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ELECTRONIC PATIENT RECORDS ON THE BLOCKCHAIN: A VALUE MANAGEMENT PLATFORM CASE-STUDY

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Robin De Meyer

Student number : 01604208

Supervisor: Prof. Dr. Geert Poels

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Permission

Foreword

With this foreword I would like to acknowledge all those who assisted me throughout the entirety of this Master's Dissertation.

First of all I would like to thank my supervisor Prof. dr. Geert Poels for inspiring my interest in this study, for his many tips and accessibility. Secondly, I would like to thank VDMbee for providing the opportunity to conduct this study and allowing me to use their tool. Special thanks go out to my contact at VDMbee, Henk de Man, for his guidance through each stage of the process, from the initial kick-off to the valuable feedback during the final stages. Next, I would also like to thank Shariq Ata for providing the case and giving extra insights about the concerned topics. Finally, I would also like to thank my friends and family for the moral support and additional tips.

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List of used abbreviations

EHR	Electronic Health Records
VMP	Value Management Platform
FHIR	Fast Healthcare Interoperability Resources
HL7	Health Level Seven
HC	Healthcare
CBMP	Continuous Business Modelling Planning
VDML	Value Delivery Modelling Language
MPI	Master Patient Index

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1 Introduction

Over the course of time, many different technologies have been explored and developed. One such technology is blockchain. Blockchain is seen as a technology with an important, and potential disruptive, implication for companies and governments in different sectors in the time to come (Webb, 2015).

Furthermore, blockchain is a type of distributed ledger, where blockchain consist of blocks of data, distributed ledger is a database spread across different nodes. In distributed ledger each participant can access this database, also called a shared ledger (Ølnes, Ubacht, & Janssen, 2017). Normally when initiating a transaction, a third party is needed to conclude the transaction between the principle parties. In most cases this will pass as a currency transaction, needing a bank, credit card provider or middleman to complete the transaction. This is exactly what the blockchain technology tries to eliminate, by creating a decentralized environment where no third party is needed to complete the transaction (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016).

Over the lifespan of the blockchain technology, different versions have emerged. The very first example of such a blockchain technology is Bitcoin, a peer-to-peer version of electronic cash. Bitcoin is based on a whitepaper published by Satoshi Nakamoto on October 31, 2008. It allows for online payments to be made directly between different parties, without the need of a financial institution (Nakamoto, 2019). This application has amassed a lot of popularity over the past years, which led to many other applications of blockchain technology. The first applications of blockchain after the Bitcoin example are categorized under Blockchain 1.0. After that, a newer generation of blockchain, named Blockchain 2.0, included smart properties and smart contracts (Swan, 2015). Smart properties elude to the digital properties or assets whose ownership can be controlled by the blockchain-application. Smart contracts, first introduced by Nick Szabo in 1994, are a new way of defining contracts between different parties. In its core, a smart contract is a computer code between the different parties that runs on the blockchain-application and contains a set of rules determined by the parties. If the predetermined rules are met, the smart contract will automatically execute itself. This makes digital relationships more functional than paper-based contracts (Szabo, 1997). After Blockchain 2.0, the current generation of blockchain emerged, Blockchain 3.0. This new generation is mainly focused on the non-financial applications of blockchain (Swan, 2015). It is this newer generation of blockchain technology that will be observed in this study. Not all the implications of blockchain are the same, however, there exist several different blockchain structures one can work with. The most important distinction one should make, is the difference between an open and a closed blockchain. In other words, is the ledger open to all or are only predefined members allowed to read the ledger. A further distinction can be made between a non-permission based blockchain and a permission based blockchain. To distinguish nodes who can have more power and additional tasks (Mainelli & Smith, 2015). In this study a closed permission based blockchain application is observed.

Since the success of bitcoin, different sectors are looking for a way to harness the possibilities and advantages of blockchain technology. These sectors are trying to digitalize and enhance their businesses using the benefits of blockchain technology. One such benefit is the possibility to carry out transactions in a distributed setting without the need of a third-party. This transaction happens in a secure and trusted environment, caused by the inherent properties of blockchain. After all, information on a block is immutable and the blockchain is identical for each entity in the network. In order to update or change any information on the blockchain, a new block has to be created, leaving a trail of the changes made. Another direct benefit blockchain technology offers, is the improvement of transaction speed. Without the need of a third-party, transactions can flow directly from the involved entities, removing the delay of the intermediate party (Agbo, Mahmoud & Eklund, 2019).

Especially non-financial applications of blockchain have emerged in different sectors. Some examples include the energy sector using a blockchain-based solution to organize the sharing of energy produced by consumer solar panels (Plaza et al, 2018). Another example comes from the supply chain sector, developing an agri-food supply chain traceability system using blockchain technology (Tian, 2016). A final example exists in the healthcare sector. A potential application in this sector, is the development of a mobile application based on blockchain where patients own, control and can share their personal data (Yue et al 2016). Nevertheless, these are not the only application of blockchain technology in each of these sectors; energy sector (Burger, Kuhlmann, Richard, & Weinmann, 2016; Lavrijssen & Carrilo, 2017), supply chains & logistics (Iansiti &Lakhani, 2017; Tian, 2016) to ultimately the healthcare sector (Hoy, 2017; Agbo, C. C., Mahmoud, Q. H., & Eklund, J. M. ,2019), the possibilities seem endless.

The development and implementation, however, of such a blockchain application is very difficult and costly (Catalini & Gans, 2016). Furthermore, the non-financial applications of blockchain technology is relatively new, making it hard to actually prove the added value it brings. There is a lack of real life business cases to actually measure all the benefits it supposedly brings (Agbo, Mahmoud & Eklund, 2019).

To determine if such a non-financial blockchain application really is worthwhile, this study will research one sector that would supposedly greatly benefit from such an application. This sector being the healthcare setting. In the medical sector, blockchain technology would mainly be used to securely share healthcare data. The sharing of this healthcare data would allow for, amongst others, a better user experience, quality of data and healthcare, reduce costs, better prescriptions of medication (Jothi & Husain, 2015). According to Hillestad et al. (2005), the implementation of such a framework could save billions on a yearly basis. The impact of such a blockchain application, however, has not been proven on a real life business case and is solely an expectation based on theoretical expectations. Moreover, the impact of a certain blockchain framework in the healthcare sector is very difficult to measure. This is mainly due to the fact that such a blockchain application would not only impact one aspect of the business but could influence the entire healthcare ecosystem. Additionally, the improvement in quality, user experience and recommendations are difficult to express in monetary values. This makes this study on blockchain technology in the healthcare sector all the more interesting.

Even more, the healthcare sector is a sector that is fairly behind on digital trends and strongly regulated. Additionally, many healthcare providers use different information systems to manage their data flows. Which could, potentially, be solved by an implementation of blockchain technology. After all, blockchain technology would allow for a trusted environment for (patient) information to be shared between different health care providers. Mainly, because every healthcare provider then has the same information available concerning a shared patient, without the power to alter any information unseen. Blockchain technology, also, allows for a framework where different entities have different rights, all thanks to the smart contracts. All this, helps protect the privacy of a patient. It also allows for a cheaper and faster way of sharing patient information. No longer does an healthcare provider have to call another provider to access certain medical information about a patient. This is now automatically regulated and fetched by the smart contracts. All these benefits help contribute to a more efficient digital healthcare system, that will help healthcare providers and other related parties to increase the accessibility to data in a secure manner.

This patient information is shared in the form of electronic health records (EHR). An electronic health record is the digital storage of medical data. Health information technology such as EHR's are seen as critical in improving the health care industry. Most of its benefits are seen in the improvement of quality and efficiency in information management. However, the implementation of such a health information system is not without its difficulties (Chaudhry et al, 2006). The availability of digital medical information is susceptible for security breaches. Also, the sharing of such electronic health records leads to interoperability challenges. Often the involved parties have different information systems that store these EHR's (Verdonck & Poels, 2020). Hereby, blockchain technology would be a potential candidate to tackle these problems.

In order to assess such a non-financial blockchain business case in the healthcare sector, a use case will be modelled in the Value Management Platform (VMP). The VMP is developed by the Dutch company VDMbee and provides a visual representation tool for the Value Delivery Modelling Language (VDML). This language offers a standardized representation for developing conceptual models used for the analysis and design of value creation and value capture in enterprise operations (Poels et al, 2018). This platform will allow this study to represent what values the different parties interchange with others in a blockchain use case. Furthermore, different monetary prices can be assigned to these values and be aggregated from each other. This would make it easier to visualize the benefits and the costs associated with the healthcare blockchain use case. Furthermore, VMP differentiates itself from other modelling tools with their comprehensive view. Where other modelling tools would only focus on one business unit in the case study (e.g. IT-Unit or care-unit), VMP allows for an entire coherent ecosystem to be modelled (de Man H., Co-founder VDMbee). Additionally, by investigating a use case this study can focus on the aspects important to this research. Hence, use cases reduce the complexity of certain scenarios by specifying what and under what conditions a scenario occurs (Bittner, 2002).

For the actual use case, multiple candidates are possible. In the academic literature, there exist several different studies that examine the use of blockchain in a healthcare setting. Some examples are Medrec developed by Azaria et al (2016), Guardtimes' HSX initiative, the analysis of an EHR permission management system by Verdonck and Poels (2020) and more. These examples, however, often limit themselves to pure theoretical studies, making it hard to implement them in VMP as many real-life values are missing. Moreover, the usage of a pure theoretical study would defeat the aim of this study as described hereafter. Only Guardtimes' HSX initiative has a practical implementation. Unfortunately, no results of such cases were found publicly available. Instead a more suitable case was found through a connection of VDMbee, Shariq Ata, Director Enterprise Architecture at the University of Chicago Medicine. Together with a major Midwest medical centre and Sirius Computer Solutions Inc., Shariq Ata conducted a proof of concept of a blockchain application in a patient consent management setting. The case adopted in this study is based upon this Healthcare interoperability whitepaper (Kannan & Holmes, 2019), supplemented with additional information and knowledge from Shariq Ata himself. Additional assumptions and limitations have been imposed on the use case, to achieve a scope that is feasible for the purpose of the master thesis project. It is tried nevertheless to do full justice to the use case.

Considering this case study in the Value Management Platform, the purpose of this study is twofold. First of all, the main objective, add to existing literature on blockchain in healthcare setting by providing a VMP model of a blockchain proof of concept in the healthcare sector. By visualizing the impact of this technology in a practical business case, the model build in this study can serve as a start for stakeholders in a healthcare sector that can be personalized through VMP's ease of use. Moreover, such a value delivery model built in VMP can help elevate the business case analysis, as analysts can anticipate to the effects of the blockchain technology on the business, visible in the model, and translate them to integrated business values. Second purpose is to add a valuable case study in the Value Management Platform with the implementation of a high technologic innovation. Moreover, show the capabilities of the platform due to the complexity of such a blockchain use case. Therefore this study does not only provide a structured value model, visualising the impact of a non-financial blockchain case, but also delivers a high-technological case study to show the potential of the Value Management Platform. Alongside the proof of usability for high-technological cases, this study hopes to offer some suggestions to improve VMP with the experience gathered while modelling the EHR on blockchain case.

2 Research methodology

In order to visualise the impact of a non-financial blockchain application, a qualitative research approach was handled. A qualitative research approach was chosen as the focus is on a single blockchain application described in the chosen whitepaper, the backbone of this study. According to Recker (2013) such a qualitative approach is preferred when you want to study specific phenomena and for explanatory research on less researched topics. The visualisation of this new phenomenon was then achieved through a VMP case study, as no blockchain use case has been modelled in the tool before.

A case study has been chosen as research method for the insights they can offer compared to other approaches (Rowley, 2002). Yin (1994) p. 13 defines a case study as:

“A case study is an empirical inquiry that:

• Investigates a contemporary phenomena within its real life context, especially when

• The boundaries between phenomenon and context are not clearly evident.”

The research method in this study meets this definition as a non-financial blockchain application in the healthcare sector has been researched, where the influence of the blockchain technology is not clearly defined, instead influences multiple business units and factors. Yin (1194) also depicts a case study as a useful research method when: “A how or why question is being asked about a contemporary set of events over which the investigator has little or no control.” (p.9) For this study, these two questions translate in:

- *How* will this patient management blockchain application be implemented in the healthcare ecosystem?
- *Why* is such a non-financial blockchain application interesting for the healthcare sector? What advantages does it bring?

2.1 Data collection

Data for the VMP model is based upon a blockchain use case. For this use case, a whitepaper describing the proof of concept of patient data management with blockchain in the healthcare sector was chosen. This specific use case in the healthcare sector was chosen, as there are not many other options of this calibre publicly available, as well as a direct contact associated with the whitepaper would prove to be very valuable. This whitepaper alone, however, lacked some critical information, to make a full integration in VMP possible.

Therefore, additional information in this study was drawn from four main sources: websites of included entities, input from Shariq Ata, input from Henk de Man and own assumptions. Here, the whitepaper provided the general idea of the blockchain application and basis of the ecosystem. This basis is then supplemented with additional insights of Shariq Ata, as well as background information, missing in the whitepaper. Whereas online sources were primarily used to estimate missing values and parameters. Whenever any of the other data sources could not provide an answers, assumptions and estimation were made. Nonetheless, all the data taken into account had to make sense in the grand scheme of things before it was implemented in the tool. Moreover, in order to put these values into perspective, arithmetical data has been taken into account. Here the focus was primarily on values that have equal proportions, information that would throw the model out of balance has been left out.

Considering this is a case study based upon a use case, the model focuses only on the aspects relevant for the blockchain application rather than taking the whole healthcare operation into account. According to Yin (2009), a case study is preferred when dealing with such new phenomena in a specific context.

2.2 Modelling

The design of this study consisted of four steps. (1) Before the case could be modelled in VMP, a basic knowledge of blockchain and VMP was required. Background information of blockchain was obtained through online sources and academic literature, as seen in the introduction. Whereas, the learning process of VMP was done via explanatory videos, provided by VDMbee itself. This allowed for a proper base to understand the case and imagine a potential implementation in VMP. (2) After this basic knowledge was acquired, the actual modelling in VMP could begin. For this modelling the Continuous Business Model Planning (CBMP) process was used. This process allows the users to build a fully comprehensive and interactive model in the VMP. In order to obtain such a comprehensive and interactive model three stages have to be completed (i.e. Discovery stage, Prototype stage and Adopt stage) each comprising of different steps. Not all these steps, however, have to completed, as well as the order is of less importance, more information on this process can be found in the 'VMP approach' section. (3) Off course, the implementation of such a complicated case is very challenging for a first time user. To facilitate this implementation, Henk de Man, a co-founder provided his expertise throughout the whole process. Roughly estimated, every other two weeks a meeting was planned to show the progress made. Here Henk de Man would give feedback and tips for the use of the program and his own vision regarding the representation of the blockchain case. Also, three different meetings with Shariq Ata were initiated to review the model thus far, give additional information and adjust where necessary. All interactions with the contacts were done via online meeting tools as it was difficult to meet physically due to geographical limitations. Therefore the third step of this study comprised of the processing of feedback. (4) After completing the VMP model, the results could be reviewed via the dashboards. Interactive interfaces that allow the users to compile all the necessary information in one place. Moreover, the assessment of the blockchain application could be strengthened with the implementation of What-if scenarios. These What-if scenarios alter certain input values to evaluate the model in the event of specific situations.

As this is a single-case study, it is hard to generalize these findings to other non-financial blockchain applications. Nonetheless, this study retains a certain validity and reliability by giving the study's interpretation of the case and explaining the thought process behind the essential parts of the model in detail. This study could thus be seen as a guideline for future similar studies on other cases.

3 Case

This section gives more background information of the story told in the whitepaper, supplemented with the own interpretation of this story to implement in the VMP. Moreover, the assumptions made, with regards to the ecosystems, are explained: in the current situation, the situation where the blockchain application is introduced and a follow-up situation three years after the initial introduction of the blockchain application.

3.1 General

The need for a healthcare interoperability system originally sprouted from a growing trend in the US, where bigger academic hospitals are acquiring community hospitals, small medical groups and solo practitioners in a geographic region. According to Shariq Ata, because of this trend, the need to share medical records in a secure setting has increased substantially. To this day, however, most healthcare providers operate independently, making access to medical records across providers rather restricted. There are several interoperability challenges related to the sharing of data between different information systems storing digital medical records. Not all systems offer an option to share with other systems. The request to exchange these medical records is also very time consuming. Even more, existing initiatives require a new intermediate party and added formalities. Therefore, there is a need for a secure medical record sharing framework that consistently gives the appropriate access to the right participant. While the healthcare providers or participants may manage the patients records, the patients retain full control of their own data. Evidentially, such a secure framework has to be financially viable, especially compared to existing alternatives.

The retention of data primarily entails which providers can exchange the records, how much they can exchange and for how long they have the rights to exchange the medical records. Ideally, patients are able to control their medical records in a remote setting, like a mobile application for example. Such a framework can be realized with the inherent characteristics of blockchain technology and the properties of its smart contracts. It is, however, important to note that the use of blockchain technology in this interoperability challenge is only possible thanks to some laws, instituted by the US government, regarding digital medical records.

As a part of the Recovery Act in 2009, the United States Department of Health and Human Services launched the HITECH Act (Health Information Technology for Economic and Clinical Health Act). It was created to promote and create a nationwide network of EHRs (electronic health records). This means that every healthcare provider was persuaded to make use of certified EHR technology. (Anderson, 2010). Additionally, the Medicare and Medicaid promoting interoperability programs, formerly known as the “meaningful use law”, set a list of core requirements in order to have a certified EHR. For this use case, the requirement to freely share electronic records is extremely important. Without this requirement, EHR software providers could limit the sharing of records with other EHR software providers. (U.S. Centres for Medicare & Medicaid Services, n.d.). Furthermore, there exists an international standard, named HL7[1] (Health Level Seven), that sets the standards of sharing clinical or administrative data, with FHIR (Fast Healthcare Interoperability Resources) as the latest adaptation. (HL7, n.d.). This means that most records will have the same structure, making it easier to share them across EHR software systems.

In order to fully assess the impact of blockchain technology in a healthcare setting, three phases where modelled in VMP:

1. The AS-IS scenario, which shows how EHRs currently are being shared.
2. The TO-BE scenario, which gives an introduction in the EHR on blockchain application.
3. The third phase takes a look at the situation three years after the implementation of the blockchain technology. A more detailed description and usage of the phases functionality in VMP can be found in the section dedicated to VMP.

As said earlier, different healthcare providers or participants have their own rights for accessing and sharing a patient's medical records. Thanks to the smart contracts, the appropriated rights will be executed in a consistent and automated manner. Based upon these rights, three groups of healthcare providers can be identified: Member hospitals, Affiliate (participating) hospitals and Third- party providers. Off course, it is assumed that the patient still owns its own record data and can influence these rights. Figure 1 and Figure 2 from the whitepaper give an initial explanation of each healthcare provider and their rights. Throughout this case explanation, all aspects of these figures will be handled in detail, linked to their implication for the VMP model.

[1] https://www.hl7.org/

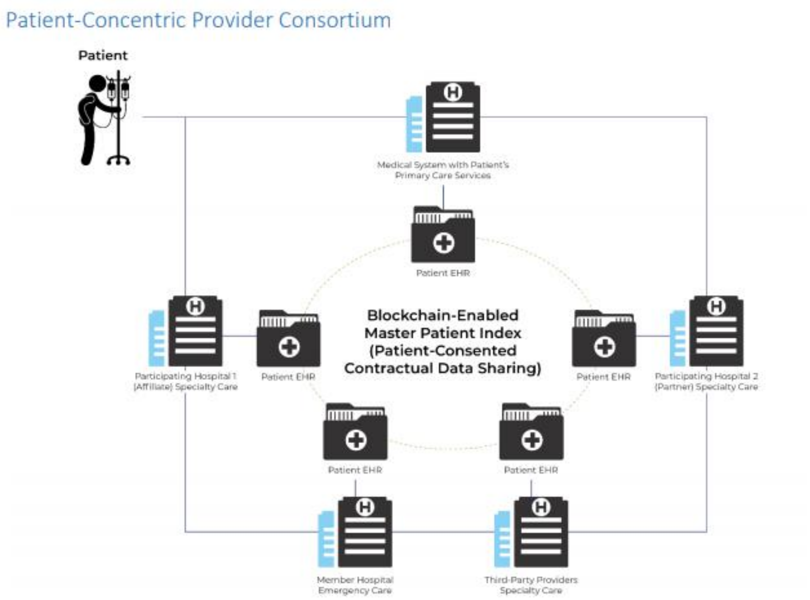


Figure 1: Organisation of Consortium

Key Elements

Patient EHRs:	Include patient demographics, medical history, prescriptions, allergies, and other health-related information.
Master Patient Index:	Patient record index stored in blockchain that is hash-coded and encrypted. Hash code uniquely identifies the patient and enables interoperability across the provider network.
Member Hospitals:	Members of the health system. Data-sharing contracts are governed through the restrictions of being a Member Hospital; all member hospitals typically share data without restriction.
Participating Hospitals:	Data-sharing contracts are governed through the restrictions of being Affiliate or Partner Hospitals.
Third-Party Providers:	Any third-party hospitals that are not typically part of the consortium but would like to access the Master Patient Index on an on-demand basis. Third-party providers are not in scope for proof-of-concept purposes.
Patients:	Patients of the consortium hospitals who give exclusive consent to view their health records.

Figure 2: EHR on blockchain important terms

It is important to note that the Academic hospital, involved in the writing of the white paper, belongs to the Member hospitals and the other types are based upon legal relationships with this Academic hospital. Essentially the data-sharing rights enforced by the smart contracts are based upon the legal relationship between two healthcare providers. The following figure defines the possible relationships a healthcare provider can have with the Academic hospital.

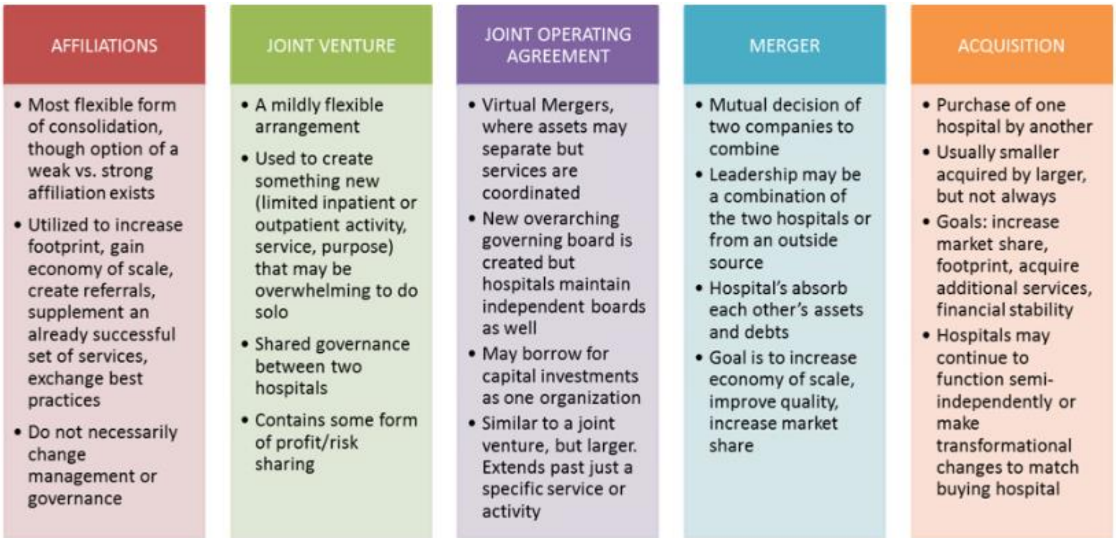


Figure 3: Legal relationships between healthcare providers

Only the affiliations relationship will form a new type of healthcare provider. The other relationships will all be placed within the Member hospitals (i.e. Joint venture, Joint operating Agreement, Merger (Community hospital) , Acquisition), together with the Academic hospital. The reasoning behind this divisions comes from the fact that the Academic hospital wants to fully share all the data across these other healthcare providers. Obviously the Third-party providers are missing from this figure of relationships, as they have no legal relationship with the Academic hospital. Together with the Affiliate hospitals, the Member hospitals will form a consortium, an alliance to realize this blockchain implication. This consortium is then responsible for everything regarding the blockchain technology. More information regarding these three types of healthcare providers and the Consortium will be given in the TO-BE scenario.

Defining these three types of healthcare providers is only relevant for the blockchain scenarios. Nonetheless, the same division will be made in the AS-IS scenario to facilitate a comparison with the other scenarios.

The three phases will be further explained in the following paragraphs. Each scenario will be supported by a figure of the Business Ecosystem Map from the app. Such a Business Ecosystem Map allows users to visualize and identify the business network with the participating actors, based upon Allee's Value Network concept (Allee, 2008), who's concept has been subsumed by the VDML standard and implemented by VMP. This will improve the readers ability to comprehend the different scenarios. A bigger picture of these Business Ecosystem Maps can also be found in Appendix 3, this ensures better readability of the ecosystems.

3.2 AS-IS scenario

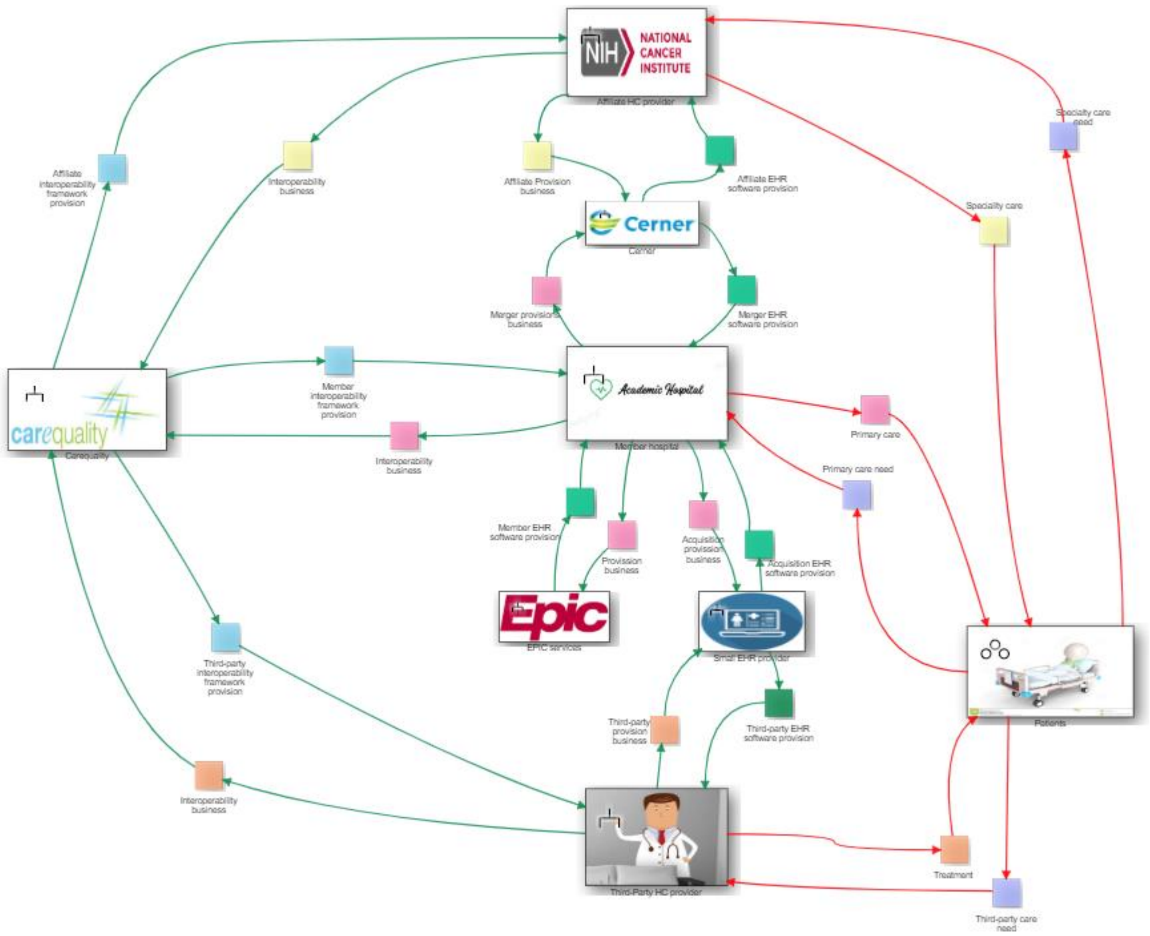


Figure 4: AS-IS Business Ecosystem Map

As can be seen in Figure 4, there are four key-participants in the AS-IS scenario (i.e. Affiliate hospitals, Member hospitals, Third-party providers and CareQuality) complemented by the patients, customers of the healthcare providers.

