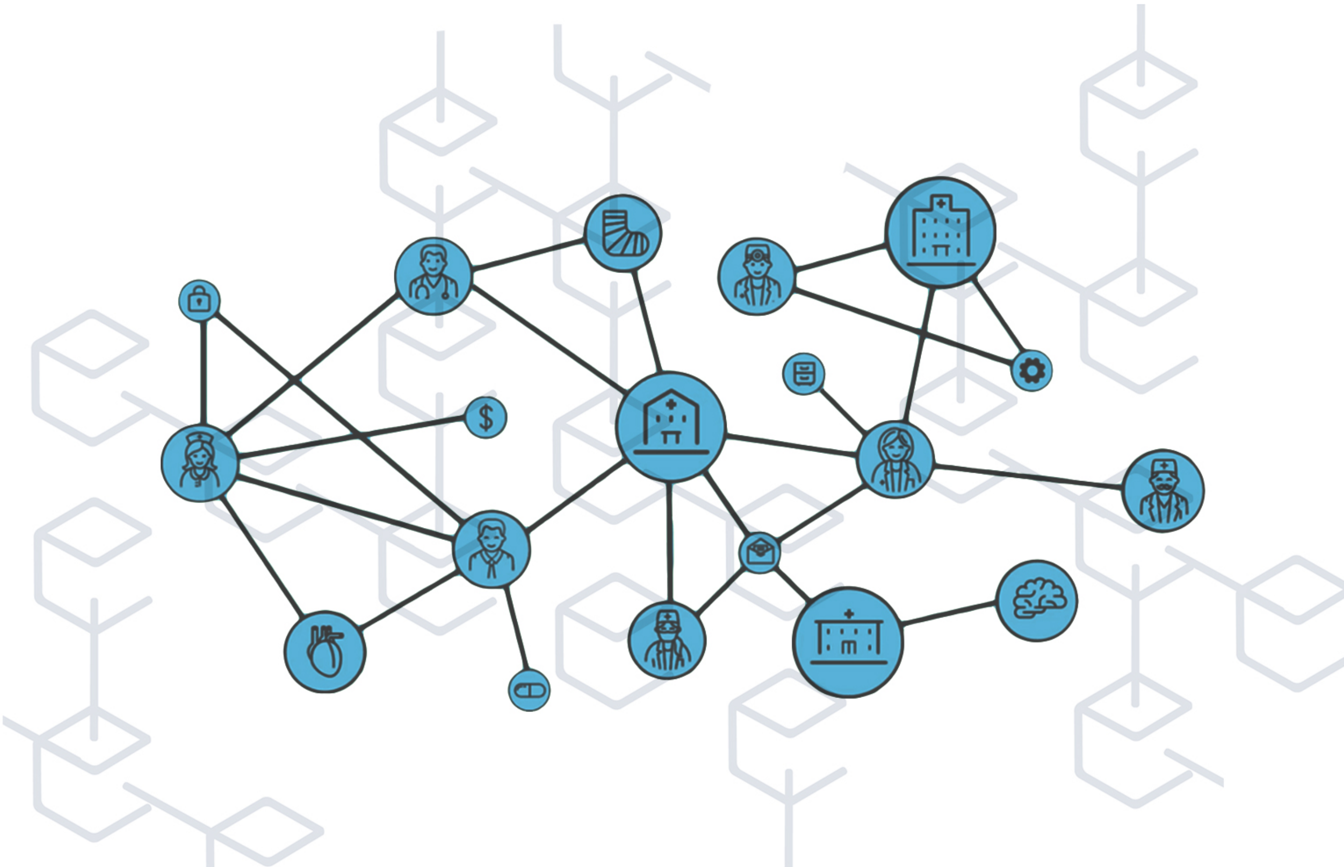
Master's Thesis Internship – master Sustainable Business and Innovation



Navigating between possibility and reality:
An assessment of blockchain's potential for the Dutch healthcare sector

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Cardiologie Centra Nederland
Onze zorg klopt!

"If there is a sense of reality, there must also be a sense of possibility" – Robert Musil

Abstract

Blockchain technology promises to revolutionise how different entities transact and interact and is regarded as the most promising innovation since the advent of the Internet. Discussions about blockchain's relevance have largely concentrated on financial applications, such a Bitcoin. This thesis examines blockchain's potential for the Dutch healthcare sector. Using a constructive technology assessment combined with a vision assessment, two guiding visions are identified that show blockchain's potential to make the healthcare sector more efficient and more personalised. However, blockchain is accompanied by substantial hype which raises concerns because many technical, organisational and societal barriers have to fall before blockchain can fulfil its promises. Technology developers, project managers, consultants, patients, medical professionals, health insurers and policy makers reflected on the use of blockchain for the healthcare sector and identified of the following that might hinder the implementation of the guiding visions: Interoperability, conservative culture, hype, incumbent power, misconceptions by non-experts, privacy and security, disruption of power structures and relationships and lack of evidence. Blockchain is still in an early phase of development. However, as the healthcare industry is becoming more dedicated to solve interoperability issues, small blockchain experiments, which include users early on and built in privacy-be-design, may find sufficient support from healthcare stakeholders to become successful. Because blockchain is economically scalable, profitable experiments can grow into complex ecosystems over time, which could transform the healthcare sector into a more sustainable system.

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Executive summary

This thesis was written in collaboration with Cardiologie Centra Nederland (CCN). CCN is an organisation of independent treatment centres for cardiovascular diseases that distinguishes itself by aligning outpatient care with the needs of patients and the referrer. Currently they have a simple system for Electronic Patient Records (EHRs) in place, and aim to evolve this into a full-fledged EHR system, including a mobile app that allows communication between CCN's self-monitoring devices and cardiac patients at home. During the start of this research, CCN assumed that blockchain technology is a useful tool to support their developments. Hence, CCN was interested in examining blockchain and discover the factors and elements that might hinder its development and implementation.

In the first phase of the thesis, technology developers, project managers and consultants were consulted in fourteen semi-structured interviews to identify guiding visions for blockchain technology. The analysis identified two visions: blockchain may increase the efficiency in healthcare by reducing administrative pressures and transactions costs in the exchange of medical data (vision 1) and ma healthcare more personalised allowing users more control in their health system (vision 2). Envisioned blockchain applications use smart contracts to deliver value in complex transactions involving many parties, tracking and tracing items though complex supply chains, the exchange of personal health records (PHRs), and algorithm-driven decision-making the context of medical prevention.

Subsequently, four focus group were organised with patients using the results of the first data collection as input. Regarding PHRs, patients were positive about having all their medical records in one place and having more control over who has access to them. Patients' mains concerns were being able to give permission to other people, such as their partner, and the applications should be easy to use while ensuring security and privacy. Regarding algorithm decision-making, patients acknowledge its potential for prevention and better diagnoses, however, they are concerned with the ease of use of sensors and devices at home, lack of evidence for their benefits and less personal contact with healthcare providers. Moreover, the findings showed that patients have many misconceptions and wrong assumptions regarding digital health applications. Thus, *user engagement, misconceptions by the public* and *privacy and security* were identified as barriers.

Next, the visions of an ideal health system were collected from the perspective of healthcare stakeholders. Healthcare providers, health insurers, pharmacists and policy makers were consulted to determine the desirability of the articulated blockchain visions and identify barriers that might hinder their acceptance and implementation. Many respondents were interested in blockchain, as it can provide more control for patients and more efficient exchange of medical data, which could make healthcare more personalised and effective. Respondents also expressed concerns that led to identifying of the following barriers: *Interoperability, conservative culture, hype, incumbent power, misconceptions by non-experts, privacy and security, disruption of power structures and relationships and lack of evidence.*

What is unique about blockchain is that its hype cycle has generated interest in IT among the public (beyond engineers and developers). This interest creates momentum for blockchain applications to bring together various parties to collaborate and explore blockchain together. Blockchain has started a new conversation in which healthcare stakeholders are questioning their and

other's roles in healthcare. These conversations have resulted in pilot programs using blockchain. For example, Mijn Zorg Log is an initiative of het National Dutch Care Institute (Zorginstituut Nederland) and the first legally certified medical blockchain application. This pilot shows how blockchain can make the transactions in the Dutch maturity care more efficient and effective, or in their words: *"how blockchain could turn healthcare upside down"*.

Although the technology used to achieve the envisioned medical blockchain applications is available off-the-shelf, the achievement of these applications in practise might take years due to the identified barriers. Nevertheless, managers are advised to evaluate the possibilities of blockchain and invest in blockchain development because the adoption of blockchain applications (e.g., replacing traditional contract by smart contracts) may imply radical changes in the role of intermediaries, managers, firm structures and procedures.

The results indicate that open blockchains, such as the Bitcoin blockchain, are not suited for the Dutch healthcare sector because of legal conflicts with the General Data Protection Regulations (GDPR). Therefore, managers are recommended to discover the potential of closed blockchains, in which they have to set up a network of nodes themselves to run the blockchain. Manager can encourage participation in closed network with financial incentives or access to blockchain data in exchange for processing transactions.

Blockchain offers economic scalability, meaning initiatives can start small and scale up the business-prototype. Managers are recommended to test blockchain in small closed blockchain experiments, which involve users early on and take privacy-by-design as a starting point. Through such experiment managers can weigh out the benefits and costs of blockchain applications. In addition, managers are advised to take the scalability potential of blockchain into account when starting experiments.

In addition to experimentation, managers are recommended to consider the risks of blockchain in practice. Although blockchain might be a safe way to exchange medical data between two transacting parties, there is still no guarantee that the data are safe. For instance, healthcare providers can still take screenshots of patients' medical dossiers and share them. Employees need to be trained on how to work with these new applications and managers may educate employees on social responsible work practices.

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Acknowledgements

Everybody is talking about blockchain. Or at least was – things have been rather quiet since Bitcoin's value dropped immensely since January 2018. Did the bubble burse? Some people seem to know. I certainly do not. What I do know is that studying the 'chain of trust' has been an incredible journey that barely felt like work up until the very end. No thesis is written alone and I am sincerely grateful for the people who helped me along the way.

I want to express my gratitude to my supervisors from Utrecht University first. Annika, thank you for the helpful feedback and guidance that allowed me to structure my ideas and take the thesis to a higher level. You told me at several stages that I tried to do too much and in retrospect you were absolutely right. In the end, we were able to narrow it down and I am happy with the result. Marlous, thank you for introducing me to transdisciplinary research, helping me organise the focus groups and your fantastic fruit basked metaphors. The focus groups turned out the be the absolute highlight of my academic career.

This leads me to thank some people at Cardiologie Centra Nederland. Igor and Borut, thank you for the opportunity and support. Borut, you are incredibly passionate about the topic and before we knew it half hour past when I asked you question. For someone who did not know who Marc Andreessen was during our first talk, your expertise and background information on relevant topics were extremely valuable. It was great working with you as a supervisor.

Additionally, I am very grateful for the input of all the respondents and participants in the focus groups. Special thanks to Anna and Andrei who reflected numerous of times on my questions and findings and provided me context throughout this research period.

Lastly, I cannot finish this section without thanking my patents, Jan and Marianne. You always told me that the doctors coat would have suited me well. It turned out that apple did not fell that far from the three in the end. Due to your incredible medical network, I had the opportunity to speak to incredibly inspiring and passionate people in the Dutch healthcare sector. Jasper, lifelong friend, thanks you for creative input in the final touch of this thesis. Mark, thank you for your feedback as fellow Sustainable Business and Innovation student and (upcoming) blockchain expert.

Martijn Piek

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1. Introduction

In recent decades, commerce has relied on trust and verified identity. Simply put: What is exchanged, and who is approving it? At present, trades are mostly conducted online and need intermediaries, such as banks and governments, to verify the identity of each transacting party and create trust between them. However, whenever intermediaries are involved, inefficiencies naturally arise, which decrease the speed of transactions and increase their costs (Shyam, 2016). Third parties also affect privacy and security, as they store information on central databases, vulnerable to cyberattacks. A famous cartoon by Peter Stein in 1993 in *The New Yorker* sums up the trust issue essential in online transactions: *"On the Internet, nobody knows you're a dog"* (Shyam, 2016). Twenty-five years later, the confirmation of identity and establishment of trust, without the validation of a third-party, is still a limitation in online transactions.

However, a new technology has emerged that promises to solve this issue, called *'blockchain technology'* or *'distributed ledger technology'* (Antonopoulos, 2014). Blockchain enables a secure exchange of an object of value (e.g., a currency or asset) between two transacting parties without needing a trusted intermediary, such a bank of government. Often regarded as the chain of trust (Shyam, 2016) blockchain is a digital ledger that logs transactions between two parties permanently and in a verifiable and efficient way (Iansiti & Lakhani, 2017). The ledger is distributed because all participants store a copy and therefore have access to all the transactions that occurred in the network. All participants therefore share a single source of truth (Antonopoulos, 2014).

Blockchain has a unique technical and social component compared to conventional digital database technologies (Wolpert, 2018). Its technical component prevents the double-spending of a digital asset without a trusting intermediary: if a fact is recorded on the chain (e.g., single transfer of a transaction from A to B), the record cannot be denied later, as the chain itself shields that information from tampering. Blockchain's social component maintains a singular ledger with a shared set of business rules with nobody being able to manipulate them or control the system. This is social innovation since it changes the equation of power in a network: no participant can take over the network, which lowers the social obstacles to creating the network (Wolpert, 2018)

Blockchain makes it possible to envision a world in which transactions, contracts, and records are stored in transparent, shared databases where they are shielded from removal and alteration. In this world, every agreement, process, task and payment has a digital record and signature that can be identified, verified, stored and shared. Individuals, businesses, machines, and algorithms can freely transact and communicate with one another with little friction. These are some of the vast possibilities of blockchain that explain how it may revolutionise business and redefine organisations and economies (Iansiti & Lakhani, 2017).

At the moment, the only well-known application that uses blockchain in practise is Bitcoin (Nakamoto, 2008). However, applications are developed that are applying blockchain technology outside the financial world (Burniske, Vaughn, Shelton, & Cahana, 2016; Shyam, 2016). This thesis examines blockchain's potential for the Dutch healthcare system. The Dutch healthcare industry faces similar inefficiencies in transactions as the financial sector. On the clinical side, it is challenging for healthcare providers to share health data with patients and other care providers, because the data of a single patient may be scattered over several healthcare institutions (Dehzad, Hilhorst, de Bie, &

Claassen, 2014). This results in a fragmented healthcare system, where the personal data of a patient is held by many organisations and not by the patient. Similarly, transactional inefficiencies occur on the payment side of healthcare, because many administrative organisations are needed to provide accountability for the transactions (Dorn, 2015).

Blockchain's potential for the Dutch healthcare sector is currently explored in the *'Mijn Zorg Log'* pilot initiated by the National Dutch Care Institute (Zorginstituut Nederland). It is the first legally certified medical blockchain application in which maturity care hours are registered on a blockchain. The first results of this pilot indicate that blockchain can make the transactions between relevant stakeholders in the Dutch maturity care more efficient and effective, while allowing users more control in the process (Zorginstituut Nederland, 2018).

Besides opportunities, scientists (Rabah, 2017) and organisations (Tierion, 2016) raise concerns. In particular blockchain's hype cycle because many technical, organisational and social obstacles need to be overcome before blockchain can live up to its promises (Iansiti & Lakhani, 2017). These barriers need to be carefully assessed, as they might overshadow blockchain's intended benefits and prevent blockchain applications from ever taking hold.

A way to bypass the hype of technology is to involve relevant stakeholders in an early phase of technological development and consider the maturity of a technology's applications and their potential impacts (Rip & Kulve, 2008). This shifts the focus from unrealistic and undesirable technological paths to directions that better align with the culture, structure and wishes of those who are intended to use the applications. The healthcare sector consists of many stakeholders, who all need to see value in using digital innovations before they will be adopted (Dorn, 2015). To assess the potential of blockchain for the Dutch healthcare sector and the elements that may become barriers to its adoption, this thesis concentrates on the perspectives of various healthcare stakeholders on blockchain technology. This led to the following main research question:

What are the drivers and barriers to the implementation of blockchain technology in the healthcare sector, based on the perspectives of healthcare stakeholders?

This thesis identified several gaps in the literature. First, current literature on blockchain is often technical and empirical data on the social and organisational barriers is lacking (Kuo, Kim, & Ohno-Machado, 2017; Nichol & Brandt, 2016). This thesis identifies new barriers, provides more knowledge on the underlying causes of barriers for blockchain and adds empirical data to the existing literature on blockchain barriers. Furthermore, there is a lack of empirical case studies on the value of stakeholder's participation in the innovation process of emerging technologies (van Merkerk, 2007). Studying emerging technologies provides increased theoretical understanding, which will help advance the methods for analysing them (van Merkerk, 2007).

By means of a visions assessment (Grin et al., 2000), this thesis identifies visions of a broad range of stakeholders that consider the future of blockchain in an early phase of development. The visions of blockchain are used to identify opportunities for innovation and conflicting points of view (Grin et al., 2000), which may form barriers that hamper the development and implementation of medical blockchain applications. This thesis thereby contributes to the understanding of whether, and how, visions are helpful in taking into account multiple perspectives in innovation process of emerging technologies.

This thesis reflects on an empirical case thesis conducted in collaboration with Cardiologie Centra Nederland (CCN) and the cardiology department of the Academic Medical Centre of Amsterdam (AMC). Both parties assume that blockchain technology may enhance the transactional efficiency between different healthcare stakeholders. This thesis tests the first ideas of CCN and the AMC with other developers, potential users (e.g., cardiac patients, healthcare providers and pharmacists) and other relevant healthcare stakeholders (e.g., policy makers and health insurers) and identifies new visions of the use of blockchain in the healthcare sector. Hence, the societal relevance of this approach lies in helping developers incorporate ideas about future developments from various viewpoints and societal backgrounds (Rip, 2002).

Because innovations can be more easily steered in an early phase of development, the results of this thesis can be used to develop better applications that better connect to culture, structure and societal needs of those who are likely to be affected by the technology in practice and to increase their future adoption (Rogers-Hayden & Pidgeon, 2007; von Schomberg, 2012). In addition, a critical evaluation of the suggested blockchain visions before the adoption phase could allow managers to more realistically value a technology's eventual performance, thereby lessening the negative consequences of hype and reducing the risk of erroneous investment (Länsisalmi, Kivimäki, Aalto, & Ruoranen, 2006; Steinert & Leifer, 2010).

The rest of this paper is structured as follows: In the first section, the theoretical background for this thesis is described, explaining how expectations and promises influence a technology over its lifecycle and how these dynamics may be managed. Subsequently, the methodology is presented, explaining how the data were collected from the consulted respondents, including blockchain-experts and healthcare stakeholders. Next, a technical background is provided, describing the relevant foundations. Then, the results of the analysis are presented, which include the visions and barriers identified by the consulted respondents. Finally, these findings are discussed and concluding remarks are provided.

2. Theoretical background and literature review

The chapter discusses how technologies are shaped by social influences. First, the hype cycle is discussed which shows how a technology's lifecycle is influenced by human expectations (Section 2.1). Subsequently, section 2.2 discusses how technologies can be managed in order to stimulate the development of responsible applications, which better match with the practises of those who intend to use them. A way to develop responsible innovation is to construct visions and discuss with potential users to discover the positive and negative impacts of a technology in an early phase of development. Identifying the potential impacts of a technology allows researchers to proactively detects potential concerns and barriers that might hamper the innovation's development and implementation in later stages. Section 2.3 highlights the factors and elements that hinder innovation in the Dutch healthcare based on a literature review.

2.1 The hype cycle

Innovations may be studied as a collection of entities, including not only the product (or process or service) under development, but also how the product operates in its context with respect to the actors involved (Smits, 2002). Hence, if a technological application is to become commercially and publicly successful, it needs to be configured in a way that makes it fit in the context where it has a function. This makes technological developments complex, as many actors contribute to innovation processes, such as scientists, businesses, policy makers, and financial institutions. Innovation processes therefore consist of multi-actor dynamics (Geels, 2002).

Multi-actor dynamics are relevant, because they result in different expectations and promises, which shape the actions and interaction between actors in the innovation process (Borup, Brown, Konrad, & Lente, 2006). Different parties hold different expectations about what the new technology can and should look like, where it should be used and what societal needs it can fulfil. In an early stage of technological development, choices about research directions and investments are based on expected outcomes, as expectations are the main available source of information (Brown, 2003). However, also in later stages of technological development, the dynamics of expectations and promises influence the ongoing process of developing innovations and their eventual adoption or non-adoption (Parandian & Rip, 2013).

Innovations typically have a temporal patterning over time, demonstrated by irregular cycles of hype and disappointment (Borup et al., 2006). Since the consequences of an innovations are uncertain, the expected desirable consequences are speculative and therefore communicated as expectations by its proponents (Swierstra & Rip, 2007). Nonetheless, the expectations and visions that help technologies develop do not guarantee success and people tend to *"overestimate the effect of a new technology in the short run and underestimate its effect in the long run"* (Dorn, 2015, p.519). Early hopes for a technology are therefore rarely proportional to its outcome (Brown, 2003). This phenomenon is referred to as *'hopeful monstrosities'* (Mokyr, 1992): hopeful because the promises accompanying the technology are high and monstrous since the promises are not in proportion of the technical possibilities.

Innovations in science and technology may follow Gartner's hype cycle (Figure 1), developed to help organisations separate the unrealistic expectations of an emerging technology from technologies that are commercially feasible (Linden & Fenn, 2003). The hype cycle is human-centric, based on human expectations about technology over time, demonstrating how a technology moves through a period of overenthusiasm to a stage of disillusionment to arrive at its relevance in the market (Steinert & Leifer, 2010).

