Aalto University
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Master's Programme in Industrial Engineering and Management

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Value Formulation of Digital Health Technologies – A Multiple Case Study on the Implementation of an Intelligent Patient Flow Management System

Master's Thesis

Espoo, July 29, 2019

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Työn nimi Digitaalisten terveysteknologioiden arvon muodostuminen – monitapaustutkimus älykkään potilasvirtajärjestelmän toteutuksesta		
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Tiivistelmä

Ikääntyvien väkimäärän kasvu haastaa terveydenhuoltojärjestelmiä maailmanlaajuisesti kasvattaen kysyntää uusille terveysteknologisille ratkaisuille. Tästä johtuen uusien digitaalisten terveysteknologisten investoinnit ovat jatkuvassa kasvussa. Näiden ratkaisujen arvoa on kuitenkin haastavaa mitata. Vaikka monia arviointityökaluja on kehitetty kyseisille teknologioille, puutteita ilmenee erityisesti arvonluonnin mekanismien selittämisessä.

Tässä työssä tutkittiin uudenlaista lähestymistä digitaalisten terveysteknologioiden arvon määrittämiseksi ja jäsentämiseksi. Hyödyntäen CIMO-logiikkaa (konteksti, interventio, mekanismi, ja vaikutus) monitapaustutkimuksessa työ pyrkii soveltamaan arvon muodostumisen PROVE-IT-mallia hoidon hakeutumiseen ja hoidontarpeen arviointiin suunnatulle digitaaliselle terveysteknologialle. Tutkimusongelma kiteytyy kolmeen tavoitteeseen. Ensimmäisenä tavoitteena on löytää mekanismit, jotka selittävät tarkastellun terveysteknologian toimivuutta. Toisena tavoitteena on tarkastella miten havaittuja mekanismeja ja niiden suhdetta vaikutuksiin voisi mitata. Kolmantena päätavoitteena on mallin kehittäminen käytännönläheisemmäksi ja yleistettävämmäksi.

Diplomityössä havaittiin CIMO-logiikan olevan toimiva tapa jäsentää arvon muodostumista ja sen mekanismeja. Kontekstien erovaisuudesta huolimatta mekanismien havaittiin olevan hyvin samankaltaiset eri tapaustutkimusten välillä, mikä kyseenalaistaa mallin yleistävän luonteen. Tämän vuoksi, työ antaa pohjan jatkotoimenpiteille mallin selkeyttämiseksi sekä suuntaviivoja sen operationalisoinniksi.

Tämä tutkimus täydentää arviointityökalujen kirjallisuutta tarjoamalla uuden näkökulman arvon muodostumiseen mekanismeja korostaen. Lisäksi työ tarjoaa näkemystä arvon muodostamisen osoittamisesta yritysten myynnin tukemiseksi.

Avainsanat digitaalinen terveysteknologia, vaikuttavuusperustainen terveydenhuolto, CIMO, markkinalaajeneminen

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Abstract

Aging populations set challenges to healthcare systems on a global scale, thus increasing demand for new technological solutions. As a result, investments in new digital health technologies are constantly increasing. Yet the value of these solutions is difficult to measure. Although many evaluation models for digital health interventions exist, there seems to be a lack of proper explanation of the mechanisms behind the value formulation.

This thesis explores a novel approach to evaluate and structure value formulation for digital health interventions. Utilizing a CIMO-logic (context, intervention, mechanisms, and outcomes) in a multiple case study, this study set out to apply a recently developed value formulation model, PROVE-IT, for a digital health intervention for seeking of treatment and triage purposes. The research problem was divided into three objectives. The first aim was to discover the mechanisms explaining the functionality of the examined intervention. Second, the thesis explored how the relationship between the mechanisms and outcomes can be measured. Third, the ultimate goal was to develop the existing model to be more practical and generalizable for all digital health interventions.

The CIMO-logic was perceived to be a suitable tool for evaluating digital health interventions and their dynamics. Despite differences in contexts, the mechanisms for each case were found to be very similar, thus questioning the generalizable characteristic of the model. As a result, this research suggests further actions to clarify each section in the PROVE-IT model besides presenting means to apply practical metrics to operationalize the model.

This thesis contributes to the existing evaluation literature by providing a new approach for value formulation by emphasizing the mechanism perspective. Furthermore, this study provides insight into the practical use of value formulation model to be utilized in sales narratives of health technology companies.

Keywords digital health intervention, value-based healthcare, CIMO, market expansion

Preface

Being born to a medical doctor seems to typically lead in a similar career path. Nevertheless, I had always developed my interest in all the things other than healthcare, which has been my father's specialty. Simultaneously, I never saw myself as a researcher. My mother's musical background still affect my current hobbies, whereas the heavily engineer-oriented background in our family led me to pursue studies in industrial engineering and management. However, the interest in healthcare never truly kicked in – until this point. Despite my long-term avoidance towards the topic, I somehow ended up in this situation of *researching* digital *health* technologies, which I even find incredibly fascinating. Thus, a cliché of never saying never remains true.

Aalto University has been a truly inspirational and educational environment to grow as an individual. I have had a chance to befriend numerous tremendous people who have also greatly influenced me. I have experienced many unique moments that still make me delighted, inspired, and thankful. During my studies, I have had an opportunity to truly challenge myself to learn my limits and capabilities. One of these challenges has been this thesis, which is simultaneously a perfect endpoint to my studies. Yet, learning never ends.

I want to send my gratitude to my supervisor Paul Lillrank of his first-class support with my thesis. During my time at the university, I have had a pleasure to work with such an inspirational character as you. I want to also heartily thank my advisor Henni Tenhunen to have this marvelous opportunity to study digital health technologies besides learning the ability to create a great confusion with just a single e-mail. Your self-sacrificing attitude pushed me forward when I was stuck.

Furthermore, I want to send my regards to Petteri Hirvonen and the rest of the Klinik team for this fantastic opportunity to use you as my case company. I want to also thank the entire team at the Institute of HEMA for all the support and great experiences with all of you.

Finally, I want to send my deepest thanks for all the support I have received from my family and my closest friends. Without you Mari and Heikki I would not be in this position. I could never wish better parents than you. I want to thank my big brother Tatu of being a relentless role model for your little brother. I also want to thank my little sister Tuulia of your everlasting encouragement when I have felt like hitting the wall.

Espoo, July 29, 2019

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Abbreviations

CPW	Clinical Pathway
DHI	Digital Health Intervention
ECPW	Electronic Clinical Pathway
ER	Emergency Room
ERP	Enterprise Resource Planning
PoC	Proof of Concept
PREM	Patient-Reported Experience Measures
PROM	Patient-Reported Outcome Measures
PROVE-IT	Prove Outcomes, Value, and Effectiveness of IT in Healthcare

1 Introduction

1.1 Motivation and Background

The overall global health expenditure is continuously increasing, even more rapidly than economic growth (OECD, 2015, 2018; Xu et al., 2018). When considering the explanations for this trend, it appears that investments into new health technologies are increasing with the total expenditure (Cinaroglu and Baser, 2018; Sorenson et al., 2013). Aging populations and increasing costs of dying patients set challenges to healthcare systems, thus causing demand for new technological solutions (Howdon and Rice, 2015). Nevertheless, the increasing expenditure into technological innovations is not necessarily an issue *ipso facto*, as long as the value of these innovations can be properly proven with an appropriate evaluation method. Yet, measuring value is challenging, and the empirical evidence of the benefits of digital health technologies is relatively limited (Goldzweig et al., 2009; Murray et al., 2016). Several studies have been conducted to interpret the meaning of value in healthcare. In his study (2010), Porter presents the value in healthcare as the health outcomes achieved per money spent. It is the fundamental principle behind the *value-based healthcare* (Porter, 2010). A special emphasis should be given to the nature of the presented definition; we understand the value here as a *relation,* not an absolute number. Thus, value is the difference between something received and something given in a transaction, thus something worth the effort (Lillrank, 2018). From the viewpoint of Adam Smith, the "received" part, the utility increasing the human welfare, is defined as value-in-use while the "given" part, the agreed price of the transaction, is defined as value-in-exchange (Smith, 1776). As in the case of services customers need to deal with imperfect information of the value-in-use, the services such as healthcare are sold only as value propositions (Lillrank, 2018).

Notwithstanding the existence of various definitions for the value in healthcare, measuring it on the empirical level is challenging. The implementation of new technologies encounters numerous difficulties (e.g., organizational issues), making it tedious to evaluate their true value in a specific context (Cresswell and Sheikh, 2012). This is especially the case when a formerly successfully implemented solution has failed when transferred to a different environment (Luoto et al., 2014; Shoveller et al., 2016). From the viewpoint of health technology companies, the ability to measure the value of their solutions is a vital selling point as otherwise the value proposition could remain rather vague. This is essential as the service and technology side has become the fastest-growing segment in the healthcare industry (Reddy et al., 2018). However, without appropriate tools to measure value, it is

evidently challenging to convince customers to understand the benefits of any digital health solution.

One of the health technology companies striving to prove the value of its service to its customers is Klinik Healthcare Solutions (or Klinik in short). Established in Finland and operated by physicians and healthcare professionals, the company has developed a digital service to recognize various symptoms and diseases exploiting Artificial Intelligence to manage patient flows effectively. Until now, Klinik has been able to provide some evidence of its value by creating a 14% savings within a single medical center (Tenhunen et al., 2018).

Although the company has been partially able to evaluate the value of its service in a specific case, there has been no general model to structure how the value of digital health interventions is formulated. This is especially the case when the solution is applied in new market entries where the contextual environment varies. During the year 2019, Klinik is performing four market expansions; two international and two domestic. These will be executed in Finland, Portugal, and Mexico. To communicate the value to its customers, the company seeks a way to evaluate its solution appropriately.

This thesis is part of the DiRVa (*Digitaalisten Ratkaisujen Vaikuttavuus* in Finnish) research project that aims to study how to build evidence of the value of digital healthcare solutions. The DiRVa research project is conducted at the HEMA Institute (Institute of Healthcare Engineering, Management, and Architecture) at Aalto University School of Science. The main objective of the DiRVa project has been to create a generic value formulation model for health technology companies to evaluate and communicate the value-propositions of their solutions to their customers. For this purpose, DiRVa has constructed a model called PROVE-IT (Prove Outcomes, Value, and Effectiveness of IT in healthcare) (Lillrank et al., 2019). By utilizing the constructed model in an international comparison of four market entries, the contribution of this thesis is to test and further develop a generic value formulation model for digital health interventions with an international contextual understanding.