3.2.1 Healthcare providers

The initial reasoning behind the healthcare provider classification (i.e. Affiliate hospitals, Member hospitals and Third-party providers) can be found in the introduction to the use case. A more detailed description will be given in the TO-BE scenario, since the classification is not relevant for the AS-IS scenario and is only present for comparison purposes between the scenarios. Nonetheless, it is possible to sketch some assumed characteristics of these three healthcare providers to increase comprehensibility of the providers across the scenarios.

3.2.2 Healthcare providers characteristics

For the first healthcare provider, the Affiliate hospitals, more specialised providers are assumed. They deliver speciality care to their patients, like cancer treatments for example. Therefore the logo of a national cancer institute is used to symbolize the Affiliate hospitals. The second type of healthcare providers is the Member hospitals, the only key-participant comprising of other kinds of healthcare providers, consisting of the Academic hospital, Joint ventures, Joint operating Agreements, Mergers and Acquisitions. Due to their close relationship with the Academic hospital and rights in the TO-BE scenario, all of them are bundled under the member hospital branch. For the sake of simplicity, these other providers are simply named after the legal relation they have with the beating heart of the Member hospitals, the Academic hospital. Therefore, the Academic hospital is the most important member of the Member hospitals, making it the logo of the Member hospitals. As a result of their importance, the Member hospitals are also assumed to account for the biggest costs and revenues compared to the other types of healthcare providers. The last type of healthcare provider, Third-party providers, is assumed to be a group of smaller healthcare practitioners (e.g. private clinics, smaller clinics, physiotherapists, individual doctors). In practice this could as well be another larger, potential academic hospital, healthcare provider. For the case study five Affiliate hospitals, fourteen Member hospitals and twenty-five Third-party providers are assumed in the AS-IS and TO-BE scenario. This distribution was approved by Shariq Ata.

3.2.3 CareQuality

The fourth key-participant in the AS-IS scenario is CareQuality[2]. CareQuality launched an initiative that hopes to improve interoperability between systems in the US, by establishing a nation-wide framework that enables exchange of data between health data sharing networks. In order to accomplish this, CareQuality sets technical and policy agreements amongst the different networks through a consensus-based process with the help of representatives. The following analogy used by CareQuality helps to put this into perspective. “What if you had a cell phone plan that only allowed you to call other customers of your carrier”. This is the very problem healthcare providers face in the AS-IS scenario. Therefore, CareQuality hopes to lift this limitation with their interoperability framework. Unfortunately, this initiative requires the cooperation of every player in the EHR distribution, from the software provision to the usage by healthcare providers, while also needing additional regulations. As explained earlier, there are already a couple of standards and regulations providers that have to abide to. Additionally, CareQuality is now an outside party involved in the exchange of medical records between healthcare

[2] https://carequality.org/

providers, potentially raising security questions. Patients would lose all their confidence in a healthcare provider when private medical data would be sold or leaked to any other party.

3.2.4 EHR software providers

Besides the four key-participants and the healthcare's patients, the Business Ecosystem Map in Figure 4, comprises of three other entities. These are the EHR software providers: EPIC[3], Cerner [4] and all other smaller companies that deliver EHR software. As stated by the HITECH Act the majority of healthcare providers, in the United States of America, is persuaded to make use of EHRs. In order to do so, the healthcare sector needs the appropriate software. Therefore, it is assumed that the healthcare providers in this case contract the biggest players in the EHR software scene, with EPIC controlling the majority of the market. Unfortunately, these services are far from cheap, leading to almost 25% of the total IT-costs (Ata, Director, enterprise architect UCM). Hereby smaller healthcare providers are not able to afford the services of these larger EHR software providers. Therefore, it is assumed that the group of Third-party providers will turn to lesser known EHR software providers, with potentially less sophisticated services. Additionally, the small acquired clinics acquired by the Academic hospital will have ongoing contracts with different smaller EHR software providers. Whereas, the Academic hospital itself will use EPIC. In due time, the Academic hospital will convert them to EPIC, once the ongoing contracts are finished. As of now, however, this difference in EHR software provider can lead to certain interoperability challenges.

3.2.5 Interoperability

To further display the interoperability problem, it is assumed that the Affiliate hospitals and the community hospital of the Member hospitals use Cerner instead of EPIC. But in reality, this is not necessarily the case. The main reason for these assumptions, stems from the extra services EPIC offers its users to share EHRs between different healthcare providers, which solve part of the interoperability problem. Most notable are EpicCare Link and EpicCare Everywhere. EpicCare Link is a web-based application that gives users secure access to select patient records in Epic via a weblink. Unfortunately it only allows the user to read the select information, not to copy or to store the data. Whereas EpicCare Everywhere is EPIC's interoperability application, allowing for a full exchange of patient data with other healthcare providers. As EpicCare Everywhere supports CareQuality's interoperability framework and follows the HL7 standards, EHRs can also be exchanged with other EHR software than EPIC itself. These services, however, are very time intensive as the EHRs have to be requested manually and are only

[3] https://www.epic.com/software#Clinicals
[4] https://www.cerner.com/

available for a limited time. The following figure, obtained by Shariq Ata evaluates the usage recommendation of these EPIC services for the different types of healthcare providers.

Capability	Clinically Integrated Network Types				
	Affiliations	Joint Venture	Joint Operating Agreement	Merger	Acquisition
EpicCare Link Web-based; Select patient information access.	👎	👎	👎	👎	👎
EpicCare Everywhere Epic's interoperability (HL7) application. Non transactional. On Demand	👍	👍	👍	👍	👍

👍 Preferred	👎 Not recommended

Figure 5: Assessment of EPIC services

Based upon Figure 5 it would thus be viable to use EpicCare Everywhere to exchange EHRs between healthcare providers. Nonetheless, as every currently available alternative, exchanging EHRs via an EPIC infrastructure is very expensive, time consuming, only for a limited time and requires an intermediate party to work at its full potential. In this study, CareQuality would then be the intermediate party.

3.3 TO-BE scenario

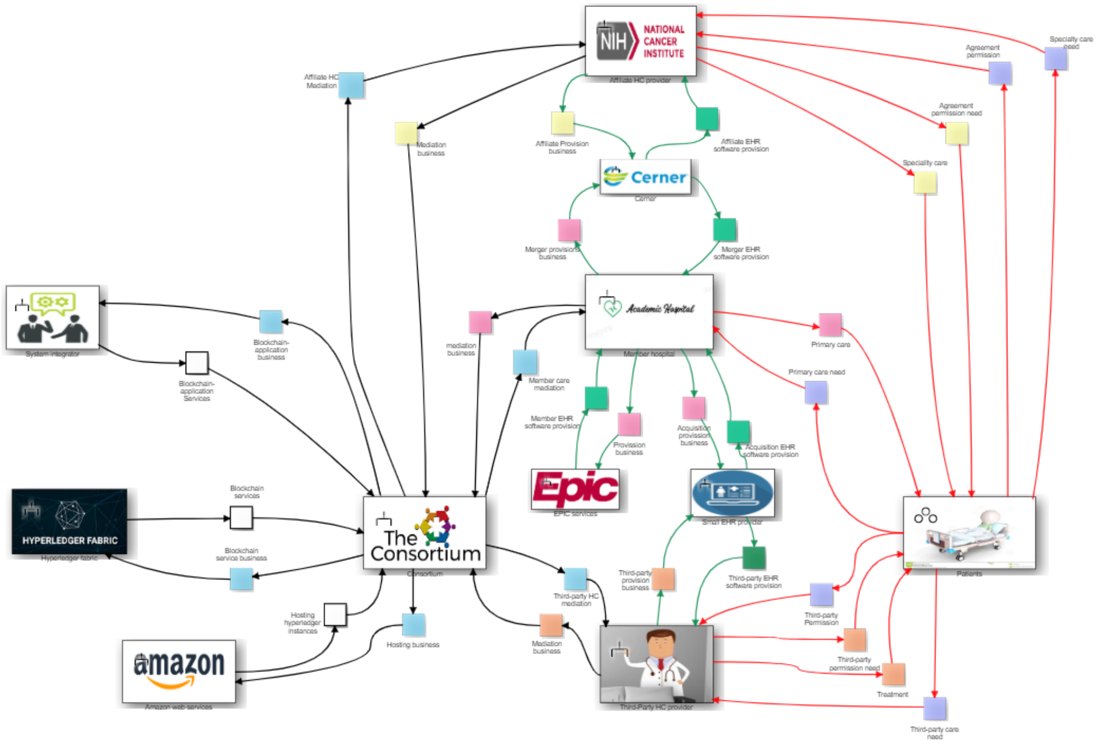


Figure 6: TO-BE Business Ecosystem Map

3.3.1 The Consortium

The purpose of the TO-BE scenario is to visualise the use of blockchain technology to exchange EHRs between healthcare providers. The most notable difference between the As-IS (Figure 4) and TO-BE Business Ecosystem Map (Figure 6) is the disappearance of CareQuality and the appearance of the Consortium, which is linked to three other entities (i.e. System integrator, Hyperledger fabric and Amazon web services). For this study, the consortium is created by the Member and Affiliate hospitals, ideally on a city or state level. In reality this consortium is not a separate entity, however, for clarification purposes it is visualized separately in the Business Ecosystem Map. Furthermore, it is assumed that this consortium entity will develop the EHR on blockchain application, with the help of the System integrator. The System integrator in this case study is also the co-author of the use case, Sirius. The composition of this consortium is specific for this study, other initiatives could use a governmental institution or private organisation that provides the non-financial blockchain application (like the examples of Verdonck & Poels (2020) and Guardtimes' HSX initiative). Besides the System integrator, the Consortium has two other suppliers. First of all, the Consortium partners with Hyperledger[5].

[5] https://www.hyperledger.org/use/fabric

Hyperledger will supply the distributed ledger technology, known as Hyperledger Fabric. This allows the Consortium to build the blockchain application. The second partner is Amazon[6]. Through their web services the Consortium is able to build the application on a cloud solution rather than develop it on inhouse storage systems. With the help of this consortium, healthcare providers will then be able to exchange EHRs via the blockchain application, making CareQuality and EpicCare Everywhere unnecessary. Therefore the role of the Consortium is to develop and maintain the EHR on blockchain application, providing it to the involved healthcare providers. This also includes offering training and customer support regarding the usability of the software.

3.3.2 "Meaningful use law"

Thanks to the meaningful use law it is possible to exchange patients' records over such a blockchain application. As said earlier this law dictates that EHRs have to meet certain restrictions. Most importantly, EHRs have to be freely exchangeable, meaning that EHR software companies cannot limit the EHRs to only work on their software. Furthermore, with the HL7 standard, most EHRs will have a standard format. This ensures that EHRs from different EHR software providers are interchangeable.

3.3.3 Master Patient Index

It is important to note that the healthcare providers keep their existing EHR software from the AS-IS scenario. The EHR on blockchain application will not replace their EPIC or Cerner software. In its essence, no patient data is stored on the blockchain. All the records remain in the inhouse storage systems. Instead a Master Patient Index is created for every patient, on the blockchain application, that links the correct record to the patient. This index contains the meta data and link to where the needed data are stored. Therefore, no EHRs are stored in blocks on the blockchain, only metadata. This also means that patient data are only stored once, reducing data redundancy. A visual representation of this Master Patient Index van be found in Figure 1.

3.3.4 Data sharing rights

Not all three healthcare providers (i.e. Affiliate hospitals, Member hospitals, Third-party providers) are allowed to exchange all data equally. Earlier it was already said that this classification is based upon the legal relationship with the Academic hospital. There is a second reason tied into this split of healthcare providers, regarding their rights for exchanging data. Namely, not every group is allowed to exchange all records equally. These rights are based upon the contract the healthcare provider will have with the Consortium. As so, all the entities in the Member hospitals have an exclusive contract to share all EHRs across healthcare providers. The Affiliate hospitals, on the other hand, have a certain agreement to only exchange a set of patient data (e.g. allergies, prescribed medicines, past treatments, etc). What the

[6] https://aws.amazon.com/

content of this data will be, depends on the specific legal contract. Of course, in this case study it is impossible to work with types of data, instead percentages are used. As so it is assumed that the Affiliate hospitals in this study are able to exchange 60% of patient's data with their contract, whereas Member hospitals can exchange 100%. Lastly, the Third-party providers, are not a part of the Consortium and therefore have no specific contract. They will only be able to access the Master Patient Index on an on-demand basis. Patients will have to grant consent to these Third-party providers, preferably via a mobile application, as they are the owner of their own data. Through this mobile application, patients will be able to see who has accessed their records, what they have added or updated and who has requested access. In a similar fashion, Affiliate hospitals can request consent to exchange data not included in their contracts. This request to the patient can be found in the Business Ecosystem Maps (Figure 6). It also important to note that the Member hospitals miss said 'request' relation with the patient, as they do not need it. As to be expected, these contracts have to be respected in a secure and consistent manner. This is done via the smart contracts, an invaluable feature of blockchain technology. These smart contracts will automatically assign consent, if and only if the correct clauses are fulfilled. As no EHRs have to be asked manually anymore, waiting times are drastically reduced.

3.3.5 Advantages of blockchain technology in the case study

It is clear that the blockchain technology offers several advantages in the TO-BE scenario compared to the AS-IS scenario. Three main advantages can be identified; trust, contract governance and shared control.

Trust refers to the inherent characteristics of blockchain technology that allows a secure environment, together with providing the participants with up-to-date information. If healthcare providers have the most recent information available, the chance of errors due to incorrect or outdated information decreases. The second advantage, contract governance, refers to the consistency thanks to the smart contracts automatically applying the correct legal contracts. Lastly, with the help of blockchain technology, data can be safely shared with other parties by solving the shared control responsibility in terms of data the healthcare providers can access, can own and can share. Ultimately, it is assumed that these advantages translate in a higher access of data compared to the cost to achieve this increase, thus reducing costs in the long run and improving care services. Mainly due to immediate availability of records and a higher transparency towards the patients and other healthcare providers.

3.4 After 3 years

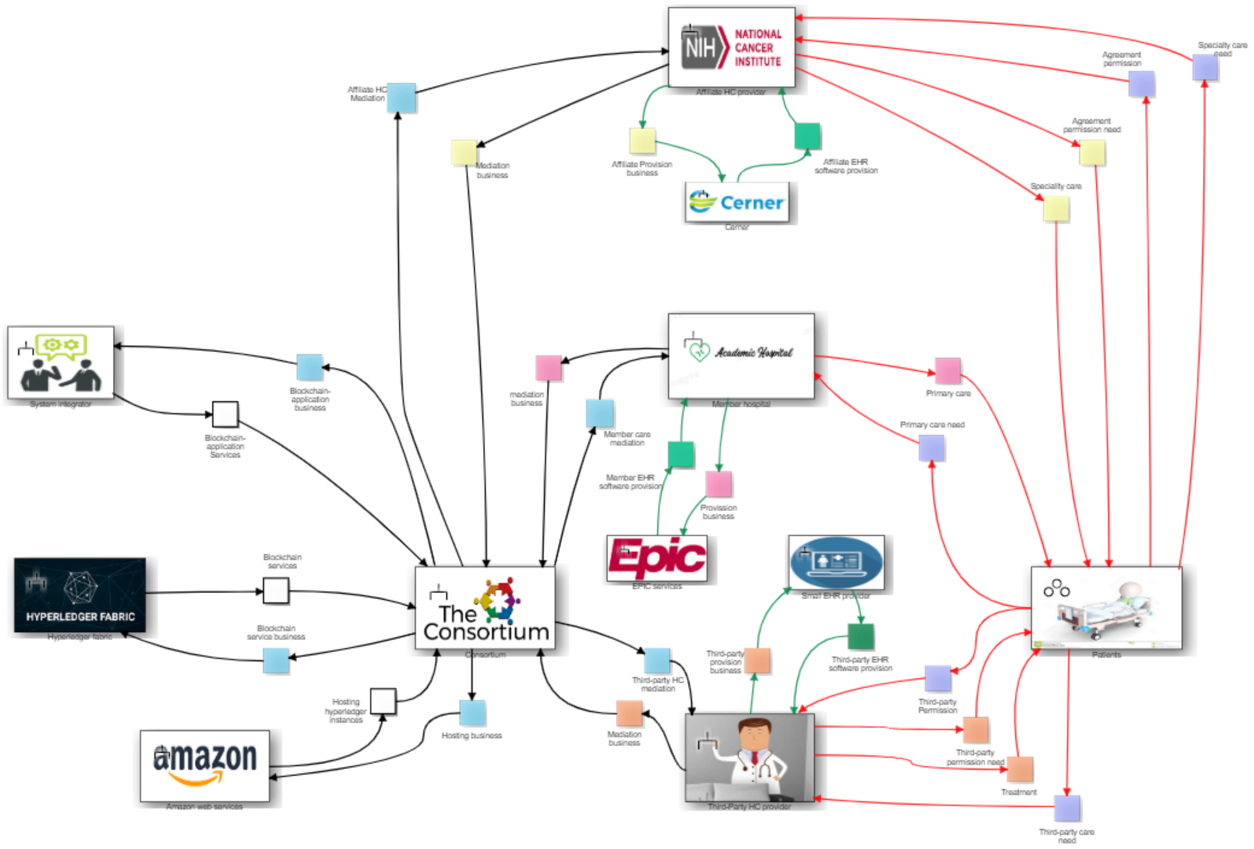


Figure 7: After 3 years Business Ecosystem Map

The purpose of this phase is to take a look at the EHR on blockchain application, three years after the introductory phase. Several assumptions are made with regards of the evolution of the application, as it is impossible to fully predict the future.

First of all, it is assumed that the effectiveness of the blockchain implementation improves over the years. Healthcare providers will rack up more experience over time by using the application. Furthermore, as a patient's EHRs across healthcare providers are more freely and easier accessible, Master Patient Indices will be more complete and detailed. This can further reduce treatment errors due to outdated or missing patient information. The second assumptions concerns itself with the amount of healthcare providers willing to join the Consortium. Thanks to the added benefits of the blockchain technology, this method will start to gain popularity and more providers will want to join the initiative. This will increase the Consortium in member size, but also convince previous Third-party providers to join either the Member hospitals or the Affiliate hospitals. Therefore the member size of ten Affiliate hospitals, twenty-three Member hospitals and forty Third-party providers is assumed in this scenario. And finally, once patients see the benefits of the implementation, more patients will allow the sharing of their EHRs through the blockchain application.

Another difference with the TO-BE scenario lies with the choice of EHR software provider, as can be seen in Figure 7. Once the previous contracts are terminated, the Academic hospital will transfer their merged and acquired companies to the same EHR software provider, being EPIC. By doing this, the case study assumes that the entire group will receive a group discount form EPIC, resulting in lower EHR software costs.

4 VMP approach

Here, more information of the tool itself will be given, complete with a detailed explanation of the Continuous Business Modelling Planning process. To further illustrate this process, all the used stages and steps will be backed with a figure of the model made in this study.

4.1 Value Delivery Modelling Language

The global market is characterized by an ever changing environment. New technologies, enhancements and ideas pop-up every day. This forces entrepreneurs to react to their changing market segment with innovative ideas, business changes and strategic ideas. This can be very challenging, however, and it increases the complexity of businesses. With the impact of these strategic decisions and the changes transcending the boundaries of one company, the complexity increases even more (Cummins, 2016). In order to help entrepreneurs face this complexity, the Object Management Group (OMG) adopted the Value Delivery Modelling Language (VDML) as a standard business modelling specification (OMG, 2015). VDML enables modelling of value creation and exchange on a strategic level (Metzger, Terzidis & Kraemer, 2015). Furthermore, VDML supports several existing value and business modelling approaches (e.g. Business Model Canvas (Osterwalder & Pigneur, 2010), Value Networks (Christensen & Rosenbloom, 1995)). Hereby, VDML tries to fill the gap between strategy and business processes on an operational level (Metzger et al, 2015). Business and value modelling both serve a purpose to fill this gap and form a cohesive overview. Starting with value modelling, where the goal is to identify the appropriate stakeholders in a network, by defining the creation and exchange of values in a given business network (Souza et al, 2018). It is important to note that VDML considers these exchanged values to be measurable (OMG, 2015). On the other hand, the business modelling approach is more used to describe the underlying logic of the separate entities for creating, delivering and capturing this value, in line with the Business Model Ontology (Osterwalder, Pigneur & Tucci, 2005).

4.2 Value Management Platform

With the Value Management Platform (VMP), the Dutch company VDMbee[7] enables in practice application of the VDML. By using VMP, business leaders have the possibility to evaluate future strategic decisions with the help of canvasses, maps and storytelling. Through the visual interfaces of the software tool, users will create a VDML model without any need of the language ‘s specifications. This increases the ease of use and removes the need for a technology-oriented profile. (Poels et al, 2018). With the help of VMP, business leaders can then visualize a response to their everchanging market segments, potentially planning one step ahead.

[7] https://vdmbee.com/

In order to evaluate a strategic implementation and assess the impact on future business structures and value objectives, VMP makes use of their CBMP approach. The CBMP process provides a high-level structured roadmap for cohesive business models, that can be compared and further developed on a strategic level. This modelling process is realised through three stages: Discover, Prototype and Adopt.

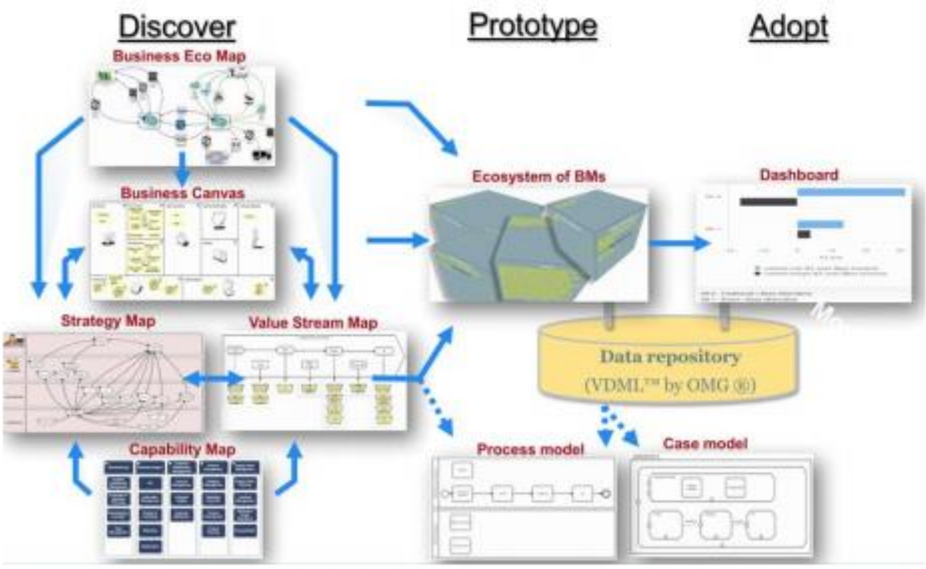


Figure 8: CBMP process

Figure 8 gives an overview of the three stages, combined with the appropriate techniques used in the platform. (Poels et al, 2019)

Additionally, users can spread the evolution of a strategic decision across different phases, allowing for a comparison between an As-Is phase and To-be phase, with a potential follow-up phase, as can be seen in Figure 9. Furthermore, a certain phase can be divided into different alternatives, to allow a visualization of different strategies in a certain phase. In practice, only one phase will be built from scratch. Other phases or potential alternatives will be based upon a copy of the original phase, modified with the necessary changes. This allows for a linkage and an aggregation of values across the phases. This also helps the platform compare similar values in different phases.

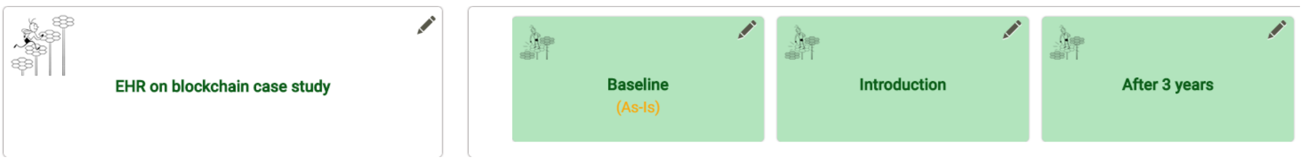


Figure 9: Phases overview

4.3 CBMP process

The different stages (i.e. Discover, Prototype and Adopt) and their different steps, visible in Figure 8, will be explained with the help of the EHR on blockchain case study. In the case of such a new technological implementation, VDMbee advises users to start from the To-Be phase. This is mainly because this scenario is the reason for modelling this case in VMP. Therefore, the starting point of this exposition is the situation where patients EHRs will be shared over a blockchain application (labelled as *Introduction* in Figure 9), rather than any of the other 2 phases. In this study no alternatives will be addressed as there were none modelled or necessary for any of the phases.

4.3.1 Discover stage

The discover stage visualizes the exploration and understanding of the As-Is and To-Be business models (Poels, Roelens, de Man & van Donge, 2018). According to Poels, Roelens, de Man & van Donge (2019) this stage can be divided in 5 steps: (a) context determination; (b) business ecosystem and business model description; (c) value stream mapping; (d) value creation design; and (e) call to action, with an overview in Figure 10. It is important to note that the steps are not mandatory or fixed in this specific order. This order, however, is to be recommended. VDMbee (de Man, 2017) also advises users to involve the appropriate stakeholders while visualizing the strategic initiative. Throughout this stage, VMP makes use of certain well known views (e.g. Business Ecosystem map, Business Model canvas, Value Stream Map and Strategy Map). These popular views can help new users to start with VDML, as they may already be familiar with these established concepts. It is also important to note that all these different views form one integrated VDML metamodel, as explained by Poels, Roelens, de Man & van Donge (2018).

Figure 10: Discover stage overview

a. Context

The first step, *context determination*, dictates the users to extensively describe the strategic initiative, including the problems, goals, opportunities, relevant parties, assumptions, constraints and other relevant details (Poels et al, 2019). Basically, the context determinations forms the very basis for the following steps and stages. In this case study the report was used, a Word-like functionality. This can be as detailed as the modeller wants. The more detailed this report, however, the smoother the next steps will be. In this study, the report is filled with information about the case's ecosystem, reasons for the initiative, what is blockchain, monetary values, etc. Examples of this study's report can be found in Appendix 1. Users can also use the SWOT analysis and Capability Map/ Library functionality during this step, two additional techniques who can help describe the context of the strategic initiative. The SWOT analysis can be implemented via a SWOT Analysis Canvas, where the strengths (S), weaknesses (W), opportunities (O) and threats (T) can be described in a two-by-two matrix. In the Capability Map, on the other hand, a hierarchy of capabilities is visualised. These capabilities are defined in the Capability Libraries and are specific for the organization or a certain sector. (Poels et al, 2019). Both of these functionalities were not used in this study, as too much initial information had to be noted to understand the case. The report functionality was therefore a better suited candidate. Moreover, often own designations were used, rather than based on industry-specific reference models, eliminating the advantage of a Capability library.

b. *Ecosystem & Business Model*

i. Ecosystem

The second step, *business ecosystem and business model description*, allows users to visualize and identify the business network with the participating actors. VMP bases its Business Ecosystem Map on Allee's Value Network concept (Allee, 2008). Where an external view of the important actors is made, together with all the corresponding values they exchange. Verna Allee's Value Network was subsumed by VDML, and became the basis of the Collaboration Diagram in VDML. This Diagram can be divided in two levels of abstraction, one level of exchanging business items, and another level of exchanging complete services/ packages, modelled as exchanges of value propositions (in VDML these are called "Value Proposition Exchange", typically conducted in Business Networks). VMP only implemented the level of exchanging complete services/ packages, as this is the level where most business model analyses/ planning concerns are located. (Henk de Man).