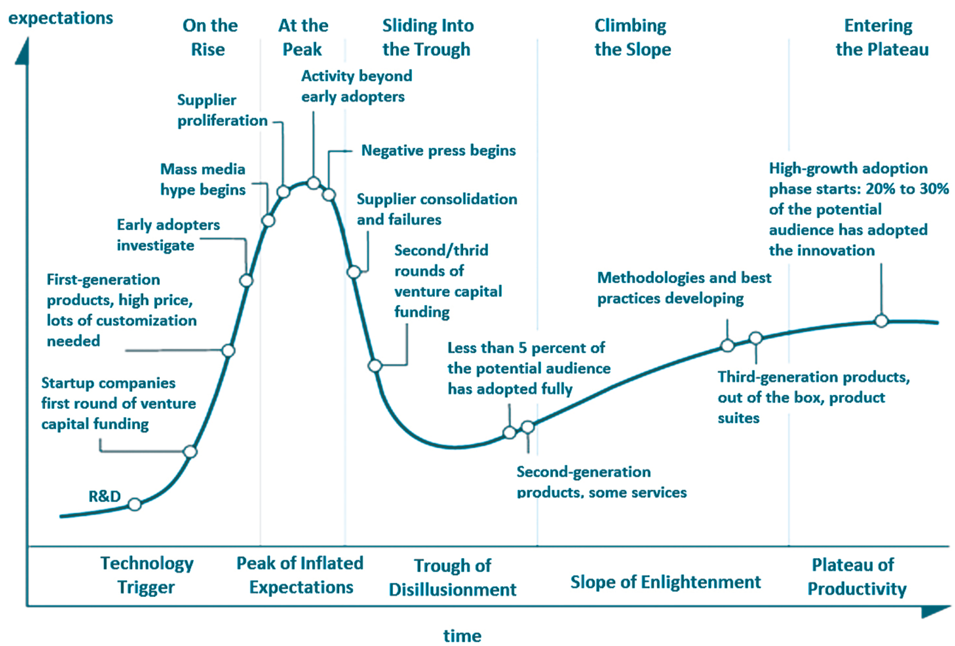

Figure 1. Gartner's hype cycle stage indicators. Source: Linden and Fenn (2003).

The hype cycle's path is divided into five stages; the *innovation trigger, the peak of inflated expectations, the trough of disillusionment, the slope of enlightenment and the plateau of productivity* (Steinert & Leifer, 2010). The *innovation trigger (1)* is a public announcement that triggers the cycle. Proponents of the technology, mostly scientists and developers, may inflate expectations by making unrealistic promises (Swierstra & Rip, 2007). The high expectations created by these promises are important in terms of gaining financial and political support for the innovation. As awareness about the technology spreads, its expectations increase. The hype cycle staggers when media further speculate and react overly optimistically to the presentation of the technology. In addition, companies aim to utilise first-mover advantages by investing in the technology (Steinert & Leifer, 2010). As the technology progresses, media coverage further boosts expectations, followed by a bandwagon effect, in which companies invest in the technology without a defined strategy or business case. At the same time, the inflated promises raise questions and doubts, which may result in fear. In response to this fear, proponents often begin to trivialise the uniqueness of the innovation and deflate expectations by toning down the inflated promises (Swierstra & Rip, 2007). At some point, the innovation has not lived up to its initial promise, resulting in disappointment and extinguishment of hype.

The hype ends with a sharp *peak of inflated expectation (2)*, for instance, when the overly optimistic expectations and investments fail to meet the performance or revenue expectations (Steinert

& Leifer, 2010). Public disappointment spreads again through the media, and the hype collapses into a *trough of disillusionment (3)*. Then, some early adopters, who further developed the technology, experience several benefits from the technology. Subsequently, the contextual understanding of the technology grows, and with some new investment, the performance of the technology and its expectations increase. This is reflected by the *slope of enlightenment (4)*. Finally, the technology is realistically valued by society and adoption accelerates in the *plateau of productivity (5)*.

Four phenomena are relevant elements to explain the shape of the hype cycle. The first is *cultural enthusiasm* because the technology promises societal benefits and profits. Second is *behavioural contagion*, as media influences may force rational people to act irrationally because they are driven by the enthusiasm of others (Steinert & Leifer, 2010). Third is the *heuristic attitudes* by decision-makers, as they tend to move with the trend, rather than to cautiously assess the technology's potential themselves (Fenn, Raskino, & Gammage, 2009). Moreover, at a later stage, the hype is counteracted by *resistance* in the social embedding of a new technology, as actors with different understandings of a technology's risks, technical or moral, may strive to hinder its adoption (Steinert & Leifer, 2010). These elements explain how hype cycles are influenced not only by the new technology and its performance, but also by the more extensive societal developments and attitudes (Geels, Pieters, & Snelders, 2007).

2.2 Guiding visions and technological paths

Inflated or unrealistic expectations can have problematic consequences, such as inflicting long-lasting damage on the credibility of industries, professional groups and markets and altering investment decisions (Brown, 2003). One reason emerging technologies might not live up to their initial high expectations and promises is because they are often developed in isolation, apart from the influence of social influences, and therefore do no align with the practice, culture, structure or wishes of their potential users (Geels, 2002). A way to bypass such an undesirable scenario is to involve relevant actors in an early phase of technological development before hype arises. This allows researchers to focus on possible directions, as envisioned by those who intend to use the applications, instead of unrealistic and undesirable paths. At the same time, developers can steer the technological applications in directions which better connect to the societal needs of those who are envisioned to be affected by the technology in practice (Schot & Rip, 1997).

Several research approaches aim to develop and design responsible applications with more societal support (von Schomberg, 2012). These approaches aim a maximising the positive impact and minimising the negative impacts of the technological innovations (Stilgoe, Owen, & Macnaghten, 2013). To achieve this, these approaches encourage societal actors and innovators to engage in an interactive learning processes (Schot & Rip, 1997). There is a growing understanding that all relevant actors, such as end users, policy makers and the public at large should be involved in this process to avoid researcher bias (Hagendijk & Irwin, 2006). Involving these actors allows researchers to discover how the development and implementation of a technology might positively and negatively affect actors. Once these impacts are identified, they can be incorporated into research, technology development and design, which could lead to more responsible innovations.

Identifying impacts early on is relevant because many options can be explored. Little is known about how the technology will develop, what applications will be realised and what societal effects those may have. Therefore, the technology can still be steered by social influences(Rogers-Hayden & Pidgeon, 2007; von Schomberg, 2012). In later stages of technological development, when positive and negative aspects of a technology are visible, the possibilities to steer are limited. This phenomenon has been described as the Collingridge dilemma of control (Collingridge, 1980) and exposes the limitations of either early or late engagement of actors in science and technology development processes.

The anticipation of possible futures is a way to address the Collingridge dilemma at an early stage of development and offers possibilities to discover societal impacts early on (Rip & Kulve, 2008). A way to investigate the future is to think about desirable visions from the perspectives of various actors (Grin et al., 2000). The most explicit visions, in an early phase of development, belong to technology developers, who shape the future with their passion and ideas (Akrich, 1992). When the ideas of developers are shared among other developers or actors, these ideas can form guiding points for an emerging technology, also referred to as guiding visions (Grin et al., 2000). Guiding visions navigate the interactions between developers and guides actions into concrete practises (Grin et al., 2000). Examples of concrete practices are the development of first products, the construction of shared standards or the inclusion of new actors in an emerging field (van Merkerk & Robinson, 2006). If developers start sharing visions, rules and routines and structures in their assessment of a technology, their actions may results in the specific technology trajectory (Dosi, 1982).

Over time, these technological trajectories may become stable patterns, enabling certain activities while constraining others. This is referred to as entrenchment, or *path dependency,* which occurs when developers commit themselves to a specific path and ignore practices that are inconsistent with their own (van Merkerk & Robinson, 2006). Although path dependence is recognised as a compelling perspective to explain the emergence of novelty, this notion has problematic implications for developers, regarding them as passive observers within a stream of events (Garud & Karnøe, 2001). Conversely, the concept of *path creation* describes developers as actors capable of reflecting and acting in alternative ways than those prescribed by current practices (Garud & Karnøe, 2001). Accordingly, actors innovate in a real-time manner, based on decisions in the present instead of the past. When developers are confronted with various visions from other societal actors, this may stimulate them to rethink their activities, assumptions and commitments. This may result in innovators diverting from their original technological path when other visions are identified (Arentshorst, Broerse, Roelofsen, & De Cock Buning, 2014). Consequently, such reflexive engagement may guide technologies towards more responsible and desirable paths.

2.3 Barriers to health innovation

Responsible innovations imply an alignment of what different stakeholders perceive as problems and purposes to be fulfilled by new technologies (Roelofsen, Boon, Kloet, & Broerse, 2011). The challenge here is to proactively detect potential concerns and barriers that might hamper the innovation's development and implementation in later stages. Different visions may result in different technological trajectories, each with specific concerns and barriers. Identifying and explaining these barriers in an early phase of development may eventually lead to ways to effectively manage them (Roelofsen et al., 2011). In other words, studying barriers to innovation provides insight into the dynamics of innovation, which is a first step in the process of overcoming them.

A barrier to innovation is any factor that negatively influences the innovation process. Innovation barriers can be grouped into endogenous and exogenous barriers (Hadjimanolis, 1999). Endogenous barriers arise due to organisational routines, lack of technical expertise, lack of resources, or human nature (e.g., risk-adverse top managers). Exogenous barriers include financial barriers (e.g., reluctance of investors), governmental barriers (e.g., policies and regulations), and collaboration barriers (e.g., differences in objectives between players).

The current literature on blockchains is often technical and does not fully take into account the social and organisational dynamics that make or break innovations (Nichol & Brandt, 2016). Assessing these barriers is a relevant next step in developing desirable blockchain applications and increase their chances of adoption. Dehzad et al. (2014) examined the barriers for digital health applications in the Netherlands and their relative importance (Figure 2). Integration and interoperability of systems are indicated at the top, followed by business case and conservative culture. On the right hand side of the figure, enabling developments are indicated. These are the open standards of application programming interfaces, strategic funding programs, collaborations and other breakthroughs for successful development. The relevant elements for blockchain in the Netherlands are discussed in the following sections.

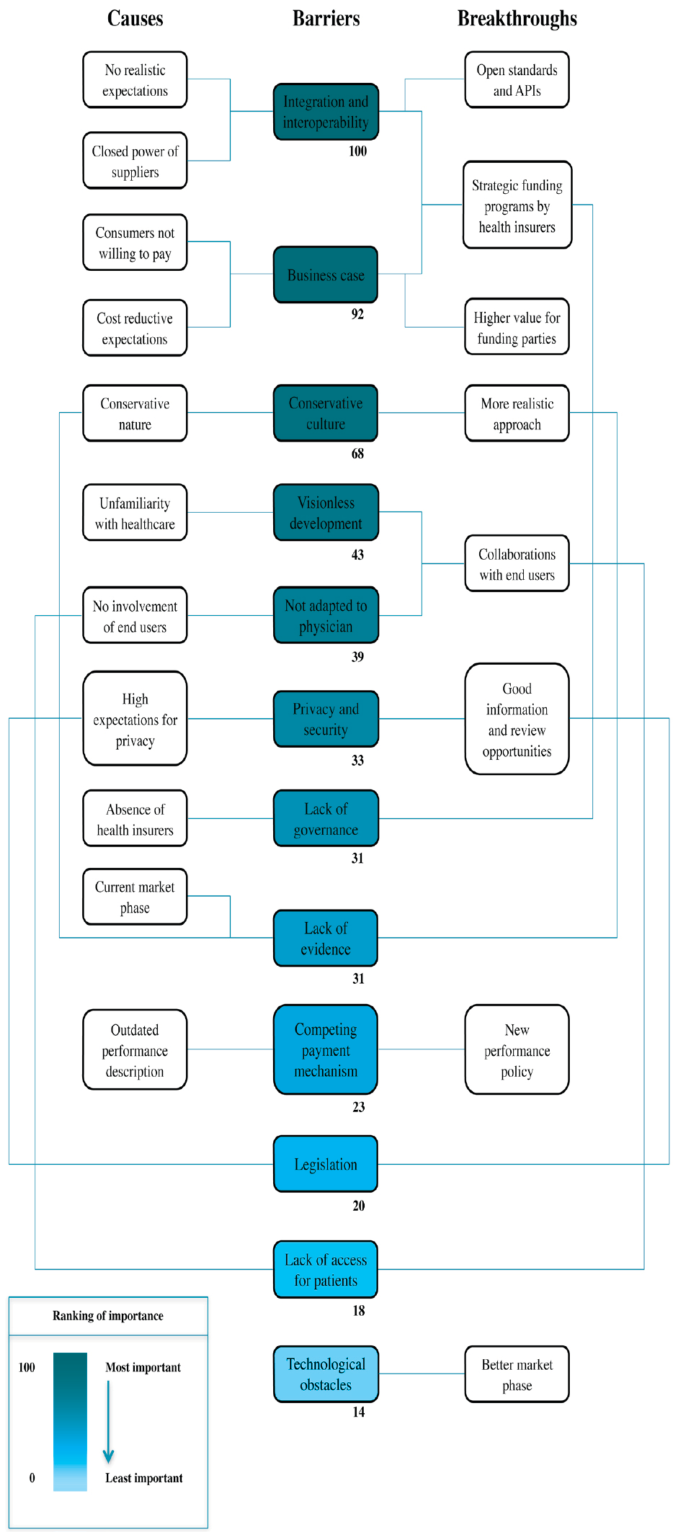

Figure 2. Barriers, causes and breakthroughs for digital health adoption in the Netherlands.
Source: Dehzad et al. (2014)

2.3.1 Stakeholders in healthcare

The Dutch healthcare sector has an effective and supportive innovation climate and the failures of new applications are rarely due to technical reasons. However, the social and organisational barriers are more challenging to overcome (Dehzad et al., 2014). The healthcare industry is characterised by many stakeholders and innovations are only adopted when several healthcare stakeholders see value in it (Dorn, 2015; Venkatesh & Davis, 2000). From the patients' perspective, such value entails a better diagnoses and less costly healthcare, leading to an improved quality of life. Healthcare providers appreciate professional fulfilment, higher income and enhanced patient health, while health insurers value cost reductions and increased market shares. Few digital health technologies bring value to all these stakeholder categories. Until that happens, the complicated and risk-adverse healthcare industry will struggle with the adoption of digital innovations (Dorn, 2015). It is therefore relevant to examine the stakeholders in the Dutch healthcare sector. Figure 3 shows the relation of the stakeholders in relation to the healthcare consumer (patient) in the Netherlands based on the findings of (Klapwijk, 2017).

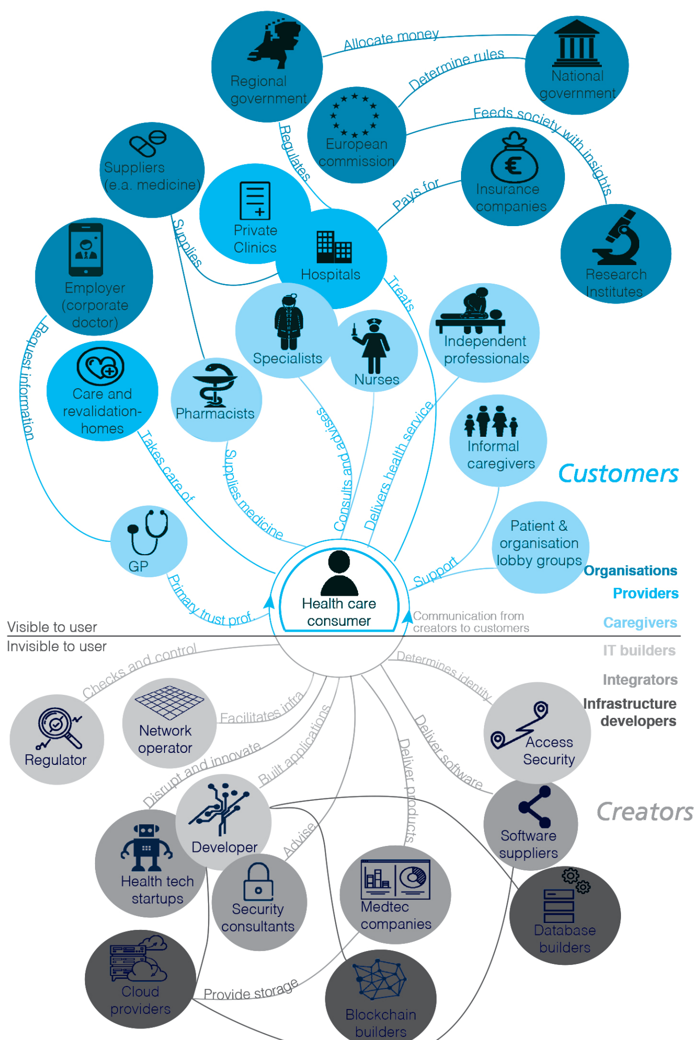

Figure 3. Stakeholder overview centred around the patient in the Netherlands. Source: Klapwijk (2017)

The *creators* are the innovators and technology developers of digital health applications. The *customers* are all actors who use IT applications in healthcare. The outer layer represents the majority of the funders, such as insurance companies. The national government has a relevant role in determining the regulations and distribution of governmental budgets for healthcare. There are often limited funds available for innovation in IT since the primary objective of healthcare industry is to cure people (Klapwijk, 2017). Due to technological advances there are more devices that generate data. This has made the industry more appealing to both large and smaller data-driven companies which have entered the healthcare market (Zorgvisie, 2016). This makes the market larger and more complex concerning the number of stakeholders and the amount of data that is collected. This creates new dynamics, as the traditional healthcare landscape is getting blurry.

2.3.2 Business models

The patients are often the end-user of a new product of service, but there are usually multiple users determinate a health innovation's adoption, such as general practitioners (GPs) and specialists (Dehzad et al., 2014). In the Netherlands, the financial structure is focussed around the insurance companies. Healthcare consumer pay a premium for their insurance. These funders are important because they have funds for innovation. The funder generally only fund proven applications with a calculated return on investment, creating a barrier to entry for many innovations that do not have a clear return on investment (Dehzad et al., 2014).)Moreover, the conventional business models are concentrated on selling more care, not on increasing the quality of life (Dehzad et al., 2014). This explains why there is resistance towards healthcare innovations.

2.3.3 Legislation and privacy

The healthcare sector is fundamentally different from other industries, because it involves decisions about human lives. This results in many regulations and protocols to provide security measures. Successful innovation needs to align with these rules and regulations (Herzlinger, 2006). Taking the regulations into account and anticipating on it early on may result in fewer problems later on.

There is a surge in data that is collected about citizens through mobile apps, devices and wearables, which makes it challenging for the users to keep track of their data. The lack of control over data is an issue, because users are afraid that their data are being used by third parties without their consent (Morey, Forbath, & Schoop, 2015). The concern about privacy is especially relevant in the healthcare context, because health data are considered extremely sensitive (Laan, 2017). Concerns about privacy and security have resulted in laws and regulations that could hamper the innovation (Kanter, 2006).

In May 2018, the General Data Protection Regulations (GDPR) was enacted. The GDPR is a regulation on data protection and privacy for all individuals within the European Union and requires that organisations inform consumers about the data they collected about them, how the data are used and who has access to the data (European Comission, 2018). The GDPR is relevant for blockchain because blockchain is a new method of exchanging, adapting and storing data with various parties. If personal data, such as medical data, is stored on a blockchain, then blockchain initiatives have to take the GDPR into account (Laan, 2017).

2.3.4 Integration and interoperability

Sufficient legal foundations are essential to ensure security and privacy of personal data and to set standards for database interoperability, confidentiality, data protection and personnel clearance for an open innovation architecture (Sharmin, Faith, Martín, & Ramalingam, 2017). Connecting all healthcare stakeholders to the same infrastructure is a challenge in healthcare. Currently, there are many IT systems that can barely communicative with each other (Dehzad et al., 2014).

To solve the problem of fragmented data in the Netherlands, a bill for the a national Electronisch Patienten dossier (EPD), or electronic health records (EHRs), was proposed in 2011 (Klapwijk, 2017). This bill stalled in the Dutch first chamber of parliament, however, due to controversy over the guarantee of security and privacy. As an alternative, the Het Landelijke Schakelpunt (LSP), or 'national transfer point', was developed, which registers where (most) health information about each patient is stored. If patients give consent to the LSP then certain healthcare providers can exchange basis health data (e.g., medications, allergies etc.) through the LSP. The LSP functions on a regional level however, and therefore does not allow the exchange of health data on a national scale (Klapwijk, 2017).

Unlike the LSP, blockchain is a global structure, where various players, sources and devices can be connected (Zorginstituut Nederland, 2018). It will require much organisation to establish a nation-wide initiative, but once in place, it would provide an open infrastructure for connecting a variety of stakeholders, such as GPS, specialists, dieticians, health coaches and psychologists (Klapwijk, 2017). A problem that needs to be addressed before blockchain can become effective is the lack of standards for health information exchange in the Netherlands (Dehzad et al., 2014) . In 2018, the MedMij initiative was launched by the Dutch government, which developed a set of rules and agreements for the exchange of health data in collaboration with the Dutch patient federation, medical professionals and health insurers (Nictiz, 2018). MedMij's aim it to provide every patient with a digital environment (e.g., an app or website) for their personal health records (PHRs). This environment must be able to communicate with the healthcare information systems of healthcare providers in a secure and familiar way (Nictiz, 2018). Healthcare providers can become MedMij certified when they meet MedMij's security criteria. This is a first step in standardising the exchange of health data in the Netherlands.