1.2 Objectives and Research Questions

The objectives of this thesis can be approached from the perspectives of dynamics, epistemology, and ontology. Regarding the dynamics, we can perceive that existing interventions produce outcomes with some mechanisms that are not necessarily confirmed. We may exploit the existing theoretical knowledge to consider the mechanisms that are generally present among digital health interventions. With this knowledge as a foundation, we may utilize the current PROVE-IT model with the empirical evidence gathered from the

informants related to Klinik expansions to discover anecdotal evidence of the mechanisms of the Klinik intervention.

To measure the outcomes of the discovered mechanisms, we need to consider the epistemology of the PROVE-IT model. Mainly, this relates to the operationalization and quantification of the model, which provide tools to further measurements of the actual magnitudes of the effects that Klinik intervention accomplishes. In this study, we aim to explore the suitable elements to measure that can be then further utilized in later studies.

Finally, concerning the ontology, we need to verify whether the discovered mechanisms are genuinely at work. This requires a critical analysis of the PROVE-IT model regarding whether the parts of the model are distinctly defined, whether all necessary parts are included, and what improvements could be performed.

To clarify the objectives, the key terms need precise definitions. We will begin by defining a framework that serves a fundamental role in constructing the value formulation model, the CIMO-logic (Denyer et al., 2008). The idea of this logic is to recognize the *context* of a given situation where a particular *intervention* takes place, producing an *outcome* based on a *mechanism*. As an approach emerging from design science, the CIMO-logic is a convenient tool to structure and present the logic to be effortlessly evaluated, reused, and transferred (Holmström et al., 2014). As a result, the CIMO-logic is a suitable tool for evaluation purposes. This logical analysis is *de facto* based on the concept of realistic evaluation, which we will cover later in this thesis (Pawson and Tilley, 1997).

To understand the framework thoroughly, each component within the CIMO needs a proper definition. Beginning with the *context*, Denyer et al. explain it as the factors of the external and internal environment besides the nature of human actors that affect behavioral change. In comparison, the dictionary defines the context as "the circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood" (Oxford Dictionaries, 2019a). In terms of healthcare, Pfadenhauer et al. (2015) have described the context as a set of characteristics and circumstances consisting of unique factors that surround the implementation effort. In this thesis from the viewpoint of healthcare, we understand the context as a set of unique factors that comprise a surrounding environment for the implementation of an intervention.

Moving on to the aforementioned *intervention*, Denyer et al. (2008) define it as an action that influences behavior. Along with intervention, it is necessary to define *implementation* as it is closely related to the previous. Pfadenhauer et al. (2015) describe the implementation as a sequence of processes intended to get an intervention being used within an organization

or a community. For example, the intervention could be a new technological solution affecting the clinical pathway while the implementation could be defined as all the means applied to adopt the new solution into use (e.g., training, policies or managerial support).

In the context of digital healthcare, we are particularly interested in *digital health interventions* (DHIs) and their implementations. According to Mehl et al. (2018), the DHI can be encompassed as a digital or mobile technology that is used to support health system needs. According to Lillrank et al. (2019) the DHI encompasses such devices, hardware, or software that take an input (e.g., measured data), process it, and displays it as a particular output to be used in healthcare operations.

A central part of the CIMO-logic is the *mechanism*. Denyer et al. (2008) define it as a key relationship between the intervention and the outcome. The underlying mechanism is the factor that explains why the intervention produces specific outcomes. As an example, the DHI might improve the availability of health services, which eventually leads to health improvements on the patient side.

Finally, yet rather self-explanatory, the *outcome* is described as the end results that the intervention produces (Denyer et al., 2008). On a practical level, the outcome could be cost savings, more efficient treatment, or improved work satisfaction from the health personnel point of view, for example.

The CIMO configuration is a useful tool when the same DHI is implemented in varying contexts. It can be assumed that when the context changes, the mechanisms of the intervention may also change, resulting in different outcomes that might be expected. This explains why applying the same digital health intervention in a new context may fail (Luoto et al., 2014; Shoveller et al., 2016).

Our **research problem** is leaning on a fundamental question: *how to formulate the value of a digital health intervention?* Formulation encompasses the structuring and creation of value with a model that can be then tested empirically. To address the problem, we set up a few research questions to outline the focus of this study. These research questions were the following:

RQ1: *How to discover the mechanisms through which digital health interventions accomplish value?*

> **RQ1.1:** *What data should be collected regarding intervention, context, and outcomes?*
>
> **RQ1.2:** *How does the context modify implementation?*

RQ1.3: *How does the context modify mechanisms?*

RQ2: *How can the mechanism-outcomes relationship be tested?*

RQ3: *How can the PROVE-IT model be improved?*

Due to the nature of discovering mechanisms besides developing the PROVE-IT model, this thesis follows the principles of an exploratory research approach (Kothari, 2004). As we conducted this research using Klinik as our case company with multiple market entries, this thesis is categorized as a multiple case study (Eisenhardt, 1989; Eisenhardt and Graebner, 2007).

1.3 Scope

The scope of this thesis was premised on several factors. First, we only studied a digital health intervention concerning a single company, Klinik, without taking other companies or similar solutions into a further examination. Second, although patients are inherently affected by digital health interventions, in this study, the interviews were focused only on the key stakeholders implementing the Klinik's solution to the targeted medical centers. Third, the thesis examined only the digitalization of the clinical pathway, particularly the seeking of treatment and triage. Furthermore, the overall research was mainly limited to primary healthcare. Finally, due to time limitations, the thesis focused only on evaluating the expected value of Klinik's DHI in each market entry, leaving the assessment of realized value for future research.

The outlines defining the scope were based on the academic interests of the HEMA Institute in the DiRVa project and the business interests of Klinik Healthcare Solutions. Regarding the former one, this thesis contributes to the development of the PROVE-IT model from an international perspective. For Klinik, this thesis provides added value by supporting the company with a model to structure the value formulation of its digital health intervention in the locations where the company is expanding.

1.4 Structure of the Thesis

The structure of this thesis comprises seven chapters. After the introduction to the thesis, we will explore the theoretical background outlining the fundamental principles and theories that are utilized in the data analysis. In the third chapter, we will become familiar with the PROVE-IT evaluation model. In the fourth chapter, we will acquaintance ourselves with the empirical background by examining the case company and four contextual environments where the market expansions take place. Thereafter, we are taking an observation on the used methodology that has been utilized while conducting this research.

Next, our focus moves on to the findings of our empirical research. Finally, in the seventh chapter, we will discuss the implications of the results besides critically analyzing the possible recommendations regarding the development of the PROVE-IT model. Additionally, we will address the limitations of this study, along with future research directions.

2 Theoretical Background

In this section, we orientate ourselves to the themes that constitute the theoretical foundation for this thesis. We will begin by becoming acquainted with the field of operations management by introducing several key concepts that will be utilized throughout this thesis. Second, we will examine the key characteristics and factors of a clinical pathway, which is a model in healthcare management. Regarding the clinical pathway, we will give special attention to the activities that relate to the very first steps in the treatment process, thus affecting the planning of the clinical pathway. Thereafter, we will take a higher-level perspective to understand the surrounding environment where these activities are implemented, that is primary healthcare. After understanding the key context of this thesis, we will explore in more detail how it has been affected by digitalization. Finally, with the knowledge from the three previous themes, we will have a critical discussion on the evaluation of digital health interventions. We will explore a few existing evaluation models and theories that are brought together in the closing chapter in the form of the PROVE-IT model. This final part formulates the core theoretical framework for our empirical study.

2.1 Operations Management in Healthcare

To build a theoretical foundation for the concepts introduced later in this study, we will first take a brief review of the fundamental principles of operations management. We are interested in examining the things that are changed in healthcare processes with digital implementations. By applying the logics of production and services to healthcare services, the field of operations management provides not only a useful toolset but also a practical approach to seeking improvement areas within the healthcare operations. Particularly, the logics of production and services help us to open the so-called black boxes (see chapter 3.2) within healthcare processes to examine their dynamics. Next, we will enlighten ourselves with the key principles in operations management relevant to this thesis. Later the presented principles are applied in the PROVE-IT model.

The fundamental principle in operations management is the *production function*. It is an activity transforming an input into a specific output. For services, the production function causes a *state change* on material and immaterial entities. The production function is organized as *processes* consisting of individual tasks, also called as *processing*. When the task is connected to other tasks, it is called *a step*. The object of operations for which these tasks are targeted is called a *flow unit*. In healthcare, the flow unit is the patient. To measure the speed the flow unit is processed, we can denote *cycle time* to determine the time to take a flow unit through all the steps within a process. In turn, throughput time describes the total time for a flow unit to move from the very beginning to the end of the production

system. The main goal is to utilize the production function as effectively as possible. This can be measured with *productivity*, the input-output relation. Before addressing the productivity more in detail, we need to define a few fundamental principles of operations management. We will begin with *setup*, *handover*, and *inventory*. (See Hopp and Spearman, 2011; Lillrank, 2018 for references)

Setup covers all those activities that are needed to be performed before processing the flow unit (Hopp and Spearman, 2011; Lillrank, 2018). This can mean either adjustment of tools, ordering of materials, or deciding on the routing of flow units. Consequently, the time used for these activities is called a setup time. As can be realized, if all the flow units are similar, the process can be standardized and setup times minimized. However, as in the case of healthcare services, the flow units, the patients, may differ significantly from each other, resulting in challenges in standardizing the process.

