutions that are compatible with the external ecosystem of the German healthcare system with all its players. An isolated solution would not create any value but value creation is essential in this context. The first solution that offers compatibility with the whole German healthcare system is the electronic health record which is going to be introduced in 2021 according to the ministry of health. The electronic health record will be provided to each insured person by the respective sickness fund and will, for the first time, connect all players of the healthcare system.

What is the primary motivation of statutory health insurance companies to engage in digitalization?

Primarily, the care quality of insured persons should be improved in a sustainable way. This is often accompanied by efficiency gains. One example illustrating this is the electronic certificate of incapacity to work for which sick employees consult their physician via an online video after which the doctor sends the certificate per app to the employee. The advantage for the patient is that he does not need to go to the doctor and is not exposed to any additional risk of infection whereas the physician does not need to render a performance in the traditional way.

Secondarily, the we are characterized by an internal motivation to promote digitalization and exposed to an external competitive pressure caused by other players such as international tech companies. If existing sickness funds do not exploit the potential of digitalization other players which do not belong to the German healthcare system will take the opportunity in the medium to long-term. Especially digital savvy people are aware of this risk and prefer to actively shape digitalization than being dominated by large tech corporations.

How do you evaluate the growth potential of digital solutions?

The growth potential of digital solutions highly depends on digital natives and their interest in such solutions. They have to increasingly put pressure on the different stakeholder of the system such as politicians. In my point of view we have currently reached this stage. At the moment there is a sense of discovery in all industries but the healthcare industry which highly advance with respect to new technologies. The healthcare system tries to catch up but is unable to do so because of its highly regulated environment. Nowadays, the awareness of the importance and the high potential of digitalization exists and is increasingly tried to be stimulated.

In your opinion, what is the most promising trend regarding digitalization and healthcare in Germany?

The logical next step in the German healthcare system will be to further open up remote treatment and telemonitoring so that for example virtual consultation hours cannot only be done for follow-up treatments but for the initial contact between a doctor a patient as well. Other important topics are the promotion of AI or blockchain which is supposed to enable the realization of the electronic certificate of incapacity to work. Of interest are also the opportunities VR provides within the treatment of anxiety disorders. Overall, there is a high growth potential which is not limited to one single technology though.

Do you think of IoT and remote monitoring of patients with chronic conditions as a win-win situation for the whole healthcare system?

From a macrosocial perspective all stakeholders benefit and the healthcare system can be designed more efficiently at the same time. However, all players benefit in a different way. Some digital solutions are of great interest for some players whereas others are less interested in the same solution. This results in very varying incentives and motivations of different care providers to deploy new technologies. First of all you have to figure out which direct financial consequences a potential digital solution has for the different stakeholders and which one is affected by it to the highest degree and in the most positive way. Subsequently, you have to get in touch with this stakeholder. Overall, realizing innovations in the German healthcare system takes a very long time which is particularly due to the different interest groups with their own motives and interests arising from the prevailing self-governing structures.

Appendix 7: Interview IV: Prof. Dr. Dr. Kurt J.G. Schmailzl

Can you shortly describe what your project digilog is about?

It´s a project that aims at bringing medical technology to patients. It's a reaction to some regions in Germany, Europe and the rest of the world that are increasingly characterized by a precarious healthcare provision. Small hospitals have to shut down, doctor´s offices located in rural areas don´t find successors, public transportation is not sufficiently developed. Digilog was started in response to these challenges and tries, in collaboration with local players, to develop and test digital companions that do exactly that: bring medical technology to patients.

Are you still in the test phase or have you already tested it on patients?

We have tested it on patients already which means that it´s over the test phase. We have tested the digital companions in different scenarios. The one that experienced the most extensive testing was the ECG patch which we tested on 500 patients approximately one month ago.

What have been the main obstacles you were confronted with so far?

Except for technological barriers that needed to be overcome we were mostly faced with regulatory issues, i.e. how to make data transfer and data storage as safe as possible, how to draft information and the declaration of consent to avoid any possible legal issues. Such legal affairs. Of course, this was not our core business. We had to ask for help and support concerning these topics. It was a bumpy path but we eventually made it. After all, the whole project requires an IT infrastructure. The procurement is so to say the easiest part. It needs to be maintained, updated, and sometimes it doesn´t work. In other words, we also needed expert advice from these areas which causes the project to be a multidisciplinary one in order to work well. It is not enough for us doctors to say we would like to do a bit of digital medicine, but it is multidisciplinary. Digilog entails 37 consortium partners. You can easily imagine that this was a challenge on its own. On the other side, this was very helpful as we received input from many different disciplines. Therefore, it´s not a project that tries to solve one isolated problem in an unidimensional way but it´s about the testing of a vision of an overall concept concerning digital healthcare provision that goes beyond everything else that exists so far.