3. Methodology

3.1 Research approach

The focus of this thesis is identifying desirable blockchain paths and barriers that need to be overcome to achieve these paths according to relevant stakeholders. This thesis uses a CTA approach, which is operationalised with the interactive learning and action (ILA) model, developed to navigate scientific and technological innovations in an early phase in more desired directions by the actors involved (Broerse & Bunders, 2000). This model along with a vision assessment (Grin et al., 2000) are necessary to determine the desirability of potential future applications and possible impacts in an early phase of development (Rip, 2002). This combination proved suitable for the analysis of emerging technologies in the fields of ecogenomics (Roelofsen, Broerse, de Cock Buning, & Bunders, 2008) and neuroimaging (Arentshorst et al., 2014). Therefore, this combination is considered a valuable method to study other emerging technologies, such a blockchain.

3.1.1 Constructive Technology Assessment

A constructive technology assessment is an approach to responsible research and innovation and a form of technology assessment (TA). CTA differs from other forms of TA as it is directed towards addressing social issues around a technology by influencing development and design practices, instead of assessing the impacts of technology to influence regulatory practices (Rip & Kulve, 2008). Since the late 1980s, CTA has been operationalised and implemented to design technologies that are better aligned with societal practises (e.g., Arentshorst et al., 2014; Roelofsen, 2011; van Merkerk, 2007). A CTA process broadens a technology's development and design by including more aspects and involving more actors from both science and society in an early phase of technological development. By ensuring that the process becomes transparent and complies with the desires of various actors, the process of technology can be shaped in a way that considers social aspects (Schot & Rip, 1997). In addition, the CTA process aims to create mutual understanding among various stakeholders and allow actors to learn about the positive and negative implications of a technology (Rip, 2002).

3.1.2 Vision assessment

Central to the research approach is identifying guiding visions, which are mental images of an attainable future shared among stakeholders (Grin et al., 2000). These guiding visions are a form of long-term consideration, turn actions into concrete practises (e.g., the development of material artefacts) and guide interaction between stakeholders. Guiding visions are therefore early signs of a technological trajectory. Visions are important elements for stabilising future expectations, because they have to be shared to some extent between stakeholders. The opportunity is to identify visions of blockchain for relevant actors and to assess the underlying assumptions regarding expectations, promises and concerns that guide the actions and interactions between actors. The aim is to make these underlying motives explicit, as they can form barriers for blockchain implantation. The following six elements are central in identifying and constructing visions (Grin et al., 2000; Roelofsen et al., 2008):

1) **The current state of knowledge and technology**: The developments currently taking place.
2) **Problem definition**: Existing challenges and ways to assess applications.
3) **The purposes to be fulfilled:** The objective of the visions.
4) **Relevant contextual aspects**: The relation between technical and contextual elements. In which context will the object be used? By whom? How? Who will benefit and who will experience disadvantages?
5) **Barriers**: Factors that hamper the realisation of future applications.
6) **Basic features of a desirable state**: Ideas about what ideal industry should look like.

3.1.3 The interactive learning and action approach

The ILA approach involves the active participation of stakeholders from science and society using interactive methods, such as focus groups and dialogue meetings (Broerse & Bunders, 2000). Key features include active participation of stakeholders in an early phase of development and the development of shared visions (Broerse & Bunders, 2000). This research approach in this thesis is comprised of three steps, based on the five-step design of the ILA approach. The five steps are 1) initiation and exploration 2) in-depth study of problems, needs and visions of involved stakeholders 3) integration of various actor groups' perspectives through mutual learning 4) prioritisation and agenda setting and 5) implementation through action research. Due to time span of this thesis only step 1, 2 and 3 were conducted. Figure 4 shows each step of the process. Step 2 was divided into phase 2 (identification of guiding visions collection) and phase 3 (reflection on guiding visions) because phase 3 was completed before phase 3 started. The results of each step function as input for the next.

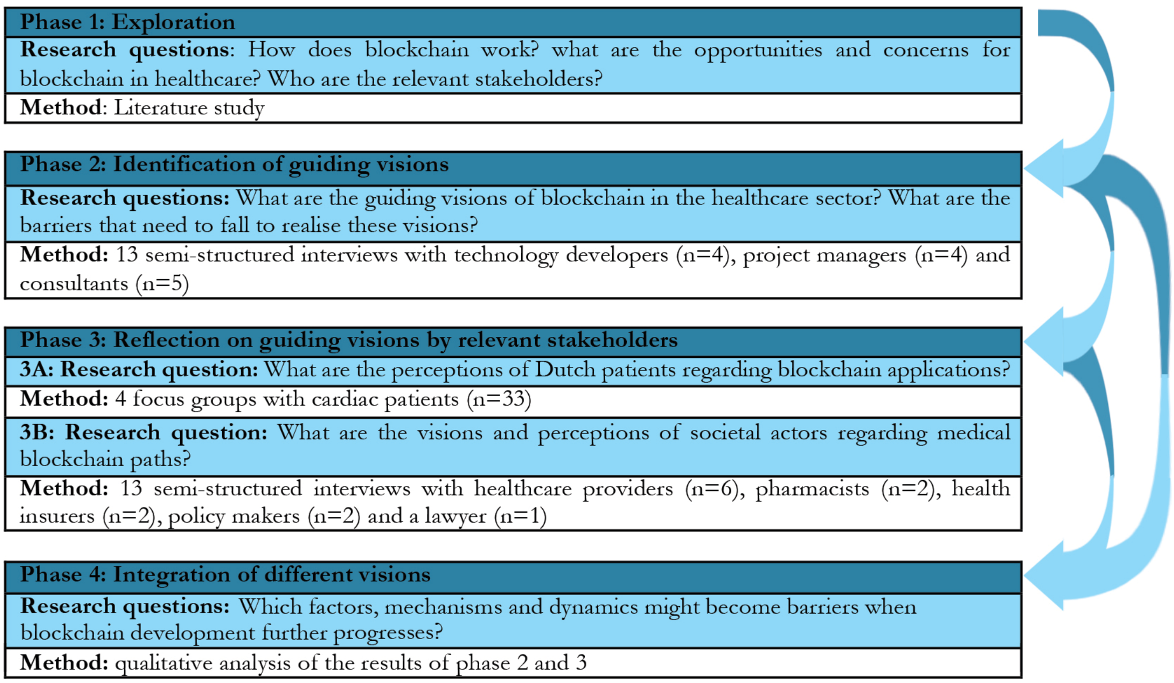

Figure 4. The structure of the CTA process of medical blockchain. The arrows represent the use of the output of one group of participating actors as input for another group.

3.2 Data collection

3.2.1 Phase 1*: Exploration*

This research started by exploring the literature to discover current blockchain developments in healthcare. The results of the literature study provided insight into the opportunities and concerns of blockchain and served as input for the semi-structured interviews. In addition, the literature study helped identify the most relevant stakeholders in the innovation process and provided insight into relevant contextual aspects in the Dutch healthcare sector.

3.2.2 Phase 2*: Identification of guiding visions*

Subsequently, semi-structured interviews were conducted to identify desirable visions and to understand the technical, organisational and social barriers from the perspective of blockchain experts involved in blockchain initiatives (n=14), consisting of consultants (n=6), developers (n=4) and project managers (n=4). These experts have the most explicit visions about this technology as they shape their future with their passion and ideas (Akrich, 1992). Table 1 lists the experts.

Table 1. The 13 consulted blockchain experts divided in three categories.

Expertise	Position	Category	Date(d/m/y)/Duration (min)
Blockchain in healthcare, agrifood and creative service development	Consultant	Consultant (1)	05/03/2018 (32 min)
Machine learning, internet of things, big data, cloud technology, security and privacy	Partner technological strategist	Consultant (2)	15/03/2018 (80 min)
Innovation, patient empowerment and sustainable healthcare	Director of research centre and technology strategist	Consultant (3)	03/04/2018 (33 min)
Blockchain and smart contract implementation and business process management	Director of consultancy firm	Consultant (4)	16/04/2018 (26 min)
Digital health and innovation	Innovation consultant of an academic medical hospital	Consultant (5)	06/06/2018 (62 min)
Computer systems, telecommunications and IT management	Postdoc and CTO of network of private clinics	Developer (1)	28/02/2018 (59 min)
Blockchain and digital identities	Software developer and CEO of a start-up	Developer (2)	12/03/18 (50 min)
Blockchain & machine learning and digital healthcare	Software developer and CTO of a start-up	Developer (3)	30/3/2018 (35 min)
Digital health, behavioural economics, HIV/AIDS treatment in resource-limited countries	Director of a research lab of a non-profit organisation and consultant	Developer (4)	11/06/2018 (66 min)
Electronic and personal health records, digital health and privacy	Project manager, consultant and postdoc	Project manager (1)	18/12/17 (43 min)
Blockchain implementation	Project and sales manager	Project manager (2)	16/3/18 (37 min)
Digital innovation and blockchain projects	Project manager	Project manager (3)	12/03/18 (30 min)
Innovation and telemedicine	Innovation manager	Project manager (4)	23/03/2018 (48 min)

The interviews were semi-structured, meaning they were planned but flexible (Kvale, 2007). They covered a sequence of themes with suggested questions, but there was openness to change the sequence and the questions based on the respondent's answers. For example, the findings of the first interviews led to new questions that were used in later interviews. The experts were selected based on their expertise with blockchain. Most of them were active with blockchain proof-of-concepts or pilots in the Netherlands. Not all respondent had experience with medical blockchain applications, but they considered themselves to have knowledge about the healthcare sector and blockchain to participate in the interviews. The respondents received a formal invitation explaining the purpose of this thesis. The interviews lasted between 13–92 minutes. To preserve the anonymity of the respondents, the names of the respondents and their organisation were not revealed. Their identities were anonymised by replacing their name with a number (e.g., developer 1 and consultant 2) (Table 1).

An interview guide was developed that concentrated on the elements considered relevant for the vision assessment: *the current state of technology, problem definitions, challenges and purposes to be fulfilled, barriers, and essential features of the desirable state*. The respondents were asked about the blockchain initiatives they were involved in to gain insight into the current applications of blockchain in their field and their future expectations. In addition, the respondents were asked what positive and negative consequences the development of blockchain application may have on society. Moreover, they were asked to imagine their desirable future for blockchain, assuming there were no technical of societal barriers. To understand the assumptions underlying the articulated visions, the participants were asked which actors would benefit from the desired blockchain applications and which stakeholders might experience disadvantages.

The visions of the blockchain experts functioned as guiding points for discovering the possibilities of blockchain technology and helped to identify relevant healthcare stakeholders for further research (Roelofsen et al., 2008). The obtained information was used as input for phase 3, in which other healthcare stakeholders were interviewed, who shared their perspectives on the blockchain experts' guiding visions.

3.2.3 Phase 3a: *Reflection on guiding visions by patients*

The blockchain-experts consulted in phase 1 identified healthcare stakeholders in the clinical, policy and public context as parties who might be affected by blockchain. In phase 3A, Dutch cardiac patients (n=33) reflected on the guiding visions in four focus groups (8–10 people per group). The aim of this session was to obtain an in-depth understanding of the arguments underlying of the potential drivers and barriers from the perspective of users.

The focus groups were prepared and conducted with a fellow student from the Vrije Universiteit of Amsterdam (VU), who studied the perspective of health consumers on electronic health (e-health) developments in the Dutch healthcare sector for his master's degree in management, policy-analysis and entrepreneurship in health and life sciences. This student was selected after a solicitation for an internship at CCN. The collaboration allowed both of us to use more data than we could have collected individually, which had positive impact on both our studies.

To create the focus groups, we looked at digital health applications that can be built upon the blockchain infrastructure, such a personal health records and telemonitor sensors and devices. Blockchain was not discussed in these meetings. The reason for this was that patients will not notice blockchain: it is an infrastructure that operates on the background, similar to the mobile network.

The other student and I facilitated the focus groups. Each focus group was led by one of us, who guided and monitored the group process, while the other took notes. The focus groups followed the design of Roelofsen et al. (2008) for reflection on guiding visons. The focus groups lasted for two hours with a break halfway. An informed consent (niet-WMO verklaring) permission was granted by the University of Utrecht for this part of the analysis. To preserve the anonymity of the respondents, their names were not revealed.

3.2.3.1 Focus group participants

The focus groups were all held in Amsterdam and were conducted with cardiac patients under supervision of cardiologists of the Academic Medical Centre (AMC) of Amsterdam. Initially the plan was to organise additional focus groups with patients from Cardiolgie Centra Nederland but not enough patient signed up to conduct the focus groups. To avoid creating anticipation about the topic, the participants were invited to participate in a 'discussion meeting about digital health developments in the AMC'. No further information about the topic of discussion was provided to participants in advance. The participants were contacted by the AMC staff in person during their visits and flyers were available in waiting rooms of outpatient clinics.

3.2.3.2 The structure of the focus groups

The focus groups consisted of five steps:

Step 1: *Getting acquainted with e-health*. To assess the level of knowledge, the participants were asked whether they used e-health and what their first thoughts were. Subsequently, all focus groups started with a short presentation describing e-health, presenting participants with the same information to establish the same level of knowledge between them. The participants were provided with examples of e-health other than the ones that were discussed with them as part of our research. Hence, they could not form an opinion about the cases relevant to this research yet.

Step 2: *Inventory of intuitive desirable and undesirable ideas*. Following the presentation, the participants were requested to write down two desirable and two undesirable or worrisome ideas on post-its that came to them after reading the examples.

Step 3: *Clarification of ideas*. As a next step, participants were asked to give feedback on their ideas and explain why the goals or applications they wrote down were desirable of undesirable. The post-its were clustered by the facilitator based on similarities in the ideas of participants, such as common goals or impacts the participants found relevant.

Step 4: *Reflection on future applications*: We presented three cases to the participants. The aim of this step was for the participants to reflect on three e-health applications and for the researchers to gain insight into the diversity of their perspectives. The cases were derived from the literature review and the interviews with blockchain experts. Limited information was presented in the applications to stimulate participants to formulate their own ideas. Table 2 presents the cases with the short explanation used in the focus groups.

NB: The data collected from case 1: personal health records and case 2: telemedicine were used in this thesis because they are potential blockchain applications.

Table 2. Cases used in the focus groups

Case 1: *The use of PHRs*
Digital health records owned by patients. Patients can have a complete overview of all their medical records and control who may access them.
Case 2: *Telemedicine at home*
Sensors and devices that monitor, collect data and advise patients at home.
Case 3: *Travel applications*
Digital applications that improve the experience of patients travelling outside their home countries.

The participants received a green and red card and were requested to respond intuitively to each case by putting the green card forward when the case was desirable and the red card when the case was undesirable. Then, the facilitator asked the participants to reflect on their decision and stimulated a discussion between participants. The discussion was visualised using post-its and flip charts so the participants could see what had already been said and what was missing. The goal was not to reach consensus among participants, but to record the perspectives present in the group. Hence, all the perspectives were written down and the participants were asked whether something was missing and whether their perspectives changed as a result of the discussion. If so, the participants were asked to switch the colour of the card in front of them and to motivate their decision. Thereafter, the next example was presented and step 4 was repeated.

Step 5: *Closure.* After the reflection, participants were asked if they changed their mind on e-health applications during the discussion and how they felt about the focus group.

3.2.4 Phase 3b: *Reflection on guiding visions by societal actors*

3.2.4.1 Participants

The aim of this phase was to identify what relevant healthcare stakeholders regarded as desirable visions for blockchain and to identify barriers that need to be overcome to achieve these visions. Apart from patients (phase 3a), the blockchain experts in phase 1 identified medical professionals, policy makers and health insurers as relevant societal actors. Furthermore, when looking at specific interests, needs and expectations, the following key stakeholders were found in the literature on healthcare innovation: regulators (e.g., ministries), healthcare providers (e.g., physicians), healthcare funders (e.g., health insurers), healthcare organisations (e.g., hospitals), technology suppliers, and patients (Omachonu & Einspruch, 2010). Accordingly, the consulted healthcare stakeholders (n=12) consisted of health insurers (n=2), pharmacists (n=2), healthcare providers (n=6), policy makers (n=2). At least two respondents were consulted from each stakeholder group to generate more objective results. Additionally, a lawyer (n=1) was consulted to gain additional perspective on the privacy side of blockchain, as processing medical data is a privacy-sensitive business. Table 3 provides an overview of the consulted societal actors.

Similar to phase 1, the respondents received a formal invitation explaining blockchain as an emerging field from which applications could arise that may have implications for the healthcare sector. In addition, the invitation explained that their input was necessary to gain understanding if blockchain applications are desirable from their point of view and to potentially detect alternative applications. Moreover, these healthcare stakeholders were asked to envision desirable futures for the Dutch healthcare sector. These visions were used in the data analysis in phase 4 to discover how the desired blockchain visions relate to an ideal healthcare system. The respondent in this phase were also asked about the elements in the interview guide in phase 1: current state, problem definition, purposes to be fulfilled, relevant contextual elements and basic features a desired state. The interviews lasted 45–75 minutes. To preserve the anonymity of the respondents, the names of the respondents and their organisation were not revealed.

Table 3. The 13 consulted societal actors divided in five categories

Expertise	Position	Category	Data(d/m/y)/ Duration(min)
Innovation and ICT	Advisor health innovation at an health insurer	Health insurer (1)	18/05/2018 (54 min)
Healthcare, hospital management	Director health at an health insurer	Health insurer (2)	12/06/2018 (28 min)
Cardiology	Postdoc and founder and director of network of private clinics	Healthcare provider (1)	28/03/2018 (28 min)
Internal medicine and endocrinology	Professor and director of an academic medical hospital	Healthcare provider (2)	14/05/2018 (35 min)
Internal medicine and dermatology	Professor and director of an academic medical hospital	Healthcare provider (3)	4/6/2018 (27 min)
General practitioner	Professor and director of an NGO	Healthcare provider (4)	25/05/2018 (43 min)
Paediatrics	Postdoc and head of the paediatrics department of an academic medical hospital	Healthcare provider (5)	4/6/2018 (27 min)
Paediatrics	Paediatrician and postdoc	Healthcare provider (6)	26/06/2018 (48 min)
Information, communication and technology (ICT) law	IT lawyer	Lawyer	13/06/2018 (13 min
Medicine development and distribution	COO of a pharmaceutical start-up	Pharmacist (1)	04/05/2018 (50 min)
Toxicology	CEO of a pharmaceutical start-up	Pharmacist (2)	04/05/2018 (50 min)
Blockchain in healthcare and Dutch policy and regulation	Senior advisor at a government agency	Policy maker (1)	16/05/2018 (92 min)
Innovation, the MedMij-program, Dutch policy and regulation	Innovation advisor at a government agency	Policy maker (2)	25/05/2018 (52 min)

3.2.5 Phase 4: *Integration of perspectives*

With the results of phases 2 and 3, similarities in the visions of the relevant stakeholders were analysed. The aim was to gain insight into shared desirable visions of blockchain and factors mechanisms and dynamics that might become barriers during the development and implementation of blockchain in the healthcare sector. To ensure that all key elements were assessed, three respondents (developer (1), consultant (1) and healthcare provider (1)) were invited to separate feedback sessions to reflect upon the results of the analysis. Figure 5 provides an overview of the consulted respondents.

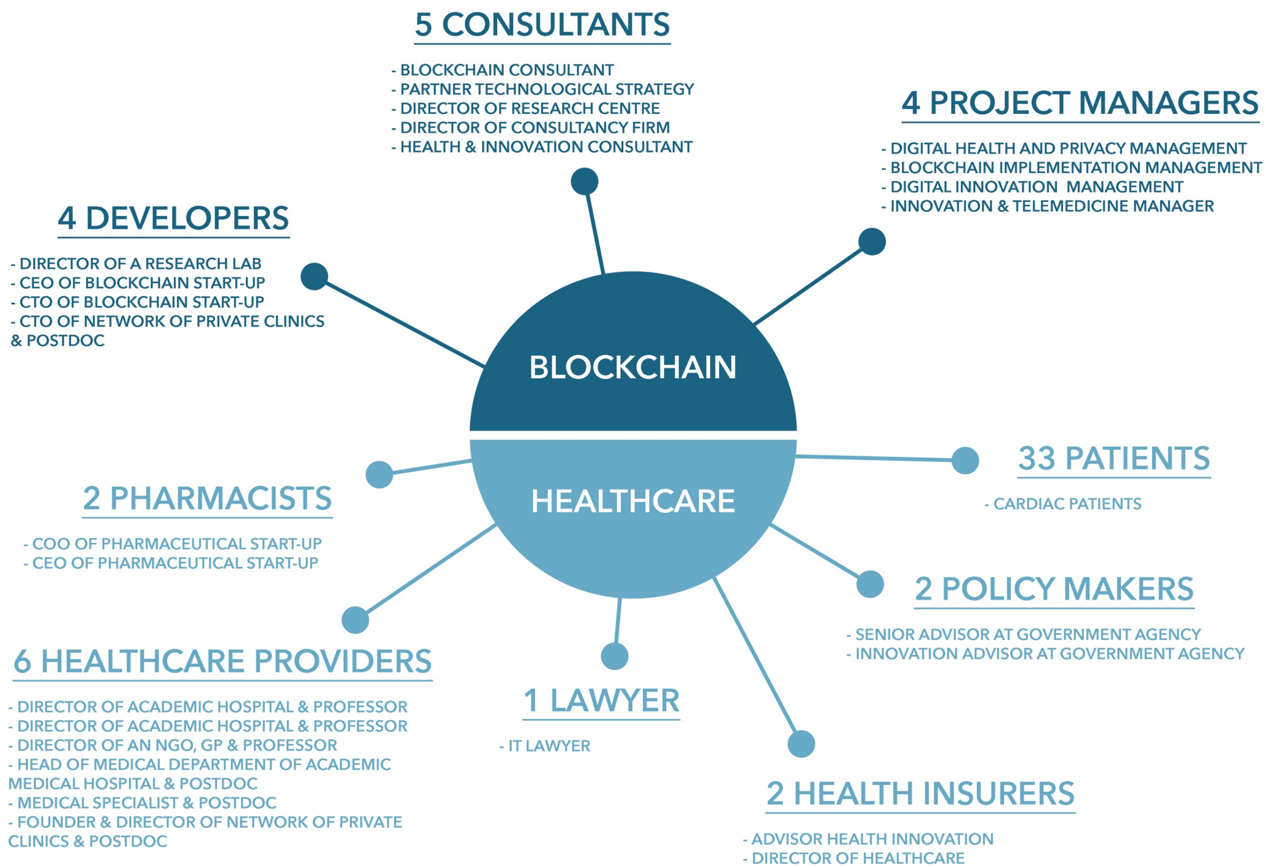

Figure 5. The consulted blockchain experts and healthcare stakeholders

3.2.6 Pilots

The first focus group and semi-structured interview functioned as pilots. This led to fine-tuning the content and optimising both designs. In the focus groups, the content of the cases was adjusted to minimise ambiguity and structural changes were made in the semi-structured interviews. The results of the pilots were used in the analysis to reinforce the findings of the main thesis because the key features of the main thesis were preserved in the pilot (Thabane et al., 2010). The pilots indicated that participants and interviewees could articulate desires and concerns regarding future blockchain applications. Based on the experience of the first focus group, the design was optimised by adjusting the content of the cases to minimise the ambiguity found in the pilot.