Moving on to the handover, it is the activity of handling the flow unit from one processing unit to another. Depending on the process, the flow unit either continues directly to the next step in the production or to an inventory. Generally, handovers can be initiated by two methods: push or pull. In the push type, the processing units push the flow units once processed to the next step according to the master schedule. In turn, in the pull type, the flow unit is not handed to the next step before it is requested. Similar to setups, handovers can also be standardized. In services, handovers require information about flow units to process them appropriately. Failures to coordinate or manage this information may lead to delays, dissatisfaction among patients, and even to treatment failures. (Lillrank, 2018)

A critical part of the operations management is *inventories*. Inventories occur when flow units are not processed immediately after the handover. In services, this appears as waiting time for patients. Although inventories are occasionally useful as buffers for addressing demand, in an ideal case, the patient would be processed by minimizing waiting times. (Lillrank, 2018)

To understand how these individual steps are interdependent, Figure 1 below illustrates the anatomy of an individual step, a single black box in the process-step perspective (Lillrank et al., 2019). Processing is the core activity causing a state change. It is a result of a cognitive setup, managerial act, that prepares and plans the activity performed on the flow unit (Lillrank, 2018). Its counterpart is monitoring ensuring everything is performed accordingly. The step is supported by a physical preparation of assembling required resources to perform the processing whereas replenishment is responsible for dissembling the resources to be ready to repeat the processing (Lillrank et al., 2019).

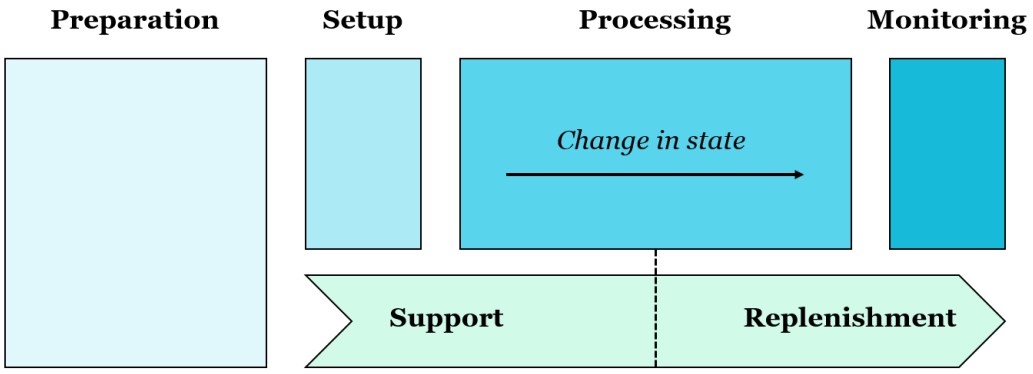

Figure 1 - Process-Step Perspective (Lillrank et al., 2019)

As described above, the production function combines individual processes consisting of steps. A closely related term *value chain* considers only those activities that are critical for the final purpose, thus the sum of processing activities. The rest is considered to be preparation, setup, monitoring or waste (*Muda* in Japanese literature). In the context of healthcare, the value chain describes the clinical interventions while all the rest is management. Thus, management is a tool to improve cycle time by, for instance, decreasing setup times. (Lillrank, 2018)

The metrics to evaluate production function are productivity and quality. Productivity describes the relation of received output (either measured in monetary value or with qualitative measures) to the input of used resources (labor and capital). Simply put, by increasing productivity, we can receive more with less. Another essential measure is quality. According to Lillrank (2015), it can be denoted as two different relations: small q and big Q. Small q is technical quality explaining how *ex ante* specification matches with the accomplished output. In turn, big Q is the relation with the customer expectation and experience, thus accounting to customer satisfaction.

2.2 Playing Field

In this chapter, we investigate the healthcare-related conceptual playing field of this thesis to build insight into our case study. First, we will briefly examine the key characteristics of primary healthcare and primary care. Thereafter, we explore in more detail the management framework for organizing treatment, the clinical pathway. Finally, we will focus our lenses on the two processes relevant to our cases that also form the clinical pathway; these are the seeking of treatment and triage.

2.2.1 Primary Care and Primary Healthcare

According to World Health Organization (1978), primary healthcare is an essential service made universally accessible to all individuals within the communities at the cost the

communities can afford. Furthermore, WHO defines primary healthcare as an approach to address the main health issues within communities besides supporting healthy environments and lifestyles.

While primary healthcare, also known as community care, is a strategic approach for supporting health and healthy lifestyle in a wide-angle, primary care is considered more as a critical part of the healthcare system. In the report of WHO, Atun (2004) comprehends primary care as an integral part of the health system addressing the most common problems in the communities with preventive, curative, and rehabilitative services. Primary care is typically the first contact for patients in the healthcare system (Atun, 2004). Relationally, primary care is thus the subset of primary healthcare.

2.2.2 Clinical Pathway

A clinical pathway, also known as a care pathway, (CPW) is a central concept in the research area of healthcare process management. Yet widely accepted concept internationally, the clinical pathway has been defined in numerous ways leading to confusion (Leuven et al., 2006). To build cohesion by recognizing its key characteristics, Leuven et al. (2006) have defined the clinical pathway as a method stating the goals and key elements of care for patient-care management for a well-defined period of time. A CPW is an operational tool to facilitate the care for a group of patients by coordinating the resources and activities (Hu et al., 2009; Leuven et al., 2006). In turn, European Pathway Association (2019) defines it as a "complex intervention to achieve common decision making and organization of care processes for a specific group of patients for a defined time frame“. Figure 2 illustrates an example of CPW below (Vissers and Elkhuizen, 2019).

Key Milestone (steps)	Day 1	Day 2	Day 3	...	Day n
1. Placed on pathway					
2. Booking of surgery					
3. Blood tests, x-rays					
4. Assessed by orthopedist					
5. Prepared for surgery					
…					

Day 1	Measure	AM	PM
Investigations	Pathology within expected range	✓	
Medications	Given as ordered	✓	
Observations	Within normal limits	✓	
Hygiene	Fluid balance chart completed		
Nutrition	No nausea or vomiting		
…			

Figure 2 - Illustration of Clinical Pathway (Vissers and Elkhuizen, 2019)

Lawal et al. (2016) provide an operational definition for clinical pathways based on four criteria. According to their research(Lawal et al., 2016), Lawal et al. argue that an intervention can be seen as a CPW when (1) it is a structured plan of multidisciplinary care, (2) is used to translate guidelines into local structures, (3) gives a detailed overview of steps, protocols and actions of a treatment, and (4) aims to standardize the care process.

Now, building the definition of a CPW around the two previous definitions, we understand it here as an operational guideline to manage and coordinate the treatment of patients by utilizing the resources as effectively as possible. In that sense, a CPW is a production plan to coordinate activities to ensure cost-efficient treatment. The realization of the CPW is called *patient journey*, an aggregate of events the patient went through during the treatment (Trebble et al., 2010). This is presented in Figure 3 below (Vissers and Elkhuizen, 2019).

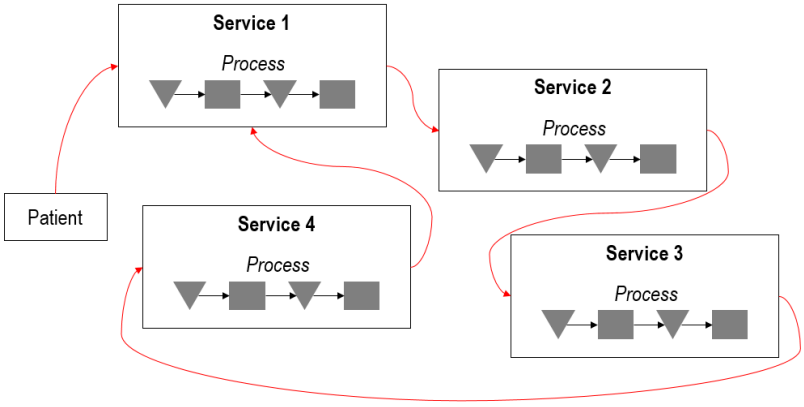

Figure 3 – Illustration of Patient Journey (Vissers and Elkhuizen, 2019)

From the operational point of view, clinical pathways are crucial for also improving the healthcare quality (Lawal et al., 2016). CPWs aim to improve the overall quality of care by reducing risks, increasing patient satisfaction, and improving the efficient use of resources (Leuven et al., 2006). As an analogy, the concept of the clinical pathway is somewhat similar to enterprise resource planning (ERP) systems (Umble et al., 2003). Both CPWs and ERPs are tools to manage and coordinate the operations within an organization to achieve given goals while monitoring that the overall quality stays on accepted levels. In analogy, the CPW can be considered to be positioned as setup in the step-process perspective (Figure 1).

2.2.3 Seeking of Treatment and Triage

We will now focus our examination on the very first steps within the treatment process that affect the formation of a CPW. These first steps comprise seeking of treatment and triage. These two steps are the core environment for the digital health intervention regarding our case study.

Seeking of treatment can be described as a patient's first touchpoint to a treatment process. In all its simplicity, in this stage, the patient seeks treatment. If the patient is unable or unwilling to seek medical attention, any other person taking care of the patient might perform this action as well. Generally, a patient may seek treatment by calling or physically visiting a health center. Additionally, online-based booking systems are increasing.

Triage implies a decision-making process that aims to identify and organize patients based on their need for urgent treatment (Kuriyama et al., 2017). Considering other definitions for triage, we can once again refer to the dictionary where the concept is defined as the assessment of degrees of urgency to medical conditions to decide the order of treatment for a large number of patients (Oxford Dictionaries, 2019b). As we can perceive, triage is the process that affects the formation of a CPW.

In this thesis, we will handle these together as one entity as they are closely interrelated. To clarify the area of our interest, Figure 4 presents how the seeking of treatment and triage are related to the entire CPW:

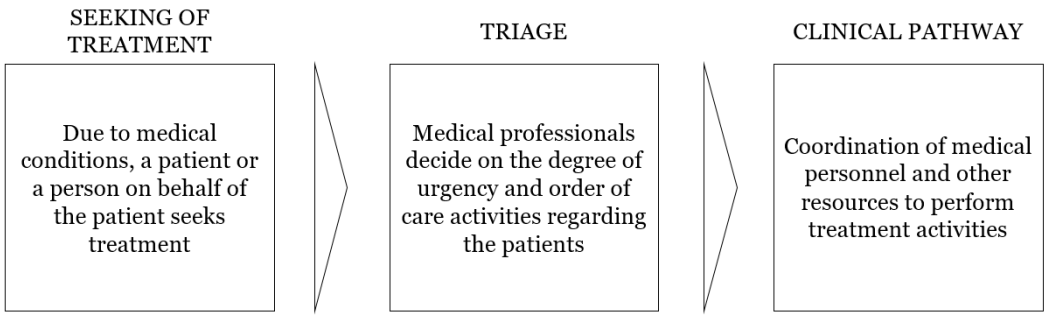

Figure 4 - Formulation of the Clinical Pathway

To conclude, both the seeking of treatment and triage act as channels to enable a patient to enter a care process, share necessary information to the medical personnel, and utilize this information to provide suitable actions for treatment.