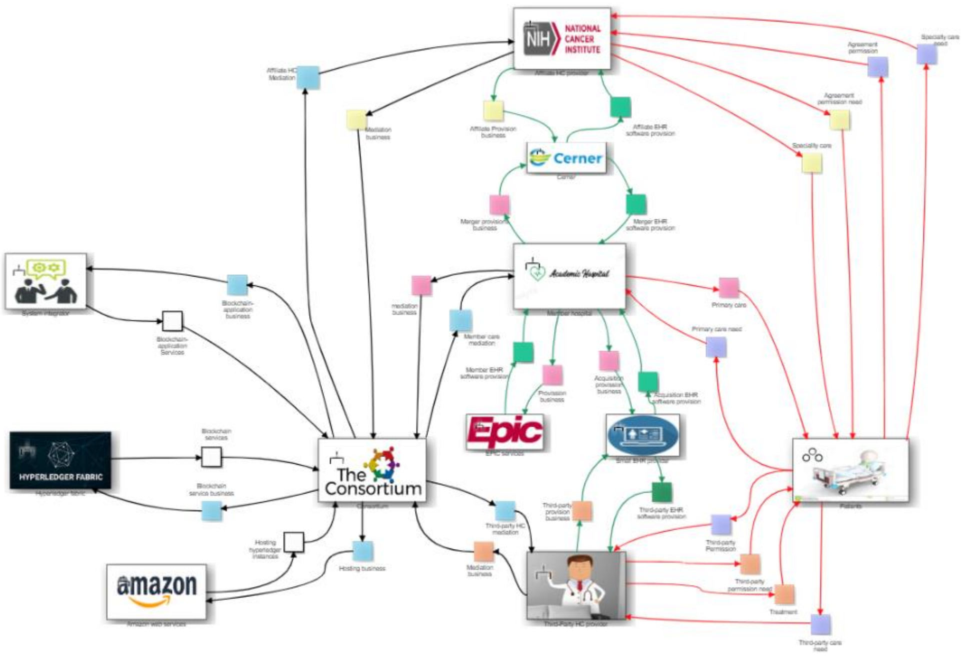


Figure 11: Example of Business Ecosystem Map

As explained before four key participants can be identified in this study: Affiliate hospitals, Academic hospitals, Third-party hospitals and the Consortium. The other actors represent essential suppliers (i.e. System integrator, Hyperledger fabric, Amazon, Cerner, EPIC and a small EHR provider) and the key participants' sole customer, the patients. This all is visible in the Business Ecosystem Map (Figure 11). VMP also allows for the use of different colours in the Business Ecosystem Map, this helps distinguish value propositions (the values exchanged between the actors). One can see in Figure 11 that the most important participants have their own colour for their respective value propositions (The Consortium has light blue value propositions, The Member hospitals' value propositions are identified by their pink colour, and so on). Furthermore, users can give the connections between actors different colours. In this case study the colour code is used to visualize the different networks present: black for the blockchain network, green for the EHR network and red for the care network.

ii. Business Model

The description of the key participants' business model can be achieved with the help of several business canvases. One such business canvas is the Business Model Canvas, based on Osterwalder's Business Model Ontology (Osterwalder, 2004). This Business Model Canvas itself is not a normative model in VDML, but VDML does give an informative mapping from Business Model Canvas to VDML. It is this informative mapping that is implemented in VMP. VMP also supports other business canvases (e.g. Integrated reporting canvas, personal business model canvas, SWOT analysis canvas, etc.). In the EHR on blockchain case, the Business Model canvas was used, as this is the most popular. The following figure shows such a Business Model Canvas for the Academic hospitals.

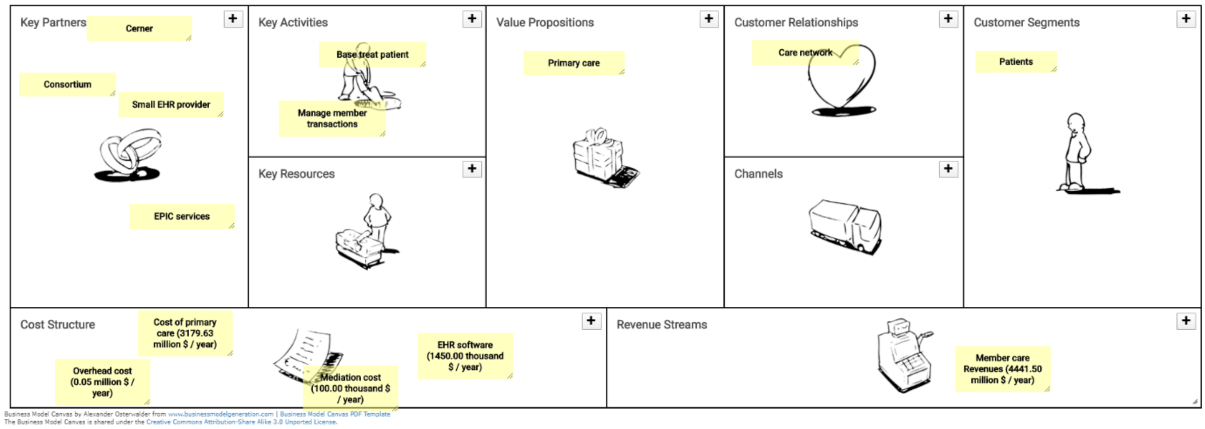


Figure 12: Example of Business Model Canvas

This business model canvas of the Academic hospitals (Figure 12) provides a perfect summary of how and what they need to do business. In total four Business Model Canvasses were made in the TO-BE phase for each key participant (i.e. Consortium, Affiliate hospitals, Academic hospitals, Third-party healthcare providers). These other Business Model Canvasses of the TO-BE phase can be found in Appendix 3.

c. *Value stream*

In the Business Ecosystem Map, several value propositions are defined between actors. Most of these propositions rely on activities. In addition, activities can also be supported by competences. This is visualized in the third step, *Value stream mapping*. (Poels et al, 2019). Originally, the Value Stream Map is not a normative notation in VDML, but due to its popularity among Business Architects, and its compatibility with VDML, it was decided to implement this view in VMP.

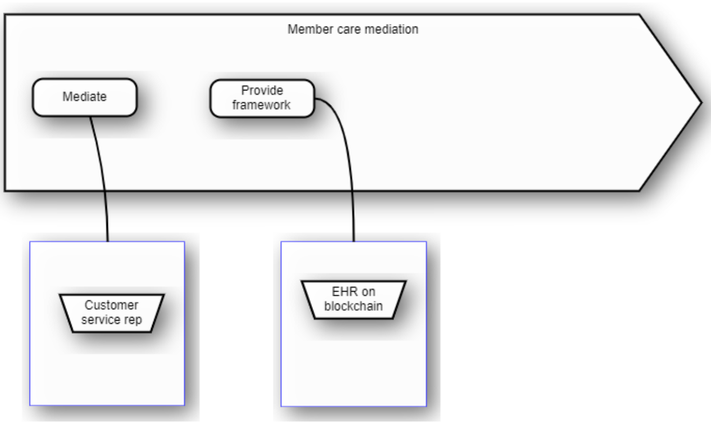


Figure 13: Example of Value Stream Map

An example of a Value Stream Map (Figure 13) can be shown with a value proposition exchanged between the Consortium and the Academic hospitals, Member care mediation, as seen in the Business Ecosystem Map (Figure 6). This value proposition is the embodiment of the provision of an EHR on blockchain application by the consortium to the Academic hospitals. Essentially giving the Academic hospitals the ability and rights to use the application developed by the consortium.

As shown in Figure 13, the Member care mediation value proposition consists of two activities, Mediate and Provide framework. Provide framework consists of the provision and rights to the EHR on blockchain application, including all the additional advantages that come with this framework. Whereas, the Mediate activity is more concerned with the interactions between the Consortium and the Academic hospitals. Primarily regarding troubleshooting and training regarding the use of the application. As said earlier, activities can be supported by competencies, portrayed by the rectangle connected to the activities. These competencies allow the business to perform the associated activity. This specific value stream, has two competencies, one for each activity, which is also the reason for choosing this specific Value Stream Map. It is thanks to the customer service representative that the Consortium and Academic hospitals are able to communicate. Also, the EHR on blockchain application is needed before it can be offered to the healthcare providers. Without these competencies the Consortium can't deliver the respective activities. In the TO-BE phase, 18 different Value Stream Maps were modelled in total.

d. Value creation

The fourth step*, value creation design*, visualizes the value objectives and the main cause-and-effect influences for these values related to the strategy (de Man, 2017). Here, VMP uses Strategy Maps, based on Kaplan and Norton's Strategy Map concept (Kaplan & Norton, 2004). Again, Strategy Maps are not a normative view in VDML, but thanks to its popularity in business management and compatibility with VDML, it was decided to implement this view in VMP.

An example of the Academic hospitals' Strategy Map can be found in Figure 14. A bigger figure, along with the Strategy Maps of the other key participants and written explanation of the values can be found in Appendix 4. Four different rows can be distinguished in such a Strategy Map (Figure 14): Business Value, Customer, Value Stream and Competency. These Strategy Maps allow users to develop a bottom-to-top view of the business. Starting with the Competency row, here the values or competencies necessary for the creation of the businesses values are shown. These are often provided by partners. Like in this case, the Academic hospitals need the EHR on blockchain application and EHR software before they can create their own values. The second row, Value Stream, tells something more about the internal processes with the respective values that are created and/or needed. For example, all the relevant values influencing the cost per treatment are visualised (i.e. labour cost, medicine supplies and medical facilities), which on its turn determines the cost of primary care. The next row, Customer, shows all the values the business offers to its customers, in this case the patients. Here, all the values that influence the patient satisfaction can be seen, and how those values are influenced by other rows. At the top, on can see the Business Value. This is the end of our bottom-to-top visualisation and shows the values the business would like to capture as a consequence of the strategy. In this case study, the focus is mainly on the impact of costs and benefits due to the implementation of blockchain in EHR sharing, on the Business Value level.

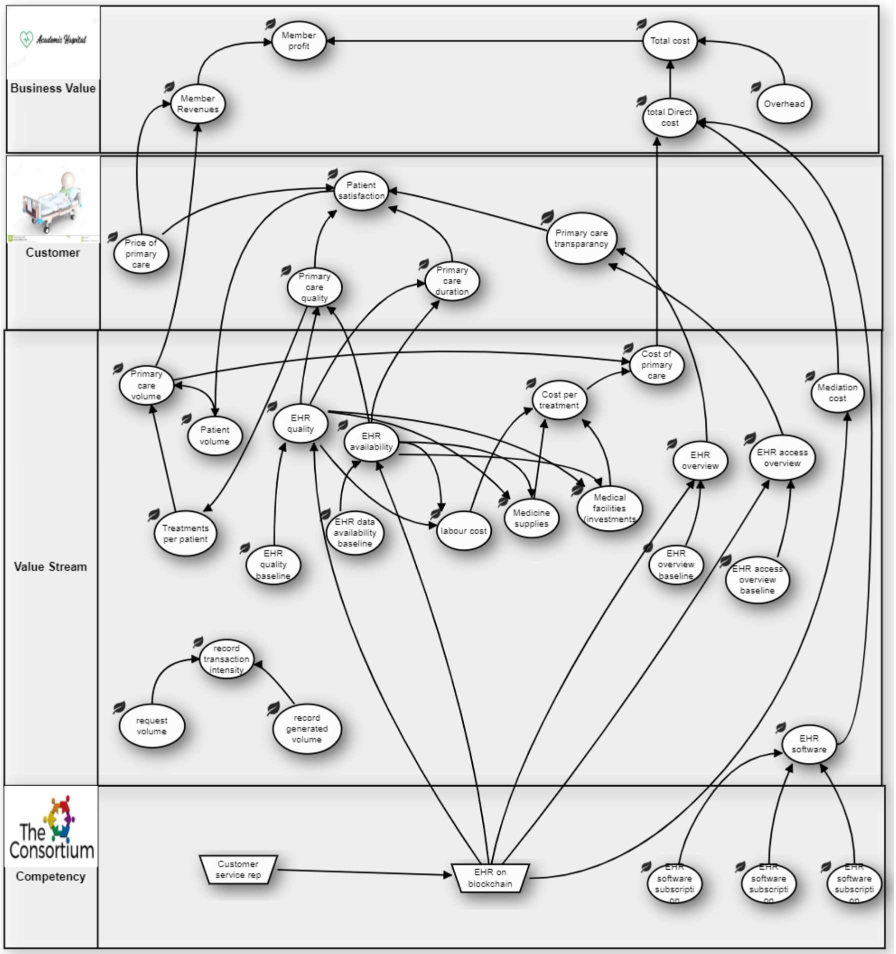


Figure 14: Example of Strategy Map

e. Call to action

Call to action is the last step of the discover stage. In order to inform the appropriate stakeholders, users can make use of the Lean Change Canvas and a customizable dashboard. Both techniques can be used to summarize the results of the discover stage. Based upon these results, stakeholders can make an informed decision of the idea. (Poels et al, 2019). This step was not utilized in this blockchain case study, therefore no examples can be given.

4.3.2 Prototype stage

The overall goal of this stage is to transform the relevant information from the discover stage into a multi-perspective ecosystem of structured business models, as explained in Poels et al (2019). In the following figure an overview is given of the four business models present in the EHR on blockchain case.

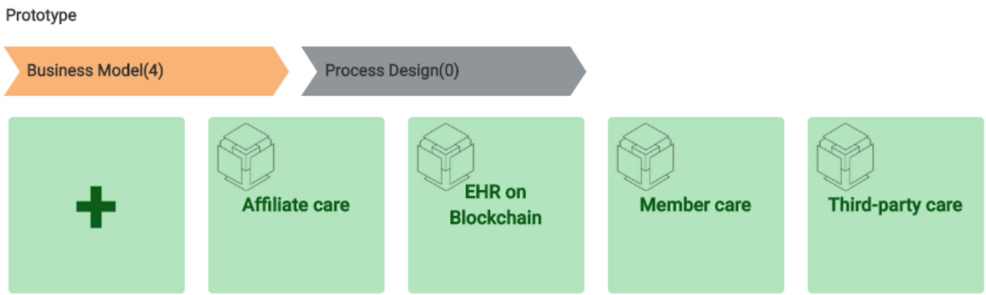


Figure 15: Prototype stage overview

These business models match the four key participants: Affiliate hospitals, Consortium, Academic hospitals and Third-party hospitals respectively, named after their primary value proposition.

VMP makes use of Lindgren's Business Model Cube (Lindgren & Rasmussen, 2013). The Business Model Cube, consists of six faces (Figure 16): Value Propositions (including My Propositions), Customers, Partners, Activities, Competencies and Values. This allows for a representation of business models living in an ecosystem of interacting business models. Again, an example business model can be given of the Academic hospitals (Member care).Combined with a figure regarding the different sides, as not all sides of the cube can be shown due to space preservation.

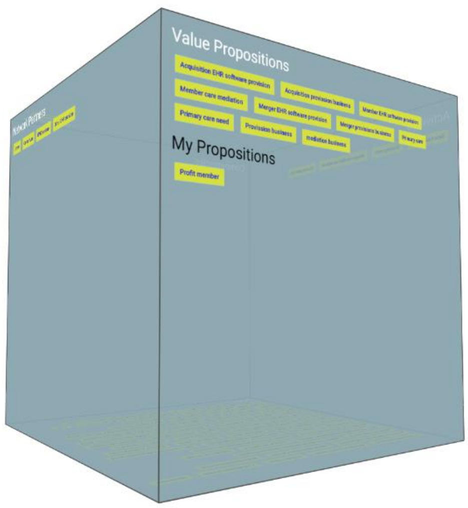


Figure 16: Example of Business Model Cube

Figure 17: Overview of Business Model Cube sides

With the help of a mapping wizard, users can fill in the Model Business cube with information from the Discover stage. While also linking it to the appropriate information in the visualization tools, creating a two-way traceability between the two stages. (Poels et al, 2018). Most of this information will already be available from the discover stage. Where the visualization tools in the discover tools are often just pictures, they become interactive tools after the prototype stage. As they become linked to the same values in different visualisation tools, allowing for the two-way traceability. Additionally, the cause-effect storytelling from the Strategy Maps helps with the designing of these relationships. The following example consists of the same value proposition Member care mediation as in the value stream example, to display the effect of mapping.

Value Proposition Details

Name	Member care mediation
Description	Member care mediation
Provider	Consortium
Provider Role	Mediator
Recipient	Member hospital
Recipient Role	Member data provider
Business Model(s)	EHR on Blockchain Member care
Activities	Mediate Provide framework

Figure 18: Example of Value Proposition details part 1

Values:

Show 5 entries

Search:

Values	Baseline	Introduction	After 3 years
	Baseline / Base Alternative	Introduction / Base Alternative	After 3 years / Base Alternative
Availability improvement of data (percentage)	-	1.44	1.44
EHR access overview (percentage)	-	1.60	1.60
EHR data corectness improvement (percentage increase)	-	0.80	0.80
EHR improvement (percentage increase)	-	7.46	7.46
EHR overview (percentage)	-	1.80	1.80

Showing 1 to 5 of 7 entries

Previous 1 2 Next

Figure 19: Example of Value Proposition details part 2

Here the information of the value proposition Member care mediation in the Business Ecosystem Map (Figure 6) is shown, Complete with its activities form the Value Stream Map (Figure 13). In Figure 19 and Figure 20, the same values can be found. Figure 20, however, comes from the Business Model Cube, whereas Figure 18 and 19 come directly out of the Business Ecosystem Map.

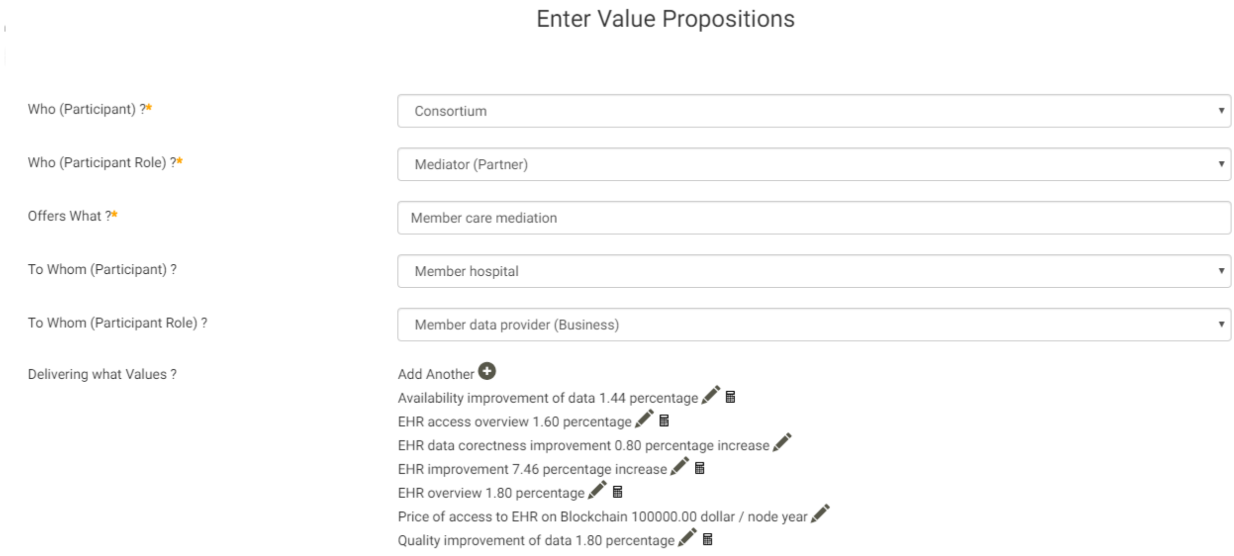


Figure 20: Example of Value Proposition details part 3

Both representations display the same information about the value proposition, confirming the two-way traceability.

The last step of the Prototype stage consists of entering value formulas and other measurements to complete the value aggregation structures. Again, the cause-effect storytelling from the Strategy Maps (Figure 14) can help determine the value formula aggregations. To further show the link between the value aggregation and the Strategy Map, an example will be given, using cost per treatment (also used in the Strategy Map description, Figure 14).

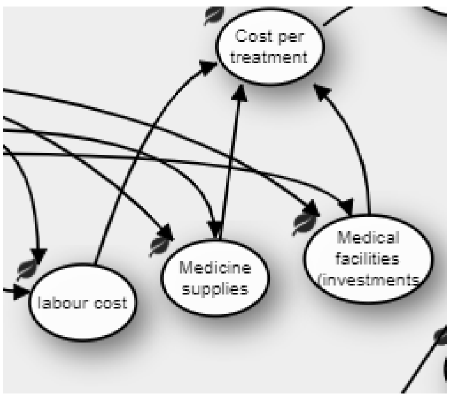


Figure 21: Aggregation Example- Strategy Map

As can be seen from the Strategy Map (Figure 14), the cost per treatment is determined by the labour cost, medicine supplies and the medical facilities costs. Here medicine supplies stands for the costs made while treating a patient concerning all types of medication. Medical facilities (investments) represent the use of medical equipment, like X-ray machines or simply the occupation of a room, and the costs associated while treating a patient. The term, labour cost speaks for itself. In other words, the cost per treatment is determined by these three variables. This can be visualized in the following aggregation view.

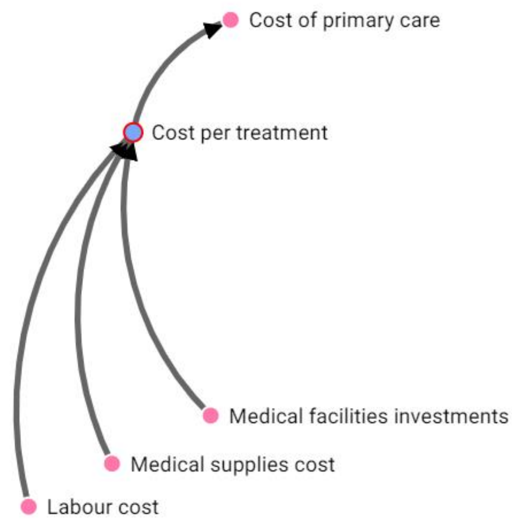


Figure 22: Example of Aggregation View

Such an Aggregation View is an implementation of VDML's Measurement Dependency Diagram. Additionally, these Aggregation Views have several similarities with the notation of System Dynamics Modelling. A widely known methodology to represent complex affairs.

Also, as displayed in the Strategy Map (Figure 14), cost per treatment, itself, determines the cost of primary care. All this can be done in the business model cube, as shown in the following figure.

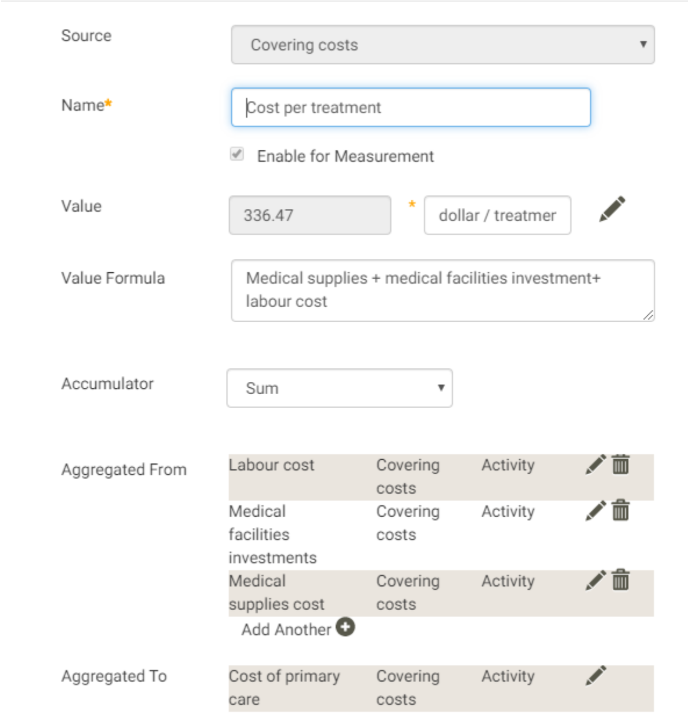


Figure 23: Example of value formula

The value formula is defined, the accumulator chosen and the variables that make up the formula. Again, it can be seen that cost per treatment is aggregated to the cost of primary care. Such a sheet has to be filled in for every value in the model, each with their respective measurements, formula, accumulator and aggregations if needed.

4.3.3 Adopt stage.

The last stage in the CBMP process (Figure 8) , Adopt stage, presents the result of the prototype stage. Compared to the call to action step in the Discover stage, decision-makers are now able to see values across all plan phase and alternatives as part of the continuous engagement of the CBMP method. Users can implement these new phases or alternatives to compare actual values to plan values. Based on this information, decisions-makers can adjust the strategic plan if needed. While building this case study, no new actual values were available, whereby the model could not be monitored through actual values.

As said earlier, the EHR on blockchain case study has three phases (i.e. Baseline, Introduction and After 3 years),without any alternatives, as shown in Figure 9 . The comparison of these phases is done with the help of interactive dashboards. These dashboards consist of presentations, bundling information from the previous steps and phases. Users can create tables, graphs, implement close-ups from the different visualization tools and much more. An example of such a presentation is given in the following figure.

Impact of blockchain on care cost structure

Show 5 entries | Search:

Values	Baseline	Introduction	After 3 years
	Base Alternative / Base Scenario	Base Alternative / Base Scenario	Base Alternative / Base Scenario
Uncategorized			
Affiliate cost / treatment (dollar / treatment)	800.00	616.50	590.74
Member cost / treatment (dollar / treatment)	450.00	336.47	308.52
Third-party cost / treatment (dollar / treatment)	60.00	54.62	50.78

Showing 1 to 3 of 3 entries — Previous 1 Next

Figure 24: Example of dashboard presentation

Here the effect of blockchain on the cost per treatment for each type of healthcare provider is given with the help of a table (Figure 24). This is perfect to compare the initial cost per treatment from the AS-IS situation with the TO-BE situation. This impact of blockchain can also displayed using a graph with curves, columns, etc (Figure 25 and Figure 26).

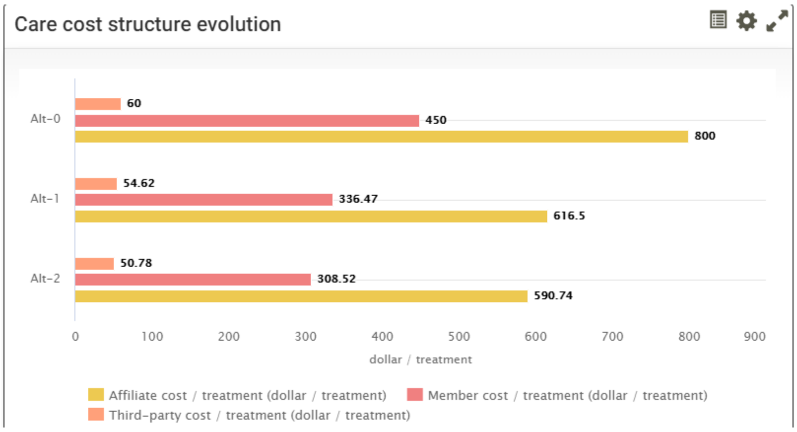


Figure 25: Example of column presentation

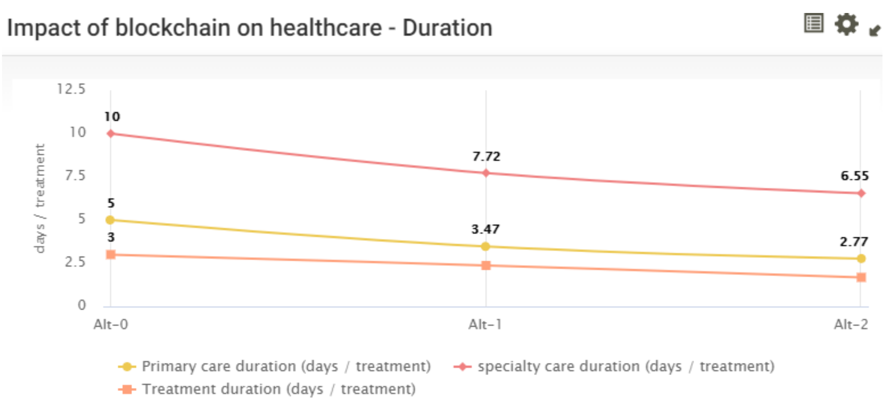


Figure 26: Example of graph presentation

Additionally, decision-makers, can make use of what-if analyses that create potential future scenarios and see the differences with the original values. In the EHR on blockchain case study four what-if scenarios were considered, Visible in Figure 27 and 28. Users can model these scenarios themselves or import certain scenarios through the import functionalities. In this study, all scenarios were built from scratch, to maximise the personalisation of these scenarios in the overall model.