3.3 Data analysis

Twenty-two of the semi-structured interviews (n=24) and all focus groups (n=4) were audio-recorded, transcribed and analysed with ATLAS.ti. The recording of one interviews was not transcribed because the content was irretrievable as only beeps were recorded. The other interview was not recorded because the interview took place before it was decided to transcribe all interviews for the analysis. Of both interviews notes were made during the interview so the data could still be used in the analysis. During the three feedback sessions (n=3), in which the results were discussed, notes were made and these notes were added to the transcript of the respondents. Most semi-structured interviews (n=20) took place at a location chosen by the respondents, the other interviews were conducted (n=4) were conducted over the phone and were also audio-recorded.

In the first cycle, structural coding was used to identify, code and describe topics. These structural codes are appropriate for qualitative studies with multiple participants and semi-structured (Saldana, 2012) and were the foundation for more detailed coding. The structural coding resulted in topic list for major categories and themes. In the second cycle, this list was analysed and the focus was on the elements that were central in the construction of visions, which were the current state of technology, problem definition, challenges and purposes to be fulfilled, barriers, and essential features of the desirable state. These elements were used to structure the data and functioned as categories. To show how the categories related to each other, axial coding was used, which resulted in sub themes. Axial coding resulted in saturation when now new info (e.g., properties, actions and consequences) emerged during coding. Using elective coding, the sub themes were constructed into main themes for blockchain visions and different barrier categories. In the result sections an overview is provided of the codes that were used in the analysis of this thesis. Figure 10 and Figure 11 provide a list of the codes that led to the identified visions and Figure 12 shows the codes that were used to identify barriers. Appendix E provides an overview of all codes in the first cycle.

3.4 Validity of results

The following strategies were applied to minimise researcher bias:

- Triangulation: different approaches (literature study, semi-structured interviews and focus groups) were used to collect data on the same subject.
- Saturation: During the vision assessment, saturation was obtained regarding the articulated visions and barriers on a general level: no new information on the visions and barriers was collected in the last two interviews.
- The semi-structured interviews and focus groups were transcribed verbatim to avoid the loss of data.

4. Technical background: Blockchain technology

Blockchain technology plays a central role in this thesis. This chapter explains how the technology works. It also explains concepts that are relevant to understand the results: *distributed ledger technology, open and closed blockchains, smart contracts, public key cryptography, hash functions and mining.*

4.1 Distributed ledger technology

The blockchain is a digital ledger to which rules with information are added—just like in a paper ledger. Once information is added to the digital ledger, it is practically impossible to alter it. Two examples of logs with information on a digital ledger:

Data	Identity	Log
01/01/2018	MPAX	Viedftyhkjqprivjkiow
02/01/2018	KFTA	Qrijksrpjworitjxdhzz

The digital ledger is scattered over a certain number of computers that form a network. These computers are regarded as *nodes*, and each node has a copy of the digital ledger (van Heukelom, Naves, & van Graafeiland, 2017). The copies of the digital ledger regularly synchronise with each other. Hence, if one node adds a rule of information to the blockchain, this rule of information is added to the other copies of the ledger.

A characteristic of the blockchain technology that makes it unique is that it merges sets of transactions into blocks (van Heukelom et al., 2017). Every block has a unique code (*header*) that refers to the header of the previous block. This is how the blockchain is formed (Figure 6). Since the headers of the block depend on the content of the block, the header of a block changes when information in its block is edited, creating modifications in all headers in the chain. One of the main strengths of the blockchain technology is that once a node wrongfully alters information on a ledger, this wrongful alteration is recognised by all other copies, which will fire off error messages. For this reason, it is impossible to wrongfully alter information on a blockchain because the network always consists of multiple nodes. This results in a high level of trust for data that is stored on a blockchain.

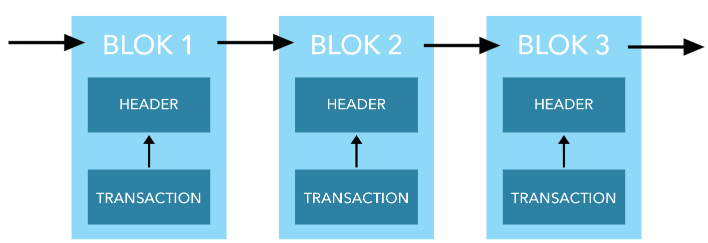

Figure 6. The formation of blocks

4.2 Open and closed blockchains

The most well-known application of blockchain technology is its use for Bitcoin transactions. Bitcoin is a *cryptocurrency* that is traded on a blockchain without the interference of a third party (Nakamoto, 2008). Blockchain technology is the main technical innovation of Bitcoin, where it serves as the public ledger of all bitcoin transactions (Antonopoulos, 2014). Bitcoin is peer-to-peer, meaning that every registered individual has equal rights; every user is allowed to connect to the network, send new transactions to it, verify transactions, and create new blocks, which is why it is called an *open blockchain* (van Heukelom et al., 2017).

A blockchain can also have a closed architecture. For instance, an organisation can control the nodes in a blockchain, allowing the organisation to limit the extent of access that certain parties have to transactions on the blockchain. In these *closed blockchains*, there are varying levels of control of who can access the data, who can modify the data, and who ultimately has authority in the system. Although a closed blockchain is in stark contrast with one of the blockchain technology's original principle—the absence of third-party control over transactions—it has advantages compared to an open blockchain. Since open blockchains are fully open, and only protected with encryption (Section 4.4), participants in closed blockchains have a higher level of privacy (van Heukelom et al., 2017). Moreover, closed blockchains are more flexible and can be designed to follow the rules and authority laid out by business agreements (van Heukelom et al., 2017).

4.3 Smart contracts

A smart contract is a programming code, in which an action depends the occurrence of one or more events. The basis of a smart contract consists of an *if-then* construction (van Heukelom et al., 2017). An example of a smart contract is a soda machine that automatically orders new soda cans once the machine is almost empty (n=<10). The smart contract, in this case, would consist of the following elements:

IF
Number of soda cans =<10
THEN
Send order to soda supplier

Smart contracts are increasingly sophisticated, using algorithms to fully customise conditions that determine when to exchange value, transfer information, or trigger events (Krawiec et al., 2016). Smart contracts and blockchain technology fit well together. The smart contract needs to be triggered by events that are entirely justifiable. The blockchain is a platform that can deliver that level of trust (van Heukelom et al., 2017). As an example, the smart contract can stipulate all the fields that need to be provided prior to blockchain storage. Once the smart contract validates that the correct data fields have been submitted, it will direct the transaction to the blockchain for storage.

4.4 Public key cryptography

Public cryptography is a critical component of cryptocurrencies like Bitcoin. These advanced cryptographic techniques guarantee that the source of transactions is legitimate and that hackers cannot steal cryptocurrencies in the network (Antonopoulos, 2014). The public key cryptography system works with a pair of keys: private and public. The public key is used to generate a public address that participants can use to receive and send funds. The private key is kept undisclosed and is used by a participant to sign a digital transaction to guarantee that source of the transaction is legitimate. Public key cryptography ensures the integrity and authenticity of a message (Antonopoulos, 2014). The following example illustrates how public key cryptography is used in practice:

> *Marlous wants to send a message containing 1 Bitcoin to Annika over an unreliable channel of communication, like the internet. Marlous uses public key cryptography to generate a private and public key. She posts her public key to Annika. Additionally, Marlous uses her private key to add a digital signature to her message to prove that she is the one who created the message. Annika can verify that Marlous created the message by comparing Marlous' public key in the message to the public key that Marlous has sent her. If the public keys match, Marlous can send the Bitcoin to Annika.*

4.5 Hash functions

All information on a blockchain is hashed, a form of pseudonymisation (Antonopoulos, 2014). Simply put, hashing is a mathematical procedure that transforms a data input, of any size (a *string*) into output data of a fixed length (a *digest)* (Antonopoulos, 2014). It does not matter if the input string is a single word, a sentence, or an entire book, the output is always of the same size. Figure 7 illustrates a hashing.

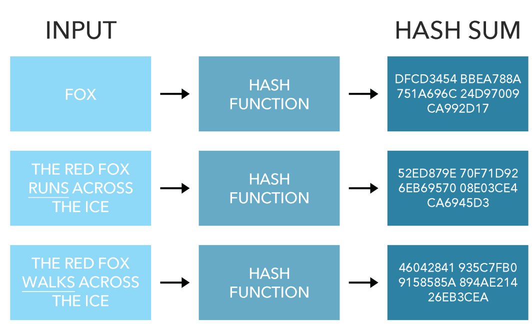

Figure 7. Hash functions

4.6 Mining

Once a transaction is signed by its owner, it waits to be added to the blockchain by so-called *miners.* The miner verifies that the transaction is authentic, making sure that the funds in the transaction have not been double-spent by validating all previous transactions in the blockchain (Antonopoulos, 2014). If the transaction is authentic, the miner includes the transaction into a new block of the blockchain, and the funds are sent from one participant's address to the other (Antonopoulos, 2014). The blockchain's protocol rewards the miners for creating new blocks—in Bitcoin's protocol miners receive bitcoins for each new block. This is what incentivises miners to perform the computational work needed to create new blocks in the blockchain.

5. Results

The consulted blockchain experts articulated 'guiding visions' for blockchain technology in the Dutch healthcare sector. These visions were discussed with healthcare stakeholders to identify benefits, disadvantages and concerns that might become barriers in the development and implementation of these visions. In addition, the healthcare stakeholders articulated desirable directions for the healthcare sector to show how blockchain relates to an ideal health system. All the collected data were analysed and structured. Section 5.1 presents the two identified visions: blockchain can make the healthcare sector more efficient (visions 1) and more personalised (vision 2). This section is structured as follows: First, the problem definitions are outlined with regards to the current state of technology. Subsequently, the desirable blockchain applications and the purposes they are envisioned to fulfil are described. Additionally, relevant contextual elements a presented for each vision that highlight how the envisioned applications relate to the healthcare context and how they might affect the position of certain stakeholders. In Section 5.2, the proposed barriers, their causes and how they might be overcome to achieve the articulated visions are described. Figure 10 and 11 and the end of section 5.1 and Figure 12 at the end of section 5.2 provide a list of the analysed codes that were used to construct the visions and identify to identify the barriers.

5.1 Guiding visions

5.1.1 Vision 1: *Towards a more efficient healthcare system*

Blockchain applications that are envisioned to make the healthcare sector more efficient allow a reduction in transactions costs and administrative process (Section 5.1.1.1) and allow a more effective exchange of electronic health records (EHRs) (Section 5.1.1.2).

5.1.1.1 Optimising administrative processes

Medical professionals (2 and 3) and health insurer (1) explained how they experience a lot of administrative pressure caused by political choices, regulations, health insurers, standards and protocols. In many cases, time spent on these administrative processes come at the cost of the quality of healthcare, as medical professionals have less time to treat their patients. Furthermore, administrative processes may result in other inefficiencies, such as delays in the information provision between stakeholders.

Desirable blockchain applications make the information provision in healthcare simpler, more efficient and more effective. In this vision, healthcare stakeholders participate in the same blockchain network, in which they share an immutable ledger containing all transactions that have occurred in the network. Since all participants share the same source of information, they have real-time transparency regarding the state of transactions. As the blockchain network ensures the integrity of the transactions without the need of trusted intermediaries, no administrative organisations are needed to validate the integrity of the transactions. This allows for efficiencies in healthcare, for instance, by reducing the time between issuing and receiving antibiotics or diminishing the transactions costs.

Consultant (3) articulated his vision as follows:

> *Ideally, I would visit my general practitioner and then my smart contract, which also includes my insurance policy, sends me a notification asking me if I visited my doctor—yes or no. Then, I will confirm that I did and, subsequently, automatic payment will occur. (consultant 3)*

Blockchain may be effective for financial settlements, because permission and authority rights can be programmed into smart contracts. Policy maker (1) and consultant (5) referred to such rights as *THAT*-information (i.e. *that* healthcare has been delivered or *that* a person has right to care or to a payment). In the aforementioned example, the only thing a person has to do is confirm *that* the person visited the doctor. Since that confirmation is stored on the blockchain, the health insurer, who also participates in the network, can see *that* care was delivered. The prices of GP visits can be programmed into the smart contact. Hence, automated payment can occur when a *that* condition (e.g., a confirmed GP visit by a patient) is met.

Policy maker (1) and a project manager (3) were actively involved in a blockchain-pilot that explored the *THAT*-principle for the administrative processes of hour registration in maternity care practice. Both respondents explained that blockchain contributed to a reduction in the administrative burdens and simplification of administrative processes in healthcare, for instance because a number of steps regarding data entry and control were no longer required. In addition, developer (3), manager (2) consultant (3) explained that the process becomes less labour-intensive, the system became less fault-sensitive and less susceptible to fraud because the information that is stored on the blockchain is immutable and transparent. Therefore, *"You do not need to check if 4 hours was truly 4 hours of work"*, according to project manager (2). He added that a similar pilot is conducted by the government of Amsterdam to optimise the registration and payment of personal health budgets (PGBs). Health insurers (1 and 2) explained that the fraud control is an immense challenge with PGBs, as fraud can go up to 20% of the total budget and is challenging to control. The health insurers were presented with the blockchain proof-of-concept for PGBs and showed significant interest in an application that could reduce fraud.

Consultants, project managers and developers emphasised how the *THAT*-principle can be used in various healthcare domains to optimise the information provision. The most frequently mentioned application by consultants was for optimisation of complex supply chains. Developer (3) illustrated this with an example of an IBM pilot in the harbour of Rotterdam that aims to optimise the supply chain of flowers that come from Africa:

> *Typically, 200 documents are involved in the transportation of flowers from Africa, which all need to be signed in a certain order, because otherwise A does not know if B has been done. In the past, this was coordinated by people who were calling and faxing all day long and who had to type things in. Because it's such a complex chain, all kinds of costs occur due to wrong information or unforeseen delays. So, if you can rationalise that away by letting all involved parties look at the same data, huge profits can be achieved. (developer 3)*

Developer (3) added that it was estimated that 'looking at the same data' could save the Dutch healthcare sector €1,2 billion a year in administrative costs. Additionally, consultants (1, 2, 4 and 5) and project managers (2 and 3) listed numerous healthcare applications for blockchain to optimise the supply chain, for instance, to track and trace medicines, sensors and devices (e.g., pacemakers), as it is valuable to know if and where falsification or mistakes occurred along the supply chain. The use of blockchain for a supply chain was discussed with pharmacists (2 and 3), who acknowledged the need for transparency between parties and saw opportunities for blockchain. Pharmacist (2) helped to draw Figure 8, which shows how blockchain could eliminate certain parties in the drug delivery process. Although blockchain could simplify the process, pharmacist (2) also raised concerns:

> *You can have this beautiful blockchain model, but you will run into problems. Many countries in Europe have different policies with respect delivering and picking up drugs. In Russia, for example, you need to collect your drugs yourself in the store. This blockchain model eliminates the retail manager and drug wholesaler, who are fundamental on the delivery side of the drugs. You need to have alternatives in line with regulations of different countries in Europe to get the drug to the patient, which is very complex per country. Moreover, you need to find a way to process and deliver individual orders. (pharmacist 2)*

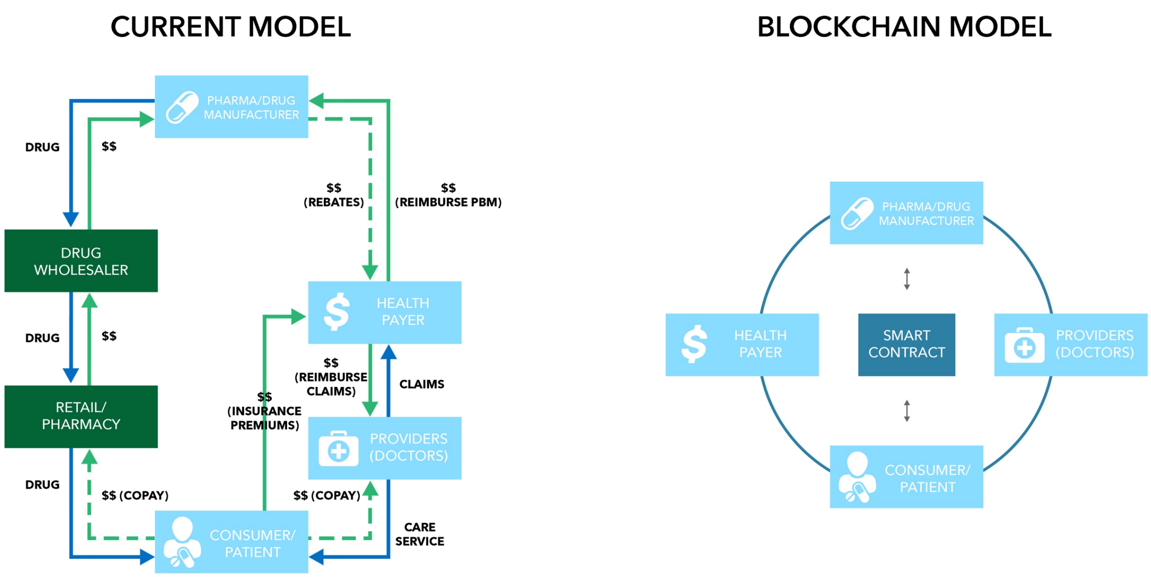

Figure 8. The current model for drug delivery in the Netherlands and the envisioned blockchain model.

5.1.1.2 Effectively exchanging electronic health records

At present, health data about patients is scattered over various healthcare providers that cannot easily share information about patients. If a patient gives consent, the LSP merges the patient's files so GPs, specialists and pharmacists can share a summary of the patient's GP file and a medication overview. Consultant (3) explained:

> *The LSP is like a dictionary or telephone directory which knows where your data can be found. These data can be collected and presented to you and to other care providers. Brilliantly thought of at that time, but utterly complex and very expensive. (developer 2)*

However, as medical professional (2) and consultant (3) explained, these files miss essential information, as the records of medical specialists, physiotherapist, dieticians, psychologist and private clinics are not included in the LSP documents. Besides these inefficiencies, medical professionals (2 and 3) experienced additional problems with the LSP. Only 35–40% of the Dutch patients registered for the LSP, which limited its effect. Medical professional (3) added that the LSP is regional, meaning that if a patient living in Utrecht needs emergency treatment in the Amsterdam, the LSP cannot provide information to healthcare providers in Amsterdam. All these inefficiencies can have dramatic consequences for patients, especially in emergency situations, when a patient might be unconscious, and doctors need to make decisions based on their instincts when no information about the patient is available.