2.3 Healthcare Digitalization

To specifically analyze digital health interventions, in this section we will explore the current megatrend of healthcare digitalization in more detail. First, we are trying to understand some of the general effects digitalization has on healthcare. Second, we take the clinical pathway into consideration and examine the influence digitalization has on it. Thereafter, we turn to the digitalization of seeking of treatment and triage by discussing the intelligent patient flow management system. Finally, we observe the ways machine learning and, primarily, Artificial Intelligence has been utilized in health interventions.

2.3.1 How Digitalization Affects Healthcare?

After the emergence of digital technologies influenced by the development of computers and the Internet, it is no wonder that digital innovations were also targeted on healthcare solutions. As healthcare remains an essential yet costly part of wellbeing, it is argued that digital solutions could reduce the costs while increasing the overall quality of healthcare (Agarwal et al., 2010). Furthermore, digitalization has been seen as an enabler for improving the productivity of healthcare systems by providing tools to address time and location limitations (Agha, 2014; Lillrank and Venesmaa, 2010).

Currently, digital health is a particularly crucial topic as there is a great need for solutions to combat increasing healthcare costs without questioning the care quality (van Leersum et al., 2019). Although some studies (Carr et al., 2014; Kvedar et al., 2014) have yielded promising results in improving the cost-efficiency of healthcare with digital solutions, it has been noted that many digital health solutions are not cost-effective (Agha, 2014).

To truly evaluate the effects of digitalization on healthcare, we can examine these digital solutions from two angles, which are also the major research topics regarding this area: *adoption* and *impact* of health technologies (Agarwal et al., 2010). According to Agarwal et al. (2010), adoption can be observed from two perspectives: the level of adoption and the adoption barriers. The former consists of scale, scope, and pervasiveness concerning the adoption of a digital solution while the barriers include factors affecting the implementation of the solution (e.g., financial, functional, or legislative barriers).

Besides adoption, also the impact of health technologies can be measured. Similarly to adoption, Agarwal et al. (2010) divide the research on the impact on two distinct factors: quality and efficiency. The quality includes measures such as safety, satisfaction, and medical errors, while efficiency can be seen from the viewpoint of productivity, cost-efficiency, and added value. From the viewpoint of CIMO-logic, the adoption corresponds to the implementation of intervention while impact coincides with outcomes.

2.3.2 Digitalization of the Clinical Pathway

One of the segments in healthcare affected by digitalization is the clinical pathway. Digitalization of the clinical pathway is occasionally referred to as electronic clinical pathway (ECPW). As CPWs are used to manage healthcare operations, digital tools can be applied to find optimal solutions for these pathways. As an example, Funkner et al. (2018) present methods for discovering pathways in advance with clustering and data mining algorithms.

Practical applications provide evidence of the benefits of digital solutions embedded in clinical pathways. In their study, Sicotte et al. (2016) present the implementation of an electronic medical record designed to act as a clinical pathway information system to improve patients' waiting times in cancer treatment. According to this study (2016), a significant reduction was perceived in the waiting times.

In addition to the research conducted by Sicotte et al. (2016), Hu et al. (2009) also suggest benefits of ECPWs in the digitalized hospital. Similarly to Sicotte et al., Hu et al. argue that ECPWs could improve the efficiency and quality of patient care. Furthermore, the benefits for medical personnel are presented as ECPWs provide a digital solution for sharing medical information that is more complicated on paper-based versions (Hu et al., 2009).

Another study examined the effects of ECPWs by piloting and evaluating the benefits of the electronic integrated clinical pathway at a Mother and Baby Unit in the United Kingdom (Hayward-Rowse and Whittle, 2006). According to Hayward-Rowse and Whittle (2006), the implemented ECPW enhanced the patient experience. Regardless of a low number of participants in the study, the results highlight the benefits of ECPWs similar to previous studies.

As digitalization supports the optimization of CPWs, it is possible to create more standardized pathways. The more standardized the CPW, the more efficient will be the patient journey. Exploiting the previously presented process-step logic (Figure 1), we can present four various process types: standard, formatted, routine, and no-routine process (Lillrank, 2018). The less complicated the setup, the CPW, the more efficient and straightforward will the process, and the patient journey be. As a result, it is possible to achieve personalized care solutions with mass production efficiency. Figure 5 presents the idea below.

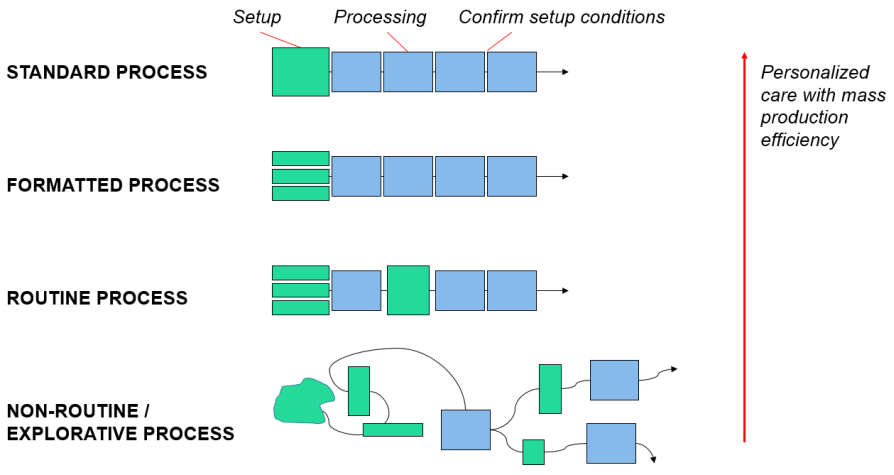

Figure 5 - Process Types by Setup-Processing Relation (Lillrank, 2018)

2.3.3 Intelligent Patient Flow Management System

Considering the digitalization of clinical pathways, we are particularly interested in the digitalization of the seeking of treatment and triage. A concept generated for this purpose is an intelligent patient flow management system (IPFM) aiming to support patients to avoid unnecessary calls and visits to their medical centers besides enhancing the efficient use of professional resources for the actual patient care (Tenhunen et al., 2018). IPFM can be described as a digital health intervention affecting the seeking of treatment as well as triage (Tenhunen et al., 2018).

According to Tenhunen et al. (2018), the implementation IPFM at a Finnish primary healthcare center resulted in significant cost-savings, namely in a 14% decrease of patient's average total service cost. They suggested that savings occurred due to utilizing less costly service contacts in the management of patients' clinical pathways. Thereby, the IPFM provided an effective digital solution for managing clinical pathways.

It is noteworthy to mention the use of machine learning in the implementation of the IPFM system. Tenhunen et al. (2018) describe that the implemented system in the study exploited Artificial Intelligence and machine learning algorithms to manage patients by performing medical diagnoses with preliminary information gathered from them. As machine learning is increasingly used in the digitalization of healthcare solutions, we will briefly take a general examination on this phenomenon before moving on to evaluation theories.

2.3.4 Machine Learning and Artificial Intelligence in Health Technologies

Currently, a trending topic, machine learning has been widely utilized in healthcare operations. One of the applications has been in genetics and molecular medicine, where machine learning algorithms to discover complex protein interactions (Hamet and Tremblay, 2017).

A more interesting application from the viewpoint of this thesis is the utilization of machine learning and related concepts in healthcare systems to optimize the coordination of actions within the CPW (Funkner, 2018; Hamet and Tremblay, 2017; Liu et al., 2015). Especially with Artificial Intelligence diagnoses can be more precise due to enhanced abilities to analyze collected patient data (Jiang et al., 2017).

Another factor implying the increasing interest in AI among digital health interventions appears in funding. According to the analysis by Zweig et al. (2016), the funding for digital health technology companies applying AI or machine learning has been increasing in a similar fashion to that of digital health funding in general. Interestingly, this study (2016) presented that funding for AI health technology companies has been distributed unevenly

in a way that solutions applying AI directly in patient care are receiving less funding. A possible reason for this could be funders' being more cautious for DHIs that need proper evidence of their effectiveness (Zweig et al., 2016).

2.4 Evaluation of Digital Health Interventions

There appear to be numerous benefits that digitalization provides for many of the current medical solutions. Nevertheless, not all digital health interventions succeed. Even successful DHIs can fail in a different contextual setting (Luoto et al., 2014; Shoveller et al., 2016). It is thus a multidimensional and complex undertaking to capture the value of various health technologies and their applications (Murray et al., 2016). This indicates the need for proper evaluation methods for DHIs (Murray et al., 2016).

In this section, we begin by exploring the state-of-the-art of the general evaluation methods for digital technologies. Thereafter, we specify our perspective to healthcare operations management and examine the logic of digital healthcare operations. Finally, with the theories mentioned above we will construct the PROVE-IT value formulation model and utilize and develop it in our domestic and international case studies.

2.4.1 State-of-the-Art of Evaluation of Digital Health Interventions

An obvious starting point to discuss evaluation models of digital health interventions is to examine the evaluation models for information systems from the general perspective. One such a model evaluating the success of an information system was developed by DeLeone and McLean (1992). Based on a particularly comprehensive literature review, DeLeone and McLean argue that the success of information systems relies on six interdependent categories: system quality, information quality, use, user satisfaction, individual impact and organizational impact (DeLeone and McLean, 1992). Figure 6 presents the model below.