Previously, you were talking about technological difficulties. Can you give me some details about the difficulties you were confronted with?

There is a blood pressure sensor that looks like a hearing aid. It works with three color LEDs within the ear. The technological challenge was the energy consumption. As you might imagine, three color LEDs need lots of electricity which prevents the usage of the blood pressure sensors for 24 hours or even longer. These are all solvable problems in times of Tesla, but for a garage company like us this represents a problem that needs to be resolved first. The data gathered by the sensors is then transmitted mostly via Bluetooth. This Bluetooth module also requires space and needs to be integrated in the sensor. The Bluetooth connection is linked to a smartphone where the problems start I´ve been talking about before, the security of the data transfer. No one is willing to send sensible health-related data to servers located in the USA. That is a no-go in Western Europe. Partially we were collaborating with Microsoft Germany and they used servers located in Germany for their Azure Cloud solution.

Which possibilities do you see with digilog at the moment and if you take into account potential technological development that could take place within the next five to ten years?
Digilog developed itself to a brand within the last two years. Currently we´re working on follow-up projects such as an apprenticeship program that is mostly addressing nurses so that they get taught media and digital competence within nine months. Competences they don´t get transmitted during their traditional apprenticeship but which they will need in the future. The most important task now is the sociopolitical impact of digilog. Among others I am responsible for the conceptualization of the digital medical healthcare in Lusatia. The coal production in Brandenburg was stopped by the government. As coal production was the major industry in that region for centuries there is a major threat of a structural change and high unemployment rates. The idea is that by means of major investments in health technology and digital medicine alternatives for the breaking off of this industry can be found. This is one part of the story. On the other side Lusatia is one of the regions that is characterized by small hospitals that struggle to survive and has increasingly less and isolated medical practices in the periphery. Digilog is one way to deal with these problems. One of the things we´re currently developing is called eSTORCH. It´s about the monitoring of high-risk pregnancies with digital companions. This includes laboratories in the living room, cardiotocography (fetal heart sounds and uterine contractions) that are transferred remotely to the eHealth Center. Another project that is developed right now tries to use VR, an immersive technology that takes users in another world, as a therapy option for anorexia. Affected persons are mostly girls who are very closed off and who don´t have a reasonable communication with their parents or a peer group. It is highly connected with their self-image, how do I see me and where do I see me in three years. Typical psychiatric offers such as talking therapies have a waiting period of twelve months. That´s where we think that digilog can become interesting. One week ago I had the opportunity to

present digilog at the Hannover Messe trade show at a booth of the Federal Ministry of Economics where it became clear where the journey is going. It's about a changed healthcare provision that is based on new digital tools and technologies. In addition, it is possible to make this economically interesting, too.

How is digilog accepted by patients?

As we had asked this questions more often we tendered a bachelor thesis and a subproject covering this topic. Shortly summarized, the result is that for example a grandmother who has nothing to do with digital things and maybe even perceives them as devil´s work is willing to participate if her doctor benefits from it. That´s the lowest common denominator. Even if the same grandmother doesn´t understand the use of digital medicine and is suspicious of it she will participate as her doctor acts as a person of trust. Such persons of trust are very important in this context.

Have you gained experience whether the used sensors are considered as disturbing?

One of your convictions is that sensor technology has to be as user-friendly as possible so that users doesn´t feel it anymore after a short period. We are not interested in any equipment that requires a user manual or even a bag to carry it around. I´ve already mentioned the blood pressure sensor which looks like a hearing aid. At a first glance it can be easily overlooked. The ECG patch, as another example, is about 5x5 cm large and a couple of millimeters thick. It is simply fixed below the collarbone without having additional cables, strings, adhesive electrodes, recorders, or similar things. As the name says it´s a tape that is fixed on the patient´s skin where it stays for a week. The users can even take a shower. Of course, I also tried it, and indeed, after a short time I didn´t realized that I was wearing a tape. I think it is very important that the used sensor technology, the digital companions, do not interfere with the user´s daily life. TIf it is perceived as disturbing acceptance for these solutions will never be achieved.

According to you, which are the most important factors that made digilog successful?