Desired applications of blockchain allow the sharing of electronic health records between healthcare stakeholders. In this vision, similarly to the previous example, blockchain becomes a shared digital infrastructure between healthcare providers through which they can easily access all the medical files of a patient. Policy maker (1) and consultant (5) explained that blockchain can be used in the same way as with *THAT*-information for the exchange of EHRs, which they referred to as *WHAT*-information (e.g., *what* care has been delivered). According to policy maker (1):

> *In the maturity care case, only 'THAT-information' is recorded on the blockchain, for example that care has been provided. Via links in the same blockchain, there could be access to 'WHAT-information' (stored outside the blockchain in a hospital), for example, what care has been delivered. That WHAT-information is only accessible to those who have permission to do so. (policy maker 1)*

Consultant (5) and developer (1) highlighted that applications that will exchange *WHAT*-information might take significantly longer to achieve because they require the interoperability problem needs to be solved first. Developers (1 and 3) explained that the reason why it is currently not possible for one doctor to share a message with another doctor or understand the contact of the message (e.g., what happened to a patient) is because the computer protocols in healthcare are outdated and do not 'speak the same language'. This is also referred to as the issue of syntax and semantics and explains the integration and interoperability issues between IT applications. According to developer 1:

> *Interoperability is the hardest problem in healthcare. To many people are saying: "We will build a blockchain and then we will integrate it with hospitals". However, this "integrating with hospitals" is the problem, not using blockchain or smart contracts. Those are the last steps when you have everything else in place. (developer 1)*

5.1.1.3 Vision 1: Contextual elements

The desired blockchain applications may hold potential to not only change information provision in healthcare but also to change the positions of healthcare organisations, such as organisations that carry out administrative processes in healthcare. Currently, VECOZO is an organisation that offers a digital environment where parties can exchange administrative data. Consultant (3) explains that if all healthcare stakeholders would participate in the same blockchain, such an organisation would no longer be necessary as a trusted third party that ensures the integrity of transactions. Policy-maker (1) added that health insurers could become the unnecessary middleman:

> *Health insurers are large administrative factories, which have become very powerful. We have given them that power. With new technologies, such as blockchain, we can decrease their power. I mean, if I am entitled to 1,5-hour home care from the government, the only persons who truly know if I received that care are my healthcare provider and me. Why do we have to attach conditions to that? (policy maker 1)*

All respondents who shared this vision and explained that ultimately the patient and the care provider are its beneficiaries. Not only could these blockchain applications make the healthcare sector more efficient, they can also increase the quality of healthcare. Healthcare providers can provide better healthcare in such a future, as they will always have relevant information of patients within their reach. This could save lives in case of an emergencies. Additionally, the respondents explained that the entire healthcare sector will profit from advances in blockchain technology, as the system may become less fault-sensitive, less susceptible to fraud and less labour-intensive.

Healthcare provider (3) added that pharmaceutical companies might be the losers of more transparency as they will have less power to influence drug prices. Additionally, some organisations may have to fundamentally shift their business models. Consultants (2 and 3) emphasised that the businesses of large EHR developers, such as EPIC and ChipSoft, may be jeopardised by blockchain's implementation. These software incumbents would need to build portals that allow healthcare providers to share information with other medical stakeholders in the blockchain network. Consultants (2 and 3) predicted that these software incumbents will either resist or react too late when blockchain becomes the new standard for information exchange.

Respondents imagined various scenarios about how, and by who, the healthcare blockchain may be developed. Policy maker (1) and project manager (3) envisioned a situation where the Dutch government builds a single public blockchain network which all citizens can use to exchange health data. Another consultant and project manager imagined a future with multiple private blockchain initiatives that can communicate and exchange information with each other.

5.1.2 Vision 2: *Towards more personalised healthcare*

Blockchain applications that are envisioned to make healthcare more personalised allow patients more autonomy over their health in terms of more control over health data (Section 5.1.2.1) and make automated decision-making in prevention and goal-oriented healthcare more effective (Section 5.1.2.2).

5.1.2.1 More autonomy in the health system

Currently, patients barely have any control over their health data. As data are fragmented over all the healthcare providers the patient sees, the healthcare providers still physically own their data. Patient (4) explained that as a result, they have to transport their health data from one healthcare provider to another on CDs or they have to re-take their medical pictures every time they visit new healthcare institutions. Patients (8) added that it took more than two years to transfer all his health data from one hospital to another. Policy maker (1) explained that healthcare providers use impractical and expensive software to store medical data and that this software was not designed to share information with patients. As a consequence, it is practically impossible for patients to see a real-time overview of their health data and they have little control over who has access to it.

The GDPR is potential driver for patients to gain more control over their health data. Policy maker (2) explained that the Dutch patient federation, medical professionals, health insurers and the Dutch government have joined forces to give patients more control over their health data by developing the MedMij program, which provides a set of requirements for personal health records, or persoonlijke gezondheidsomgevingen (PGOs). Policy maker (2) explains that MedMij's goals is for all patients to have a PGO containing all their health data. The idea is that electronic health record developers, such as EPIC and ChipSoft, become MedMij-certified by building portals that allow data sharing with PGOs. These portals would allow healthcare providers that use her software to share information with patient's PGOs. However, MedMij does not ensure a better information provision between healthcare providers. As policy maker (2) explains:

> *You still cannot not take your photos from one hospital to another. MedMij is not going to improve that, but if I have my photos from hospital A and I am sent to hospital B, I have my photos in my PGO and I do not have to go through radiation again because I can show my images with my phone. (policy maker 2)*

Desirable applications of blockchain technology allow exchange of EHRs to PGOs and vice versa between different healthcare providers and patients. Patients are envisioned to determine who they share information with. They can manage permissions using their public key in combination with their digital signature, granting care providers access to their medical data (Figure 9). In this vision, patients receive notifications when healthcare providers want to see information in their PGO or if they want to use their data for research. Hence, patients gain full control over their health data. Such blockchain applications would allow patients to give permission to a particular stakeholder temporarily, for example, patient X, who is receiving treatment in hospital B, can provide hospital B access to his files. Policy maker (1) explains that this could be useful, for instance, when a patient forgets medicine when travelling abroad:

How easy the world could be… Back home I receive medicines from three different pharmacists, who are all friends in my blockchain network in which I can see and manage everything. Now, I forgot my medication on an island somewhere abroad and I can make the local pharmacist member of my blockchain network. He can then take a look and order my drug. Once I received my medication, I can withdraw that authorisation again. (policy maker 1)

Developers (1 and 2) added that that patients could financially be rewarded for their data. For instance, their data can be exchanged for tokens, which, similar to bitcoins, have monetary value. Hence, blockchain is envisioned to build its own economy for the exchange of health data.

Pharmacists (1 and 2), health insurers (1 and 2) and developer (3) additionally envisioned an ideal health system where patients becomes more informed and take a more active role in their health. The health insurer envisioned a future where patient make their own decisions with respect to their referrals and choosing the hospitals where they will receive treatment. Both pharmacists also regarded a future where the patients have more control over their healthcare as desirable. As pharmacist (1) explained:

Knowledge and responsibility are often confused. "I have no idea" does not mean that you have no idea. You also have no idea how a car is put together, but you can drive it. The same applies to medicines: "I have no knowledge about my medication" but you use them. You become responsible for something that you do not understand, which is fine, as long as someone with expertise has checked that it is ok. (pharmacist 1)

Figure 9. Managing permissions on a blockchain.

LOGBOOK						
DATE	IDENTITY	LOG	PERMISSION			
01/01/2018	MPAX	QRIKJSPRJQORTZXJHSZ	✓	✗	✗	✗

Developer (3) emphasised that blockchain could be a tool to give patients control over more than just their health data. He envisions blockchain as fundamental backbone for a transition to a complete self-service system, where patients determine everything regarding their health. As he explains:

At the moment, the medical specialist is currently central in the process of a patient receiving care, as a patient can receive care when the specialist is available and if the hospital has the right resources. Ideally, on-demand healthcare can be built on top of the blockchain network. Like Netflix, you meet the conditions and have access *to healthcare independent of time and location, or even of the specialist. That would be the holy grail of blockchain. (developer 3)*

Patients were asked about their desire for a PGO or more control over other aspects of their health. Patients (3, 8, 20 and 31), who found a PGO desirable, explained that it would be necessary feature to give other people, like a partner, permission to access their health files. Patient (9) experienced a difficult situation when her partner suddenly died, and she was not allowed to access to access his savings, because she did not have permission. Additionally, Patients (5, 8, 11 and 20) were concerned with the privacy of a PGO, especially for younger people:

Look we are old, so it does not really matter. But young people have their whole lives ahead of them. If their health information leaks to health insurers or potential employers that could have dramatic consequences for their future. (patient 5)

On the contrary, patient (30) worried about having to give permission every single time a healthcare provider wants to use their health information for research. This patient would rather give permission for this all at once.

5.1.2.2 Prevention and goal-oriented healthcare

Policy maker (2) explained that 10% of the current Dutch GDP is used for healthcare. Healthcare provider (1) and health insurer (1) worry about keeping the cost of healthcare stable as people become older and sicker in the current health system. Healthcare provider (1) added that chronic care currently accounts for 40% of the total healthcare costs but will rise to 60% within the next 10 years. To accommodate this increase, fundamental changes are needed in the healthcare sector. Healthcare provider (1) explains:

Our current system is still built for providing acute care—we have someone with a problem, we look after him, we solve the problem, and we send him home. Now it is the case, however, that people always have to come back because they have chronic problems and we have become better in treating them. (healthcare provider 1)

An ideal health system, according to all healthcare providers, provides 'the right care in the right place'. To achieve such a system, healthcare providers aim to streamline hospitals in the Netherlands based on quality differences. For example, as health insurer (2) clarified, it is not necessary to have two hospitals in the province of Groningen with intensive care units. Additionally, all healthcare providers work on scalable models that make care independent of location. For instance, they could provide care with artificial intelligence and telecommunication technology, which equip patients with mobile devices and sensors at home. These systems may monitor and advise patients and are important for making care delivery more efficient and effective. As healthcare provider (1) explained:

If you now have high blood pressure, the doctor helps you and gives you medication. If you then come back to the doctor and say: "my blood pressure is still high", it will cost two hands again. So every step you can automate means that two hands fewer are needed, and we (healthcare providers) are short of hands. (healthcare provider 1)

Policy maker (2) added that 80 billion of the healthcare costs are spent on supporting and treating patients, instead of concentrating on the onsets of symptoms that lead to medical complications. Consultant (5) added:

Now the focus is still on fighting the disease. Instead, we should be asking: What are the goals in your life? What is your quality of life? What functionalities do you need to improve your quality of life? Because a certain disease is different for someone who is 35 and an athlete than for someone who is 83 and near the end of life (consultant 5)

Healthcare providers (1 and 2), policy maker (2) and consultant (5) explained that telemedicine technologies not only allow more effective care at home but could also contribute to prevention and making care more personalised. Home devices and sensors collect a lot of data about a person's lifestyle and indicate how a person can stay healthy. Healthcare providers (1, 3 and 5), developer (3) and health insurer (1) added that, through collecting this kind of data, care could be adapted to the demand or need, which would be a great step to make the health sector more efficient. Healthcare provider 5 predicted:

We will see more collaborations with surrounding care providers. The walls will become much less visible. In the ideal world, we have a multidisciplinary consultation about a complex process at the patient's home at the kitchen table, where we are virtually present instead of getting everyone to the same location. Those two days a year, in which the patient is in the hospital, are so important that it has to be with us. (healthcare provider 3)

Desirable applications of blockchain enhance efficiency in the information provision between wearables, sensors, and the patient's PGO and healthcare stakeholders. All these data can be used for automated decision-making in prevention and creating specific goal-oriented plans per patient. In this vision, blockchain's secure design becomes the foundation on which various applications, such a telemonitoring applications, can be built and allow information exchange between all relevant stakeholders. Consultant (5) envisioned a future in which care providers could intervene earlier in case of medical complications, because patients are monitored with sensors and wearables, which could prevent them from having to go back to the emergency room. Additionally, health insurer (2) saw value in the collection of new data about the quality of life of a patient three to six months after a medical procedure (e.g., a bypass operation), which can be safely shared with various medical professionals, such as pharmacists (1 and 2), who indicated that they could make better medicine for patients when real-world evidence could be easily shared by them. Pharmacist 2 clarified:

Scientific evidence backed up with real-world evidence, would be ideal. One patient will say that he prefers to take medicine once a day, while other patients will prefer to take their pills twice a day because they brush their teeth twice a day. We could even develop new business model, for instance, if a drug does not work for a patient he will get a refund. All kinds of new models could be explored if we can effectively exchange health data. (pharmacist 2)

Hence, the blockchain infrastructure supports the transition of making healthcare more personalised, for instance, creating a health plan based on the goals of the patients. Developer (2) added that monitoring people with sensors and wearables may lead to people changing their lifestyles in a more positive way, because they know they are being monitored.

In every focus group there was consensus among patients that regarded algorithm decision-making in prevention and telemedicine for better diagnoses is desirable in many situations unpreventable in the future. Some were concerned with the usability of sensors and devices at home (patients 20, 25 and 30) and the lack of evidence for their benefits (patients 12 and 17).

5.1.2.3 Vision 2: Contextual elements

Artificial intelligence (AI) applications working on top of blockchain could change certain power structures in healthcare. The first two sections explained how large centralised organisation, such as VECOZO or the LSP, might become unnecessary third parties if blockchain becomes the new standard. A medical professional explained that if we move towards more personalised healthcare, other large organisations might also be affected, such as Zorgmail, or 'Caremail' (a secure mail function to communicate with healthcare providers) and Zorgdomein, or 'Caredomain' (a digital platform where care demands meet care supply). Developer (3) explained how these large centralised organisations have a monopoly position on communication in healthcare, similar to the LSP and VECOZO. For example, all GP referrals go through ZorgDomein. If the patients become the centre of their health with on-demand access to healthcare independent of location, they choose where they receive treatment instead of the GP. Hence, ZorgDomein may no longer be needed. In addition, all healthcare providers explained how algorithms are taking over tasks of healthcare providers.

Patients (1 and 2) were concerned that technology might become dominant over person-centred care. They favoured a communication route with optimal use of digital applications in combination with in-person contact with a healthcare provider. While developer (3) saw the replacement of healthcare with technology as a holy grail, none of the consulted healthcare providers felt that digital health would jeopardise their position. Health provider (3) explained that shifts will occur, but this will only contribute to common goal: *"the right care in the right place"*. Healthcare providers (4 and 6) explained that they see themselves in the role of coaches in the future, supported by A.I. devices. They explained that these devices may be better in determining, identifying and assisting patients in many situations, for instance, because they can research literature banks in an eye blink. However, none of the healthcare providers felt that computers will fully replace their function. Healthcare provider 6 explained:

I do not think that a computer could run a complete consultation hour. If you ask it: "What is the best treatment for this a very specific tumour?" Yes, it will you a quick accurate answer, because the question is focussed. However, if you tell it: "I have a headache, help me," the computer must be able to analyse all the problems that can cause a headache, which won't be effective. (healthcare provider 6)

Figure 10. Coding table vision 1: Effective healthcare

By	Quoted statement	Structual code (first order concept)	Catergory (second order concept)	(sub)theme (axial code)	Main theme (vision)
HP1	De werkdruk is te hoog. Dat komt omdat die EPD-systemen veel meer tijd vergen dan wat we vroeger deden. Daar komt dat door. Alles wat er extra bijkomt wordt afgewend op de dokters. Er is zijn niet extra personeelsleden bij gekomen om dat te compenseren.	Adminstrative pressure	Problem definition	optimising adminstative processes	Efficient healthcare
HI1	Het probleem in Nederland is dat wij alles georganiseerd en gecontroleerd willen hebben. Met blockchain moet je zoveel dingen omgooien dat gaan we hier in Nederland doen. Heel veel regelgeving en administratieve processen	Strict policy and adminstation load			
HP2	Wat dokters doen is het ze proberen een papieren dossier, een werkwijze die er al 100 jaar is na te bootsen in het EPD. Ze vinden het een administratieve last	Adminstrative pressure			
HI1	Wat nu met PGBs gebeurd is heel veel fraude. Zit een netwerk achter. 20 % is fraude.	Fraud in PGBs			
HI2	PGB rechtszaak hebben wij ook gehad. We kijken ook naar fraude doen we veel onderzoek naar.	Fraud in PGBs			
C4	evidence trail voor het gebruik van medicijnen. Volgen van medicinen bijvoorbeeld.	Supply chain efficiency	Purpose to fulfill		
M2	Foutgevoelig, fraudegevoelig, arbeidsintensief dat hoeft allemaal niet meer met blockchain. Je hoeft niet meer te controleren of 4 uur ook daadwerkelijk 4 uur is geweest. Als mensen een half uur fraude per dag plegen, wat een enorme besparing zou dat opleveren	Fraud prevention			
PH2	Je hebt de Falcified medicine Act binnen Europa willen we totale trial vanaf de band tot aan de patiënt. Die is niet op een blockchain gebouwd. Blockchain zou daar bijzonder geschikt zijn.	Supply chain efficiency			
PM1	Dan zie je ook dat kan op alle domeinen. Het kan ook voor PGB.	Blockchain for PGBs			
M2	Budgetten PGB wordt ook naar gekeken is ook interessant want je krijgt een PGB voor het inkopen van zorg, maar je wil wel zeker weten dat het daarvoor wordt gebruikt dus wat je kan doen is werken met geoormerkt geld	Blockchain for PGBs			
C4	Dat zou voor mij een ideaalbeeld zijn, dat als je bij een huisarts bent geweest, dat je van je smart contract, dat tegelijkertijd ook je polis is voor je verzekering, een berichtje krijgt 'U bent bij de arts geweest klopt dat ja of nee?'. Dat je dan zegt 'ja dat klopt, nee dat klopt niet'.	Automatic payment doctor visit			
PM1	Wij hebben in eerste instantie gekeken naar bestaande processen. Zo lopen de hazen in het veld. Als je daar nou informatie over levert. DAT er is geleverd. DAT is er aangebracht ect. Dat ben je er	THAT-information storage			
C5	WAT informatie en DAT informatie. De transacties zijn interessant om van elkaar te weten dat scheelt veel administratie en daar wordt het onweerlegbaar door wat niet onbelangrijk is binnen de zorg. Dat wil je er op zetten	THAT-information storage			
D4	Een heel mooi voorbeeld is onder andere IBM maar ook in de haven van Rotterdam hebben ze als voorbeeld genomen in Afrika worden steeds meer bloemen verbouwd rozen en daar onderweg veel mis	Supply chain efficiency			
C5	Verschillende supply chain processen in medicatie. Je wil zeker weten dat je pacemaker doet wat hij moet doen. Dat is wel prettig op stap voor stap te verifiëren. We hebben ook intern allerlei processen die supply chain geregeld zijn. Dat er geen gaasjes achter blijven in mensen.	Supply chain efficiency			
D3	Daar wordt naar schatting 1,2 miljard bespaard omdat mensen naar dezelfde data zitten te kijken. Dat is een van de dingen je met blockchain achtige constructie laten we er nou voor zorgen dat de partijen in de keten het over dezelfde data hebben	External administrative efficiency			
C2	bloed is ook een dingetje. Met transport gaat wel is was mis met barcodes enzo. Lullig als iemand het verkeerde zakje krijgt.	Supply chain efficiency			
C1	Wat ook nog een belangrijke is en die linkt wat minder aan hele directe zorg is supply chain. Transparantie door de hele keten, dan kijk je meer naar de farmacie. Het tracken van implantaten dat je daarvan de registratie op de blockchain zet. Datzelfde zou je natuurlijk kunnen doen met medicijnen.	Supply chain efficiency			
HP2	Dat zou voor mij ideaal zijn. We hebben zo veel administratief personeel voor interne verrekeningen. Dat zou interessant zijn	Internal administration efficiency			
D4	De kliniek moet op papier wat invullen eens in de zoveel tijd worden die papier naar een medical officer gebracht die moet het laten intypen en dan zoveel maanden later is het op het hoofdkantoor en kunnen ze zeggen tegen de financier doe ons zoveel geld.	Fraud prevention			
C4	alles wat met betalingen te maken heeft en daarmee dus fraudecontrole	Fraud prevention			
M2	De medische sector is enorm complex, enorme administratieve organisatie. In de zorg en met name een hoop te winnen door het vereenvoudigen van processen. Je ziet dit in het kraamzorg voorbeeld.	Maturity care blockchain pilot	Current state		
PM1	kraamzorg zijn er ook permissies. De aanbieder gaat niet betalen bijvoorbeeld. Iedereen heeft een aantal rollen elke kant op. Permissies kan je dus van tevoren bedenken. Je koppelt digitale identiteit en permissies. Dat staat op een blockchain.	Maturity care blockchain pilot			
PH2	You can have this beautiful blockchain model but you will run into problems. Many countries in Europe have different policies with respect delivering and picking up drugs. In Russia for example, you need to collect your drugs yourself in the store.	Finding good alternatives	Concern		
HI1	Terwijl dat ene landelijke EPD wat eigenlijk er min om meer doorheen was. Ik denk dat als dat al was geweest dat al die digitale vragen die er nu zijn al veel eerder had opgelost dus dat een punt waar wij heel veel last met elkaar van hebben.	Interoperability	Problem definition	easily exchanging EHRs	
D1	And this is only the beginning. If you have two doctors that want to exchange patient data or if you want a patient to be able to aggregate data from different hospitals or this type of thing, then you need to be able to solve the interoperability problem	Interoperability			
C2	Je krijgt alleen niet alles (psychologische informatie) maar wel alle medische informatie. Onwijs complex, briljant bedacht, maar ook heel duur.	LSP incomplete data			
HP2	Probleem is dat maar 35% van de patiënten zijn aangemeld. 60% van de patiënten komt buiten regio Noord-Holland en meldt zich aan bij ons. Wij moeten voor paar honderd duizend euro apothekersassistenten gaan inhuren.	LSP limitation			
D3	Taalbarrière heb je. Je kan informative wel uitwisselen. Standaardisatie van 4.0 FHIR is nog niet voldoende doorgevoerd.	Interoperability			
D1	Ok, we build this blockchain and yeah we will integrate it in the hospitals. But this 'we will integrate it with the hospitals' is the hardest of everything.	Interoperability			
PM1	De achterliggende informatie is WAT informatie. Dan leg je het weg. Dat staat niet op zichzelf want dan kan met digitale identiteit op blockchain doorstapelen op achterliggende gedachten	WHAT-information exchange	Purpose to fulfill		
C5	Toen kwam het inzicht dat blockchain wel zeker iets kan betekenen m.b.t. PGOs. Wij hadden een EPD waar de patiënt toegang tot krijgt. Bij PGO is het omgekeerd en krijgt de patiënt de regie en krijgen instelling daar toegang toe.	WHAT-information exchange			
C4	Dat betekend dat er partijen geofferd moeten worden; de VECOZOs van deze wereld worden overbodig in basis. Je kan zelfs nog zo ver gaan of je nog een ketenregisseur nodig hebt een andere partijen	Losers	Contextual element		
PM1	Zorgverzekeraar bepaalt hoe jij en ik moeten kakken. Zijn grote administratie fabrieken die kunnen worden afgebouwd met dit soort technologieën.	Losers			
C2	Er zijn alleen maar winnaars. En dat zijn alle patiënten.	Winners			
M2	De grote winnaars zijn in mijn ogen de patiënten, maar ik vind het lastig om te voorspellen het zou ideaal zijn maar we weten het niet	Winners			
MP3	De winnaar zijn de patiënten	Winners			
C2	Het LSP is een soort woordenboekje, telefoongids, waar precies in staat waar data vandaan komt en waar het vinden is. Dan wordt het allemaal opgehaald en verzamelt en aan jou gepresenteerd. Zit identificatie en authenticatie overheen.	LSP explanation	Current state		
C5	Bestuurders en inhoudsdeskundige achter het is een visie voor over 20 jaar. Of blockchain dan de technologie is weten we niet	WHAT-information exchange			
C1	Nou ik denk wel de partijen die heel erg vasthouden aan de tijd van vroeger. Dus heel erg op eigen database blijven zitten, weet je, je moet uiteindelijk dingen gewoon open gaan gooien, en partijen die ook daar conservatief in blijven, dat zijn denk ik wel de verliezende partijen	Losers	Contextual element		
MP3	Als er meer transparantie is er op een andere manier winst gemaakt moet worden. Kijk ik snap heel goed dat om iets te ontwikkelen dat het veel geld kost	Losers			
C3	Epic & Chipsoft worden mogelijk End-of-life in een blockchain toekomst.	Disruption of power			
C1	Ik denk wel dat op termijn en EPIC en Chipsoft gewoon doorgaan en de oogkleppen dicht doen, dat dat op een geven moment niet meer niet meer goed gaat	Disruption of power			
M3	Dat er een blockchain is daar met zijn allen gebruik van kunnen maken om de hele administratieve processen optimaliseren. In zo'n ideale situatie zou natuurlijk ook mooi zijn als er een financiële blockchain komt dat zijn natuurlijk ideaal zijn als je een hoop extra werk..	blockchain initiators			
PM1	Wat nou als die overheid gewoon 20 nodes in het land plaatst en dat jij op dat platform gewoon je blockchain mag draaien. Dan hoeven al die andere deelnemers geen node meer te draaien. Waarom zou je dat niet doen?	blockchain initiators			