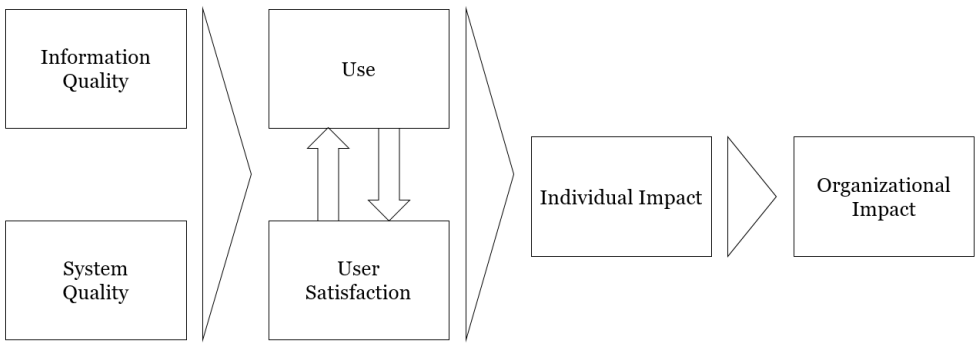

Figure 6 - Evaluation Model for Information System (DeLeone and McLean, 1992)

A brief clarification of these six categories and their interdependencies follows. System quality measures the quality of information processing system while the information quality

refers to the quality of the information system outputs. Furthermore, use is defined as the recipient's consumption of the information output while user satisfaction measures the recipient's response to the use of the output. Finally, the individual impact can be understood as the influence of information on the recipient's behavior while the system impact is the respective influence on organizational performance. According to this model, system quality and information quality affect independently as well as jointly both use and user satisfaction. Additionally, the amount of use affects positively or negatively the degree of user satisfaction and vice versa. In turn, use and user satisfaction have their influence on individual impact, which lastly has its effect on organizational impact. (DeLeone and McLean, 1992)

While DeLeone and McLean's model acts as a general evaluating framework for information systems, it is also a foundation for other evaluation models directed for the area of healthcare. One such example is a HOT-fit framework developed by Yusof et al. (2008). The HOT-fit framework namely combines human, organization, and technology fit together. Beginning with the technological factors, there are two primary components in this category: information, and service quality. These evaluate such measures as ease of use, availability, and usability. Next, we have human factors consisting of system use and user satisfaction. The system use is concerned with the information outputs as well as the user itself, considering the level of use, training, knowledge, and acceptability, to name a few examples. Finally, the organizational factors describe the nature of a healthcare institution from the viewpoint of structure and environment. The structure consists of factors such as culture, hierarchy, and communication. In turn, the environmental factors can be examined, for instance, from the perspective of financing source, government, population, or competition. Figure 7 presents the HOT-fit model.

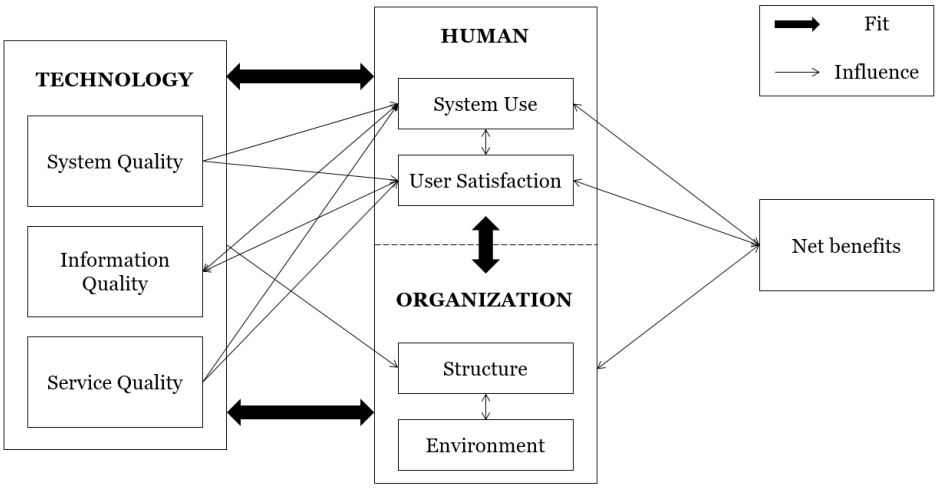

Figure 7 - HOT-fit Model (Yusof et al., 2008)

By understanding the factors of the model, we will now go through their interdependent relationships. The technological factors affect jointly and individually human factors. Additionally, organizational factors influence system use. Similarly to DeLeone and McLean's model, system use and user satisfaction affect each other interdependently in a negative or positive sense. Also, organizational factors can influence each other. Finally, both human and organizational factors are direct antecedents of net benefits, while these also have subsequently an impact on both human and organizational factors. In general, Yusof et al. (Yusof et al., 2008) argue that their framework can be potentially useful in any health information system evaluation.

The two previously presented frameworks provide useful but rather generic evaluation models (DeLeone and McLean, 1992; Yusof et al., 2008). Both models provide several examples of suitable measures but do not strictly specify them. As a contrast, some researchers have taken a more specific angle to the evaluation by examining a single attribute in the DHI. To give an example, many studies have evaluated the cost-effectiveness of digital health interventions in various instances such as prevention of depression and anxiety or treatment for drug and alcohol dependence (Murphy et al., 2016; Paganini et al., 2018; Weisel et al., 2018).

As we can deduce, there are evaluation models that aim to take a very general perspective on the value of digital health interventions. Diversely, the other evaluation models take a very specific angle, thus addressing value from the viewpoint of a single attribute in the DHI. Nonetheless, there is an evident lack of frameworks providing not only an all-encompassing evaluation but also a practical perspective for decision-makers and solution providers to measure the value of any DHI not restricted to a specific medical condition. One such attempt is a model generated by WHO for evaluating DHIs (World Health Organization, 2016).

The primary purpose of the WHO evaluation model is to give practical guidelines to evaluate the outcomes of a digital health intervention. WHO defines evaluation as a systematic and objective assessment of either an ongoing or already implemented intervention to determine the realization of objectives, effectiveness, efficiency, impact, and sustainability. Furthermore, in WHO's model, the evaluation is utilized to measure either the interaction of users or a health system with the DHI, or changes caused by the DHI. Additionally, WHO emphasizes the link between the monitoring activities with those of evaluation. If monitoring is inadequate, the evaluation of the impact is not reliable. As a result, it is impossible to deduce whether the not desired outcomes were not achieved due to the intervention or the implementation. Therefore, monitoring activities are essential for a

successful evaluation. To clarify the difference, WHO defines evaluation to measure how outcomes affect the users of the DHI. On the contrary, monitoring measures whether the intervention functions appropriately. (World Health Organization, 2016)

In general, the WHO evaluation model is a framework providing guidelines for evaluation based on the various factors. We will briefly go through these steps with the illustrative figures supporting the explanation. The model links the stage of maturity of the intervention to the stage of evaluation and claims to understand the DHI more thoroughly. Table 1 illustrates this idea.

Table 1 - Linking Stages of Maturity with Evaluation Methods and Claims (World Health Organization, 2016)

	Stage of maturity	Stage of evaluation	Claim
Early	**Pre-prototype:** hypothesis building, needs/context assessment, testing of usability, feasibility, and technical stability	**Feasibility:** assess whether the DHI works as indented in a given context	**Technology:** prototypes are functional and usable. Feasibility testing demonstrates end-user acceptance and expected data integrity and validity
	Prototype: creating and testing user-focused designs, functionality, technical stability, and usability	**Usability:** assess whether the DHI can be used as intended by users	**Intervention:** implementation protocols are utilized as intended by users **Technology:** technology withstands testing under optimal field circumstances
	Pilot: testing whether the DHI produces desired outcome under controlled circumstances	**Efficacy:** assess whether the DHI can achieve the intended results in a controlled setting	**Health:** health improvements demonstrated on a small scale, under optimal circumstances, warranting further testing
Mid	**Demonstration:** DHI is not anymore under controlled circumstances but yet limited in terms of population/geography. Costs and requirements are considered	**Effectiveness:** assess whether DHI can achieve the intended results in a non-controlled setting	**Health services delivery:** at moderate-scale implementation in a non-research setting is determined to be: feasible, high quality, cost-effective, improving the effectiveness of giving positive change in health outcomes
Advanced	**Scale-up:** approaches are ready to be optimized and scaled up across multiple subnational, national, or population levels	**Implementation science:** assess the uptake, integration and sustainability of evidence-based DHIs for a given context, including policies and practices	**Technology:** technology is functional and being effectively implemented at scale. Support systems ensure availability **Health services delivery:** at large-scale implementation through integrated service delivery is determined to be: feasible, high quality, cost-effective, improving the effectiveness of giving positive change in health outcomes
	Integrated and sustained programme: efforts concentrate on determining the needed components of an environment that support impact of the DHI at a large scale. DHI has been integrated into a broader health system		

The stage of maturity is emphasized as it directs evaluation to the right path besides clarifying the expectations. Based on the stage of maturity, the model provides the following steps to decide on suitable evaluation activities. First, the evaluation type needs to be decided; that is whether the evaluation is formative or summative. Formative evaluations focus on the development and design of effective intervention strategies and are typically conducted before or during the implementation phase. Formative evaluations divide into three types. The first type is needs assessment, which is conducted before the start of the DHI. The second type concerns process evaluations that might be conducted at specific points during the lifecycle of the DHI to evaluate its output to its users. The third type is implementation monitoring, which is mainly a continuous act of data collection to measure the fidelity of the DHI. (World Health Organization, 2016)

In turn, summative evaluations concentrate on the extent to which desired outcomes were achieved. These type of evaluations are conducted at the end of an intervention. These evaluations mostly regard the performance, outcome (e.g., knowledge or behavior change),

or impact (e.g., health outcomes such as mortality or disease risk) evaluation. Further, economic evaluation or other analysis leading to new research questions are also part of summative evaluations. (World Health Organization, 2016)

The next step is to define a suitable study interference for the intervention. WHO has recognized five different interference categories, which are the following: descriptive, exploratory, analytic, explanatory, and predictive. According to WHO (2016), most of the evaluations concern analytic or explanatory interferences.

Finally, when the study interference has been chosen, the model links corresponding alternatives for study designs and respective evaluation methods to conduct the evaluation. WHO suggests that a mix of various methods might be an appropriate choice. Table 2 illustrates these activities for formative evaluations, and below that Table 3 presents the same for summative evaluations.