That what I just said belongs to it. Things need to be easy to use and handle. The second factor is a global approach. It is not a single parameter but the variety of parameters that come together in the eHealth Center, whether it is about an ECG, blood pressure, laboratory value, ultrasound images or a smartphone picture out of which an application builds a blood count that shows the number of red blood cells. These are all components that might not be needed all together for one single patient but which, in its entirety, represent a portable hospital.

How widespread are medical IoT innovations in Germany so far?

They are still in their initial phase. Some colleagues are fascinated by this topic, are engaged in it and try to push it but all in all it´s still in its infancy. I estimate that over 90% of German hospitals are still working with paper-based records. The last example I was told was Dubai where a complete paperless hospital was built from the ground up. Such digitalization of health related data is a requirement for IoT and other new technologies. Something that is still emphasized too much is medical call centers which administrate an electronic health record and call patients. That´s where paramedics with headsets are seated in front of monitors. Actually, this is the last century. When it comes to digital medicine, diagnosis supporting or treatment processes, doctor supporting algorithms, we are at the very beginning.

What are the reasons that make digital medicine to be at the very beginning in Germany?

We have a common mistrust and a lacking willingness to invest money in it. That´s different in countries such as Denmark, Austria, or Estonia. They have a different culture regarding both factors. A couple of months ago I went to a big hospital in Aarhus, Denmark. Ten to 15 years ago the government decided to shut down almost half of the Danish hospitals. Instead they extended certain hospitals to 'super-hospitals' which are fully digitalized. I think they told me that the hospital in Aarhus costed 1.6 billion euros. Imagine this sum: this would start a discussion in Germany for many years.

Do you think that IoT innovations will be successful in the long-run or is it more likely that they remain a niche product?

It will definitely be a success. For sure, there will be some things where the wheat needs to be separated from the chaff. There is also a lot of profiteering happening. But I am convinced that it will change the whole medicine. Digitalization in conjunction with another medical driver, genetics, will revolutionize medicine and medical care.

What needs to be changed in order to trigger this change?

Physicians need to be convinced and we must take them their fear of an emerging system that competes with their remuneration. Doctors need to be on board. That is something we achieved with digilog in our catchment area. Our strategy was to go over general practitioner´s practices. The ECG tape is issued to the patients by these practices. While they would otherwise have been sent to cardiologists with months of waiting they message digilog and get the ECG tape sent within 48 hours. As soon as the ECG tape is returned after one week, they get the findings within another 48 hours. That´s an advantage general practitioners recognize. This is also, why they themselves contacted statutory health insurance companies to require the preservation of this technology after the expiration of digilog. To convince all these players and take them on board is one important precondition for IoT innovations to be quickly successful.

Appendix 8: Overview over Obstacles and how to Overcome them

Obstacle	Examples	How to overcome
Technological	• Energy consumption of blood pressure sensors: in general problems are solvable but they might be a major difficulty for small companies	→ Internal problem which can be solved by involving experts → Possibly technological progress
Technological/ Regulatory	• Compatibility of solutions to external systems, e.g. electronic health record → ensure that the development of one single system is possible for value creation	→ Legislator → If necessary: technological progress
	• Ensure availability of necessary structures and data highways for a potential future system that covers the whole country	→ Legislator → If necessary: technological progress
Regulatory	• Data security during the data transfer and the data storage, especially GDPR	→ Not very likely to change in the near future; difficulties arising due to this can be overcome as can be seen in existing digital solutions → Legislator
	• Social Security Framework	→ Legislator
	• Remuneration for digital/IoT services: those remunerations that exist have high barriers and prerequisites and are limited to a very low number of applications	→ Legislator
Cultural	• Common mistrust of digital solutions	→ Cultural change
	• Lacking willingness to invest in digital solutions	→ Cultural change → Legislator

	• Medical profession: Fear liability Fear digital competition, missing remuneration due to lacking business models Fear losing control Inviolability of medical profession Have already enough work and digital solutions would increase their effort Lacking push of doctors which would be needed as innovation in medicine comes through doctors	→ Cultural change → Legislator (e.g. liability, remuneration and lacking business models)
	• Evidence and acceptance of innovations in medicine take their time	→ If at all with a cultural change
Self-Governing Structures	• The prevailing self-governing structures in the German healthcare system cause different motivations and incentives of the different involved for each single innovations	→ Legislator
Multidisciplinary Approach	• For the successful project digilog 37 consortium partners with different backgrounds were needed; a multidisciplinary approach seems to be needed at least at the beginning of more complex IoT solutions	→ This approach seems to be inevitable at least for more complex solutions → Valuable experiences of past projects could be shared with new ones

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