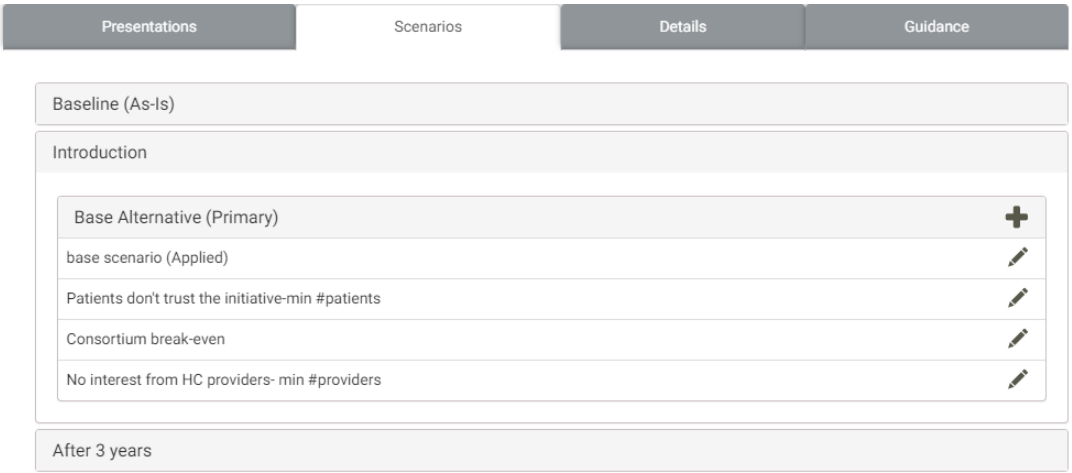


Figure 27: Example of What-If scenarios part 1

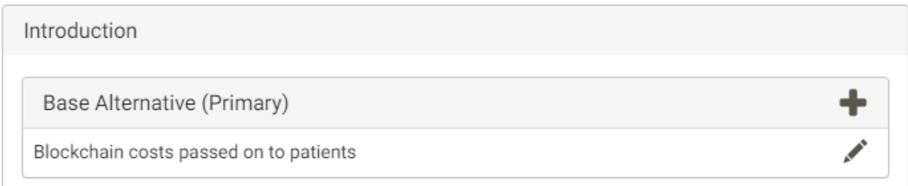


Figure 28: Example of What-If scenarios part 2

These scenarios all describe a certain concern or possibility that can occur in this specific case study. VMP allows the development of these scenarios by changing specific input values, with the option to compare them to the base scenario. These scenarios then have to be manually entered in each separate presentation of the dashboards.

Impact of blockchain on direct cost structure

Show 10 entries Search:

Values	Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients
Uncategorized				
Member total direct cost (million $ / year)	3181.18	5.58	3333.29	6.49
Consortium total direct cost (thousand $ / year)	2235.73	2235.73	4304.33	4304.33
Affiliate total direct cost (million $ / year)	1618.81	2.19	2511.17	2.77
Third-party total direct cost (thousand $ / year)	28756.81	295.49	63573.50	380.45

Showing 1 to 4 of 4 entries Previous 1 Next

Figure 29: Example of comparison between base scenario and What-If scenario

An example of such a scenario, where the patients do not trust the blockchain application and the effects on costs for the key-participants, can be found in figure 29. Here it can be seen that the dashboard allows for comparison between the base values and the scenario values after only changing the amount of patients.

A more detailed description of the scenarios can be found in section 5.2 of this dissertation.

5 EHR on blockchain in VMP

The following paragraphs go in more detail of how the EHR on blockchain case was modelled in the VMP application, allowing for a better understanding of the model and possible replication. This is done by explaining the different steps taken to visualise the impact blockchain technology can have in the healthcare sector. The whitepaper's proof of concept will be used as a basis. Obviously, not all necessary information can be found in this whitepaper. Therefore, information from the whitepaper will be supplemented with information found online, insights from Shariq Ata, input from Henk de Man, assumptions and personal estimations. One such example of personal estimations, are the input values and multipliers used to represent the impact of blockchain. These estimations and assumptions can deviate from real-life values. VMP's ease of use, however, allows users to alter these input values and multipliers, allowing for a better, or more case-specific, representation of a EHRs on blockchain case. Furthermore, only the EHR software costs, patient care provision costs that are impacted by the blockchain technology and a general overhead cost are taken into account. After all, this study's main focus is to provide a possible model of blockchain technology and its impact in the healthcare sector. Even more, only the TO-BE and After 3 years phases will be discussed in detail, as they revolve around the blockchain application. The AS-IS phase will only be referred to, whenever data from the other phases integrates with data from the AS-IS phase, or when comparisons are made. Afterwards, some What-if scenarios will be addressed, explaining their relevance and interpreting the results.

5.1 Building the VMP model

The impact visualisation of blockchain technology in the healthcare sector can be divided in two main components. The first component concerns itself with the representation of better access to data thanks to the blockchain application. Whereas the second component focusses more on the possible reduction of costs realised by the implementation of blockchain technology. In order to demonstrate these improvements, comparisons will be made with the AS-IS phase.

5.1.1 Access to data

As described in the case description, there are several challenges associated with the exchange of patient EHRs. With the help of blockchain technology, healthcare practitioners try to tackle these challenges. This EHR on blockchain application would then improve the EHRs, increasing the accessibility to data for both the healthcare providers as the patients themselves, through the creation of the MPI (Master Patient Index). Of course, this improved accessibility is not present in one single value but obtained through a series of activities, competencies and value propositions. The explanation will be given for all three healthcare providers. Recurring steps, however, will only be explained once. Additionally, it is important to note that all the results are obtained through formulas. This is a considerable functionality of this model, as it allows other users to adjust the values in the model to their liking, by changing certain multipliers or input values.

5.1.1.1 Member hospitals

5.1.1.1.1 Provision of the EHR on blockchain application

Before blockchain technology can improve any EHRs and create a higher accessibility to data, the EHR on blockchain application has to be provided to the Member hospitals. This is done by the Consortium, through the value proposition Member care mediation, visible in the TO-BE Business Ecosystem Map (Appendix 2), resulting in the following Value Stream Map.

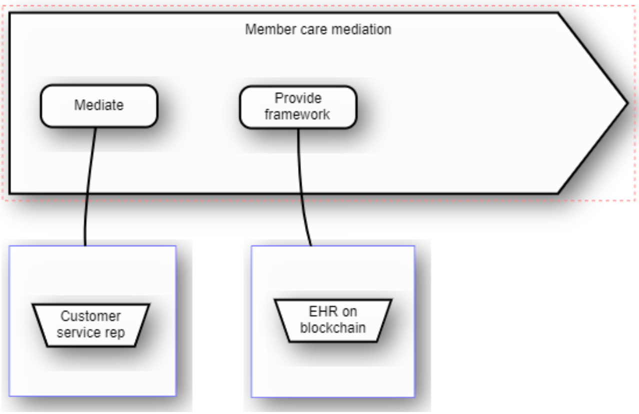


Figure 30: Member care mediation Value Stream Map

The focus is here primarily on the activity Provide framework, made possible by the EHR on blockchain competency, visible in Figure 30. This activity provides the Member hospitals with five features, made possible by blockchain technology, as seen in the figure below.

EHR access in app overview (percentage increase)	-	0.60
EHR data corectness improvement (percentage increase)	-	0.80
EHR easier availability (percentage increase)	-	0.20
EHR in app overview (percentage increase)	-	0.80
EHR speed of delivery (percentage increase)	-	0.20

Figure 31: Five features of EHR on blockchain

EHR access in app overview stands for the ability to see who exchanged or requested the exchange or patient records via a mobile application, comparable with a logbook. Whereas, EHR in app overview stands more for EHRs the patients or healthcare providers will be able to see. EHR easier availability displays the fact that EHRs are now easier to exchange between healthcare providers, thus easier and more freely available. Furthermore, the exchange of these EHRs is now instant, thanks to the smart contracts, this is displayed by EHR speed of delivery. Tied with the faster delivery and easier availability of EHRs is the improvement of data in the records itself. This feature is a more indirect result of the blockchain technology, as the process to exchange a patient record is now easier. Moreover, through the shared control, faults in the patient records will be detected faster. Of course, it is very hard to assign values to these variables, therefore, a percentage increase is assumed. This percentage increase represents how much the current (AS-IS) situation will improve thanks to these features.

5.1.1.1.2 EHR characteristics

In order to get the appropriate EHR values in this phase, rather than sole percentage increases, new values have been created. Values that represent the state of the EHR characteristics in each phase.

EHR characteristics

Show 5 entries Search:

Values	Baseline	Introduction	After 3 years
	Base Alternative / base scenario	Base Alternative / base scenario	Base Alternative / base scenario
Uncategorized			
EHR access [Base treat patient] (percentage)	0.40	0.72	0.84
EHR access overview [Base treat patient] (percentage)	0.10	0.80	0.90
EHR availability [Base treat patient] (percentage)	0.60	0.86	0.87
EHR quality [Base treat patient] (percentage)	0.60	0.86	0.93

Figure 32:EHR characteristics

Four different values are distinguished, each representing a characteristic of EHRs, displayed in the figure above. The first characteristic, EHR access, represents the ease of obtaining and adapting information available in the EHRs. EHR access overview, the second EHR characteristic, takes the traceability into account. In how much detail is het possible to know the entities that accessed, adjusted or shared the EHRs. The second characteristic, EHR availability, compared to EHR access, is more concerned with how easy it is to exchange the EHRs with other entities. The last EHR characteristic, EHR quality, is a more general parameter that represents the quality of the data stored in the EHRs. Again, these values are expressed in percentages, where 100% represents a perfect characteristic with no chance of available errors. Additionally the use of percentages allows for a uniform comparison with the other phases. The idea is that these EHR characteristics will improve thanks to the features made possible by the EHR on blockchain application. Therefore, the values of the previous phase will be multiplied with the percentage increases of the blockchain features. Off course, the AS-IS phase has no previous phase, instead, input values will be used.

Figure 33: EHR availability Aggregation View

The figure above shows the EHR availability, from Figure 32, in the TO-BE phase (blue circle), calculated from the EHR availability in the AS-IS situation (pink circle) and the improvement thanks to the EHR on blockchain application. Note that the EHR availability of the AS-IS phase is not directly multiplied with a feature of the blockchain application, an intermediate value is used instead.

5.1.1.1.3 Intermediate values

Unfortunately, as VMP does not support different function in the same formula, intermediate values will have to be created to replace the five features.

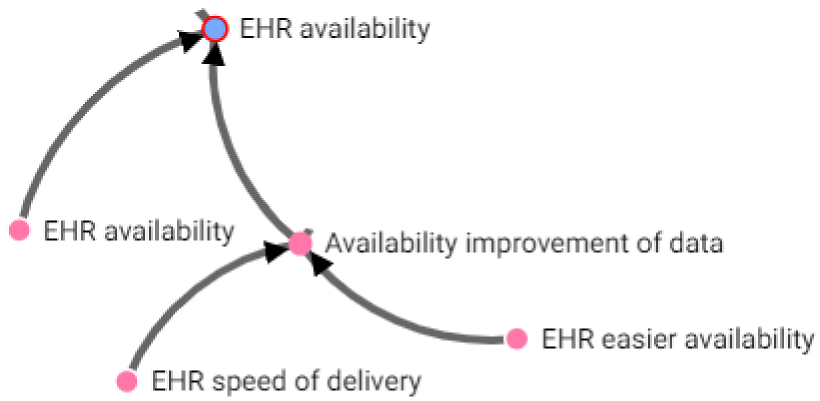


Figure 34: EHR availability extended Aggregation View

A perfect example for the need of such an intermediate value occurs with the EHR availability characteristic from Figure 33. Here, the availability of EHRs is both influenced by the speed of delivery and the easier availability the blockchain application provides, visible in Figure 31. This makes it impossible to take the two features into account, and calculate the improvement with regards to baseline value. The creation of such an intermediate value is usually not a problem, however, it can pollute more extensive Aggregate View Maps with unnecessary variables. An example of such a polluted Aggregate View can be found in Appendix 5. As can be seen in this appendix, due to all the intermediate values it becomes difficult to see the desired aggregation and origin of certain values.

5.1.1.1.4 EHR characteristics in the third phase

As can be seen in Figure 32, the EHR characteristics continue to improve in the last phase. The same calculation method is used as in the TO-BE scenario, however, a multiplier is used to contain the effects of the blockchain application features. Otherwise, the aggregation would lead to unrealistic values for this last phase.

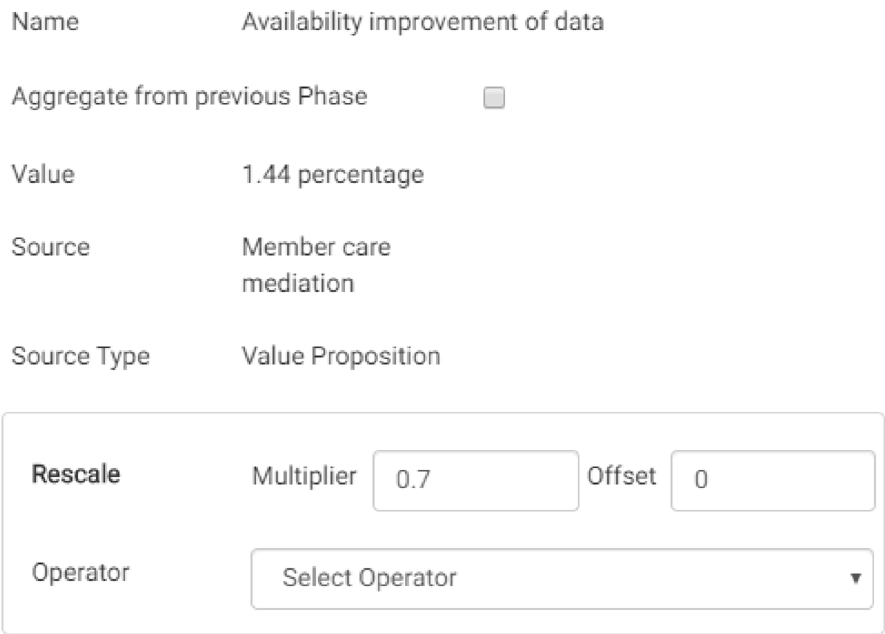


Figure 35: Example of multiplier to contain effect

5.1.1.1.5 *Effect on Primary care*

Often, investments are made with the intent to improve efficiency and service to the customers. Therefore, it is assumed that the improved EHR characteristics will eventually impact the care provision delivered to the patients. The effects of higher accessibility to data can be found in four final values delivered to the patients, as can be seen in the figure below.

Impact of blockchain on treatments

Show 5 entries Search:

Values	Baseline	Introduction	After 3 years
	Base Alternative / base scenario	Base Alternative / base scenario	Base Alternative / base scenario
Uncategorized			
Patient satisfaction [Primary care] (%)	50.00	72.00	86.00
Primary care duration (days / treatment)	5.00	3.47	2.77
Primary care quality (percentage)	0.50	0.79	0.91
Primary care transparancy (blocks / treatment)	5.00	12.16	13.91

Showing 1 to 4 of 4 entries Previous 1 Next

Figure 36: Final values delivered to patient

Primary care duration is the average amount of days one treatment takes, from preparing the treatment to finalizing the results. As EHRs are easier and faster obtainable thanks to the blockchain technology. Primary care quality, on the other hand, concerns itself with the overall quality of the treatments, the closer to 100% the less chance on human errors or failed treatments (e.g. wrong prescriptions, unnecessary treatments, ignorance of previous treatments, unnecessary waiting times). This percentage increases as more information becomes available and proves to be more accurate, lowering the possibility of errors and failures. The third indicator of higher data accessibility is Primary care transparency. This variable displays the amount of information about the treatment the patient will get the see. As well as to which patient records the healthcare provider has accessed and requested. This will then be available to the patient via a mobile application.

The same though process is used as for the EHR characteristics from Figure 32, variables in the TO-BE and After 3 years are calculated by multiplying or dividing the value from the previous phase with an improvement percentage. These improvement percentages are thus made available thanks to the improvements of the EHRs. Obviously the AS-IS scenario has no previous phase and is thus, again, determined by an input value. In order to contain the effect of the improvement, a multiplier is used. An example for Primary care quality is given in the Figures 37 and 38. The calculation of Primary care transparency and duration is done in a similar manner.

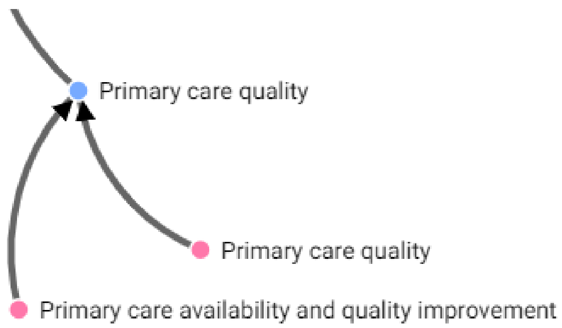


Figure 38: Primary care quality Aggregation View

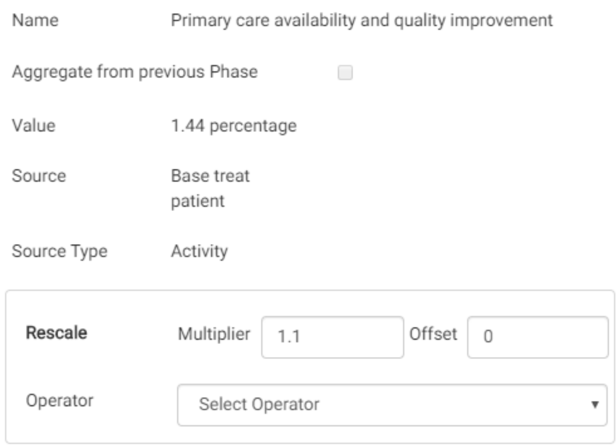


Figure 37: Example of intermediate value form

Again, intermediate variables had to be used. To explain the full process, the Primary care quality example will be further elaborated. Basically, the improved care quality is thanks to both the increase in EHR availability and EHR quality. This increase is determined by dividing the sum of these EHR characteristics in the TO-BE phase with the same parameters in the AS-IS phase. This improvement variable is then multiplied with the Primary care quality from the AS-IS phase. All these computations lead to the following formula:

$$Primary\ care\ quality = \frac{EHR\ availability\ and\ quality}{EHR\ availability\ and\ quality\ (AS-IS)} * Primary\ care\ quality\ (AS-IS)$$

An overview of this calculation in VMP itself can be found in Appendix 6. This method of representation was chosen over the Aggregation View Map, as the aggregation view was rather confusing and polluted.

A similar working manner is true for the other Primary care variables from Figure 36.

5.1.1.1.6 Patient satisfaction

Ultimately, the three primary care variables, together with the price of primary care, will determine the patient satisfaction. Where 100% displays a perfect satisfaction. Additionally the colour (i.e. red, orange, green) of the smiley next to the values in figure 36 determines if these outcomes are acceptable (i.e. unacceptable, somewhat acceptable, acceptable).

This entire roadmap can be found in the strategy map (Appendix 4).

5.1.1.2 Affiliate hospitals

As can be seen in the strategy map of the Affiliate hospitals (Appendix 4), the story to calculate the EHR characteristics and Primary care variables is similar to the Member hospitals and, therefore, will not be repeated. There is one difference, however, that sets the Affiliate hospitals apart from the Member hospitals, being the special type of contract they have with the consortium. An agreement that depicts which types of records they can exchange. This is displayed by the Agreement coverage value in the competency lane from the respective Strategy Maps.

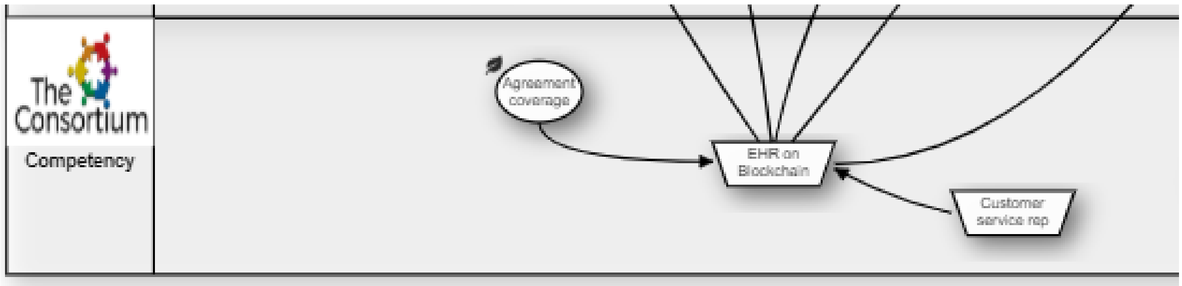


Figure 39: Agreement Coverage in Strategy Map

Since this differentiates the Affiliate hospitals from the Member hospitals, it is important to process this difference in the VMP model.

5.1.1.2.1 Agreement coverage

Normally, for a given treatment, an amount of records is needed, and thus requested, but also there is new information added to the EHRs. Together these two form the record transaction intensity, the totality of exchanging EHRs in the blockchain application.

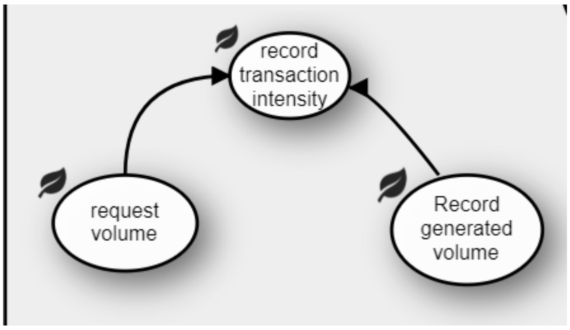


Figure 40: Record transaction intensity in Strategy Map

For example in the Member hospitals, 5 blocks would be requested and 10 are generated, resulting in a transaction intensity of 15 blocks / treatment. An overview of this value in the VMP can be found in Appendix 6.

In the case of the Affiliate hospitals, however, only records in the agreement can be exchanged.

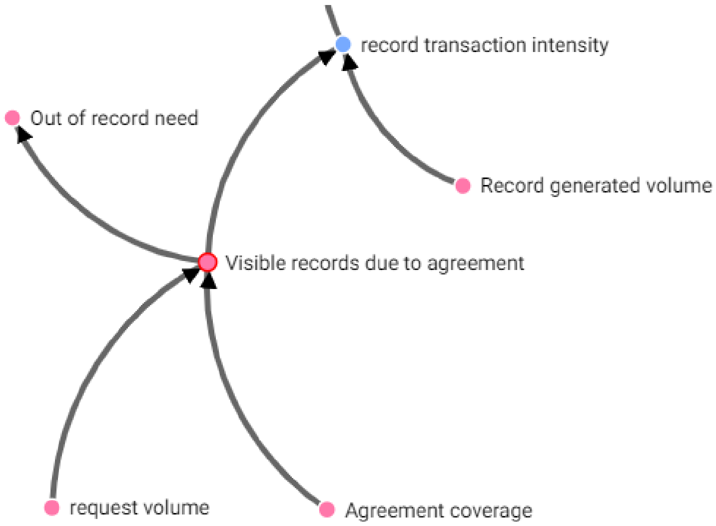


Figure 41: Record transaction intensity Aggregation View

This relation is visualised in the aggregation view above. Whereas the healthcare provider would like to request 6 blocks, only 3.6 blocks will be available with an agreement coverage of 60%. Of course, in practice such a contract will not contain a percentage but specific parts of the EHRs. Nonetheless, for the sake of simplicity and visualisation, a percentage is assumed in the VMP model. In total, this would then result in a transaction intensity of 13.6 with a generated volume of 10 blocks, instead of a transaction intensity of 16 blocks / treatments. If the healthcare provider needs the other 2.6 blocks from the initial 6, a request will have to be put forward to the patient in question. This patient will then decide if he wants to grant the request and allow the provider access outside of his contract. This is visualised in the Business Ecosystem Map (Appendix 2) with the Agreement permission value proposition. The following figure shows the Value Stream Map of this value proposition.

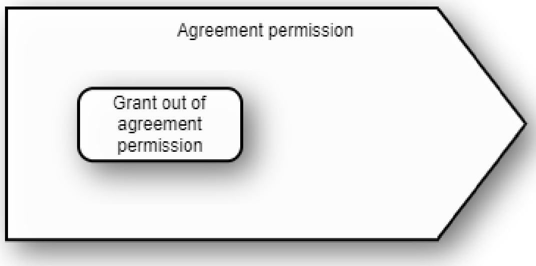


Figure 42: Agreement permission Value Stream map

5.1.1.3 Third-party providers

The full roadmap of the Third-party providers is the same as the Member hospitals and the Affiliate hospitals, as can be seen in the Strategy Map (Appendix 4). Also, the absent of any agreement with the consortium will be handled in a similar manner as the Affiliate hospital's story. Instead of a 60% agreement percentage, a percentage of 0% will be true, as they always have to request access to the MPI. Patients can then determine the Third-party's rights, in terms of time frame and amount. In the case study, however, for treatments taken into account it is assumed that the patient gives consent for the full transaction intensity value. Basically, if the patient would not grant the request of a Third-party provider, the respective treatment will not be able to take place and thus be less relevant to the case study.

5.1.1.4 Overall transaction volume

The total amount of records exchanged for all the healthcare providers is visualised in Figure 43. As more users start to join the healthcare providers and grow accustomed to the application, more EHRs will be exchanged. This figure gives a structured overview in how the exchange volume is expected to grow over the two last phases.

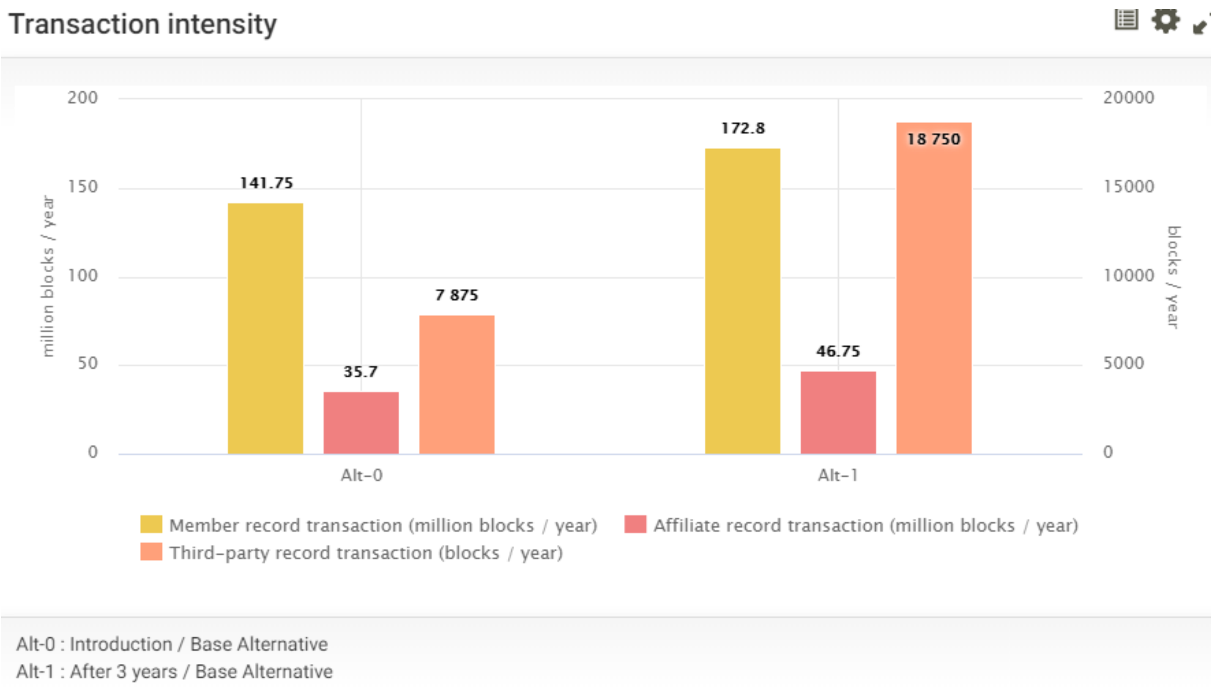


Figure 43: Transaction intensity presentation in Dashboard

Not directly visible in Figure 43 is the distribution between requested and generated records. The study assumes that in the third phase, more information will already be available in a patients MPI. Therefore, more records will be requested for a treatment than generated, compared to the TO-BE phase.