Table 2 - Formative Evaluation Activities[1] (World Health Organization, 2016)

Formative				
		Needs assessment	**Process evaluation**	**Implementation monitoring**
Stage of evaluation	**Feasibility/usability**	**Descriptive:** Landscape analysis, literature review **Qualitative:** Participant observation, FGDs, IDIs, case studies **Quantitative:** Mobile phone ownership and use, user profile survey **Mixed methods:** Combination of quantitative and qualitative data	**Qualitative:** FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data	**Qualitative:** Participant observation, FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data
	Efficacy	**Descriptive:** Contextual adaptation	**Qualitative:** FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data	**Qualitative:** Participant observation, FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data
	Effectiveness	**Descriptive:** Contextual adaptation	**Qualitative:** FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data	**Qualitative:** Participant observation, FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data
	Implementation science	**Descriptive:** Contextual adaptation	**Qualitative:** FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data	**Qualitative:** Participant observation, FGDs, IDIs **Quantitative:** System-generated monitoring data **Mixed methods:** Combination of quantitative and qualitative data

[1] Focus Discussion Group (FGD), In-Depth Interview (IDI)

Table 3 - Summative Evaluation Activities[2] (World Health Organization, 2016)

Summative					
		Outcome evaluation	**Impact evaluation**	**Economic evaluation**	**Financial evaluation**
Stage of evaluation	**Feasibility/usability**	**Quantitative:** User satisfaction, service delivery/utilization **Qualitative:** IDIs, FGDs **Mixed methods:** Combination of quantitative and qualitative data	N/A	N/A	Affordability, financial evaluation
	Efficacy	**Quantitative:** User satisfaction, cross-sectional coverage surveys, service delivery/utilization **Qualitative:** IDIs, FGDs **Mixed methods:** Combination of quantitative and qualitative data	**Quantitative:** Disease surveillance, cross-sectional coverage or longitudinal surveys, verbal autopsies, death audits **Qualitative:** IDIs, FGDs **Mixed methods:** Convergence of quantitative and qualitative data	If comparator is available: CEA, CBA, CUA, CMA	Affordability, financial evaluation
	Effectiveness	**Quantitative:** User satisfaction, cross-sectional coverage surveys, service delivery/utilization **Qualitative:** IDIs, FGDs **Mixed methods:** Combination of quantitative and qualitative data	**Quantitative:** Disease surveillance, cross-sectional coverage or longitudinal surveys, verbal autopsies, death audits **Qualitative:** IDIs, FGDs **Mixed methods:** Combination of quantitative and qualitative data and qualitative data	If comparator is available: CEA, CBA, CUA, CMA	Affordability, financial evaluation
	Implementation science	**Quantitative:** User satisfaction, repeated cross-sectional coverage surveys, service delivery/utilization **Qualitative:** IDIs, FGDs **Mixed methods:** Combination of quantitative and qualitative data	**Quantitative:** Cross-sectional coverage or longitudinal surveys, verbal autopsies, death audits **Qualitative:** IDIs, FGDs **Mixed methods:** Combination of quantitative and qualitative data and qualitative data	If comparator is available: CEA, CBA, CUA, CMA	Affordability, financial evaluation, OneHealth modelling

As we can perceive from both formative and summative evaluation activities, there are plenty of similar activity suggestions for various stages. Although the activity recommendations are directional and useful starting points for evaluation, more precision is needed.

The final evaluation model we will be addressing is the NASSS framework standing for nonadoption, abandonment, scale-up, spread, and sustainability (Greenhalgh et al., 2017). The four potential uses for NASSS are to inform the design of new technology, help to detect solutions with limited chances to achieve large-scale, sustained adoption, support planning of the implementation, and provide tools to learn from program failures.

The framework consists of six main domains with key questions in each as illustrated in Figure 8. The domains are the condition, the technology, the value proposition, the adopter system, the organization, and the broader context. Additionally, there is a seventh domain covering the interactions and adaptations over time. Each of the domains can be classified

[2] Cost-effectiveness analysis (CEA), Cost-utility analysis (CUA), Cost-benefit analysis (CBA), Cost-consequence analysis (CCA), Cost-minimization analysis (CMA)

as simple (straightforward or predictable), complicated (multiple interacting elements), or complex (dynamic or unpredictable). The intention of the entire framework is to direct discussions to the correct paths besides supporting idea generation by undergoing through each question within the domains. (Greenhalgh et al., 2017)

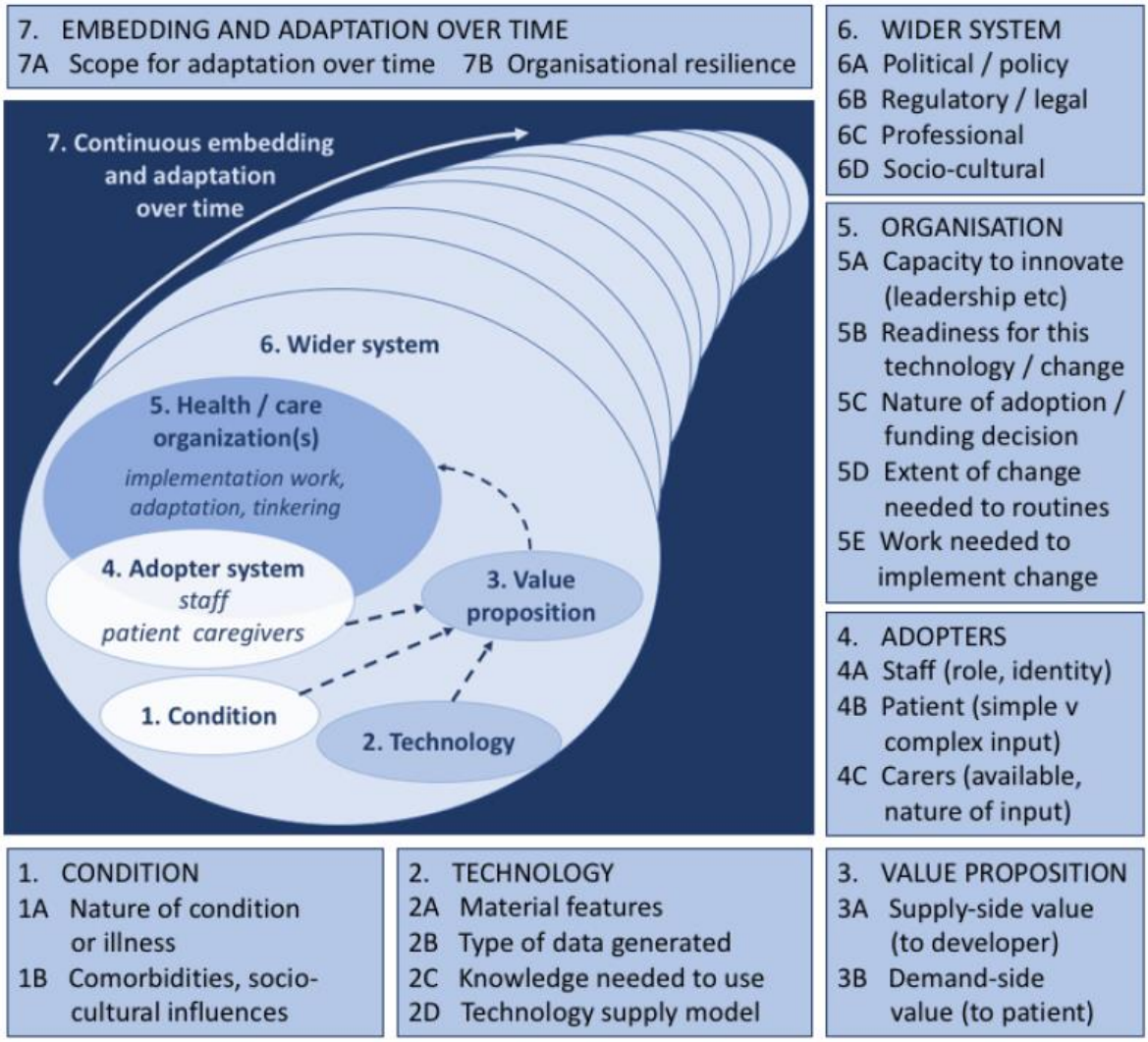

Figure 8 - NASSS Framework (Greenhalgh et al., 2017)

2.4.2 What Is Missing from the State-of-the-Art?

As a conclusion, existing evaluation models either provide generic measures, or conversely, very specific metrics to evaluate DHIs. As we are interested in a generic evaluation model that suits for various DHIs yet providing practical guidelines for decision-makers and digital solution providers to build evidence of the value of DHIs, we need a model operating in-between, a basis for mid-range theories. The inclusion of the stage of maturity besides various evaluation activities are clear benefits of the WHO model (2016). However, the entire model is very outcome-emphasized and does not address the dynamics of the evaluated DHI. In turn, the NASSS model by Greenhalgh et al. (2017) supports the

comprehensive analysis of adoption and continuous use of DHIs but does not address mechanisms of these technologies either.

To address these problems, the CIMO-logic (Denyer et al., 2008) was perceived to be a useful foundation for a mid-range evaluation model. The objective of the DiRVa project was to construct a model that supports structuring the value formulation of any DHI (Lillrank et al., 2019). By emphasizing the understanding of mechanisms behind the value formulation, health technology companies could communicate the value of their solutions more clearly. We will next construct this model to test it within our empirical cases.

3 Building the Model – The Conceptual Tools

As described previously, the PROVE-IT model is predominantly based on the CIMO-logic (Denyer et al., 2008). We will next explore this logic more thoroughly besides the Black Box concept to ultimately construct the model which will be then later utilized.

3.1 CIMO – The Logic of Evaluating Interventions

Now, that we have familiarized ourselves with the existing theories, perspectives and models for the evaluation of digital health interventions, we will explore in more detail how the presented topics are used as building blocks for a value formulation model, PROVE-IT, developed at the HEMA Institute (Lillrank et al., 2019). As described earlier, the existing evaluation models have their limitations. Either the current models take a very general perspective on evaluation without providing practical guidelines for decision-makers and solution providers to evaluate the value of a DHI under observation, or the other models take a particular perspective on a single metric evaluating the DHI. Thereby, there is an apparent demand for a more nuanced evaluation framework providing not only clarity and focus but also a general perspective on evaluation.

To clarify the primary objective of the PROVE-IT model, it is worth emphasizing the time perspective this model takes. While evaluation is generally seen as something that has already occurred, the time perspective of the PROVE-IT model is more in the future. More specifically, PROVE-IT model aims to provide practical support for solution providers and decision-makers to formulate value of a DHI.