Figure 11. Coding table for vision 2: Personalised healthcare

Nu hangt het nog te veel af van wanneer de speciliast tijd voor jou heeft. Met blockchain zou je dit kunnen veranderen.	Dependent on specialist	Problem definition	Autonomy patient in health	Personalised healthcare
Ik heb wel voor het dan maar elektronisch was heb ik vier weken in het VU ziekenhuis gelegen en alle gegevens van de onderzoeken die er waren zaten daar in mijn patiëntendossier. Het heeft het tweede half jaar geduurd voordat die hier in het AMC was, 2,5 jaar	Data fragmentation			
We stimuleren in Nederlands dat zorgorganisaties een hek er om heen zetten en vooral goed voor zichzelf zorgen soms ook voor de burger maar dat is pas in tweede instantie en zich onderscheiden van een ander omdat we marktwerking in de zorg wi	Data fragmentation			
Cd'tje raakte de mist in en ik hoor helemaal niks. Toen raakte ik met je vader in gesprek. Ik zei nou toch eens kijken wat er aan de hand is want ik weet van niks. Uiteindelijk komt na een paar maanden het cd'tje boven water	Data fragmentation			
Medicatie bij 7 apotheken maar daar ben ik vriendjes mee met de blockchain ik kan het allemaal zien. Wat zou het handig zijn als ik op Vlieland mijn medicijnen ben vergeten. Ohja ik maak jouw even lid van mijn blockchain	Invite people to blockchain	Purpose to fulfill		
Mensen, in dit geval patiënten, kunnen via de blockchain zelf bepalen hoeveel schakels zij vertrouwen	Determine who to trust			
Nee maar dat zit met die machtigingen, wat u zegt dat is even iets maar ik denk dat dat niet opgelost kan worden met maar 1 machtiging. Want de andere kan op vakantie zijn of je partner kan in het ziekenhuis liggen of weet ik veel wat allemaal, als die informatie snel beschikbaar moet zijn hè.	Specifc permission			
Daar gaat MedMij in de basis niet iets aan verbeteren maar het gaat straks wel zo zijn als ik over mijn foto's beschik van ziekenhuis A en ik word naar B gestuurd en ik heb het in mijn PGO staan kan ik zeggen ik wil niet nog een keer die straling oppakken want ik heb hier gewoon mijn beelden	MedMij	Current state		
ancer was discovered simply because the patient donated her blood sample. I do not remember what she donated exactly but blood of his woman was used for the cure. Again this woman was not credited, was not compensated and the company made millions and millions of euros	Tokens for data	purpose to fulfil		
So basically all the blockchain solutions in healthcare that I've seen and read about are saying the same thing: data transfer for tokens. Okay the patient sends his data to the researchers and receives some tokens	Tokens for data			
Als de patient centraal staat moet hij ook een regisserende rol krijgen in zijn gezondheid. Dat ik een vraag stel aan de patiënt klopt het en dan staat er cardiologie en moet ik ergens een dokter krijgen die patiënt heeft gezien	More responsibility patient			
Hetzelfde geldt voor geneesmiddelen: 'Ik heb geen kennis van geneesmiddelen maar uiteindelijk moet je wel gaan gebruiken'. Uiteindelijk wordt je verantwoordelijk voor iets dat je niet begrijpt. Dat is prima, want er zijn heel veel dingen die ik niet begrijp	More responsibility patient			
Echt heel ver weg denkend dat jij gewoon zelf bepaald waar je zorg gaat consumeren. De huisarts heeft nu die rol, als verwijzer.	More freedom in referrals			
Dus als jij nu een vliegticket boekt kan je bij elke maatschappij elke stoel selecteren maar een plek in de spreekkamer die ook van te voren gepland wordt want een arts heeft al zijn schema's allang vastgelegd is niet toegankelijk sterker nog bij het AMC krijg je een brief rond deze tijd moet u verschijnen	More freedom in referrals			
self-service system kunnen gaan. Een soort Netflix voor de zorg. Je voldoet aan bepaalde criteria. Je registreert eenmaling end an kan je zorg krijgen onbeperkt onafhankelijk van tijd en ruim	More freedom in referrals			
maar als je een tweede persoon aangeeft zeg maar je hebt een man met een partner, ik heb een man, als die degene is die daar toestemming voor zou geven zeg maar dat denk ik Ja dat lijkt me wel wat.	Specifc permission			
en dat als er wat mis is dan kan ik daar een arts aanspreken of mijn partner of wie dan mee is. En dan kan ik zeggen dit is mijn dossier, ik voel me niet goed,help	Specifc permission			
Ja zoals het hier staat ben ik wel voor het PGO maar niet dat ik elke keer toestemming moet geven, daar ben ik niet voor.	Specifc permission	Concern		
Kijk naar wat er gebeurt is met de juffrouw met de naam Barbie Ik ken er niet maar in het ziekenhuis waar zij gelegen heeft zijn er iets van 56 of 57 mensen geweest die in haar dossier hebben gekeken	Privacy & Security			
Als een patiënt dus dat dossier in de cloud opslaat en die patiënt heet toevallig Barbie of iets vergelijkbaars dan een heel verhaal over gehackte Cloud dossiers, dus dat is wel iets waar je goed bij na moet denken.	Privacy & Security			
Dat is toch laatst nog in het nieuws geweest dat bij ziekenhuis zijn er mensen gewoon nieuwsgierig naar wat je hebt.	Privacy & Security			
Denk aan onze eigen leeftijd u bij de ben nog jong staat aan het begin van je carrière en die staat nog aan het begin van die op PGO als daar iedereen zomaar in kan kijken dan zal de verzekeringsmaatschappij zeggen van die meneer daar komt in de toekomst in hoge kosten.	Privacy & Security			
Mijn man is onverwacht overleden en zijn telefoon was met een code en die wist ik niet, maar ik moest er in	Specifc permission			
We geven 80 miljard uit aan ondersteunen en repareren. Terwijl ik denk dat we de meeste interventies mensen zicht geven op hun gedrag op het uiteindelijke ontstaan van ziekte	High costs	Problem definition	Prevention	
Ik zie echt wel een grote kentering dat zie je nu ook dat we met zijn allen zien we hebben niet meer het geld, we geven nu al 10% GDP aan zorg uit, eigenlijk wil je dat dat niet verder gaat	High costs			
Chronische zorg is nu ongeveer 40% van de kosten maar dat wordt binnen nu en 10 jaar 60% van de kosten van de zorg. Dat betekent dat er schaalbare modellen nodig zijn.	Increase chronic care			
Ons huidige systeem is nog steeds gebouwd op acute zorg; we hebben iemand met een probleem, die kijken we na, dat lossen we op, en die sturen we naar huis. Maar nu is het geval dat mensen steeds terug moeten komen omdat ze chronische problemen hebben	Increase chronic care			
Het gaat om een twee weg gegevens niet alleen je fitbit maar je je ziet natuurlijk steeds meer dat chronische patiënten ook met tele-monitoring rond lopen denk aan hartfalen die gegevens worden aan de kant van je PGO vastgelegd die moeten ook weer je systeem in kunnen.	automated descision making	current state		
Wij willen steeds op een hoger niveau standaardiseren en protocollen maken. We hebben nu een bepaald niveau van intelligentie en automatisering. Wat je eigenlijk wil is dat het systeem steeds meer zelf leert en steeds meer gepersonaliseerd wordt en dat je per patiënt optimale keuzes kan maken	automated descision making			
Het blijkt dat men inmiddels vanuit de data op dit moment al voor 80% juist kan voorspellen of dit kind de komende week of maanden rustig is. Dat geeft het kind weer iets terug in een soort visueel iets dat ze kunnen zeggen, net als een buienradar je hebt 80% kans dat het droog blijft.	automated descision making			
Je kan zien dat mensen hun gedrag ook gaan veranderen als ze thuis gemonitord worden via telemedicine.	telemedicine			
Als je nu hoge bloeddruk hebt, dan denkt de dokter met je mee, en geeft je medicijnen. Als je dan je weer terugkomt 'dokter mijn bloeddruk is nog steeds hoog' kost dat weer twee handen. Dus elke trap die je kan automatiseren betekent twee handen minder aan de patiënt en we komen handen te kort	A.I.			
In de ideale wereld hebben we een multidisciplinair overleg over een complex proces, bij de patiënt thuis aan de keukentafel, waar wij virtueel of niet mee bezig zijn in plaats van dat we iedereen hier halen	Virtual consults	Purpose to fulfill		
self-service system kunnen gaan. Een soort Netflix voor de zorg. Je voldoet aan bepaalde criteria. Je registreert eenmaling end an kan je zorg krijgen onbeperkt onafhankelijk van tijd en ruimte.	On demand home care			
Want er zitten ook wat automatische triggers in nu al een soort persoonlijke alarmknop dan krijg je een telefoniste aan de lijn en wie ze dan moet bellen. Dat kun je automatiseren. Stap 2 is sensoren en wearables aanbieden zodat er op afstand gemeten kan worden en dan eerder ingrijpen.	automated descision making			
terwijl dat hele basale kwaliteitsinformatie is bijvoorbeeld wie er nog leeft 3 tot 6 maanden na een bypassoperatie. Toen dacht ik waarom heb ik dit nergens op een wat eenvoudige manier op blockchain vastgelegd	After care			
Basis van de evidence die er is op dit moment ondersteund met real world evidence, vinden wij dat deze patiënt dat product nodig heeft. Factor prijs komt er ook bij. Arts houdt op bij geneesmiddel categorie. Het laatste stuk welk geneesmiddel voor de patiënt uiteindelijke gebased op zijn leefstijl.	Personalised medicine			
je bent ziek dus je gaat naar een arts en die vraagt naar de problemen en symptomen en die gaat dat bestrijden en de bron ziekte weg te nemen, in plaats van te vragen; wat zijn de doelen in je leven? wat is voor jouw kwaliteit van leven? wat heb je daarvoor nodig qua functionaliteit?	Personal health plan			
e hele chronische zorg moet bij mensen thuis plaatsvinden en de zorg zal meer aangepast worden op de vraag of behoefte op wat wij denken aan te bieden. Dat zou het ideale concept zijn dat de zorg wordt aangepast op de vraag, bij de mensen thuis, on-demand en schaalbaar.	On demand home care			
de holy grail zou zijn dat je de specialist kan vervangen door technologie	automated descision making			
De kwaliteitsverschillen die er zijn en de discussie die daarover loopt ook nog veel breder moet zijn en kunnen uitwerken voor het algemene publiek. Dat wij wel of niet een gespecialiseerde intensive care in noordoost Groningen nodig hebben.	High costs			
De eerste zorg is dat de technologie dominant wordt ten opzichte van de persoonsgerichte zorg, dus je zult er bijna altijd en communicatie route hebben van optimaal gebruik van ehealth in combinatie met de persoonsgerichte zorg.	automated descision making	concern		
Maar ik denk dat werkgevers. De huisarts kan ook een coach zijn in plaats van allen maar beoordelen of iemand door gestuurd moet worden. Doet hij natuurlijk niet. Dat coachen doen ze ook al. Maar het zal nog meer die kant op gaan	coaching role	Contextual element		
Een heleboel vakken gaan verdwijnen dat wij veel meer coaches worden dat je veel meer met de beslissing in de hand met de patiënt samen bedenkt wat voor de patiënt het fijnste is. Dus ik denk dat die hele medische opleiding moet ook echt veranderen.	coaching role			
Nu hangt het nog te veel af van wanneer de speciliast tijd voor jou heeft. Met blockchain zou je dit kunnen veranderen. Organisatie als zorgDomein en Zorgmail zou je onder druk kunnen zetten, precies op dezelfde manier als met het LSP. De macht gaat terug naar de patient.	Disruption of power			
Hoeft hij niet naar het ziekenhuis te komen als dat niet nodig is en zit de dokter in een coachende rol die technologie in kan zetten om een patiënt in zijn eigen omgeving te beoordelen en te behandelen.	coaching role			

5.3 Management of barriers

Visions 1 and 2 showed how blockchain's digital ledger may stimulate a better information provision between healthcare stakeholders while giving patients more control over their health. While the principle of blockchain worked the same in both visions, some of the envisioned applications (financial settlements, exchange of EHRs, PHRs and automated decision-making) will be more difficult to achieve than others. Currently, the same principles of hour registration and payments in the maturity care case (Section 5.1.1.1) could be expanded to other cases as well, such as for PGBs or supply chain optimisation. Connecting EHRs to blockchain, on the other hand (Sections 5.1.1.2 and 5.1.2.1), is more challenging to achieve, because it requires the coordination of various healthcare providers (e.g., GPs, pharmacist and specialists) and therefore may take longer.

The consulted blockchain experts and healthcare stakeholders mentioned various barriers that need to be overcome to achieve the desired applications. The barriers were structured in three categories: technical (Section 5.3.1), organisational (Section 5.3.2) and societal (Section 5.3.3), although there was overlap between them. For instance, integration and interoperability of IT applications, a fundamental requisite before blockchain can become effective, is hampered by technical, organisational and societal barriers. For barriers with overlap, the identified causes were categorised as technical, organisational or societal.

5.3.1 Technical barriers

Lack of evidence and *interoperability* were identified as causes that might lead to technical barriers currently or in the future.

5.3.1.1 Lack of evidence

The blockchain is currently in an immature phase of technology. Consultant (2) emphasised the high-maintenance of blockchain's proof-of-work protocol in which the miner has to validate all transactions and create new blocks by executing a certain amount of computational work. This process is excessively energy-intensive and costly, as one Bitcoin transaction uses as much energy as an average American household uses in a week. Consultant (2) explained that there are ways to perform mining with less energy-intensive protocols, such as proof-of-stake, in which the creator of a block is randomly chosen after showing ownership of a certain number of cryptocurrency units. However, no real-world applications run on this protocol at this moment. Blockchain needs to technically mature to see how the mining principle can be applied more efficiently.

Despite blockchain's high energy consumption, consultant (4) and developer (1) explained that most of the current blockchains in the market, such as Bitcoin and Ethereum, have a scalability issue. When the number of blockchain transactions increases, the pressure on the network surges, which reduces the speed of the blockchain and could make the network crash. Blockchain's scalability issue explained why it is impractical to store EHRs (*WHAT*-information) on a blockchain, as they contain large files that would drastically slow the blockchain. Healthcare provider (2) mentioned that blockchain's scalability issue makes it too risky and experimental at this stage to be a serious option for an academic hospital. He explained:

The big problem with blockchain, as I understand it, is its capacity. The capacity we need for EHRs is extreme because of large images, such as video, MRIs etc. Every patient in this hospitals has 10 MRIs. (healthcare provider 2)

Developer (1) emphasised that there are applications for using blockchain for EHRs in the short term. For example, medical records can be stored 'off chain' in an encrypted database and only put hashed hyperlinks to the data on the blockchain.

5.3.1.2 Interoperability

Blockchain has its technical challenges, but consultant (4) and a developer (1) predicted that the technology will evolve very rapidly in the upcoming years, as much progress has already been made in the last two years. Since the technology progresses fast, consultant (2) and project manager (2) expressed concerns related to the number of blockchains that are being developed. Here, technical challenges could occur as project manager (2) explained:

If we let everyone develop and use their own blockchain, we are simply moving the current problem of different centralised databases to different blockchains. We still have data systems that cannot communicate with each other. (project manager 3)

Consultant (2) explained that a standard for blockchain use or frameworks to couple different blockchains need to be developed. Policy maker (1) agrees that the government should regulate blockchain initiatives before the technology moves beyond a point that is uncontrollable:

If we want to regulate blockchain, we need to act now. If the government waits too long, as was the case with mobile apps and the internet, we let it overcome us. (policy maker 1)

Consultant (5), active in an academic hospital, was not worried about the lack of governance resulting in technical problems later. She explained how she is now part of a network of 15 innovation consultants in various hospitals and that the communication between healthcare providers is strong. According to consultant (5), data fragmentation occurs because Dutch hospitals were busy with the implementation of their own EHR systems and therefore had no eye for looking for ways to collaborate with other hospitals. She added that the problems of sharing EHRs is acknowledged by all healthcare providers and is regularly discussed in meetings between directors, managers and consultants of various hospitals:

Now that we organised our EHR systems, we are looking outside: "what else can we do, how can we build on these systems and what can others do? There is consultation between hospitals and connections are on different levels. 'Blockchain islands' will never occur. Everything new needs to be connectable. (consultant 5)

Consultant (1 and 4) and policy maker (1) emphasised that the integration and interoperability between IT applications is fundamental for blockchain to become a successful innovation for healthcare. Open standards and application programming interfaces (APIs) for IT traffic were considered as relevant for overcoming interoperability challenges. Consultant (1 and 4) and policy maker (1) explained that an industry-wide collaborations are needed to solve the issues of data fragmentation. According to developer (1):

> *You need hospitals and institutions willing to couple their systems with a blockchain solution to form a community together that sends, receives and exchanges data with researchers and patients. If there is no interoperability these blockchain initiatives are philosophical mind-exercises. They are useless. (developer 1)*

Project manager (3) added that the European Union is currently working on a blockchain standard, defining exactly what blockchain is and of what features it should include. Developer (2) emphasised that the absence of such standards and national regulations is one reason so few proof-of-concepts have evolved into pilot-projects yet. In his view, the government should provide an open framework for experimentation for with funding for blockchain pilots. Policy maker (1) did not agree with this reasoning:

> *If you are going to wait for regulation to change, the world has already changed when the new regulation is in place". You can have standard but you need collaboration the most. If one hospital still tries to prevent me from getting a second opinion in another hospital, blockchain has zero value (policy maker 1)*

5.3.2 Organisational barriers

Integration and interoperability issues are technical challenges, but, as many respondents point out, underlying their complexity are social and organisational barriers. The following organisational barriers were identified: *privacy and security* and *business agreements and models.*

5.3.1.1 Privacy and security

The previous section explained that it currently technically infeasible to store EHRs on the blockchain. Consultants (2 and 4), developer (2) and lawyer (1) also explained that storing EHRs on a blockchain may conflict with the GDPR law. Developer (2), consultants (2 and 4) and lawyer (1) emphasised that it is impossible to store health data on an *open blockchain* fall under the GDPR-regulation, as data are accessible to the public. The consulted lawyer clarified that health data fall under the regulation of sensitive data and sensitive data should not be out in the open. Even though the data are hashed it remains traceable to individuals. Developer (2) explained this problem using the open blockchain of Bitcoin as example:

> *Because your Bitcoin address is public, it is possible to correlate data back to you. For instance, if you purchase a pizza, your home address is linked to the transaction. The same happens when you buy a pair of shoes. This implies that certain algorithms can link your consumer behaviour to you. This is a breach of privacy. (developer 2)*

Policy maker (1), developer (2) and consultant (4) explained that *closed blockchains* may not conflict with the GDPR because data are not accessible to everyone. In a closed blockchain, the administrator of the network defines the access, reading and writing rights. Policy maker (1) clarified that the Mijn Zorg Log-application runs on a closed blockchain and it was legally certified by a respected Dutch law firm. However, developer (1) questioned the security of closed blockchains, as it has a limited number of nodes (compared to an open blockchain), which makes the system more sensitive to data breaches. Policy maker (1) reacted to this concern and clarified that Mijn Zorg Log stored all data in a decentralised manner, with copies on 9 nodes, which was mathematically calculated by their engineers to be sufficient to warrant the security of the network. Consultant (1) added that a privacy-by-design should be adopted when developing new applications that takes into account privacy throughout the entire engineering process.