5.1.2 Cost reduction

The improved EHR characteristics do not only effect the care delivered to the patients, but can also effect the costs associated with a treatment. Here, the reduction effect is primarily assumed on the care provision cost rather than on the IT-costs, considering that the EHR software costs remain in the TO-BE scenarios and new mediation costs have to added, it would be difficult to assume any significant reduction in IT-costs. In reality, however, it is perfectly possible that the EHR on blockchain application costs less than any other alternative. Additionally, the reduction of care provision costs has to be put into perspective, regarding the introduction of the costs associated with the blockchain application.

5.1.2.1 Cost types

The costs for a treatment have been split in three different cost types, to maximize the visualisation of the cost reduction effect. The first cost type includes any type of labour done during the treatment, from start to finish. Especially the amount of administrative labour and care provision are taken into account. Thanks to the EHR on blockchain application, EHRs are now exchanged instantly, massively reducing the time intensity. The administration department will not lose any more time requesting any EHRs from other healthcare providers. Also, improved availability and completeness of data can spare the caregiver time diagnosing the problem, through detailed knowledge of allergies, past treatments, etc. The second reduced cost type takes all the medicine supplies used during the treatment into account. Certain patients may be immune or allergic to a specific type of medication, wasting supplies and potentially worsening the condition. The third and last cost type revolves around all the medical facilities, assets owned by the healthcare provider (e.g. operation chambers, hospital beds, advanced medical machinery like MRI scans). For example, waiting times on hospital beds can be reduced if the patient EHRs can be accessed instantly. Another example, for this cost reduction, can be given regarding the usage of scanning machinery. It could be that a patient already has had a recent scan with another healthcare provider, freeing the occupation of the machinery for more pressing treatments. Of course, more types of costs can be distinguished concerning care provision. In this study, however, the focus lies on the costs expected to be impacted by the blockchain application. Additionally, the given explanations for the cost reduction are only assumed effects, and could deviate from any real-life relationships between the costs and the blockchain application.

The three types can be seen in the following strategy map of the Member hospitals. The same distinction is made for the other healthcare providers (as can be seen in the Strategy Maps of Appendix 4), therefore, only an example will be given for the Member hospitals.

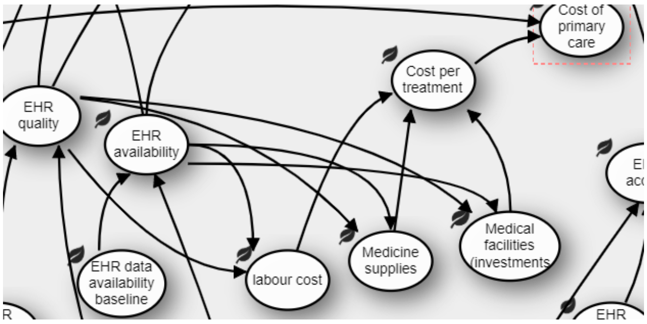


Figure 44: Cost per treatment distinction Strategy Map

5.1.2.2 Calculation

The actual calculation of the cost per treatment for the TO-Be phases is given in the next aggregation view.

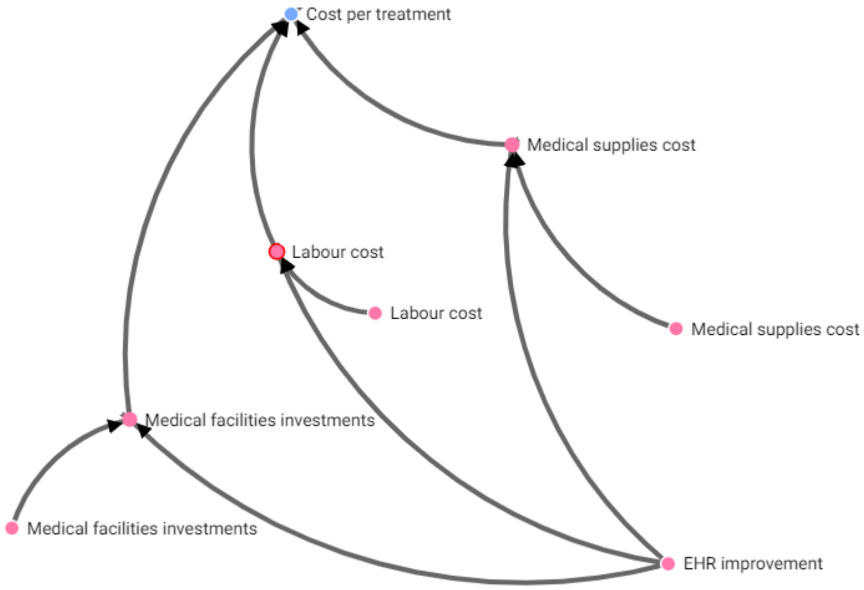


Figure 45: Cost per treatment Aggregation View

Again, the same method is used, multiplying the AS-IS values with the improvement in EHR and controlling the effect with a multiplier. The EHR improvement itself is calculated by comparing the values of the different EHR characteristics from the AS-IS phase and TO-BE phase. Hereby, the EHR improvement is thus the amount the new EHR characteristics are better than the old EHR characteristics, given by a percentage.

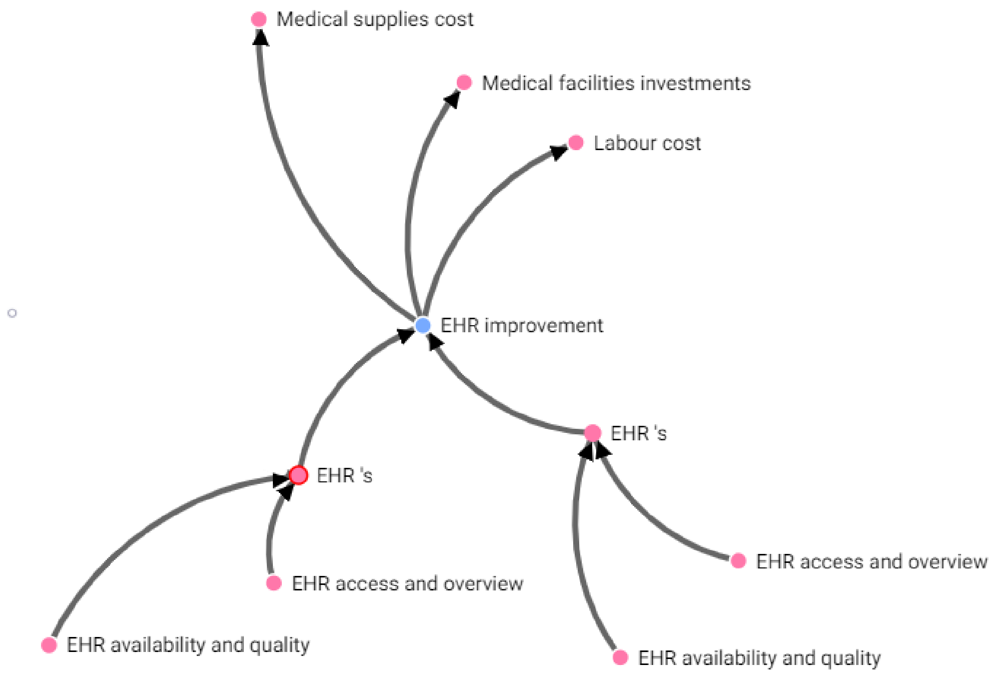


Figure 46: EHR improvement Aggregation View

The EHR characteristics are grouped by two, as this was needed for other calculations. Nonetheless, the same result should be acquired with separate EHR characteristics in the formula.

5.1.2.3 Overview

This next figure gives an overview of the impact of EHR improvements on treatment costs. As this figure is acquired form the dashboard, an evolution of these cost types throughout the three phases can be shown.

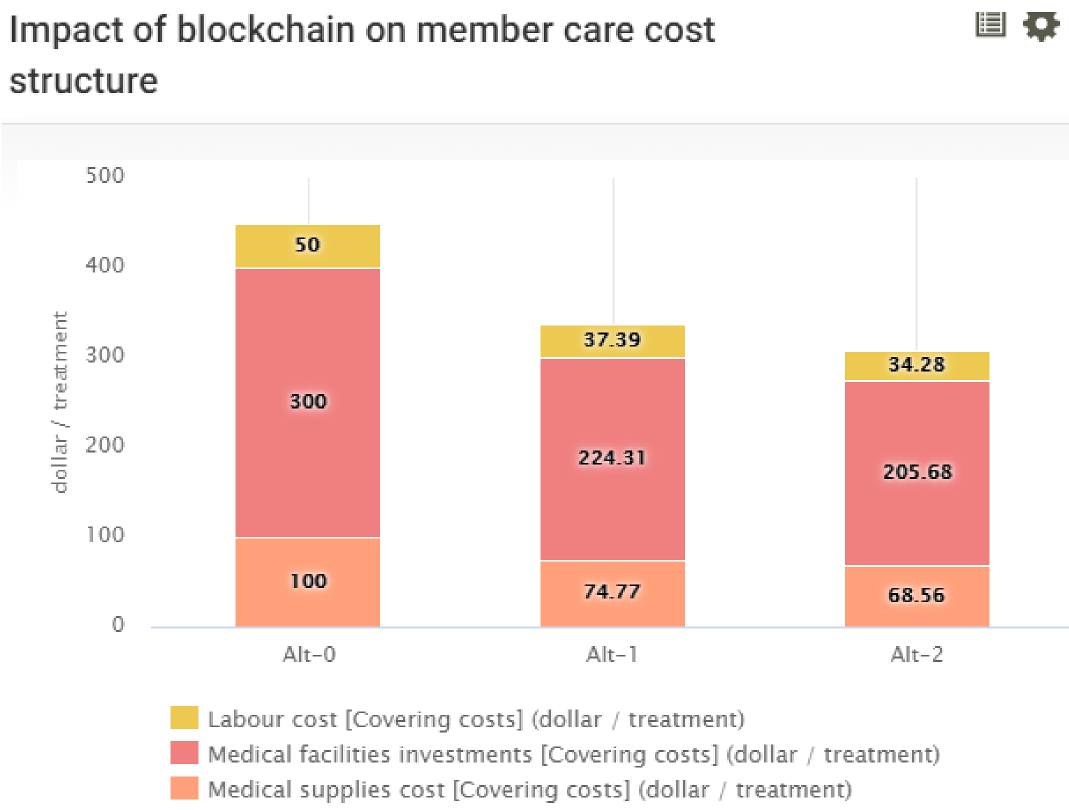


Figure 47: Impact on treatment costs presentation

Again, similar results can be found for the other healthcare providers, as can be seen in Appendix 7.

5.1.3 Main value indicators blockchain application

For decision leaders it is important to see the overall impact the strategic decision will have, and whether this investment will be worthwhile. In the EHR on blockchain model several values were taken into account that seek to represent the impact of this blockchain application. Rather than mere percental increases, relevant values were chosen that give an effective context of the application's impact when compared to the AS-IS phase. These values can be divided in two sections, the impact on healthcare services towards the patients and the impact on the cost structures. All these values can be viewed in the dashboards of the VMP model, either in table form or in a more graphical representation.

The impact on healthcare services is visible in each of the healthcare providers' dashboard. The figure below gives, again, an example of the Member hospitals. The same presentation can be found in Appendix 8 for the Affiliate hospitals and Third-party HC providers.

Impact of blockchain on treatments

Show 5 entries   Search:

Values	Baseline	Introduction	After 3 years
	Base Alternative / base scenario	Base Alternative / base scenario	Base Alternative / base scenario
Uncategorized			
Patient satisfaction [Primary care] (%)	50.00	72.00	86.00
Primary care duration (days / treatment)	5.00	3.47	2.77
Primary care quality (percentage)	0.50	0.79	0.91
Primary care transparancy (blocks / treatment)	5.00	12.16	13.91

Showing 1 to 4 of 4 entries   Previous 1 Next

Figure 48: Access to data main value indicators

This representation gives a detailed evaluation of several key-values that will be improved thanks to the blockchain application. These key-values give the decision leader easily imaginable parameters to work with. Of course, before such an investment can be made the impact on the cost structure has to be measured, to know if the extra cashflows are (self-)sustainable. Again, these values are expressed in the dashboards for the decision leader to evaluate. For the variables taken into account in this study, the following improvements from the AS-IS phase to the TO-BE phase can be expressed. These numbers are specific for the Member hospitals.

- Impact on healthcare services
    - 31 % patient treatment duration reduction
    - 29 % quality of primary care increase
    - 22 % patient satisfaction increase
    - 143% transparency of primary care increase
- Impact on cost structures
    - 21% reduction in primary care cost
    - 3% reduction in IT-cost

All these improvements are thus made possible thanks to the blockchain application.

5.2 What-if scenarios

A major functionality of VMP is the ability to insert some What-if scenarios. By changing specific input values, the impact of a certain scenario can be examined. This allows users to prepare for certain future events or adjust the existing strategy based upon current input values. In this study four scenarios have been implemented. These four scenarios will act as examples to show the usefulness of this functionality. Therefore, most the scenarios are negative from nature, primarily because a negative scenario can reveal more information to decide whether the blockchain application is worth implementing, as it helps to prepare for the worst-case scenario. Additionally, three of the four What-if scenarios are placed in the general overview dashboard, rather than any dashboard specific to one entity. The final scenario is implemented in the Member hospital dashboard, however, a same effect can be expected for both the Affiliate hospitals and the Third-party providers. Ultimately, the What-if scenarios are implemented in the dashboards where the most impact can be spotted.

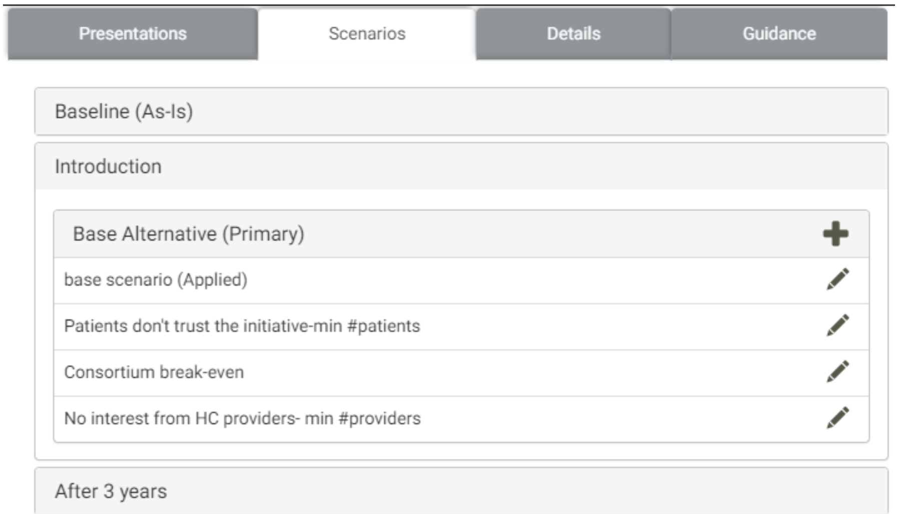


Figure 49: What-If scenarios part 1

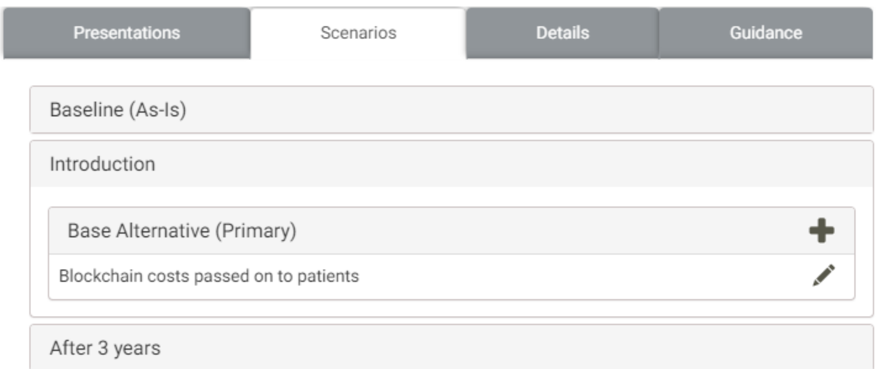


Figure 50: What-If scenarios part 2

An overview of the scenarios can be found in Figure 49 and 50. In the following paragraphs, each scenario will be discussed in detail. Furthermore, it is important to note that all these scenarios can be customized at will. Moreover, the obtained results and conclusions are specific to this case study, whereby it is not possible to generalize these findings to other cases.

5.2.1 Scenario 0: base scenario

This scenario contains the initial data of the model built in VMP, therefore this scenario is marked as applied, as seen in Figure 49. Normally this dataset would not occupy a scenario slot, however, this scenario had to be imported from a previous safe file to overwrite an incorrect dataset.

5.2.2 Scenario 1: Patients don't trust the initiative-minimum amount of patients needed

This first scenario explores the possibility of distrust towards the EHR on blockchain application from the patients. They do not trust this new technology and will not allow their EHRs to be shared across such an application. Of course, this can be quite catastrophic for the healthcare providers and their consortium, as the framework will not unlock its full potential without the cooperation form the patients. Therefore, it would be interesting to determine the minimum amount of patients needed to make the investment worthwhile. To make the investment worthwhile, it is decided that the healthcare providers have to reach a break-even equilibrium in the year of implementation. Whereby, it is assumed that, a profit margin around zero represents a break-even equilibrium.

Impact of blockchain on profit margin

Show 10 entries

Search:

Values	Baseline		Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients
Uncategorized						
Affiliate profit margin (percentage)	2.41	2.41	24.79	0.03	27.94	10.19
Consortium profit margin (percentage)	-	-	6.71	6.71	18.31	18.31
Member profit margin (percentage)	4.22	4.22	28.37	0.01	34.33	17.11
Third-party profit margin (percentage)	24.81	24.81	31.48	0.04	36.41	9.37

Showing 1 to 4 of 4 entries

Previous 1 Next

Figure 51: Ecosystem profit margins scenario 1

In order to calculate these break-even profit margins, a trial-and-error approach was used. Estimating the minimum amount of patients until the profit margins were as close to the break-even equilibrium as possible. Figure 51 shows the amount of patients associated with these zero profit margins. For the

After 3 years phase, as more patients start to trust the application, an increase of forty percent was handled.

Healthcare provider capacity

Show 5 entries   Search:

Values	Baseline		Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients	Base Alternative / base scenario	Base Alternative / Patients don't trust the initiative-min #patients
Uncategorized						
Affiliate patient volume (patients)	500000.00	500000.00	525000.00	547.00	850000.00	765.80
Member patient volume (patients)	3000000.00	3000000.00	3150000.00	3995.00	3600000.00	5593.00
Third-party patient volume (patients)	100000.00	100000.00	105000.00	789.00	250000.00	1104.60

Showing 1 to 3 of 3 entries   Previous 1 Next

Figure 52: Minimum amount of patients

Two conclusions can be made from this scenario. The first conclusion regards to the difference between the amount of patients in the base scenario and Scenario 1. The difference between these two scenarios is enormous, meaning that the healthcare providers have to lose quite the amount of patients before the investment becomes unworthwhile. Secondly, with an increase of 40% in three years' time, a more prosperous profit margin can be obtained than the AS-IS phase, still proving the investment to be worthwhile, regardless of the patient loss.

5.2.3 Scenario 2: Consortium break-even

In the base scenario a set price has been estimated that the healthcare providers have to pay the consortium for the blockchain framework. Eventually this results in a profitable operation for the Consortium. As the Consortium is formed by the Affiliate and Member hospitals, no mark-up has to be assumed for the Consortium. Moreover, it is perfectly logical that they offer their services at base cost. This can potentially lower the entry-cost to join the consortium. Therefore a break-even scenario is initiated, meaning a profit margin of zero for the Consortium. Also, for this scenario, a more practical and realistic viewpoint was handled.

Cost of blockchain service

Show 5 entries Search:

Values	Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Consortium break-even	Base Alternative / base scenario	Base Alternative / Consortium break-even
Uncategorized				
Price of access to EHR on blockchain (thousand $ / node year)	60.00	56.27	80.00	66.63
Price of access to EHR on Blockchain [Member care mediation] (dollar / node year)	100000.00	96266.59	110000.00	96634.65
Price of access to EHR on Blockchain [Third-party HC mediation] (dollar / node year)	30000.00	26266.59	50000.00	36634.65

Showing 1 to 3 of 3 entries Previous 1 Next

Figure 53: Cost of blockchain service presentation

With the above access prices, the Consortium will not generate any profits, meaning the Consortium will have a profit margin of zero, visible in Figure 53.

Impact of blockchain on profit margin

Show 10 entries Search:

Values	Baseline		Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Consortium break-even	Base Alternative / base scenario	Base Alternative / Consortium break-even	Base Alternative / base scenario	Base Alternative / Consortium break-even
Uncategorized						
Affiliate profit margin (percentage)	2.41	2.41	24.79	24.79	27.94	27.94
Consortium profit margin (percentage)	-	-	6.71	0.00	18.31	0.00
Member profit margin (percentage)	4.22	4.22	28.37	28.38	34.33	34.33
Third-party profit margin (percentage)	24.81	24.81	31.48	31.49	36.41	36.42

Showing 1 to 4 of 4 entries Previous 1 Next

Figure 54: Ecosystem profit margins scenario 2

As to be expected from the small difference in price between the base scenario and Scenario 2, no significant impact is visible in the profit margins of the healthcare providers. Essentially, the costs to access the blockchain application are rather minimal, compared to other alternatives or existing costs. This means, that the impact of moderate changes in this price is negligible.

5.2.4 Scenario 3: No interest from HC providers-minimum amount of providers needed

As apparent from the similar naming, this scenario follows the same idea of scenario 1. What if the Academic hospital had difficulties convincing other healthcare providers to initiate a consortium. It can be that they do not trust such a new innovation and/or are comfortable with their current solutions. The focus here, however, is primarily on the amount of Affiliate hospitals and Third-party providers. Since, it is assumed, that the Academic hospital can apply enough pressure to persuade the other Member hospitals in joining the initiative. Essentially, how many Affiliate hospitals and Third-party providers would then be needed, considering all else equal.

During the research of this scenario the following healthcare provider values were implemented.

Blockchain initiative interest

Show 5 entries Search:

Values	Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / No interest from HC providers- min #providers	Base Alternative / base scenario	Base Alternative / No interest from HC providers- min #providers
Uncategorized				
Affiliate volume [Mediation business] (providers)	5.00	1.00	10.00	2.00
Third-party volume [Mediation business] (providers)	25.00	2.00	40.00	4.00
Total Member volume (providers)	14.00	14.00	23.00	23.00

Showing 1 to 3 of 3 entries Previous 1 Next

Figure 56: Minimum amount of healthcare providers

A significant difference in amount of providers can be observed. Therefore a significant decline in the Consortium's profit margin would be expected. The opposite seems to be true, however, as an enormous increase in the profit margin is obtained, as can be seen in Figure 56. It appears that the Member hospitals can carry all the essential costs and the other healthcare providers cost more than they actually generate, cost-wise. Off course, this effect is rather extreme and lacks practical relevancy, as it defeats the purpose of this framework to exchange EHRs with other healthcare providers. Nonetheless, this scenario proves that not as many providers are necessary as in the base scenario to make this initiative work. Moreover, this scenario helps show the power of VMP, as not every cause-effect relation is as expected. Naturally, a logical mindset has to be maintained while interpreting these results.

Impact of blockchain on profit margin

Show 10 entries | Search:

Values	Baseline		Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / No interest from HC providers- min #providers	Base Alternative / base scenario	Base Alternative / No interest from HC providers- min #providers	Base Alternative / base scenario	Base Alternative / No interest from HC providers- min #providers
Uncategorized						
Affiliate profit margin (percentage)	2.41	2.41	24.79	24.79	27.94	27.94
Consortium profit margin (percentage)	-	-	6.71	35.44	18.31	36.18
Member profit margin (percentage)	4.22	4.22	28.37	28.37	34.33	34.33
Third-party profit margin (percentage)	24.81	24.81	31.48	31.48	36.41	36.41

Figure 57: Ecosystem profit margins scenario 3

5.2.5 Scenario 4: Blockchain costs passed on to patients.

The fourth and last scenario explores a common practice with innovations in a business setting. Basically, the healthcare providers will pass on the additional costs from the initiative to the clients. Therefore, this scenario will examine a price increase of 80 dollars per treatment, from the TO-BE phase onwards.

Treatment price

Show 5 entries | Search:

Values	Baseline		Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Blockchain costs passed on to patients	Base Alternative / base scenario	Base Alternative / Blockchain costs passed on to patients	Base Alternative / base scenario	Base Alternative / Blockchain costs passed on to patients
Uncategorized						
Price of primary care [Primary care] (dollar / treatment)	470.00	470.00	470.00	550.00	470.00	550.00

Showing 1 to 1 of 1 entries | Previous 1 Next

Figure 58: Treatment price increase

In order to measure the reaction of the patients on this price increase, patient satisfaction will be used. This variable is the weighted average of four values.

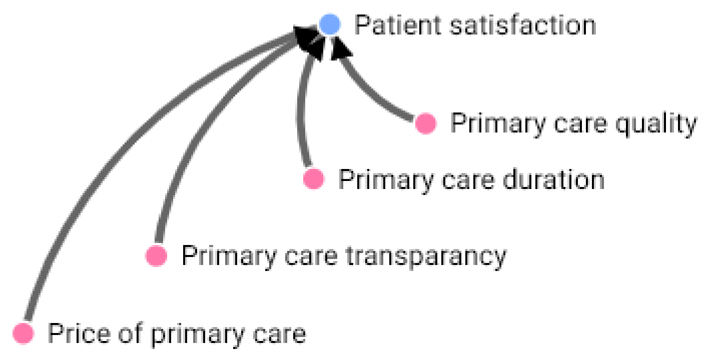


Figure 59: Patient satisfaction Aggregation View

The following weights were assumed in this calculation, respective in the order of the figure (i.e. Price of primary care, Primary care transparency, Primary care duration, Primary care quality): 10%, 20%, 35% and 35%. The higher the weight, the more important the value is perceived by the patients.

Values	Baseline		Introduction		After 3 years	
	Base Alternative / base scenario	Base Alternative / Blockchain costs passed on to patients	Base Alternative / base scenario	Base Alternative / Blockchain costs passed on to patients	Base Alternative / base scenario	Base Alternative / Blockchain costs passed on to patients
Uncategorized						
Patient satisfaction [Primary care] (%)	50.00	50.00	72.00	70.00	86.00	84.00

Figure 60: Patient satisfaction presenation

As a result of the price increase, only a decrease of 2% in patient satisfaction can be observed in Figure 60, from 72% to 70%. Meaning that added benefits in TO-BE phase outweighs the price increase. Healthcare providers can potentially afford to charge a higher price, as the patient satisfaction increases considerably compared to the As-IS scenario. Obviously, the impact of such a price increase is dependent on the amount it increased by. Such a relation, however, is not expressed in the model. Therefore, a price increase of 80 dollars per treatment is assumed to be quite reasonable for the patients. Moreover, only an importance of 10% is ascribed to the price of a treatment, which also explains the low impact. Whereas the other values are assumed to be valued on a higher level of importance by the patients.

This impact was examined in the Member hospitals, however, a similar effect can be found with the other healthcare providers.

5.2.6 Conclusion scenarios

The exposition of these What-if scenarios provide several take-aways, considering the implementation of the blockchain application. Through the first and third scenario (i.e. minimum amount of patients and minimum amount of HC providers) it becomes clear that the implementation threshold regarding initiative participants is rather low, with all else equal. A significant decrease in both the amount of patients and the amount of healthcare providers seems to be still sustainable. Moreover, from the third scenario it is clear that the Academic hospital does not need any Affiliate hospitals or Third-party providers to make the investment worthwhile. As long they can persuade the rest of the Member hospitals and a portion of their patients, an initial launch of the blockchain application would be worthwhile. Of course, in order to enjoy the full benefits of exchanging EHRs over blockchain technology a more extensive network of participants is desirable. This should prove to be no problem, if they can present the advantages of the application to other healthcare providers over time.