To understand how current evaluation models, especially the WHO model (World Health Organization, 2016) are utilized in the PROVE-IT model, it is essential to investigate the fundamental theoretical idea framing the foundation for this model. This is the CIMO-configuration stemming from the concept of *realistic evaluation* (Pawson and Tilley, 1997). In their book, Pawson and Tilley (1997) present the need for an evaluation logic that besides explaining simply the outcomes that interventions create also explain the reason, *the mechanisms*, why interventions cause particular outcomes. Taking a critical observation of various evaluation logics, the authors present their logic with the following equation:

$$context\ (C) + mechanisms\ (M) = \ outcomes\ (O) \qquad (1)$$

The equation (1) presents that causal outcomes follow from certain mechanisms that act in a given context (Pawson and Tilley, 1997). However, not all mechanisms are necessarily causal. Pawson and Tilley (1997) derive their logic from natural science, where generative logic such as presented in equation 1 is typical. On the contrary, in social sciences, the usual research logic has been based on experimental and control groups. However, the evaluation

in social sciences tends to fail to identify the reasoning why interventions cause specific outcomes in different contexts. Pawson and Tilley (1997) underline the problematic successionist causation logic in social sciences of explaining the outcomes. Instead of concentrating on the underlying mechanisms behind social interventions, many of the social scientists maintain their focus on various variables correlating with the intervention under observation (e.g., education affects crime rates). In other words, a great deal of research among social sciences is *method driven*, overlooking the explanatory factors between the intervention and the outcome. (Pawson and Tilley, 1997)

As we can perceive, the CMO evaluation logic by Pawson and Tilley (1997) establishes the foundation CIMO-logic described earlier in chapter 1 (Denyer et al., 2008). The two logics are mainly the same disregarding the added I (intervention and implementation), which is mostly for the clarification purposes emphasizing the digital health interventions. Figure 9 illustrates the CIMO-logic below:

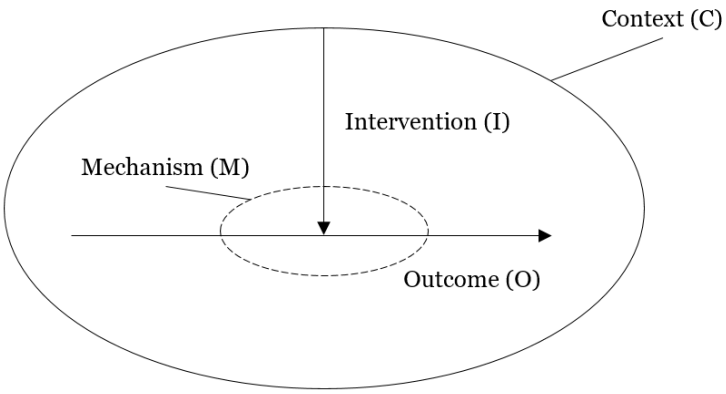

Figure 9 - CIMO Configuration (Denyer et al., 2008)

The CIMO configuration forms the backbone of the PROVE-IT model (Denyer et al., 2008; Pawson and Tilley, 1997). In other words, the PROVE-IT model can be perceived as an elaborated CIMO-configuration tailored to the needs of digital health interventions. The model can be seen as a value formulation model that can be utilized both with forward or backward orientation. The model has been designed for digital health technology companies to prove the value of their DHIs to their customers by utilizing PROVE-IT to understand the expected mechanisms and outcomes. Despite this forward or predictive nature, the model is meant to be used historically to explain why a DHI accomplished specific results (Lillrank et al., 2019).

To advance to the construction of the PROVE-IT model itself, we will begin by discussing the so-called Black Box concept stemming from the system theory as it constitutes the logic

for using the PROVE-IT framework. Thereafter, we will study the CIMO-configuration of the PROVE-IT model in more detail.

3.2 Black Boxes and Input-Output Model

The black boxes are entities with given input and output. The Black Box-logic divides a system into individual entities which together form a hierarchical system. Only inputs and outputs can be observed unless we look inside the box. These boxes can form larger systems within each other, as illustrated in Figure 10:

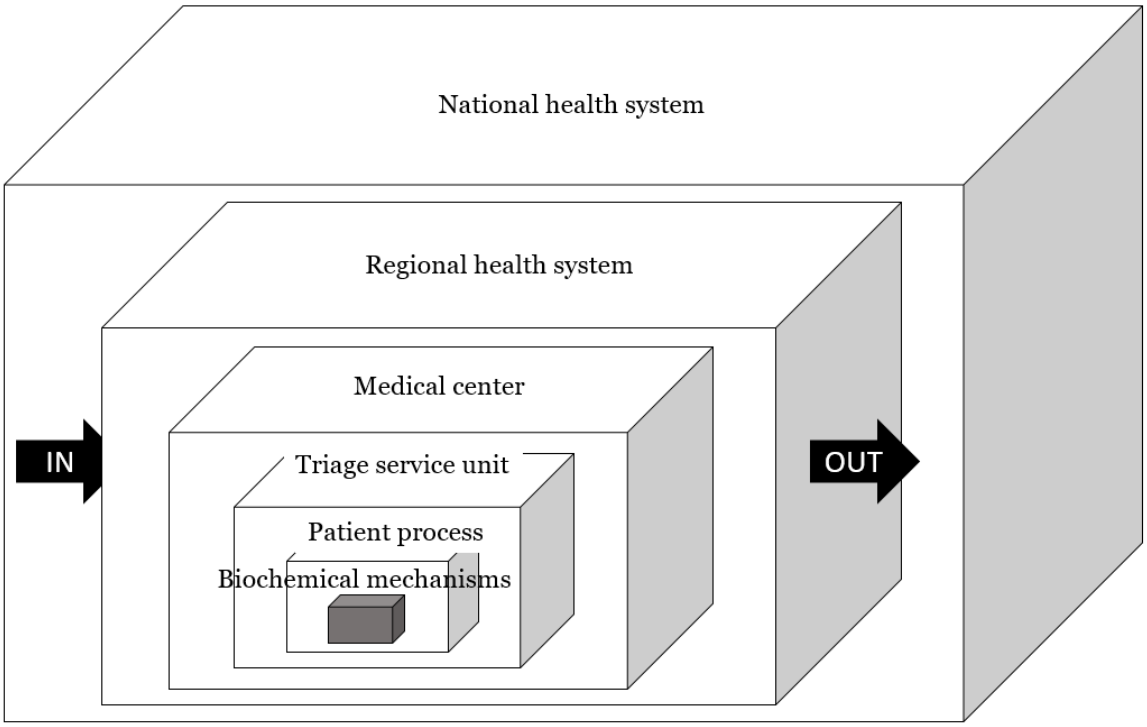

Figure 10 - System Hierarchy of the Black Boxes in Healthcare (Lillrank et al., 2019)

The Black Box-logic indicates that it is not possible to observe what occurs inside the box unless it is opened. Further, the logic helps to understand hierarchies within various systems (e.g., hierarchies of mechanisms). To avoid studying only inputs and outputs, CIMO-logic suggests opening black boxes, thus discovering the mechanisms. Thus, these two logics are essential behind the PROVE-IT model as they support the understanding of the functionality of a DHI. It should be underlined that not all black boxes can be necessarily opened, which appears as an inability to distinctly prove the existence of a mechanism.

As the outcome of a given black box in a specific context acts as an enabler for the other context that is linked to the former, it is vital to examine the first black box to understand the outcome of the second box. Figure 11 illustrates this idea:

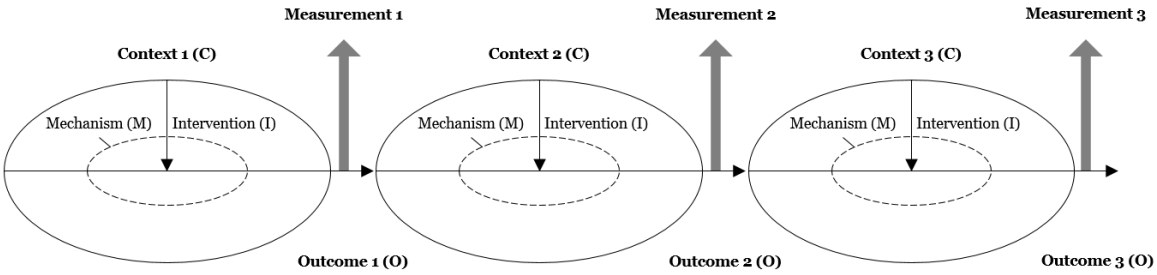

Figure 11 - Outcome Chain of an Intervention through Varying Contexts (modified from: Lillrank et al., 2019)

3.3 PROVE-IT Model

The PROVE-IT model consists of three steps guiding the user to perform the value formulation process for evaluating the value of any digital health. Beginning with the first step, the model suggests considering the CIMO-configuration for the intervention in question. More specifically, four key questions needed to be answered are the following:

- **Context (C):** To which context, to whom, and to what purpose is the intervention targeted?
- **Intervention (I):** What is the technology of the DHI?
- **Mechanisms (M):** What causal, stochastic, or enabling mechanisms are expected to determine the expected outcomes of the intervention?
- **Outcomes (O):** What are the expected outcomes of the intervention?

As the CIMO-configuration is the very core of the PROVE-IT model, we will clarify each component more in-depth. Each component consists of several elements that need to be explored and analyzed to understand the value formulation. Despite the order of factors in the CIMO configuration, we will begin with the intervention and implementation as they need to be described first.

Intervention

The very first step of the CIMO-configuration is to recognize the characteristics of the intervention. Generally, this is a description of the DHI and its implementation. In general, we can observe the intervention from three perspectives: data collection (input), processing, and displaying (output). The data collection part of the DHI gathers and measures data from various devices such as sensors or mobile phones. In turn, data processing typically exploits various algorithms (e.g., machine learning) to generate useful metrics. Finally, the output of the DHI is usually various user interfaces or reports that help healthcare professionals and patients to act appropriately.

The digital intervention itself causes certain effects that occur due to three intervention-related mechanisms. First, DHIs increase the precision of information due to collecting more data points than non-digital tools and being less prone to errors (Galliher et al., 2008). Second, collecting data with digital tools is typically cheaper than, say, using physical resources such as workforce. Third, a key characteristic of DHIs is the ability to break time-location limitations as they are available online. Figure 12 illustrates the building blocks of the intervention besides its mechanisms.