5.3.1.2 Incumbent power

The GDPR not only adds complexity to the blockchain's design, but also to the managers of many healthcare organisations, who have to alter their business practices and build systems that allow patients insight into their data. Consultants (1) and policy maker (1) explained that there are a limited number of health software developers in the Netherlands, such as EPIC and ChipSoft, which have a dominant role in all hospitals. According to project manager (3) these incumbents have negatively influenced innovation for years. These powerful parties have to adapt their systems if they want to build software that allows healthcare organisations to share information with other healthcare providers or patients. Consultant (1) and developer (1) clarified that there is little incentive for these incumbents to open up their systems, for instance, to GP practises and other smaller parties, or new initiatives such a blockchain. New applications might therefore fail due to the resistance to change of these incumbents.

Moreover, these software supplies have multimillion dollar business agreements with larger hospitals in the Netherlands. New solutions might disrupt their revenues and this would hinder these incumbents to engage in new innovations, as these powerful stakeholders might profit more from non-interoperability. Hence, money plays an important role at all levels for organisations to engage in collaborative efforts to increase the information provision in healthcare. Consultant (1) believes that only political influence will incentivise these incumbents to change. Policy maker (2) highlights that the MedMij initiative of the Dutch government might stimulate these power software suppliers to build portals PGO, which would be an important foundation for blockchain. He believes that if these suppliers will not collaborate, other organisation will seize the business opportunity to build portals to transfer EHR data to PGOs.

5.3.3 Societal barriers

On the societal level, *conservative culture, hype, the disruption of relationships and power structures* and *misconceptions by potential users* were identified as barriers.

5.3.3.1 Conservative culture

Consultant (5) explained that an important social issue with respect to IT integration is the not-invented-here syndrome that ails the Dutch healthcare sector. Consultant (1) added that the whole industry developed in islands, in terms of IT, people and processes and managers still think this way. This means there is no push for professionals to change anything and it is easier to keep doing things the way they are. Because patients are not accustomed to changing hospitals or GPs, like people do with brands, there is also no bottom-up incentive to alter the current situation. In addition, healthcare is a slow and risk-adverse industry. Because human lives are at stake, managers choose applications that carry the least risk. At this stage, blockchain entails risk for managers, because there are still many uncertainties.

Consultant (1) added that many hospitals have a limited budget to spend on IT, as it is not their primary goal compared to treating patients. This means that innovation comes from funding by insurance companies, but they are only willing to pay for proven applications. Developer (1) recognised this issue as he is hostile towards start-ups with new applications compared to vested incumbents. He quoted the recognised start-up dilemma: *"Nobody ever got fired for buying IBM"*. Developer (1) added that there is also an investment risk for managers to engage in blockchain, as it costs €100.000–200.000 to develop and maintain a blockchain solution. The experiments of start-ups are important because they can show the efficiency gains that can be achieved with blockchain. Developer (1) and consultant (2) explained that if more examples of blockchain initiatives reach the markets that show their benefits could incentive healthcare providers to explore blockchain. Developer (1) explained blockchain is interesting because you can start small and easily include larger parties later on. Developer added this is important because the most effective strategy is not to right the existing system but to build a new system that will make the current system obsolete.

5.3.3.2 Hype

Although all of the respondents articulated desirable future directions for blockchain-technology, developer (1), health insurer (1) and consultant (2) were concerned with the blockchain's current hype. Consultant (2):

> *My experience with blockchain: "It solves everything, which I enjoy". I woke up with a headache this morning, I took some blockchain, and now my headache is over. Blockchain has become a sledgehammer to crack a nuts now. It is indeed a very promising technology, but it has a very specific application field in practice. (consultant 2)*

Developer (1) and consultant (2) explained that many problems that people want to solved with blockchain can be solved with conventional database technology, which also allows parties to 'look at the same data' and manage permissions. Blockchain's hype may results in its unnecessary use as it becomes 'a solution looking for a problem'. Developer (1) and consultant (2) regarded this as undesirable, because blockchain is a more complicated and expensive solution than other database technologies. For example, consultant (2) argued that blockchain is not needed for PGOs:

If we implant a chip in our body with all our medical records. We bypass the problem that we need the internet for caregivers to see our medical files. This would be practical when I pass out in a desert with no internet connection. No blockchain is needed for such a solution and it might be more effective. (consultant 2)

Another undesirable consequence of the blockchain hype is 'virtue signalling' (developer 1). Managers might be more interested in making themselves look good by developing blockchain applications which are popular now, than finding better applications to complex problems.

On the contrary, developer (1), consultant (5) and policy maker (1) explained that blockchain's hype has a positive effect as well. Blockchain's hype has generated interest in ICT and mathematics far beyond engineers and developers to a much wider public. This interest creates momentum for blockchain applications to bring together to integrate IT applications. Blockchain has started a new conversation in which current healthcare stakeholders are revising their own and others' roles. This might be an important driver for managers to build the integrated IT applications that they have had in their minds for years but could never develop, as nobody had the courage or interest to fund them until now. Hence, blockchain might be an important enabler for interoperability and integration.

5.3.3.2 Disruption of power structures and relationships

Blockchain's adoption might create shifts in roles and power structures, since several intermediaries could be eliminated. Developer (1) and consultants (1 and 4) explained that policy makers, health insurers and managers in the Netherlands will adopt solutions that might put many people's jobs at risk. Consultant (1) therefore considers it unlikely that policy makers and health insurers will invest in a blockchain solution that might jeopardise the LSP, an infrastructure that cost 300–400 million euros. The same might be true for other large centralised organisations, such as VECOZO, ZorgMail and ZorgDomein, and other intermediaries that might become unnecessary in the healthcare system. As developer (1) explained:

Basically you are saying: "Well, we are going to put the patient in the centre and remove all intermediaries". Those intermediaries are tightly coupled with health insurers, hospitals, and IT providers. These business relationships have cemented gradually over time. For example, all of the IT providers to GPs use ZorgMail and ZorgDomein. You have to convince them all that what they have now is wrong and that blockchain is better. (developer 1)

According to policy maker (1) and consultant (4), similar organisational resistance will occur with other professions, such as administrative jobs, that might disappear with the adoption of a blockchain platform. Policy maker (1) referred to this as:

Talking to a turkey about Christmas. How will you find organisations willing to cooperate in a system where they will have to cut themselves out? (policy maker 1)

Developer (1), policy maker (1) and consultant (4) agreed, however, that the automation transition, for which blockchain is a driver, is unstoppable and that innovation will disrupt these relationships and structures at some point.

5.3.3.2 Misconceptions by non-experts

Developer (2) argued that much of blockchain's hype is created because blockchain is complex and many non-experts do not fully understand how the technology works and how it can be used. Consultant (1) explained that this leads to false assumptions by the public about the technology, which may result in non-adoption of innovations. An example that healthcare providers often give for not using new innovations is that they think that their consumers cannot understand the data or use the technology.

Respondents had different views regarding the user experience of blockchains. According to a consultant (3), if only permissions are managed on a blockchain, patients will only receive notifications asking them for permissions. They will have no idea what technology is behind it, as people can use mobile applications without understanding how the mobile network behind it works. None of the respondents mentioned that blockchain's design would be too complicated for users. Policy maker (1) explained that the results of the maturity care pilot indicated that participants needed some training in the beginning, but thereafter found the blockchain application easy to use. Nevertheless, patients (3 and 8) considered multiple verifications of authorisation requests as inconvenient, which may result in the solution not being used.

Communication and education were considered by developer as ways to overcome misconceptions by the public. Consultant (1) added that both patients and hospital workers should be educated. In every focus group with patients, they told the same story of a female Dutch celebrity whose medical files leaked when she had to undergo treatment while abroad. Blockchain does not prevent a hospital worker from taking screenshots of someone's medical files in a hospital and sharing them. Consultant (1) explained that managers should educate workers in social responsibilities of such applications:

> *If workers in a safari park assist poachers in killing animals, they are thrown out on the street. In a similar way, healthcare workers should become aware of the responsibilities that they have and serious measures should be taken if they violate the privacy of patients. (consultant 1)*

Medical professional (6) explained that in his hospital, such a policy is already in place. In one example, a patient was diagnosed with Ebola and staff members who looked at the patients' medical records were at risk of getting fired.

Figure 12. Coding table technical, organisational and societal discussions

By	Coded statement	Structual code (first order concept)	Catergory (second order concept)	(sub)theme (axial code)	Main theme (vision)
M3	Er is een enorm debat gaande over blockchain. Wat betekent het? Aan welke kenmerken moet het voldoen om blockchain genoemd te worden? Men verwacht dat deze discussie nog 18 maanden gaat duren over standaarden. Er zijn wel wat kenmerken die eruit zullen komen.	Development of standards	Interoperablity	Roadblock	Technical discussion
D2	This comes from the regulators. They open this world for us and say you know we support you. We will help you. You have a trial regulatory framework you can work in.	Open framework for experimentation			
C2	Buckminster Pulle zegt altijd: Je moet een bestaand systeem niet willen veranderen maar je moet er een systeem naast zetten waardoor het bestaande systeem onnodig word. Blockchain is schaalbaar dat biedt kansen.	Small experiments			
PM1	Wat ik vast stel is dat standaardisatie nog steeds nodig is en dat je moet willen samenwerken. Zolang een ziekenhuis probeert te voorkomen dat ik een second opinion bij een ander ziekenhuis ga halen, heb ik aan blockchain ook nik	Colloboration			
C4	Hier zijn we nog te vroeg voor. Dat kan heel snel gaan; binnen nu en twee jaar kan dat anders zijn. Als je ziet wat het ecosysteem voor ontwikkeling heeft doorgemaakt de laatste 2 jaar is dat fantastisch, maar we zijn er nog lang niet	Tech evolves fast	More advanced market		
D1	I mean we are just starting. And just compare it to the last year, it's crazy how the whole industry evolves. I mean you have all these events everyone is talking about that. One year before or one year and a half. Nobody spoke about	Tech evolves fast			
C1	Mensen die kwaad willen kunnen daar altijd wat mee doen, screenshot van maken. Authorisatie is authorisatie is een vertrouwen element dat de arts in. Maar je kan wel bewijzen en iemand terecht stellen daarvoor. Timestamp functie.	Visionless development	Misconception by non-experts		
C1	**Oplossing moeten privacy-by-desing beginnen. Daar is het mis gegaan met het internet.**	Privacy by design	Privacy		
C2	De trust van blockchain zit in de blockchain en dat kost tijd en geld. Als je nu ziet wat er nu met Bitcoin gebeurt dat slaat dat helemaal nergens op dat kost zo onwijs veel energie. Het is niet een duurzame oplossing.	High energy consumption	Lack of evidence	Barrier	
HP2	Het systeem is niet rijp voor dit soort discussies. Het grote probleem van blockchain, wat ik begrijp, is de capaciteit. De capaciteit die wij nodig hebben voor die EPDs is extreem	Immature technology			
M2	Ja het is nu al onoverzichtelijk. Wat je nu ziet gebeuren dus dat er zoveel initiatieven zijn. Nu valt het nog mee, maar dat als er niet tijdig regulering plaats gaat vinden we zo'n zelfde aantal leuke initiatieven krijgen en kleine oplossingen krijgen op een blockchain,	Lack of governance	Interoperablity		
C2	Waar ik mezelf een beetje zorgen over maak is alle verschillende vormen van blockchain. Hoe ga je die straks aan elkaar koppelen?	Lack of governance			
PM1	*Als je het niet doet dan overkomt het je. Dat heb je met apps gezien, met internet gezien. Prima als je het wil reguleren, maar dan moet je er wel snel bij zijn. Als je een rol aan tafel wilt kan ik me daar alles bij voorstellen.*	Lack of governance			
C4	Heel veel van de data waar we het over hebben zijn ook zaken als röntgenfoto's ect, opgeslagen als pdf/JPEG. Wat iedereen ook roept, file storage op een blockchain kan niet. Punt	Scalability issue	Lack of evidence		
D1	Currently ETH has a scaling problem. Every time there's this new ICO, because everyone mostly does it on ETH. You have extended periods of time where you when you have poor performance on the network. This of course will improve in time	Scalability issue			
D1	you will need a cloud solution to be able to transact these files because you cannot store half of a terabyte on a phone. You cannot store MRI, you will use 2 MRIS and then your memory is full. So we'll need to think about at that particular time when we when we reach there.	Scalability issue			
C4	Moet je ook wel vanwege privacyoverwegingen. In een open blockchain, als je daar de toegangsrechten wil regelen, en de data wil opslaan dan kom je geheid met GDPR-issues in de problemen	GDPR and storage	Privacy		
D2	Could you explain the privacy part to me. To get more detail. Interviewer: Let's take the bitcoin for example. If you purchase a pizza your home address is linked to the transaction. A repetition off such behaviour. Maybe you're buying a pair of shoes later.	GDPR and storage			Organisational discussion
C2	Er is nu een nieuwe complexiteit met de GDPR. De vraag is als je iets vastlegt mag je het dan vastleggen? Is het te herleiden tot het individu? Anders krijg je gedoe met de GDPR. Dat is een interessant spanningsveld.	GDPR and storage			
L1	**Blockchain toepassingen zijn onder de huidige wetgeving makkelijker als er zo weinig mogelijk persoonsgegevens aan gekoppeld zijn. Laat staan medische gegevens dat maakt het een tikkie zwaarder. Dat lijkt mij op dit moment geen goed idee**	GDPR and storage			
D1	So you have a blockchain as a service from Microsoft or Hyperledger by IBM, so if you're controlling your nodes then what is the difference from just having replicated my sequel for instance. What does it bring you to your enterprise?.	Closed blockchain disadvantage	Security		
PM1	**Waarom heb je er 13.000 nodig? Wij hadden er 8 en dat is meer dat genoeg.**	Closed blockchain disadvantage			
C1	Je hebt Epic en Chipsoft, en die hebben een monopolypositie in de markt met z'n tweeën. Die hebben er natuurlijk helemaal geen baat bij om die data open te gooien	No incentive for incumbents to change	Incumbent power		
PM1	Wat kan ik met EPIC en Chipsoft? Maar die hebben nog niet in de gate dat ze hun systeem moet kantelen. Naar een systeem dat handig is voor het ziekenhuis en voor de burger	Business model innovation			
D1	Disruption of profits revenue (if can profit from non-interoperability). ChipSoft/EPIC extra maintenance costs of 100000. Do you think they will happy? They have to tilt their business models.	Disruption of revenue streams			
M3	Grote partijen, zoals Chipsoft en Epic. Mijn ervaring met de gezondheidszorg; je hebt drie, vier grote leveranciers van dossiers daar worden via aanbestedingen procedures gedaan en dat legt eigenlijk de hele innovatie in de sector lam.	Incumbents hinder innovation			
C5	We moeten af van het not-invented here syndroom binnen de zorginstellingen om ook de vruchten te gaan plukken van de best practises. Dus wij ontwikkelen natuurlijk ook allelie innovaties om zorg te verbeteren om te komen bij het ideaalbeeld.	Non-invented here	Conservative culture		Societal discussion
C1	cultuur een belangrijke factor is, zeker bij artsen. Artsen vertonen risicomijdend gedrag en de openheid van een medisch dossier een bedreiging voor een arts. Een arts een fout te maken en hij is de zak.	Risk-adverse attitude			
C1	Veel zorgverlener vinden het allemaal helemaal prima zo. Er is geen iniatief bottom up voor hun om iets te veranderen. Patienten dreigen toch niet om weg te lopen.	No incentive to change			
C1	Mijn resultaten lieten zien dat we vaak weinig budget is voor IT in een ziekenhuis. Het komt dan aan op zorgverzekeraars en die gaan lulraak in alles investeren. Die willen er wat voor terug zien.	Little budget for IT innovation			
D1	So yes for IBM Microsoft, probably bringing like an army of consultants, they incentivize everyone, lobbying, and also of course a hospital would want to get to a solution from IBM rather than someone from small start-up. 'Nobody ever got fired for choosing IBM'	Risk-adverse attitude			
D1	let's try a project its cost a lot of money. 100.000k to start. You need the consultants will increase the same amount. So 200.000k	Risk-adverse attitude			
HI1	Iedereen roept van alles. Iedereen is heel bang voor wat er met die Bitcoin gebeurd. Daar refereert iedereen ook aan. De onwetendheid en de hype. Brian wil ook graag met de zorg wat gaan doen. We hebben 5 miljoen verzekerden	Risk of tech not deliviring	Hype		
C2	Mijn ervaring met blockchain is, het lost alles op en dat vind ik heel fijn. Ik stond vanmorgen op met hoofdpijn en ik neem blockchain en nu is het over. Ik vind het een redelijke hype en verder is het een hele gave technologie, maar het heeft een heel specifiek toepassingsgebied	Solution for everything			
D1	Tech solves problem. However, people don't have necessary good intentions, as they want to profit. Fooling someone selling something of making yourself look greater than you are. This is called virtue signalling.	Virtue signalling			
C2	Beetje futuristisch ik zou mijn gegevens geïmplementeerd willen hebben in mijn lijf. Een chip. Je wilt het ook niet in je telefoon hebben namelijk. Je zou een mix kunnen doen. App met gegevens en een chip	Blockchain might not be best solution			
D1	**Shifts in power. In NL they don't just throw people out on the street. In Ukraine that would be different the Netherlands is more solidary.**	Loss of jobs	Shift in power		
C4	Ik had een gesprek met iemand van de zorgverzekeraars maar zei ook: 'Je moet het ook zien we houden ook eens systeem in stand dat zorgt voor duizenden banen en dat is de downside die je kan hebben. Bij iedere technologische revolutie is iedereen daar bang voor.	Loss of jobs			
D1	Basically you are saying: well we going to put the patient in the center and remove all intermediairies…those intermediaries are tightly coupled with insurers, with hospitals, IT providers. For example all GP IT providers are intergrating Zorgmail and ZorgDomein. you have to convince them	Disruption of relationships			
PM1	Dat betekent dat het eenvoudiger kan, effectiever en efficiënter, en met minder administratie lasten, maar ook met verschuivingen van macht en invloed processen en posities. En dat bedoel ik met de kalkoen op kermis plaatsten. Want misschien heb ik bepaalde organisatie wel helemaal niet nodig	Loss in jobs			
D2	**People do not understand it. They need education.**	Uncertainty	Misconception by non-experts		
C1	Patienten hebben vaak ook verkeerde aannames. Artsen ook. Ze denken dat iets zo is en nemen dan patienten in bescherming	wrong assumption			
C3	Ik denk dat de patiënt er niks anders van ziet dan dat ze een nieuwe appje op mobiele telefoon hebben en op een knopje drukken. Ze hebben geen idee wat op de achtergrond gebeurt.	Tech is on the background			
HP6	Ja ik heb buikpijn daar kan hij niks mee. Maar wil je aan hem vragen wat is de beste behandeling voor deze tumor. Ja. Dat is het voorbeeld dat ik voor me krijg. Dat is een gerichte vraag. Kan hij gericht zoeken. Dat kan hij vast beter. Dat is niet gewoon maar blanco beginnen wat is u probleem.	AI will not replce docters			
D1	You cannot stop it in de end. Industry automation transition. Scripted. No humans. Blockchain is a driver for automation. In healthcare you will need people in automated decision making. Integrity. Along with machine learning AI	Automation cannot be stopped	Shift in power	Driver	
C4	Bij iedere technologische revolutie is iedereen daar bang voor. Want heel veel banen verdwijnen. Tot op heden hebben we altijd iets gevonden waar we ons mee bezig houden. Desnoods worden we allemaal yogaleraar, vind ik prima.	Automation cannot be stopped			
C1	Je hebt een ecosysteem nodig. Je hebt startups nodig die met nieuwe innovatieve ideeën komen en het IOT stuk faciliteren. Je hebt de wat grotere bedrijven nodig, zoals Deloitte, om echt veel meer dat soort veranderprocessen te begeleiden en systemen te integreren.	Colloboration	Interoperablity		
C5	lijstje van 15 verschillende innovatieadviseurs een brief mailtje sturen of bericht via slack: "Jongens ik heb een probleem van een arts wat hebben jullie nu al in huis?" Omdat ik een relatie heb met deze adviseur vertrouw ik. Op bestuurlijk niveau werden er ook visies afgestemd	Colloboration			
C5	Ik denk dat data de afgelopen tijd in de weg heeft gestaan van innovatie en uitwisseling. Iedereen was gefocust op eigen toko in orde hebben, Nu wordt er naar buiten gekeken; 'he wat kunnen we nog meer hoe kunnen we hierop bouwen en wat doen anderen	Colloboration			
C4	Een industriële brede samenwerking waarbij men echt verandering door wil voeren, niet alleen in woord. Dat betekend dat er partijen geofferd moeten worden	Colloboration			
C1	Daar zie je dus ook dat je gewoon ergens een beetje push van een overheid nodig hebt of van een startup die het echt veel beter doet, die dat niet meteen een in groot ziekenhuis, maar in een in een kleine kliniek gaat doen om te laten zien dat het kan. En die kleine proefjes zijn belangrijk	Government push			
PM2	Bijvoorbeeld LSP chipsoft EPIC kunnen toetreden en daarmee een grote groep zorgaanbieders ontzorgen of omdat ze EPD-leverancier zijn en makkelijk die gegevens kunnen uitspuwer of gespecialiseerde dienstverleners. Stel chipsoft wil niet mee doen.	Government push			
C4	In een gesloten blockchain kun je reading and writing rights beter regelen, maar dan moet je nog steeds denken is daar een meerwaarde om daar niet een partij tussen te zetten? Zeker ook met andere zaken, zoals de hele GDPR, die er nu aan kom	Closed blockchain benefits	Privacy		
C5	Binnen de zorg kan je alleen met gesloten werken dat komt de GDPR en de eisen die worden gesteld aan de governance. Persoonsgeven is heel lastig.	Closed blockchain benefits			
C4	Privacy issue loop je wel weer tegenaan. Je baas mag jouw bezoekjes aan de dokter niet zien. Afrekeningsmodel is eerder GDPR-compliant. Noodzakelijk kwaad ben je al kwijt.	GDPR and storage			
PM1	Dit soort gespreken gaat het om. Het hoeft geen blockchain te heten maar als we dit soort gesprekken voeren daar gaat het om. Een aan slinger ding om de discussie te voeren over waar het werkelijk om gaat	Blockchain started new conversation	Hype		

6. Discussion

6.1 Guiding visions

This thesis argued the CTA approach (in this case the ILA design) combined with a vision assessment (Grin & Grunwald, 2000) may be useful for assessing a technology in an early phase of development. The results of the interviews, focus groups and literature study indicated that blockchain is an early phase of technological development, strongly reflected by the limited medical applications in practise. With respect to the methodology, the thesis indicated that a CTA approach with a visions assessment allows researchers to construct guiding visions of blockchain experts and healthcare stakeholders and identify benefits, disadvantages and specific concerns with respect to these visions from the perspective of relevant healthcare stakeholders. Assessing these visions contributed to understanding possible similarities and incongruences in the perspectives of different stakeholders, which provides opportunities to establish more responsible blockchain applications. This case study thereby adds new knowledge that visions can be useful for studying emerging technology, which was an identified gap in literature (Merkerk, 2007).