Several costs and benefits are assumed to be associated with the blockchain application. For example, in this model, a cost reduction is assumed due to a decreased chance of errors and improvement of time consumption related to EHRs. Even if this is not the case, to this extent, the fourth scenario shows that patients will accept a certain increase in the price of a treatment with the new blockchain application. This will help fund the costs from the blockchain application, as well as improve the financial standings. Moreover, thanks to the blockchain application an abominable increase in profit margins is visible. With the help of scenario two, these new profit margins seem to be very robust, as the blockchain costs are only marginal compared to the other costs made in healthcare organisations. Traditionally, the healthcare sector knows very low profit margins. This means that such improvements in profit margins are not necessary, which opens doors for other possibilities. Instead of using the decrease in errors and loss of time consumption for a higher profit margin, healthcare providers can use these advantages to further invest in improved healthcare (e.g. more worthwhile investments, better people management, etc) or invest in further improvements of the blockchain application. All this helps to prove that the blockchain application is not necessarily something to help the IT-infrastructure, but is beneficial for the entire healthcare business.

Through these scenarios, it is rather safe to assume that the EHR on blockchain application has many advantages above the current situation, even with the considerable drawbacks visualised in the different scenarios.

6 Improvement suggestions Value Management Platform

By modelling this case study in VMP, a decent understanding of the tool has been developed. With this experience, some suggestions for future improvements of the tool can be listed. These suggestions are based upon a personal opinion to enhance the overall user experience of the tool. In the following paragraphs a description will be given for each suggestion, complete with the appropriate argumentation.

6.1 Textual user guides

VMP has many outstanding functionalities, with the ability to make one integrated VDML metamodel comprising of different views. In order to build such a model, however, it is very important to use the proper method from the start, otherwise several important functionalities of the tool will not work as intended. For this purpose, VDMbee provides new users with plenty of video material to master all the different aspects of the tool. These videos are a great way to learn the tool, complete with the underlying theoretical relevance, as well as included examples to further illustrate the functionalities. Naturally, it is impossible to remember everything from all these videos, whereby it is possible to forget how certain aspects work while actually modelling. For this purpose, more detailed textual user guides can prove to be more usable as the current range of textual user guides is rather limited at the time of making this EHR on blockchain model. Moreover, these user guides explain in detail what you can do with the tool, but sometimes lack the information for how you can achieve this. Of course, video material is preferred to learn something new, however, textual user guides can offer a fast alternative to refresh some topics, rather than having to scourge through video material to find the right timestamps. Some functionalities could also use a more detailed textual user guide, besides their initial description (e.g. Strategy map and Value Stream Map). Additionally, some complete written out cases of the entire CBMP process could further improve the user experience in this area.

6.2 Aggregation formulas

As discussed in section 5.1 Building the VMP model, aggregations can be made between values with the help formulas. This has proven to be very beneficial to build a truly comprehensive model. At times, however, a desired value can consist of a more complex formula or multiple arithmetic operations, like a combination of a summation and multiplication. As of now, such formulas are not supported by VMP. This forces the use of intermediate values, which can pollute a certain aggregation view or model. Such a polluted aggregation view, can be found in Appendix 5. Therefore, the support of more complex formulas could reduce the need for intermediate values and give the users more freedom.

6.3 Dashboard

6.3.1 Presentations

In section 4.3.3 the Adopt stage, Figures 24-26 show that presentations in the dashboard can be represented in different manners (e.g. tables, columns, graphs). These presentations are entirely interactive, the interactivity for tables, however, is more advanced than that of other representation alternative. As a matter of fact, through a table, the user can pull-up the entire aggregation view of one certain value. This would be a welcome addition for the other alternatives as well, since graphical representation methods can give a better understanding of a presentation than a regular table.

6.3.2 What-if scenarios

Section 4.3.3 explains the full usage of the What-if scenarios, with some proper examples in Section 5.2. As can be seen through the four examples in Section 5.2, this is a fantastic functionality. For these scenarios to work, they have to be manually added to the desired presentations. For some scenarios, however, it can be beneficial to see the impact on multiple presentations. Therefore, it could prove beneficial to apply a certain scenario to a selection of presentations. Even more, allowing users to save a certain selection of presentations could prove useful for demonstrations in the tool, as permanently leaving the desired scenarios in a presentation can cause unclear graphical representations or over-stacked tables. These suggestions would provide a smoother user experience while working with the What-if functionality, primarily when demonstrating results to outsiders. Of course, this is not always needed, as such this needs to be an addition, rather than replace the current manner of implementing scenarios.

7 Discussion

7.1 Results

7.1.1 First research objective: Develop a model to visualise the impact of a non-financial blockchain application in the healthcare setting.

Through the Value Management Platform a model of an EHR on blockchain proof of concept was developed. This VMP model shows how the ecosystem of such a blockchain will be structured, complete with the participants needed to pull off such an implementation of blockchain technology (e.g. Hyperledger Fabric, Amazon Web Services, Consortium, Patients, different kind of healthcare providers, etc.). By building this EHR on blockchain case in a tool like VMP, that lets you build high-level value deliver models, it is possible to make a better analysis of the business case in the whitepaper. Not only the obvious effects of the blockchain application are explored, but the entire impact of the blockchain technology implementation on the business ecosystem is explored. This allows for a better identification of the effects on the business, and translate these effects into actual business values. Therefore, this study visualises the impact of blockchain with the help of some key-values. These key-values are divided in two main subgroups. The first division visualises the increased access to data thanks to the EHR on blockchain application, visible in Figure 48. Due to this better access to data, the overall healthcare towards patients improves, patient satisfaction will increase along with the transparency of the process behind the treatments and the duration (read: time consumption) of a treatment will decrease compared to the current situation. The second division focuses more on the reduction of costs, the blockchain technology can bring, with respect to all the business activities related to healthcare. Several different cost reduction are obtained in the VMP model compared to the current situation, resulting from a decrease in cost per treatment, as can be seen in Figure 47. Another VMP functionality taken into account for this study are the What-If scenarios. These scenarios bring extra value to the assessment of the EHR on blockchain application, since the worthwhileness of the application can be put to the test by only changing some determined input values. For the parameters and scenarios specific to the study, the implementation threshold seems to be rather low and robust. After all, the EHR on blockchain application seems to be worthwhile, even after the analysis of the scenarios' outcomes. The value delivery model also allows for a clear comparison of the current situation with the desired situation and even a possible future situation, since all the respective situations are modelled in the VMP. This model then helps to convince readers of the added benefits of a non-financial blockchain application in the healthcare setting. Moreover, the results in this study are not entirely limited to adopted case, as the model can be tweaked with light changes through the input values and multipliers to form a basis for similar cases. Since such a value model says much more than a plain whitepaper, this model can be beneficial to decision leaders as it actually visualises the impact blockchain technology can have in the healthcare sector. Decision leaders can alter certain input values to change the model to their needs, receiving a well-rounded basis to assess whether the investment is worth its cost. This value model, however, can also be very valuable to many other stakeholders, not only decision leaders. There are three groups of stakeholders who come to mind. First of all, the independent interested parties who want to actually see what this popular blockchain technology can achieve. Second of all, future implementers who want to know what is needed to launch such an application can really benefit from this value model. Last of all, a group more tied to the actual case study, the consortium can convince new healthcare providers to join the initiative by implementing actual values in the value model and showing the obtained benefits of the blockchain technology to potential candidates.

7.1.2 Second research objective: Provide a high-technological case in the Value Management Platform to show its usability

While explaining the EHR on blockchain application in the Value Management Platform throughout this study, several touchpoints were discussed that explain the usefulness of this tool as a way to model such a high-technological case. One of the main advantages of the VMP, compared to other modelling tools, is the ability to take the entire ecosystem into account, instead of being restricted to only one or a set of business units. This allows users to take the entire story into account and give a comprehensive view of all the aspects the technology can influence. For example, in the EHR on blockchain case, the impact on the IT-side (EHRs) can be modelled, but also the impact of blockchain technology on healthcare towards patients and different costs aspects can be represented. Even more, all values can be put into relations to each other with the help of aggregations and arithmetic functions, delivering a fully integrated and interactive model. Moreover, the values linked to these formulas are easily changeable by any user of the model. Furthermore, the What-If scenarios, were also found to be very useful for such high-technological cases, as the implementation of such innovative cases are based upon several uncertainties and assumptions. After all, the What-If scenarios let the users see outcomes of small alternations in the base alternative. With this high-technological case in VMP, also some suggestions were made to further improve the tool, based upon own experiences while modelling the case study. As such, more detailed textual user guides, expansion of the formula support, equal interactivity in the graphical presentations as the tables and multiple presentation selection options for the What-if scenario functionality were suggested, with a smoother user experience in mind.

7.1.3 Limitations

The primary focus of this study consisted of modelling the EHR on blockchain proof of concept in the Value Management Platform. Therefore the ecosystem proposed in this study tries to represent that of the story in the whitepaper. This means that not all entities, who can benefit from the blockchain application, are taken into account for this model. For example, insurance agencies, governmental institutions, research centres, and so on, could also benefit of these easier accessibility of medical data. The same is true for the entire impact of blockchain technology in the healthcare sector. There could be many other values that are impacted by blockchain, but are not included in this study. Moreover, the VMP model is obtained through the own interpretation of the whitepaper and can therefore deviate from the original authors standpoint. Furthermore, several parameters assigned to the different values can differ from actual numbers, as they are based upon estimations from online sources or Shariq Ata.

8 Conclusion

The main goal of this study has been to visualise the impact of a non-financial blockchain application. In order to achieve this visualisation, a model in the Value Management Platform (VMP) was built. This model is based upon a EHR on blockchain proof of concept in the healthcare sector. With the help of this VMP model, the impact of such a blockchain application on all the different business units can be shown and a better analysis of the application can be made. Through the complex and high-technological nature of blockchain technology, it was also possible to show the usability of the Value Management Platform for such specific cases. Additionally, based upon the experienced gathered from this case study in VMP, some suggestions were given to further improve the tool.

This study sprouted from VDMbee's interest in blockchain technology. For this reason an appropriate blockchain use case was sought to model in the VMP. Such a blockchain case was found through the 'healthcare interoperability using blockchain technology' whitepaper. This whitepaper explains the setting and findings of a blockchain proof of concept for a blockchain application to manage patient consent. With the help of Shariq Ata (Enterprise architect director, University of Chicago Medicine) and Henk de Man (Co-Founder VDMbee) the proof of concept, explained in the whitepaper, was integrated in the VMP. Through this VMP model, it is then possible to visualise the benefits blockchain technology can bring in the healthcare sector. Such a visualisation was desired, as the knowledge surrounding non-financial blockchain applications is rather limited, especially in the healthcare sector. The research objectives of this study were achieved successfully. The involved parties were delighted with the final model and results it shows. VDMbee concluded that the VMP model is suitable to demonstrate the potential of their tool, already using the model to convince two potential partners.

With these provisions in mind, this study hopes to contribute to the academic knowledge of non-financial blockchain applications, business transformation and value modelling, as it gives more insight in what an implementation of blockchain technology can do, especially in a healthcare sector.

To provide a more accurate assessment of blockchain technology in the healthcare sector, future studies could expand the current model with a more extensive ecosystem and more accurate parameters linked to the values. Furthermore, future research is needed, where different kinds of blockchain technology initiatives in the healthcare sector are compared, to determine the best approach. An important variable is the approach of the Consortium, to know which entity is best suited to manage such an application. Moreover, practitioners could make a critical comparison of blockchain technology implementations with same-purpose innovations that want to improve the healthcare sector.

References

Agbo, C. C., Mahmoud, Q. H., & Eklund, J. M. (2019, June). Blockchain technology in healthcare: a systematic review. In Healthcare (Vol. 7, No. 2, p. 56). Multidisciplinary Digital Publishing Institute.

Allee, V.: Value network analysis and value conversion of tangible and intangible assets. Journal of intellectual capital 9, 5-24 (2008)

Anderson, H. (2010, February 8). The Essential Guide to HITECH Act. Retrieved 3 July 2020, from https://www.healthcareinfosecurity.com/essential-guide-to-hitech-act-a-2053

Azaria, A., Ekblaw, A., Vieira, T., Lippman, A.: MedRec: Using Blockchain for Medical Data Access and Permission Management. In: 2016 2nd International Conference on Open and Big Data (OBD). pp. 25–30 (2016). https://doi.org/10.1109/OBD.2016.11.

Bittner, K. (2002). Use case modeling. Addison-Wesley Longman Publishing Co., Inc..

Burger, C., Kuhlmann, A., Richard, P., & Weinmann, J. (2016). Blockchain in the energy transition: A survey among decision-makers in the German energy industry. Berlin: Deutsche Energie-Agentur GmbH & ESMT European School of Management and Technology (November 2016).

Catalini, C., & Gans, J. S. (2016). Some simple economics of the blockchain (No. w22952). National Bureau of Economic Research. https://doi.org/10.3386/w22952

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., ... & Shekelle, P. G. (2006). Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Annals of internal medicine, 144(10), 742-752.

Christensen, C. M., & Rosenbloom, R. S. (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research policy*, *24*(2), 233-257.

Cummins, F. A.: Building the Agile Enterprise: With Capabilities, Collaborations and Values. Morgan Kaufmann (2016).

de Man, H.: Continuous Business Model Planning with VDMbee, https://vdmbee.com/2017/12/, last accessed 2020/05/20.

Guardtime health, whitepaper (2019, April). Retrieved 20 January 2020 from https://guardtime.com/health

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R., & Taylor, R. (2005). Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. Health affairs, 24(5), 1103-1117. https://doi.org/10.1377/hlthaff.24.5.1103

HL7. (n.d.). HL7 Standards Product Brief - FHIR® R4 (HL7 Fast Healthcare Interoperability Resources, Release 4) | HL7 International. Retrieved 3 July 2020, from https://www.hl7.org/implement/standards/product_brief.cfm?product_id=491

Hoy, M. B. (2017). An introduction to the blockchain and its implications for libraries and medicine. Medical Reference Services Quarterly, 36(3), 273–279. http://dx.doi.org/10.1080/02763869.2017.1332261.

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. Harvard Business Review (January/February 2017).

International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe) (pp. 1-4). IEEE.

Jothi, N., & Husain, W. (2015). Data mining in healthcare–a review. Procedia computer science, 72, 306-313. https://doi.org/10.1016/j.procs.2015.12.145

Kannan, P., & Holmes, M. (2019). Healthcare interoperability using blockchain technology. Retrieved 20 June 2020 from https://www.siriuscom.com/2019/04/health-system-sets-the-stage-for-transformation-with-blockchain-technology/

Kaplan, R.S., Norton, D.P.: Strategy maps: Converting intangible assets into tangible outcomes. Harvard Business Press (2004).

Lavrijssen, S., & Carrilo, A. (June 2, 2017). Radical innovation in the energy sector and the impact on regulation. TILEC Discussion Paper No. DP 2017–017 (Available at SSRN: https://ssrn.com/abstract=2979206).

Lindgren, P., Rasmussen, O.H.: The Business Model Cube. Journal of Multi Business Model Innovation and Technology 1(3), 135-182 (2013).

Mainelli, M., & Smith, M. (2015). Sharing ledgers for sharing economies: An exploration of mutual distributed ledgers (aka blockchain technology). The Journal of Financial Perspectives, 3(3), 38–69.

Metzger, J., Terzidis, O., & Kraemer, N. (2015). Value Delivery Architecture Modeling–A New Approach for Business Modeling. *Journal of systemics, cybernetics and informatics*, 13.

Nakamoto, S. (2019). Bitcoin: A peer-to-peer electronic cash system. Manubot.

Object Management Group: Value Delivery Metamodel, version 1.0. OMG (2015).

Ølnes, S., Ubacht, J., & Janssen, M. (2017). Blockchain in government: Benefits and implications of distributed ledger technology for information sharing.

Osterwalder, A., & Pigneur, Y. (2010). Business model canvas. *Self-published. Last*.

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the association for Information Systems*, *16*(1), 1.

Osterwalder, A.: The business model ontology: A proposition in a design science approach. PhD dissertation, University of Lausanne. Lausanne (2004).

Plaza, C., Gil, J., de Chezelles, F., & Strang, K. A. (2018, June). Distributed solar self-consumption and blockchain solar energy exchanges on the public grid within an energy community. In 2018 IEEE https://doi.org/10.1109/EEEIC.2018.8494534

Poels, G., Roelens, B., de Man, H., & van Donge, T. (2018). Continuous business model planning with the value management platform. In 12th International Workshop on Value Modeling and Business Ontologies.

Poels, G., Roelens, B., de Man, H., & van Donge, T. (2019). Revisiting Continuous Business Model Planning with the Value Management Platform. In *13th International Workshop on Value Modeling and Business Ontologies* (Vol. 2383).

Recker, J. (2013). Scientific research in information systems: a beginner's guide. Springer Science & Business Media.

Rowley, J. (2002). Using case studies in research. Management research news.

Swan,M.Blockchain: BlueprintforaNewEconomy;O'ReillyMedia,Inc.: Sebastopol,CA,USA,2015. [CrossRef]

Szabo, N. (1997). Formalizing and securing relationships on public networks. First Monday, 2(9).

Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID and blockchain technology. 13th international conference on service systems and service management(ICSSSM), 24–26 June 2016, Kunming, Chinahttp://dx.doi.org/10.1109/ICSSSM.2016.7538424.

Tian, F. (2016, June). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In 2016 13th international conference on service systems and service management (ICSSSM) (pp. 1-6). IEEE. https://doi.org/10.1109/ICSSSM.2016.7538424

U.S. Centers for Medicare & Medicaid Services. (n.d.). Promoting Interoperability Programs | CMS. Retrieved 3 July 2020, from https://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms

VDMbee. VMP User Guide. (n.d.). Retrieved May 23, 2020, from https://vdmbee.com/2016/09/vmp-user-guides/

Verdonck, M., & Poels, G. (2020). Architecture and Value Analysis of a Blockchain-Based Electronic Health Record Permission Management System. In 14th International Workshop on Value Modelling and Business Ontologies (Vol. 2574, pp. 16-24).

Webb, A. (2015). 8 tech trends to watch in 2016. Harvard business review, December 8th 2015 (Retrieved from https://hbr.org/2015/12/8-tech-trends-to-watch-in-2016).

What We Do. (2018, October 19). Retrieved 19 May 2020, from https://carequality.org/what-we-do/

Yin, R.K. (1994) Case study research: design and methods. 2nd edition. Thousand Oaks, CA: Sage.

Yin, R. K. (2009). Case study research: Design and methods 4th edition. In *United States: Library of Congress Cataloguing-in-Publication Data*.

Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is current research on blockchain technology?—A systematic review. PLoS One, 11(10), e0163477. http://dx.doi.org/10.1371/journal.pone.0163477.

Yue, X., Wang, H., Jin, D., Li, M., & Jiang, W. (2016). Healthcare data gateways: found healthcare intelligence on blockchain with novel privacy risk control. Journal of medical systems, 40(10), 218. https://doi.org/10.1007/s10916-016-0574-6

Appendix

Appendix 1: Examples of report functionality

Protected health information sharing with Blockchain technology

Context

Growing trend, in US (more specifically Chicago), where bigger hospitals are acquiring community hospitals, small medical groups and solo practitioners. Hence, there is a growing need to securely share medical records.

- need for a secure data sharing framework
- framework should allow each participant or provider to manage a patient's records
- patient retains control over which provider can access the data
- Framework should limit data replication within hospital records
- Framework should provide direct access to electronic health record (EHR) data wherever needed

How? --> with Blockchain technology:

- simplifying collaboration between partner providers and patients
- enhancing collaboration between partner providers and patients
- securing collaboration between partner providers and patients

EHR(electronic health record):

- digital version of a patient's paper chart
- make information available instantly and securely to authorized users
- can be inclusive of a broader view of a patient's care compared to standard clinical data.
- contain information from all clinicians involved in a patient's care
- patient-centered and real-time
- Information is available whenever and wherever it is needed

Smart contracts:

- can carry digital assets or tokens between parties
- conditionally transfer digital assets or tokens between parties
- their excecutions run in a predictable and transparant manner

Problem

Heavily depended upon access to patient records across providers in a geographic region.

Interoperability challenges related to the sharing of data between different informations systems storing EHRs where each have their own data format and protocol to share EHRs.

On top, sharing of records have to be asked and provided manually. This is very time consuming.

Today:

- most providers operate independently
- access to medical records is available in a limited manner via point solutions(solving 1 specific problem)
- formal partnerships, access via system integrations
- Success with Health information exchange (HIE) but new entity and formality around integration

Advantages of Blockchain in this consent management of patients setting:

- Trust (ledger framework and cryptography)
- Contract governance (Digital Smart Contracts)
- Shared control (smart contracts, distributed ledgers and key infrastructures)

Figure 61: Problem definition

Implementation

Implementation cost: (depends on the number of nodes and amount of data)

	Blockchain Nodes	Storage	Network	Cost/Month
Development	$15	$381	0	$385
Test	$30	$1110	0	$1140
Production	$272	$2,148	$70	$2,420
			Total	**$4036**

d

Assumption:

1. Number of Nodes per EHR System = 1
2. Number of Patients across UCMC & Ingalls = 4 M
3. Number of Records per Patient = 25
4. Average Size of each Record = 100 KB

Table represents the hosting cost of 1 node.

Blockchain nodes: These are the annual fixed hosting costs per node.

Storage: storage of meta data for the FHIR services and Access management related info. Costs made from AWS. Roughly estimated= 4M patients * 25records per patient * 100KB. -> depending on variation in final solution
4M patients in EHR, bound to grow as more hospitals and clinics are added to the node.

Network: 70 network production cost -> depends on the number of transactions and overall volume.

One node is required for each EHR

restriction of 25 records per patients is only for proof of concept. Technically you can have as many records per patient as one wants. No limits. Each record consists of master patient ID, healthcare and meta data about the FHIR to dynamically fetch the data from various healthcare providers.

We assume 44 nodes in this use case. 14 member, 5 affiliate en 25 third party

Technical details:

- **Engagement Layer:** A view of blockchain data. Visualizing the data of patients who have provided consent for data-sharing between consortia. UI shows patient information along with allergies, medications and events.
- **Integration Layer:** Node.js SDK for Hyperledger Fabric. Web app uses the Node.js SDK to query/update the blockchain.
- **Member HIE Contract:** Enables and governs the contractual rules in patient EHR data exchange between Ingalls and UChicago Hospitals.
- **Affiliate HIE Contract:** Enables and governs the contractual rules in patient EHR data exchange between Silvercross (Affiliate) and UChicago Hospitals.
- **Hosting Platform:** Amazon Web Services, Containerized-->hosting of hyper ledger
- -> An EC2 instance is a virtual server in Amazon's Elastic Compute Cloud (EC2) for running applications on the Amazon Web Services (AWS) infrastructure.
- **Blockchain:** Hyperledger Fabric V1.1
- **Smart Contracts:** Golang
- **Integration:** APIs Node.js SDK -> also via AWS (link)
- Outsourcing is possible (blended with own input and R&D)
-

Figure 62: Blockchain technology prices in report

Hyperledger fabric:

Hyperledger introduces a completely different idea of a blockchain network that is not transactional at its core. This is to say that the peers within a Hyperledger ecosystem are the various enterprises looking to exploit the technology.

Among other Hyperledger projects, Hyperledger Fabric is the most popular. What sets Fabric apart from other platforms on the Hyperledger ecosystem is that it enables developers to create applications using general purpose programming languages like Go, Java, and Node.js.

Hyperledger mainly targets the blockchain for enterprises. Moreover, it's designed to suit a higher degree of confidentiality for the platforms. (B2B) Hyperledger will approve a set of predefined members to get access. Moreover, they will also decide who can join the consensus and who can't. Hyperledger lets the users choose between No-Op, or an agreement protocol (PBFT) to reach the verdict. So, all the parties agree in such a way that everyone can influence the outcome. So, any third party can't force their decisions on the nodes

There is no mining in Hyperledger Fabric. Instead, you have an arrangement of nodes which enact different roles and aid in the creation of a block.In Permissioned blockchain networks like Hyperledger, it is the common interests of all participating organizations and entities that go towards creation of a block. Also, since the identity of all participants is known, consensus is typically very cheap compared to the Bitcoin “trustless” mining. In a Fabric network, you have various nodes carrying out Endorsement, Ordering, Committing peer roles.

https://www.youtube.com/watch?time_continue=2&v=DqtzxJP6Y9k&feature=emb_title

The responsibility of creating new blocks lies with Orderers node in Hyperledger. New block creation in Hyperledger Fabric in brief (Single channel). 1) Client (User) initiates a transaction to peers (part of organizations specified by the smart contract endorsement policy). 2) Endorsed transaction response generated by the peer (node) and returned to the client application. 3) These all transactions responses packaged together to forma a fully endorsed transaction, which is distributed to the entire network. 4) Orderer nodes of that network will receive these transactions and will create the blocks. 5) These blocks will be delivered to all peers which will be validated and appended to the ledger

Medblock:

Solution is business-to-business and comprehensive. Focuses on the privacy of information by adopting the blockchain for access control and encryption purposes. In their design, a certification authority acts as a system administrator of the blockchain, where the blockchain manages pointers of the record as to find the true storage address of information of the EHR. A processing layer that is composed of local community hospitals and their servers can access and modify patient records, which are then uploaded to a supervising hospital

MedRec:

They propose a modular design in order to integrate existing, local data storage solutions while facilitating interoperability. Through incentivization (e.g., access to aggregate, anonymized data) of medical stakeholders such as researchers and public health authorities, they aim to engage these stakeholders in becoming the miners of the blockchain network. 2 incentive models:

- Ethereum's inherent incentivizing model: transactions require Ether. Ether can be earned by mining. Care providers are thus incentivized to participate in mining in order to fund the continuation of their activities. Patients will also have to pay Ether, or have the destination party fund them.
- second model: Brings medical researchers and health care authorities to mine in the network, in return they gain access to aggregate, anonymized medical data as mining rewards.

By integrating with providers' existing data storage infrastructure, MedRec facilitate continued use of their existing systems. Medical records are stored locally in separate provider and patient databases; copies of authorization data are stored on each node in the network. Furthermore, because the medical data stays distributed, our system does not create a new, central target for content attack.

Ethereum:

Originally not a good solution for enterprises since it is a public blockchain. But several companies have come with an ethereum enterprise solution. All by all it is more a B2C blockchain. The transaction on Ethereum is public, so everyone will be able to see your transitions with another party. You can use Ethereum in both ways, public or private. In Ethereum they use Proof of Work as a consensus algorithm. This mechanism is overly slow and depends on everyone on the network to reach a single point of agreement. Furthermore, this protocol is also power hungry, so it would take up a lot of your power to reach the agreement.

Transactions are collated into blocks; blocks are chained together using a cryptographic hash

Proof-of-work= is a consensus mechanism. It deters denial-of-service attacks and other service abuses such as spam on a network by requiring some work from the service requester, usually meaning processing time by a computer.(wikipedia)

Mining= Mining is a computationally intensive work that requires a lot of processing power and time. Mining is the act of participating in a given peer distributed cryptocurrency network in consensus. The miner is subsequently rewarded for providing solutions to challenging math problems. It is done by putting the computer's hardware to use with mining applications.

All the information on cryptocurrency transactions must be embedded in data blocks. Each block is linked internally to several other blocks. This creates the blockchain. These blocks must be analyzed as fast as possible to ensure a smooth running of transactions on the platform. However, the issuers of such currencies do not have the processing capabilities to handle this alone. It is where miners come in. Ethereum Mining is the process of mining Ether. Every developer seeking to engage and make use of smart contracts on the Ethereum blockchain needs Ether to proceed

Proof-of-work refers to the solving of complex equations, which is a basic requirement for a miner to clear for their block to be added to the blockchain. (https://www.huffpost.com/entry/ethereum-mining-101-your-complete-guide_b_58b6e1eee4b02f3f81e44e9f?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAANg6FJdocjx-m5P4bzu2i1BA33hLeng9Os5chh54r8108kdTRlXDKODZsMK2bOZwEmozXREWmqqlyX9jXKbjuvq7n0WIlSkzv31YAzgN85dlr7VaJdn5IiB8okfT8m9nNygQEWAa-

Figure 63: blockchain technolgy terminologies in report

Appendix 2: Business Ecosystem maps

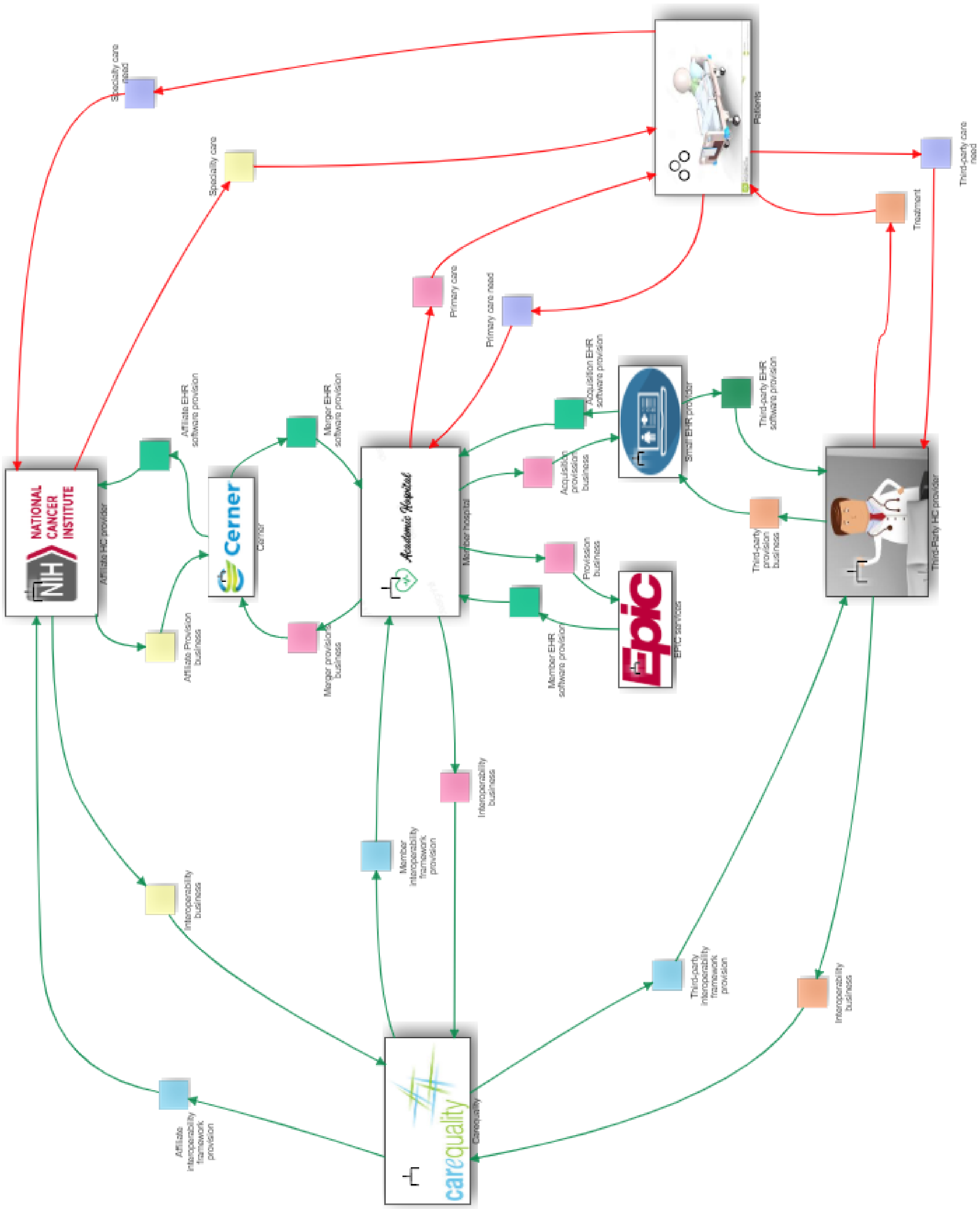


Figure 64: AS-IS Business Ecosystem Map big

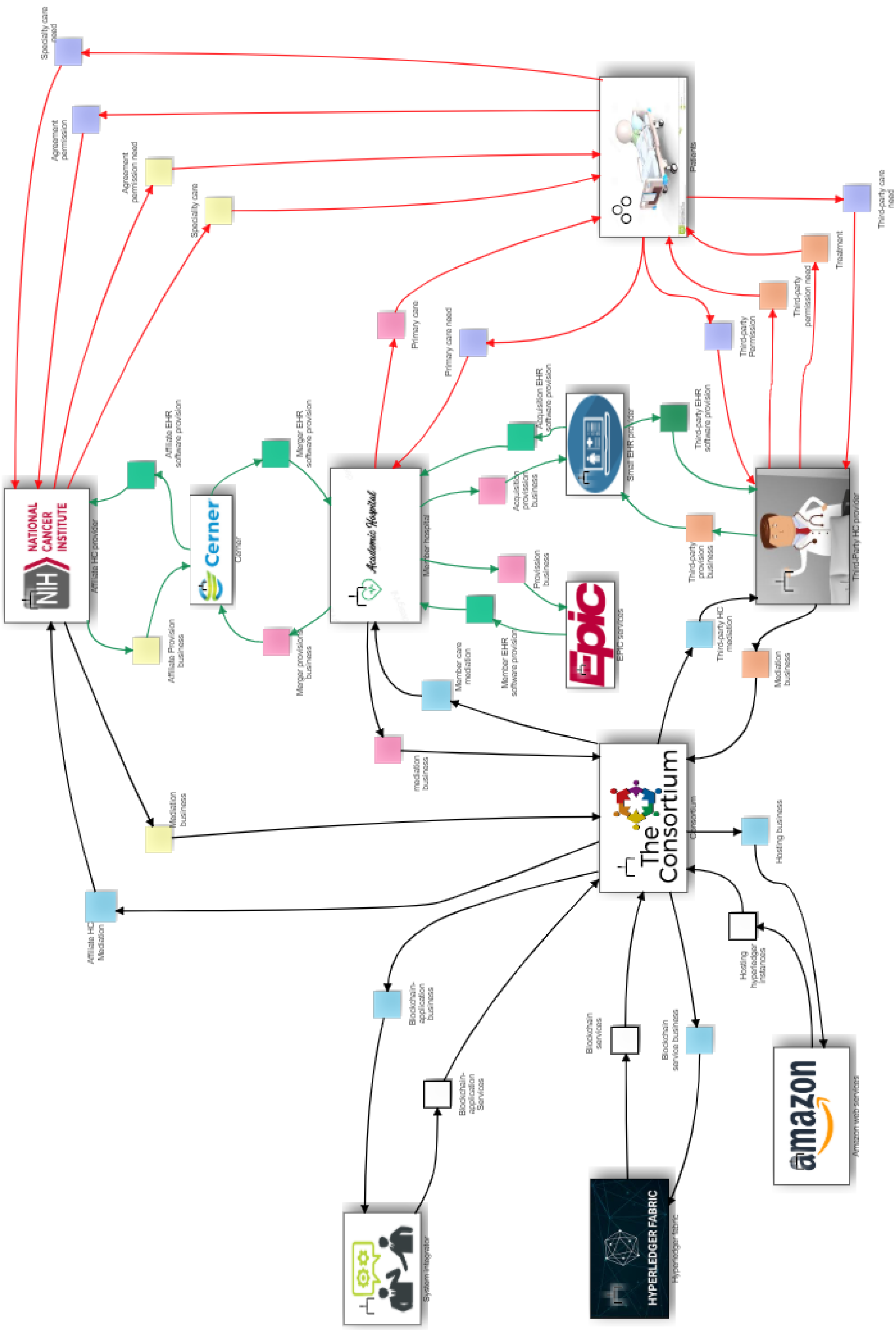


Figure 65: TO-BE Business Ecosystem Map big

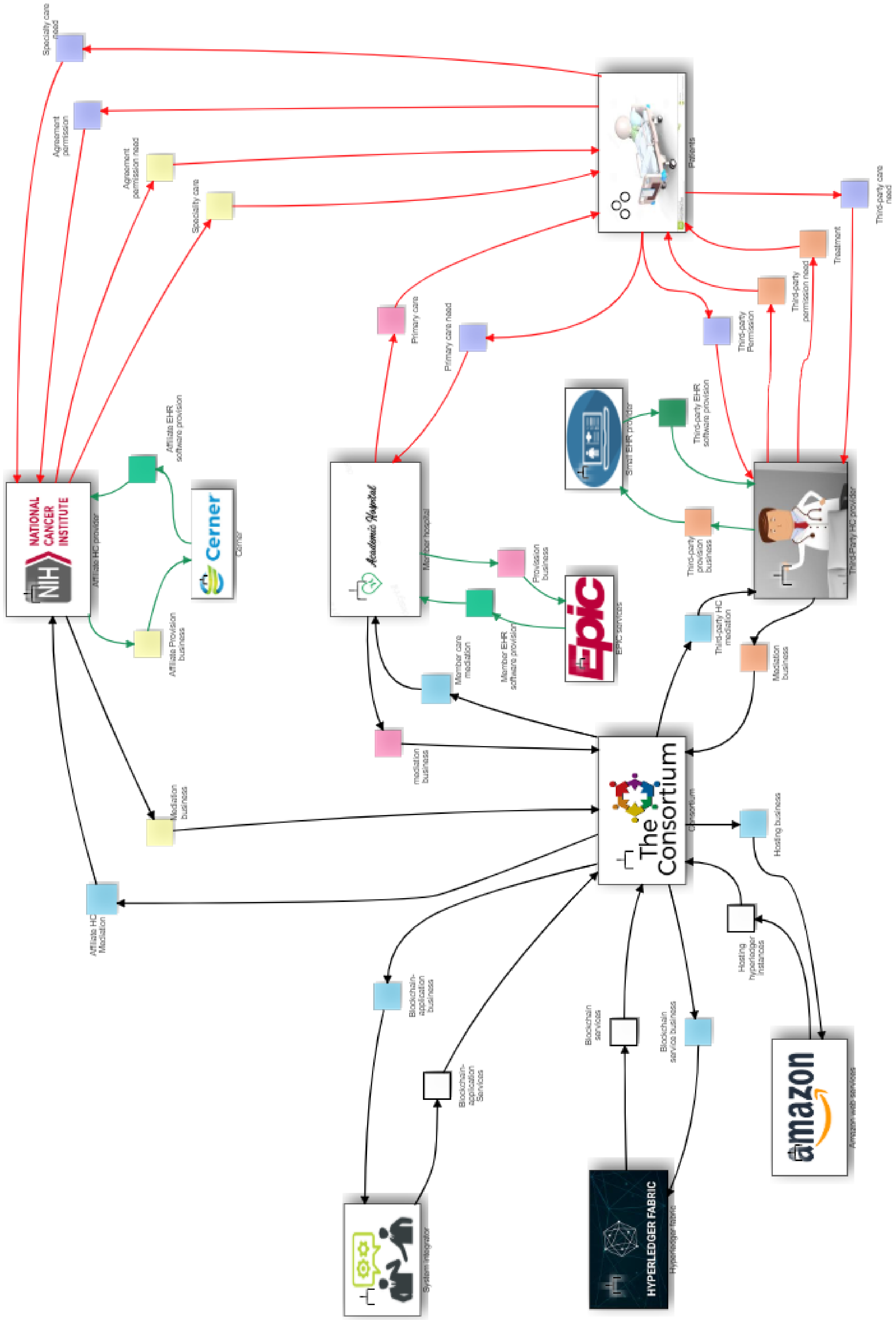


Figure 66: After 3 years Business Ecosystem Map big

Appendix 3: Business Model Canvasses TO-BE phase

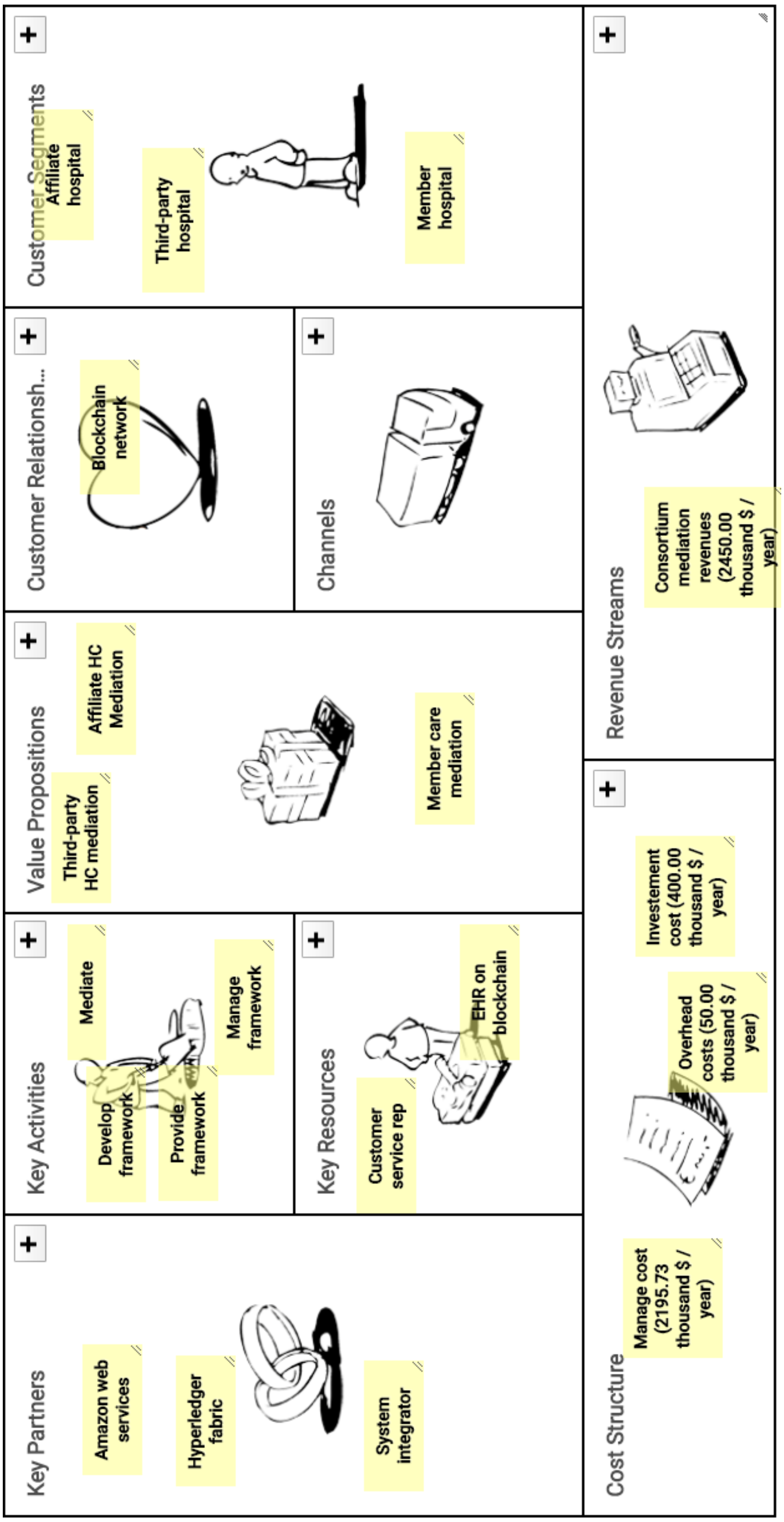


Figure 67: Business Model Canvas Consortium

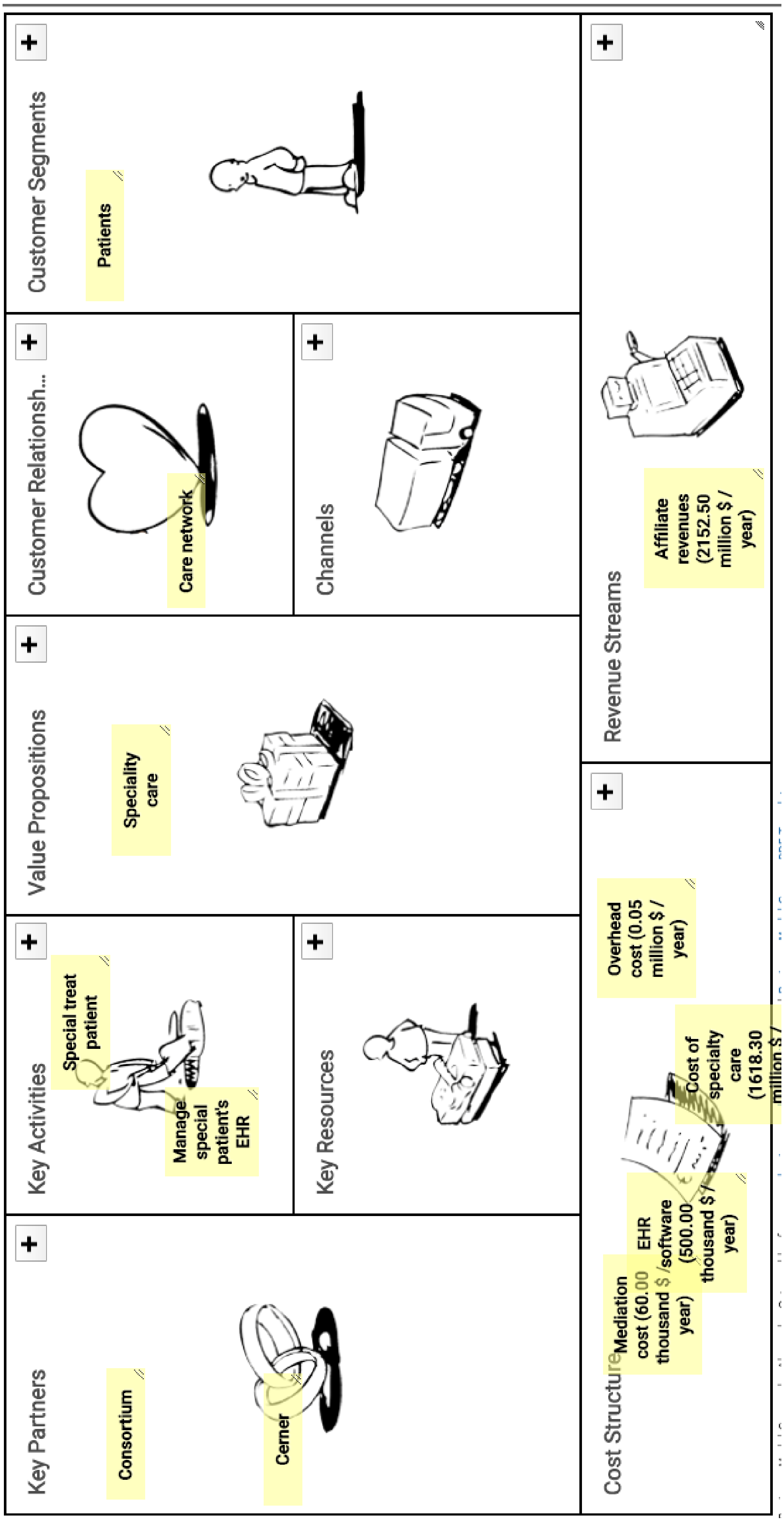


Figure 68: Business Model Canvas Affiliate hospitals

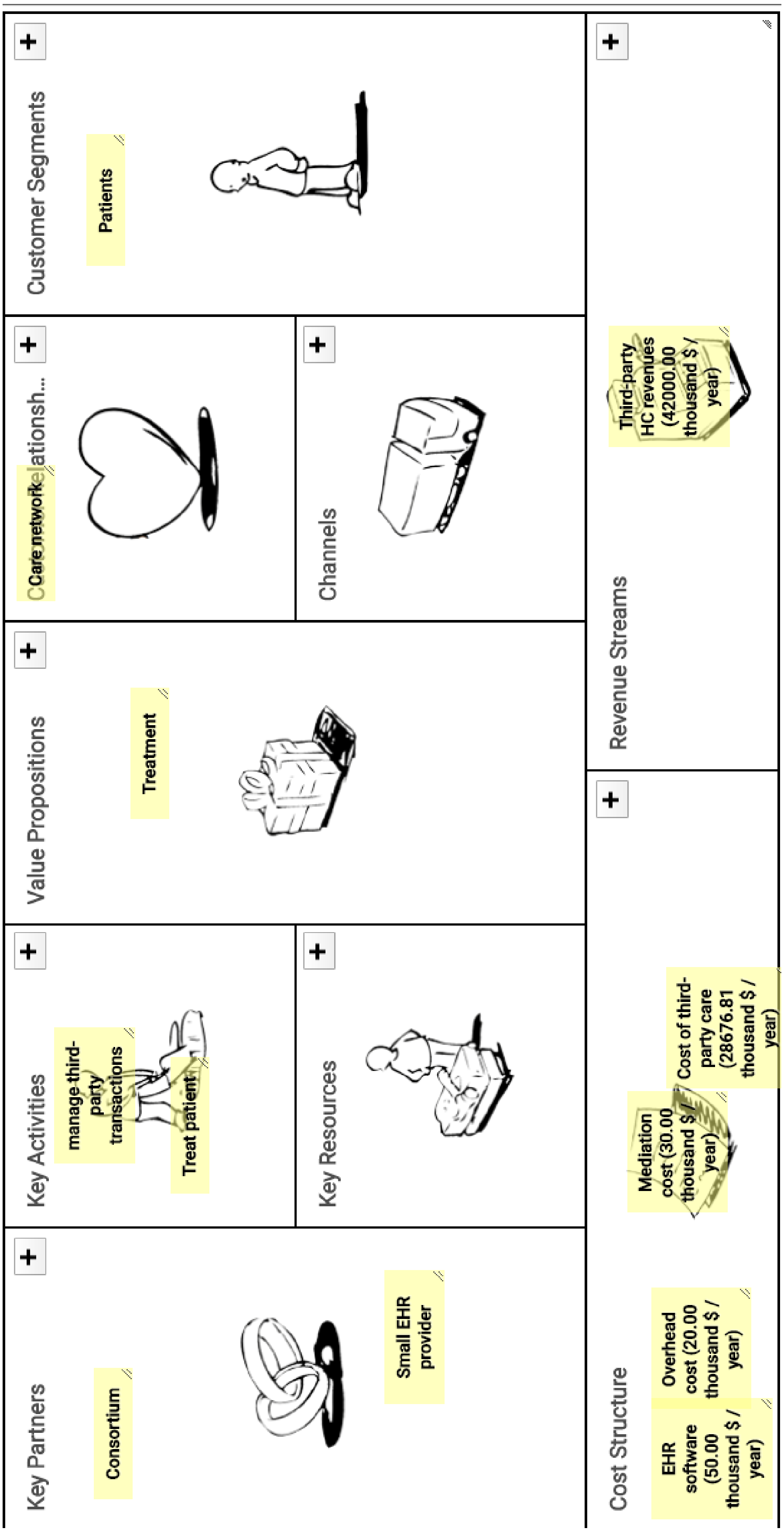


Figure 69: Business Model Canvas Third-party HC providers

Appendix 4: TO-BE Strategy Maps

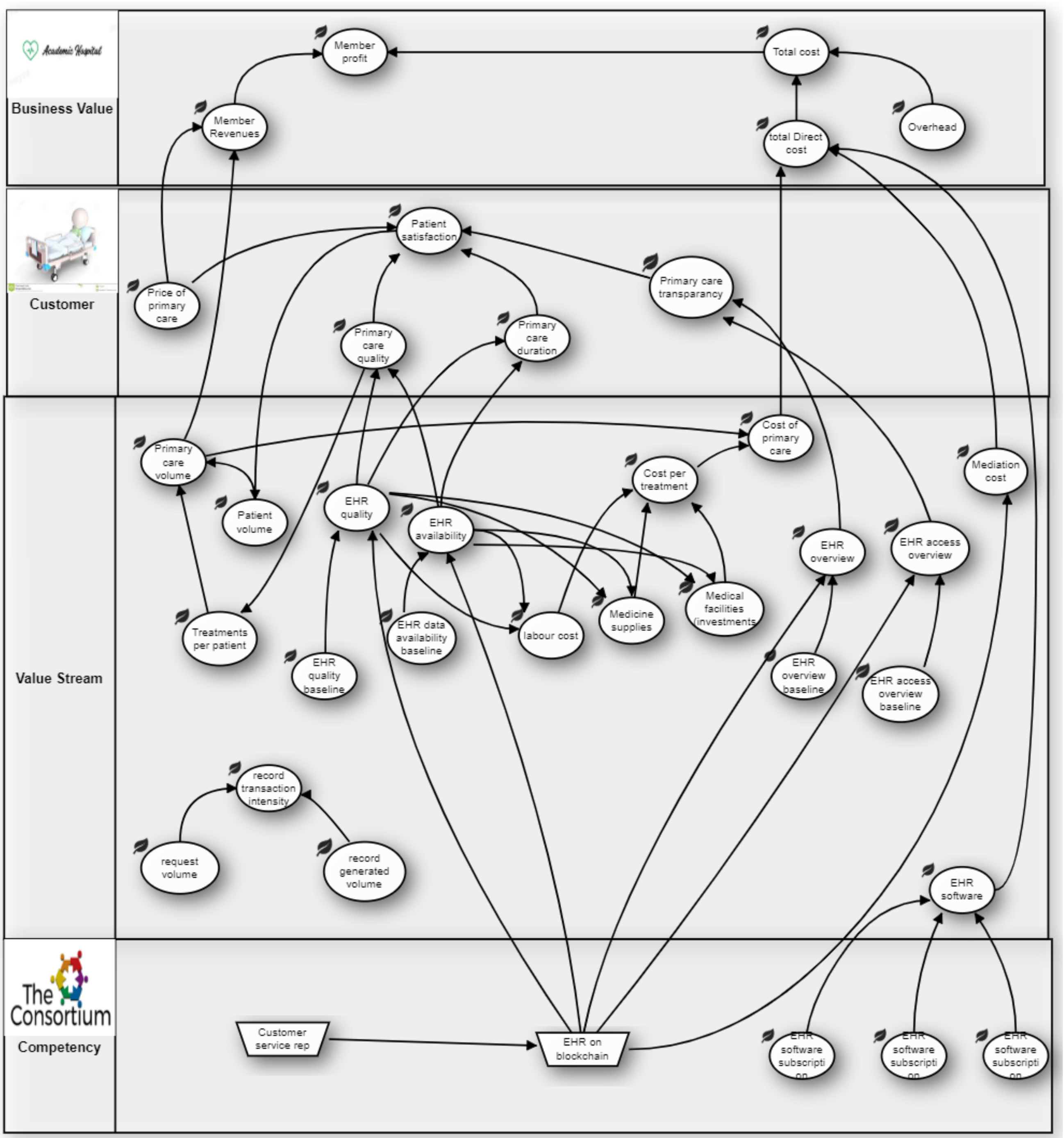


Figure 70: Member hospitals Strategy Map big

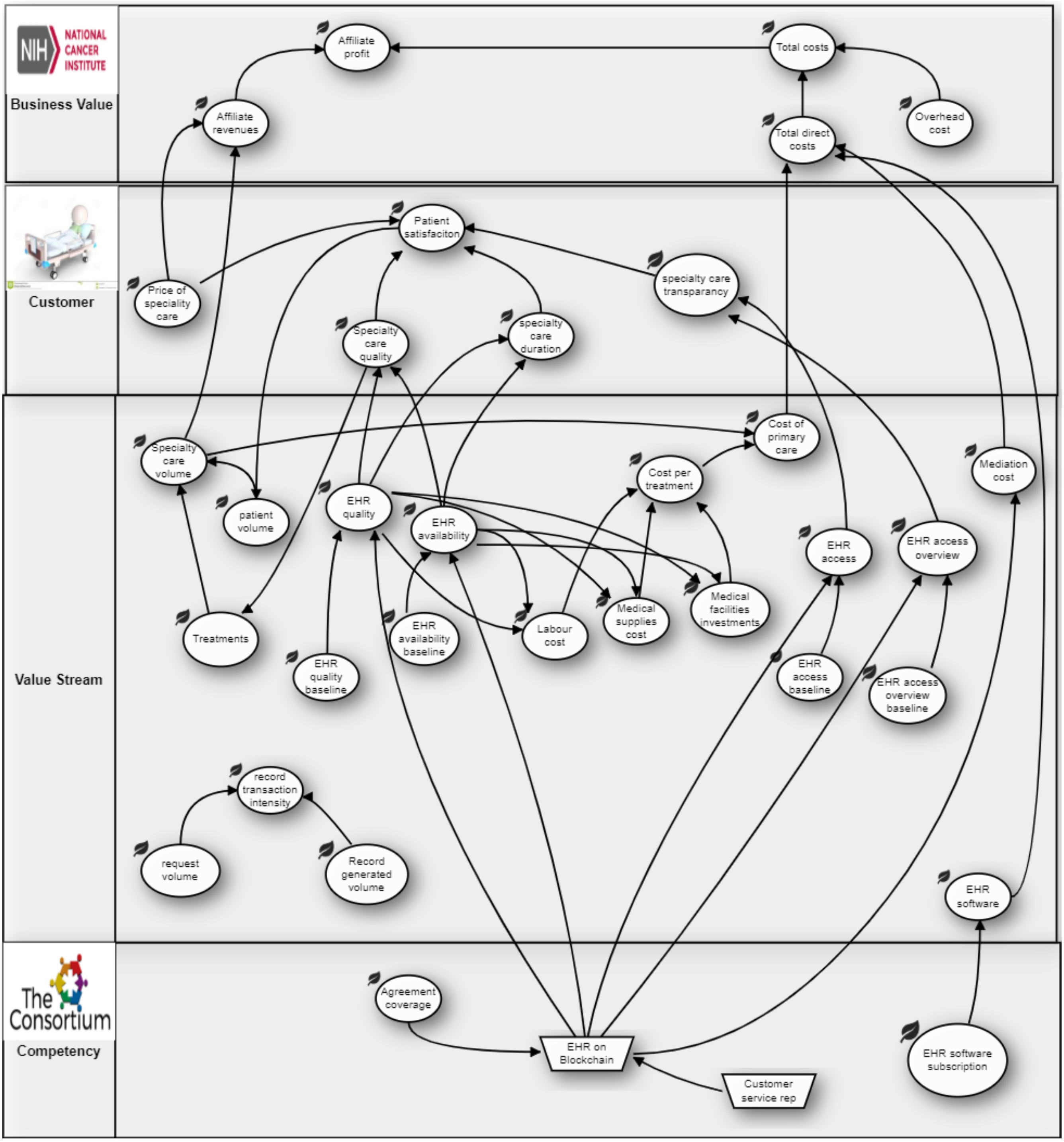


Figure 71: Affiliate hospitals Strategy Map

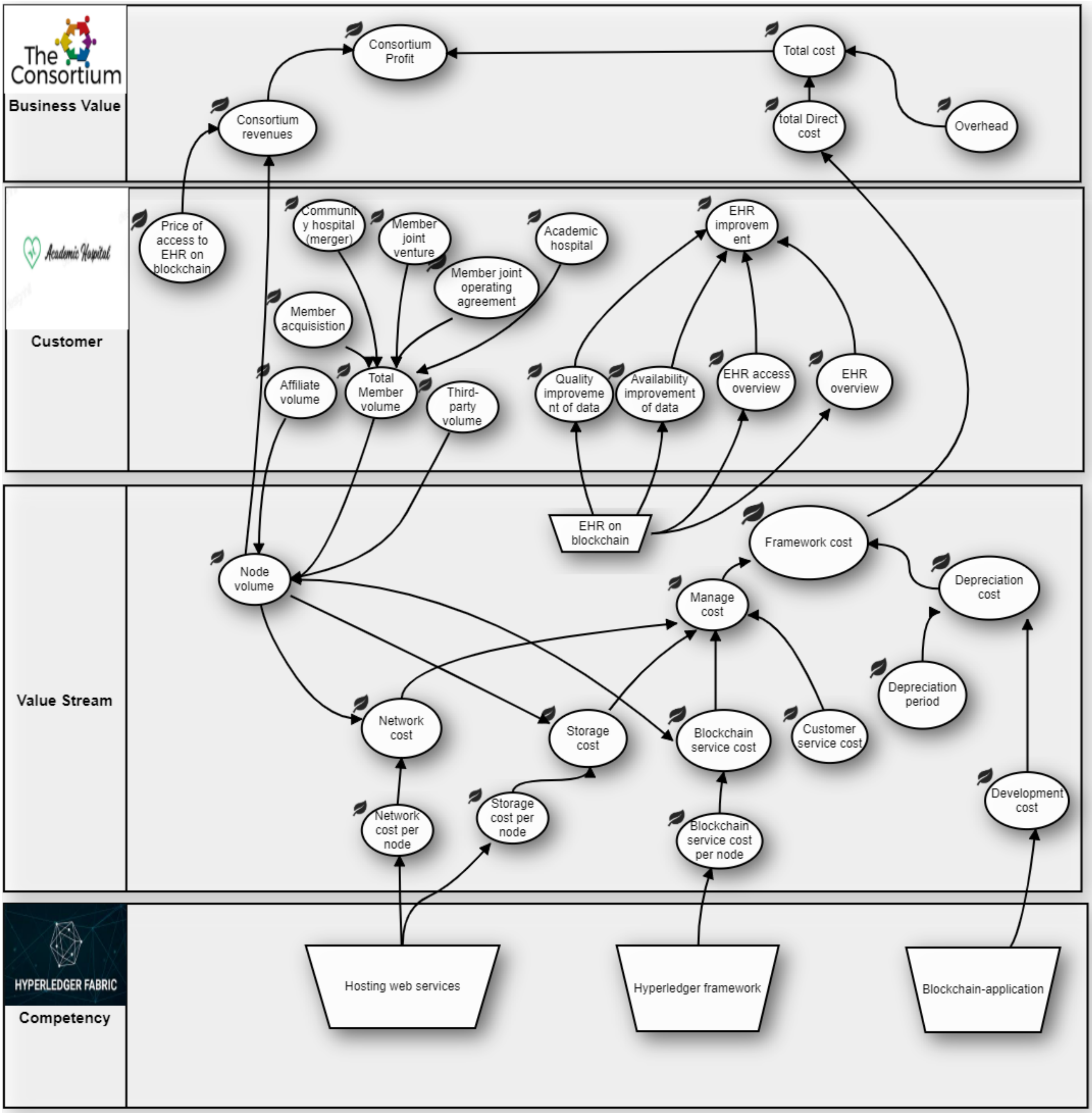


Figure 72: Consortium Strategy Map

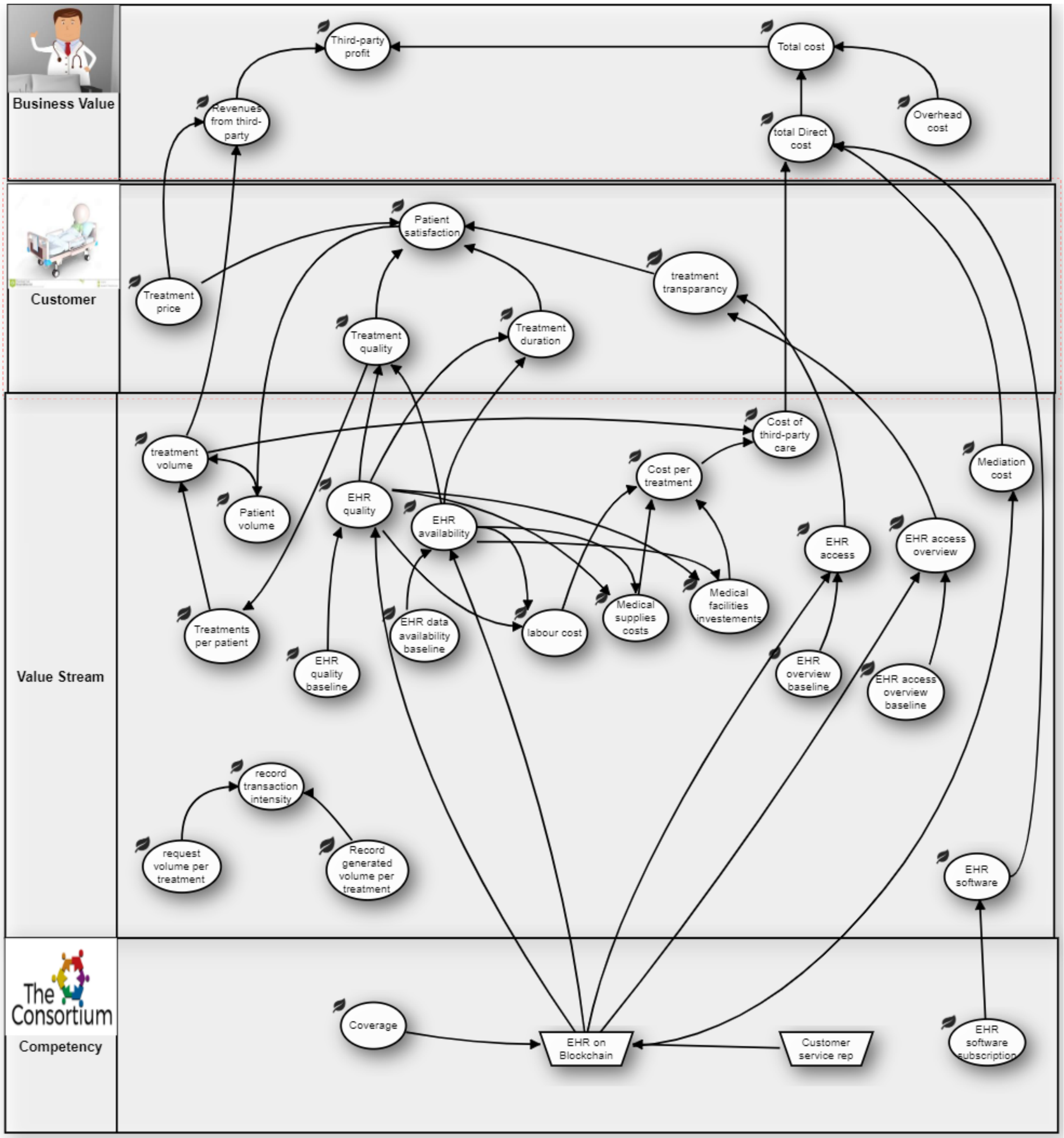


Figure 73: Third-party HC providers Strategy Map

Consortium strategy:

- **Consortium profit=** Revenue - total cost

  -> Consortium doesn't really make a profit. They adapt their price to keep the price fair for all the involved parties and break-even themselves.
- **Revenue=** Price of access to EHR on Blockchain * Node volume

  -> Fair price. Node volume is the amount of different healthcare entities on the framework.
- **Total cost=** Total direct cost * overhead
- **HC efficiency:** The improvement of HC the different healtcare entities have thanks to the EHR on blockchain and can provide their patients. Influenced by the quality, availabilty, access and overview.
- **HC volume=** Patient volume * treatment volume per patient

  -> the total amount of treatments for a node. This is also influenced by HC efficiency. The more efficient the healthcare provider is, the more patients they can treat and the amount of treatments per patients go down (unnecessary treatments will go down).
- **EHR on Blockchain:** influenced by the permission coverage

  -> coverage is 100% for the member hospitals and adjusted for the other providors
- **Framework cost=** Hosting cost + transaction cost + storage cost + blockchain service cost+ maintenance cost+ development cost

  -> All the costs made to maintain and develop the framework. Given by 3 partners: Hyperledger fabric, AWS and the system integrator.
- **Hosting cost=** Node volume * hosting cost per node
- **Transaction cost=** Transaction per node volume * cost per transaction * node volume.

  -> the transaction cost is variable, and dependent on the amount of transactions there are made.
- **Transactions per node volume=** Healthcare volume * record transaction intensity.

  -> the amount of records there are requested and updated to give out to other entities per node.
- **storage cost=** Node volume and storage service provided by the AWS (hosting web services)

  -> assumptie dat dit een vaste kost is en niet verandert.
- **Blockchain service cost:** Set cost the consortium has to pay hyperledger fabric for the provided services.
- **Maintenance cost=** services provided by the system integrator and UCM itself
- **Development cost=** Services provided by the system integrator and UCM, but these costs are depreciated linearly over the years.

Figure 74: Consortium Strategy Map values explanation

Healthcare entities:

- **Profit=** Revenue- total cost