The identified guiding visions and barriers come from two overall positions: the 'regime of hope' and the 'regime of truth' (Moreira & Palladino, 2005). The hope is that more efficient and personalised healthcare application systems with results from further blockchain development (the articulated visions) and assessing what might happen, as opposed to what can happen, when blockchain applications become less effective than promised due to the identified barriers. The hype cycle reflects a similar uncertainty. Developers, consultants and managers might hold promises from the regime of hope and may attract political and financial support to develop blockchain applications, while they may be confronted by the regime of truth when they come to the conclusion that blockchain could fail or becomes less effective than expected (Brown & Michael, 2003).

6.2 Overcoming barriers

The existing literature on blockchain is mostly technical and little empirical data has been collected about the social and organisational dynamics on the development and implementation of blockchain (Nichol & Brandt, 2016). In the empirical analysis of this thesis, two visions were presented that were used to identify the technical, organisational and societal barriers from a multi-stakeholder view, adding new knowledge to this identified gap in the literature. The results of this thesis show similarities and differences with the barriers to digital innovation found by Dehzad et al. (2014), who urge that more research is needed to discover the underlying causes and breakthrough opportunities of their identified barriers. The barriers, their underlying causes, and the roadblocks to overcome them are discussed in this section and illustrated in Figure 13.

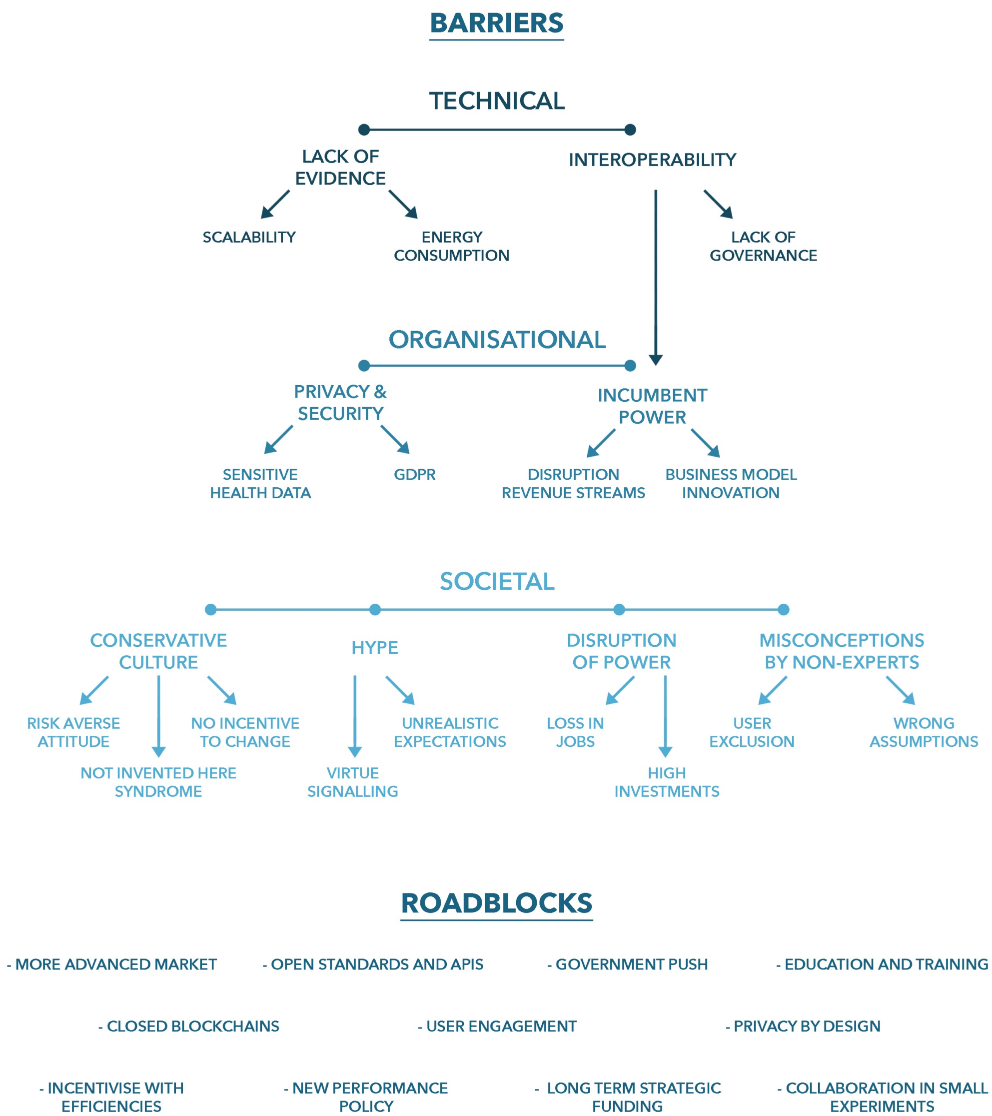

Figure 13. The barriers and roadblocks to overcome them

The unique barriers were *hype* and *disruption of relationships and power structures*. *Hype* becomes a barrier because the blockchain may be exploited in an undesirable way, especially when there might be less complex and costly alternatives at hand. This barrier might be caused by initiators who are not interested in solving complex problems, but rather in making themselves look good—and working with blockchain is very appealing at this stage. Small experiments with blockchain allow initiators to see if the value of blockchain weigh up against the costs. Regarding the *disruption of relationships and power structures*, actors explained that it is very unlikely, especially in the Netherlands, that powerful actors (e.g., policy makers and health insurers) will collaborate in applications that eliminate intermediaries from the healthcare system. This barrier might exist because the Netherlands values solidarity and it is unlikely that a solution that will make people lose their jobs will be adopted.

Integration and interoperability were regarded as the most important barriers for digital health applications in the Netherlands (Dehzad et al., 2014). The findings of thesis, however, indicate that blockchain might be an enabler for IT integration. Creating interoperability requires frictionless submission of data and the permission to view it (Krawiec et al., 2016). Blockchain is most effective when a specific set of standardised information (*THAT*-information) is stored directly on-chain for direct access, supplemented by off-chain data (*WHAT*-information) links when needed. Blockchain's *hype cycle* is valuable for stimulating courage and interest among healthcare stakeholders to collaborate in consortiums for IT integration. These blockchain companies are forming consortiums that may help to prevent network incompatibility and bring forward interoperable applications that should have started out together years ago. The incumbent power of the few technology suppliers (e.g., EPIC and ChipSoft) may hinder these efforts, as is it may not be lucrative for them to use of open standards and application programming interfaces and develop new business cases. Governments need to push these incumbents into actions and not let them hinder the development of open systems.

The Dutch government and health insurers might be the only ones to break the fragmented IT system (Dezhad et al., 2014). The thesis found that, through the MedMij initiative, policy makers and health insurers are currently stimulating large software suppliers to build portals that allow the transfer of EHRs between healthcare providers and patients. Policy makers and health insurers are even strategically funding the development of PHR initiatives (Zorgvisie, 2018). Hence, interoperability and integration is happening in the Netherlands, which is a fundamental perquisite for blockchain to achieve its potential. Policy makers and health insurers may play a similar role in the funding of new blockchain initiatives that face a problem with their business case. As blockchain initiatives can lead to cost reductions in the long run and may lead to a healthier population, health insurers may strategically choose to fund innovators that deliver long-term value. New performance policy in which health results are the measuring tip would stimulate innovators to develop solutions aiming at long-term value. Such policy would also stimulate more value based healthcare in which healthcare providers are paid based on the patient's health (Zorgvisie, 2018).

The results showed that stakeholders have different perspectives. For instance, developers and consultants explained that the *technical obstacles* and *privacy and security* concerns were the least pressing issues with respect to blockchain. However, the same concerns were most frequently mentioned by potential users (patients and medical professionals). This could be because medical professionals face liability concerns because they have to recommend digital health applications to patients and balance out the risks of using them. Underlying their arguments may not only be their risk-adverse attitudes to engage in technologies accompanied with insecurities, but also the fact that privacy has become a much more important issue in Europe since the GDPR. New applications should therefore always start with a privacy-by-design approach to circumvent problems with the GDPR and engage users in the development process to prevent them from having misconceptions about the technology.

6.3 Limitations

This thesis consisted of a single case-study no definitive conclusions can be stated. Nevertheless, this thesis may represent a starting point for more detailed quantitative studies, which could make the results more generalisable. For example, the findings of this thesis may be used to compare how barriers impact blockchain adoption internationally. In such an analysis, the Netherlands might be taken as a reference for other Western European countries. Integration and interoperability barriers, for instance, may be more complicated to overcome is larger countries, such as the US, with many federal states. Conversely, developing countries may be able to leapfrog straight into using blockchain. Users only need a smartphone and a mobile network to connect to the blockchain network, which makes digital banking of exchanging medical records accessible even in the absence of landlines or proper institutions (Qiang, Yamamichi, Hausman, & Altman, 2011).

Interviewing a wide range of actors resulted in a general overview of differences in visions of an emerging technology. Here, a limiting factor was the technological phase of blockchain at the time data were collected. Many medical professionals and almost all patients were not familiar with blockchain and were not equipped to enter a dialogue about the topic. Instead, these respondents were provided with case applications that could be connected to blockchain technology, such as personal health records and telemedicine devices and sensors. Hence by reflecting on the visions of a blockchain expert's perspective, creativity regarding alternative blockchain use was partly impeded. To avoid this as much as possible, the respondents were asked what they perceived as desirable applications of blockchain and were specifically asked for alternative and their own associations and ideas throughout the interview.

Furthermore, it was difficult to engage people at this early stage of development. Although 33 patients participated in this thesis, almost all of them were recruited via a medical professional from the author's personal network. Although many other patients were contacted, only a few were willing to participate in this thesis. This may have significantly influenced the results. For instance, if all these patients were very satisfied with their doctor, they might have valued personal contact with the physician more than patients who do not have a good connection with their physician. In future thesis, the data collected from these patients should be compared to a different sample to make the results more generalisable. This sample should consist of patients with various medical conditions and from a different hospital than the ones consulted in this research group. To avoid country bias, patients from different countries should be consulted. Some of the focus group participants explained that diabetes patients are working with similar telemedicine devices and sensors that monitor them a home. Because automation and interoperability between different IT applications will be relevant for their future, they are considered an interesting group to compare the findings of this thesis.

6.4 Future research

The thesis consisted of the first three steps of the ILA-model: initiation and exploration; in-depth study of problems, needs and visions of involved stakeholders; and integration of various stakeholder perspectives. In line with the ILA model, the next step of this research would be to organise an interactive session with representatives of different stakeholder groups. The identified visions and barriers in this thesis are a suitable starting point to stimulate constructive interaction and mutual learning between participants. The results of such sessions will provide new knowledge to further construct shared desirable visions, which can be used in the next steps in the ILA design process (prioritisation and agenda setting (4) and implementation through action research (5)), in which concrete actions are taken with respect to the development of innovations. The results on the mutual learning session are relevant to manage blockchain development towards more responsible applications, which are better align with the practice, culture, structure and wishes of their potential users.

This thesis found that blockchain may be a relevant enabler for interoperability and IT integration between different healthcare stakeholders. Interoperability is one the most complex challenges in healthcare and the industry has been struggling with it for decades. More research in what drives healthcare stakeholders to collaborate into IT integration is considered relevant. Even if blockchain fails in healthcare, the knowledge on what drives and hinders collaboration is relevant for the next digital solution that aims to integrate IT applications in the healthcare sector. In addition, only a few healthcare stakeholders were consulted for this research. These stakeholders were chosen because they remain relevant in a blockchain future. No respondents were consulted that were regarded as intermediaries that become unnecessary in a blockchain future. Consulting these stakeholders may help identify new barriers that this thesis did not find. A social network analysis, which investigates the social structures in networks, might be adopted to identify these intermediaries and study their relevance in the healthcare ecosystem.

6.5 Managerial implications

The results of this research provide practical knowledge for managers, policy makers, healthcare providers, patient-organisations and developers on how to change policy and improve applications. The findings suggest that health funders, in particular health insurers, are important for strategically funding blockchain proof-of-concepts, so more applications are implemented in practice. The consulted health insures acknowledged the value of blockchain, but indicated that the technology is too immature at this stage. Even if some blockchain applications are still away, managers are recommended to evaluate their possibilities now and invest in the technology that can enable them. If contracts are automated for instance, traditional firm structures, procedures, and the role of intermediaries and managers might fundamentally change (Iansiti & Lakhani, 2017). Healthcare providers will also have to makes changes to make smart contracts viable. They need to develop new expertise in software and blockchain programming and to rethink their current business models.

Managers, or other societal actors considering developing blockchain applications, are advised to take into account the risks of blockchain in practice. For instance, although blockchain might be a safer way to exchange medical data than other applications, there is still no guarantee that patients' health data are secure. With blockchain, it is still possible for healthcare staff to take screenshots of patients' medical dossiers and share them. Staff needs to be trained on how to work with these new applications and managers should emphasise the social responsibility of working with these applications. Such a policy may prevent information from leaking in hospitals. Furthermore, users, especially older people, will need training in how to use blockchain applications. These users should be involved in the development process, as they have specific concerns that managers and developers might fail to see.

Moreover, managers are recommended to conduct small targeted experiments to discover the value of blockchain. One of the main benefits of experimenting with blockchain is that it offers economic scalability (Krawiec et al., 2016), meaning experiments can start small and scale up the prototype when the experiment becomes profitable. To succeed with blockchain, a network of interconnected computers (nodes) must be present to supply the computing power necessary to create blocks once a transaction is submitted (Krawiec et al., 2016). This thesis highlighted that *open blockchains* are not suitable for the Dutch healthcare system because the conflict with the GDPR. If developers use a *closed blockchain*, they need to set up a network of nodes themselves. Managers should evaluate critically if setting up such a network will save costs compared to how they are operating now. Because it is challenging to forecast the potential costs of operating a blockchain, managers will only understand it when they start experimenting. Manager are recommended to encourage people to become nodes through financial incentives (e.g., access to blockchain data in exchange for processing transactions) and to take the scaling possibilities of blockchain into account.

7. Conclusion

This thesis was guided by the following question: *What are the drivers and barriers to the implementation of blockchain technology in the healthcare sector, based on the perspectives of healthcare stakeholders?*

To answer this question, the research presented in this thesis combined a constructive technology assessment approach with a vision assessment to provide insight into visions of desirable blockchain applications in the Dutch health system from the perspective of relevant healthcare stakeholders. These guiding visions were used to identify barriers that might hinder, and strategies that may stimulate, the responsible development and implementation of medical blockchain applications.

In this first part of the analysis, the visions that currently guide blockchain developments were explored. Blockchain-experts (n=13) who are currently shaping the future of blockchain were consulted, including technology developers, consultants, and project managers. Subsequently, Dutch cardiac patients (n=33) articulated benefits, disadvantages and specific concerns regarding the blockchain applications envisioned by the experts. Next, other relevant healthcare stakeholders (n=13), including health insurers, policy makers, healthcare providers and pharmacists provided insight into how the envisioned blockchain applications relate to an ideal health system. This helped further identify the positive and negative effects of the articulated blockchain applications.

The results were integrated to explore similarities and differences in the concerns, opportunities and barriers from the perspective of the various stakeholders. Hence, the guiding visions and barriers in this thesis present empirical data from perspectives of various healthcare stakeholders on desirable directions of future medical blockchain developments, how these applications are envisioned to be used in healthcare and their impacts, positive and negative, on individuals, the healthcare industry and society. The guiding visions and barriers also show who the potential users of these applications will be and who might be affected by the implementation of these applications. The visions illustrate what barriers need to be overcome to achieve the desirable applications.

In this research, two visions were identified from the perspective of the consulted blockchain-experts. In vision 1, the envisioned blockchain applications *increase the efficiency in healthcare* by reducing the administrative pressures and transactions costs in healthcare and enhancing the exchange of health data between healthcare stakeholders. At the same time, blockchain applications are envisioned to *make healthcare more personalised* (vision 2) by allowing patients more freedom of choice and control over their health. In the envisioned applications, blockchain becomes a shared transactions layer that uses smart contracts to automate payments and transfer currency or health data as negotiated conditions are met. The results of this thesis showed how these applications can deliver significant value in complex transactions (e.g., transfer of an asset or medical record) that involve many parties, tracking and tracing items though complex supply chains, and algorithm-driven decision-making in medical prevention.

Through presentation of blockchain applications to healthcare stakeholders, this thesis to identify the following barriers *Interoperability, conservative culture, hype, incumbent power, misconceptions by non-experts, privacy and security, disruption power structures and relationships and lack of evidence.* Identifying and assessing these barriers in an early phase may be a first step in the process of overcoming them in later stages.

This thesis reasons that there is much potential for blockchain to optimise the Dutch healthcare sector. However, immense hype surrounding blockchain may stimulate the unnecessary and development of costly and complex blockchain applications. Conversely, blockchain's hype is also a relevant driver for collaboration between healthcare stakeholders, which is essential to overcome the complex IT integration and interoperability challenges in the Dutch healthcare sector. Since the consulted healthcare stakeholders appear dedicated to solve interoperability, small experiments with blockchain are relevant to show healthcare stakeholders what is 'possible'. This may inspire healthcare stakeholders to stimulate them to engage in industry-wide consortiums, bringing forward digital health applications that should have started out together years ago.

8. Reflection

I started this journey almost a year ago with a tailor-made course in which I aimed to discover the potential of a medical application, MedTravel, for cardiac patients in the Netherlands. The aim of the application was to facilitate direct contact between cardiac patients and medical professionals in case on an emergency while the patient was abroad. When doing desk research, I discovered that such an application can never be effective if patients and cardiologists cannot share medical information with each other. Often blockchain was mentioned as a potential solution for this problem. This inspired me to write my master thesis about this topic.

The goal of this thesis was to construct desirable visions and identify barriers for blockchain in the Dutch healthcare sector which required an understanding of the technical, social and organisational challenges around this emerging technology. In my opinion this goal was reached successfully. By applying different methods and transcribing all my interviews my findings considered rich material. The problem was, for which I was frequently warned, that I was doing too much. This made it difficult to structure the whole story, but I feel confident that the results are unique and will be valuable for further research and for CCN.

I started of reading much literature and had trouble finding the right theoretical angle for this thesis. I think I have written 5-6 theoretical sessions in the last months, but practise is also part of the process. The interviews and focus groups went really well and I was fortunate to get a wide range of people to participate. The results of the focus groups were less relevant for this particular research because blockchain was not discussed during the focus groups. However, the results are valuable for other studies on PHRs, telemedicine and other digital health applications. Organising and hosting the focus groups was a fantastic experience and I look forward to doing it again in an academic setting.

Structuring was the main challenge for me during this thesis. I never transcribed or coded before so I really had to start from scratch. I think my first interviews contained 80 codes each while my latter interviews were around 15 so I learned be more specific and concise in structuring my data. The learning process was very valuable in the end. The advices of me supervisor were valuable here as it gave me new perspective usually backed up with some literature or other useful documents that helped me to progress. Having more structure is also something that will be useful for my working life after this thesis.

The place where I wrote most of my thesis was at CCN, which was a great work environment. A stimulating atmosphere with bright individuals to exchange thoughts with along the way. I was completely fresh in the IT realm and the CCN staff helped a lot with my questions on technical matters. Overall I am content with the end results and process which barely felt like work to me because I was enjoying it so much. It also made me interested in doing more research, which was an unexpected surprise!

9. Literature

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