- **Total cost=** Total direct cost + overhead
- **Total direct cost=** Cost of primary care + mediation cost
- **Mediation cost=** price per record transaction + record transaction volume
  -> this is the cost, the healthcare providers have to pay the consortium for all the services it gives as mediator between the entities.
- **Cost of primary care=** cost of primary care baseline +/- primary care volume * cost per treatment
  -> thanks to the EHR on blockchain the cost of primary care can go down
- **Cost (reduction) per treatment=** EHR quality and EHR availability
  -> the cost can go down, in line with how efficient the treatments get with the EHR on blochchain.
- **Record transaction volume=** Primary care volume * record transaction intensity
  -> the amount of records needed to flow between the entities.
- **record transaction intensity=** request volume per treatment + record generated volume per treatment.
  ->Amount of records needed/ produced out of 1 treatment
- **Revenue=** price of primary care * primary care volume
- **Price of primary care:** influenced by the total direct cost, if these go up/down, thanks to the EHR on blockchain, the price can also go up/down.
- **Primary care volume=** patient volume* treatments per patient
  -> important to visualize that if the patient satisfaction rises, more patients can be and will be willing to recieve treatment at the hospital. The same goes for the amount of treatments per patient, if the quality rises, the amount of treatments can reduce.
- **Patient satisfaction=** price of primary care, primary care quality, primary care duration and primary care transparancy.
  -> all these factors can make a visit more enjoyable for a patient.
- **Primary care quality=** EHR quality and EHR availabililty. The quality of the primary care goes up, if the quality of the data in the records is better and if there is more data available from a patients medical history.
  -> These 2 also have a baseline, to represent the quality and availability before the blockchain application.
- **Primary care duration=** EHR quality and EHR availabilty. The duration of healthcare goes down, cause they dont have to call other healthcare providers anymore to request data about the patient. Also, certain research can be skipped because other healthcare providers already performed it recently on the patient.
  -> same baseline as primary care quality
- **Primary care transparancy=** EHR overview and EHR access overview. The patients know who can acces their EHR's and who updated certain records. Also they know what each record says.
- **Permission coverage=** idem consortium

Figure 75: Healthcare Strategy Map value explanation

Appendix 5: Polluted Aggregation View

Figure 76: Polluted Aggregation View

Appendix 6: Value proposition form details

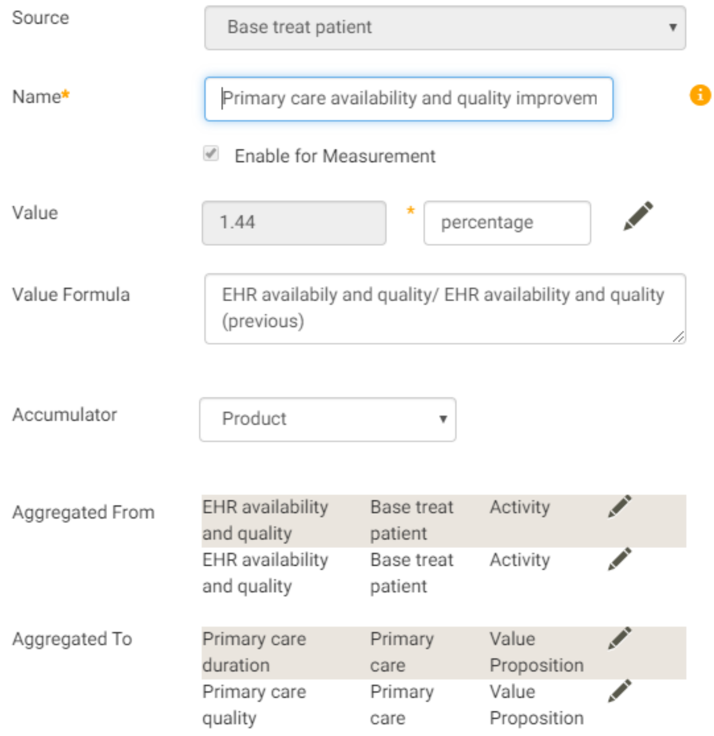


Figure 77: Value form details Primary care quality

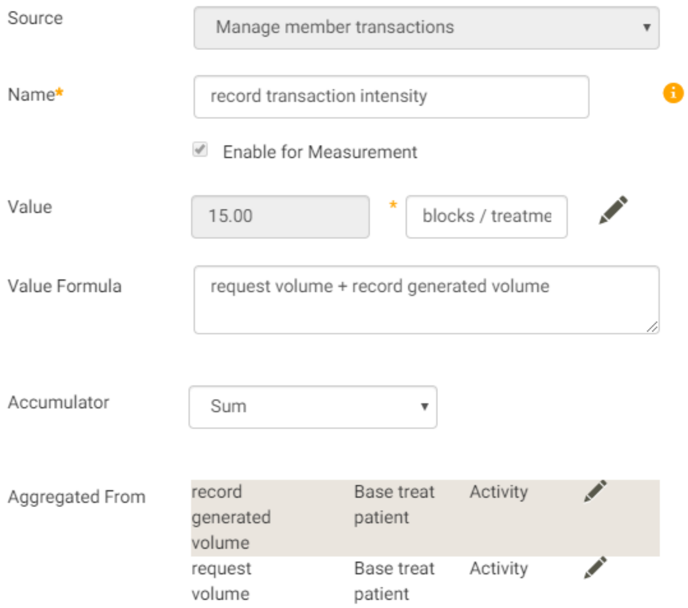


Figure 78: Record transaction intensity detail form

Appendix 7: Cost per treatment distribution

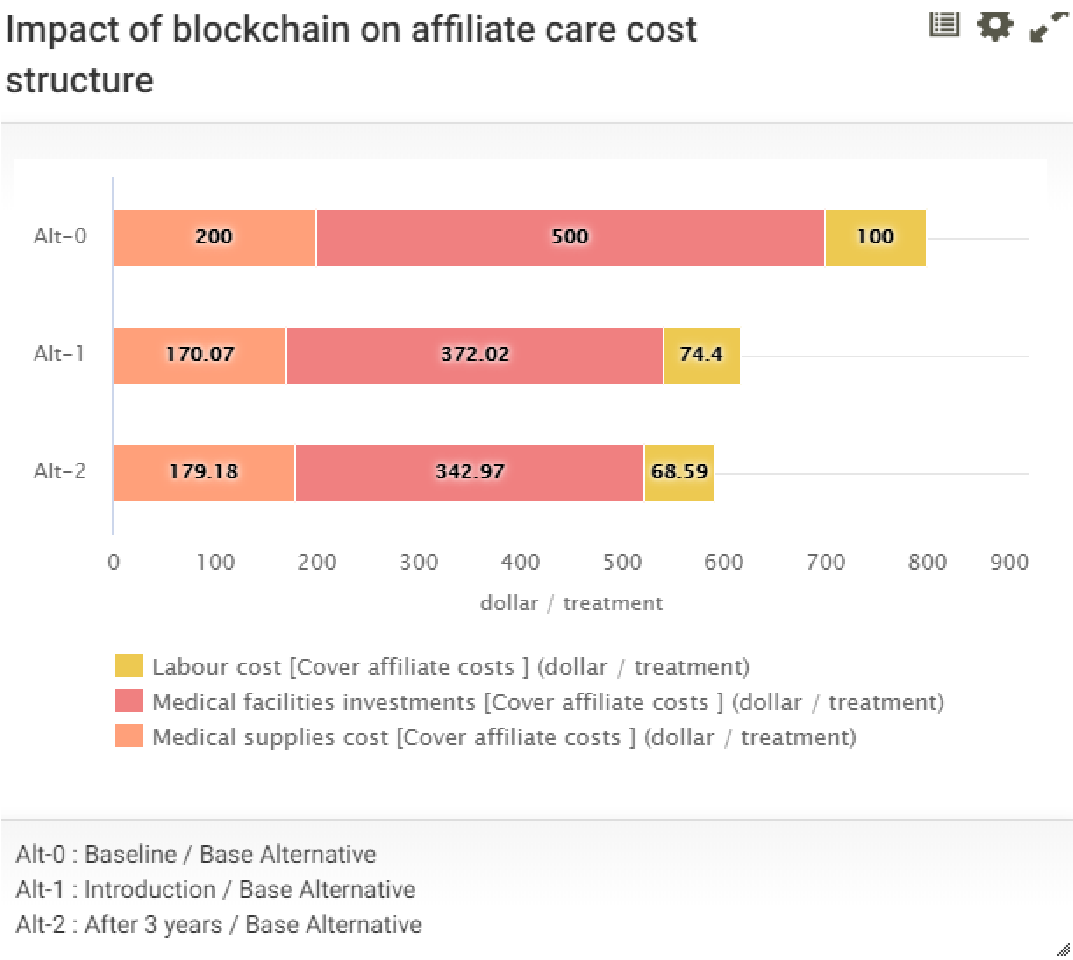


Figure 79: Cost per treatment distribution Affiliate hospitals

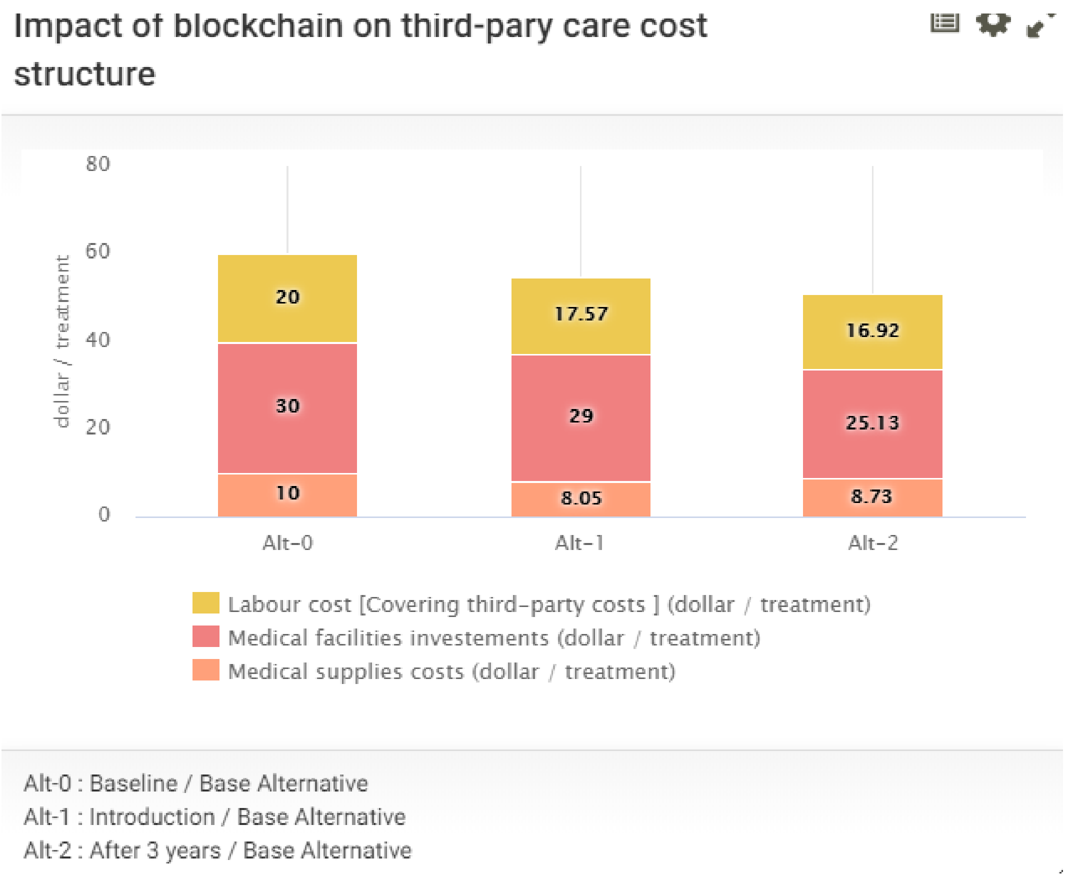
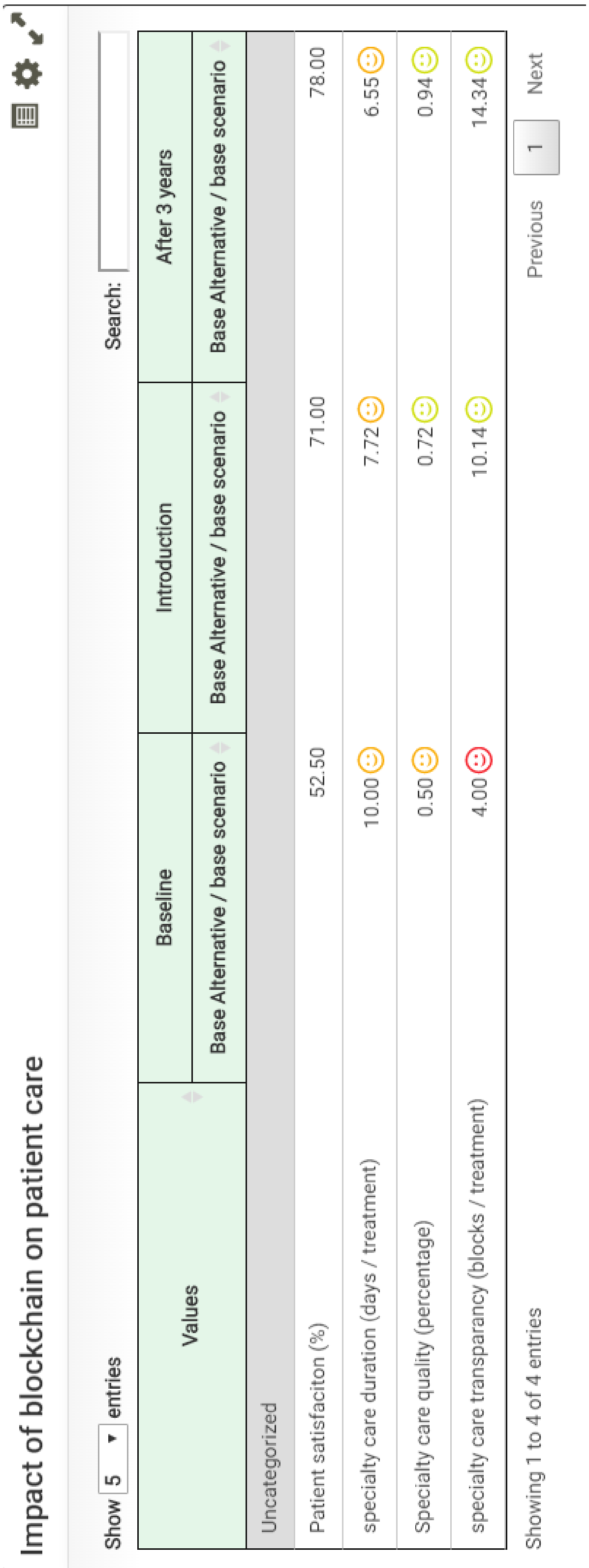


Figure 80: Cost per treatment distribution Third-party HC providers

Appendix 8: Main value indicators Dashboard presentation



Impact of blockchain on patient care

Show 5 entries

Search:

Values	Baseline	Introduction	After 3 years
	Base Alternative / base scenario	Base Alternative / base scenario	Base Alternative / base scenario
Uncategorized			
Patient satisfaciton (%)	52.50	71.00	78.00
specialty care duration (days / treatment)	10.00	7.72	6.55
Specialty care quality (percentage)	0.50	0.72	0.94
specialty care transparancy (blocks / treatment)	4.00	10.14	14.34

Showing 1 to 4 of 4 entries

Previous 1 Next

Figure 81: Main care value indicators Affiliate hospitals

Impact of blockchain on third-party patient care

Show 5 entries

Search:

Values	Baseline	Introduction	After 3 years
	Base Alternative / base scenario	Base Alternative / base scenario	Base Alternative / base scenario
Uncategorized			
Patient satisfaction [Treatment] (%)	52.50	67.50	85.00
Treatment duration (days / treatment)	3.00	2.37	1.68
Treatment quality (percentage)	0.60	0.76	0.86
treatment transparancy (blocks / treatment)	4.00	10.94	11.68

Showing 1 to 4 of 4 entries

Previous 1 Next

Figure 82: Main care value indicators Third-party HC providers