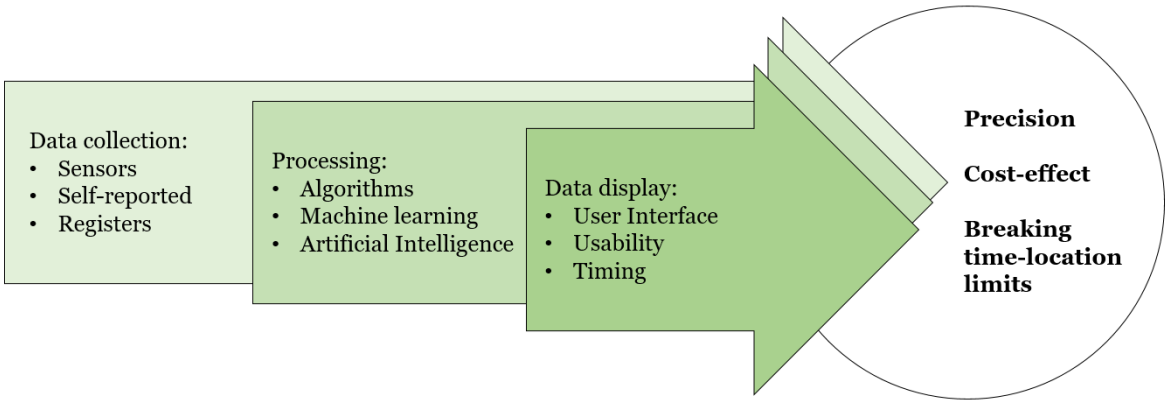

Figure 12 - Three Perspectives of Intervention with Its Mechanisms (Lillrank et al., 2019)

Based on these key characteristics of a DHI, the PROVE-IT model suggests several key questions to recognize the intervention under examination: What data is gathered and how? How is data processed and displayed? To whom the data is presented? What knowledge will become more precise and how? How information is transferred to the user, and how is she guided? How will time-location-limits change?

Context

As defined earlier, a context is a set of unique factors that formulate an environment for a digital health intervention. The description of the context begins by recognizing the very fundamental environmental upper-level factors such as geographical, organizational, and legislative characteristics. After that, we can move forward on the more precise factors. Due to being a relatively broad concept, we will emphasize several perspectives to address the context in the PROVE-IT model. These perspectives together formulate the overall context. Figure 13 presents this division below:

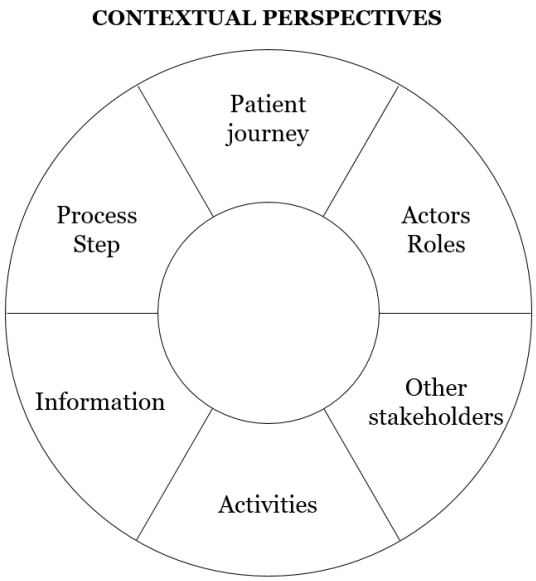

Figure 13 - Contextual Perspectives (Lillrank et al., 2019)

To begin with, the first perspective under examination is the patient journey perspective. It is the description of all activities that comprise the entire treatment process (Lillrank, 2018; Lillrank et al., 2019). It is accomplished with the CPW. In this perspective, it is relevant to understand in which part of the CPW the DHI is targeted. The possible target areas are the following: seeking of treatment, data collection for diagnosis, clinical decision-making, the composition of the treatment plan, the realization of the treatment plan, controlling the exceptions, and monitoring the patient's condition (Lillrank et al., 2019).

Second, the user performing an evaluation needs to map all possible stakeholders relevant to the intervention and the claims of these stakeholders. They can be described as entities regarding individuals or organizations. In turn, the relevancy refers to all those stakeholders that have an interest in the DHI (e.g., entities that are affected by it or developing it). The claim is defined as a statement of expected benefits of the DHI. While the determination of relevant stakeholders and their claims provides all the possible intentions and anticipations concerning the DHI, the value proposition is a statement of the benefits to end-users defining which expectations are aimed to be fulfilled. (World Health Organization, 2016)

To clarify, the stakeholder perspective can be divided into two main groups of participants within a context: actors and other stakeholders. It is relevant to recognize who are the specific actors in a particular context, and what are their interdependent relations and hierarchies. Typically, an actor has a specific description of tasks and authority. In turn, other stakeholders comprise all those actors who are not directly acting with the intervention but are affected by it or have an interest in it. The clarifying questions regarding the stakeholders are mainly: Who are the stakeholders, what are the interests of each of

them, and how are these interests realized and measured? How do the views and opinions of each stakeholder become apparent in defining and measuring the outcomes and costs? In turn, to clarify actors, the following questions are useful: Who uses the intervention? What competence is required for using it? How do work activities change? How the DHI affects the roles, relationships, and hierarchies between the actors?

The fourth perspective on the context is the acting perspective, which is different from the actor perspective mentioned above. The purpose is to answer what activities are performed to achieve the desired end-result without taking into account the actors themselves. As the DHI may change activity-actor entities, the actors are not considered in this perspective. The clarifying key questions to recognize activities are the following: Does DHI bring new activities or change the existing ones? Do some activities become obsolete due to implementing the DHI?

By recognizing activities within an organization where the intervention is implemented, it is possible to understand how the intervention changes processes and other factors. It is worth mentioning that we consider only activities that modify the patient's condition or any related information flows. Together these activities form a value chain that needs to be considered together with the information and process-step perspective considered next. (Lillrank, 2018)

The fifth perspective on context is the information perspective. The idea is to recognize what information is generated by whom and how it is processed. Particularly concerning the digital health interventions, it is suggested to analyze how the intervention is related to the existing IT-systems. A few clarifying questions to understand the information perspective are: What information the DHI generates and to whom? What information is new, changed, or removed by the DHI? How is information integrated and coordinated?

Finally, the last view on the context is the process-step perspective that encompasses the operational logic on the intervention. As described in chapter 2.1, healthcare services are processes consisting of individual steps. As illustrated in Figure 1, these steps consist of several elements: preparation, setup, processing, and replenishment, and monitoring. For DHIs, it is relevant to recognize in which elements the intervention takes place.

Process-step perspective examines the touchpoints of a DHI on a process level, thus increasing the understanding where the DHI influences. To clarify this perspective with questions, a few key questions are: Which parts within a step are affected by the DHI? How standardized are the processes?

Outcomes

The third part of the CIMO-configuration is to describe the expected outcomes relevant and valuable for each stakeholder. The viewpoint is typically the direct health outcomes from the viewpoint of a single patient meaning an achieved change in the patient's condition in a single patient episode. The term outcome is also used for calculating direct or indirect costs or as an indirect health outcome in a chain of events, where one outcome enables the realization of another. To clarify, we will use terms direct and indirect health outcomes besides direct and indirect cost outcomes separately.

As mentioned at the beginning of this thesis, value-based care stems from the concept of value being a relation between health and cost outcomes (Porter, 2010). A fundamental rule for examining outcomes is to recognize which outcomes are relevant for their contextual black boxes. As described earlier, it is essential to study the smallest black box (micro-level) to understand the effects in the most significant black box (macro-level). If there is no outcome in the smallest black box, the first level interface, there will be no outcome at all (Figure 11).

Also, for outcomes, several key questions may help in their recognition process: What are the expected outcomes for each stakeholder? What is the outcome in each of the recognized black boxes, and how are these related together? What are the costs related to the recognized outcomes? What should be done to actualize potential outcomes?

Mechanisms

The final part of the CIMO-configuration is the examination of mechanisms. Mechanisms explain the reasoning why the DHI causes specific outcomes in a given context. As these mechanisms may be relatively difficult to interpret, we will examine them from three angles. First, as illustrated in Figure 12, the intervention itself has three mechanisms; precision, cost-effect, and breaking time-location limitations. Second, besides the intervention-related mechanisms, there are also context-related mechanisms. These are actualized in three defining prerequisites for purposeful action (Lillrank, 2018):

- **Can do:** What actor can do with the increased competence from the DHI?
- **Know what to do:** Does the actor know what to do based on the improved information and coordination due to the DHI?
- **Want to do:** Does the actor have the motivation?

The first "can do"-condition relates to the mechanism that the intervention acts as an enabler by making it possible for an actor to perform something that was no possible *ex*

ante. Diversely, the "can do" also refers to those activities that may have become obsolete due to the intervention. With "can do" the actor can plan activities more effectively than earlier.

The second, "know what to do"-question asks whether the intervention enables actors to access new or more detailed knowledge that improves the processes and overall quality.

Finally, the "want to do"-condition considers the actor's motivation. The key focus is to understand what motivational factors, both positive and negative, change due to intervention.

To summarize, both intervention and context have their mechanisms. Besides these, there is also a third angle to mechanisms; that is general healthcare mechanisms recognized in the healthcare research literature. These explain the main dynamics why a DHI produces certain outcomes in a given context. As a conclusion, there are seven general healthcare mechanisms, which will be covered below.

The first of healthcare mechanisms is *proper timing*. Proper timing ensures that activities are performed on optimum times; not too early, nor too late. This mechanism encompasses preventive activities as well as accessibility and availability of services. An example of preventive work could be vaccination (Owens et al., 2004). From the viewpoint of operations management, proper timing relates to handling the arrivals besides scheduling and routing the activities (Jacobs et al., 2011).

Another mechanism is *proper competence level*. This mechanism means that for activities, the sufficient proper resource is always used to avoid overtreatment and unnecessarily expensive activities (World Health Organization, 1978). Thereby, the competence level and the cost-efficiency is always the most optimal for each activity. According to Tan and Heng (2007), by utilizing the lowest sufficient level of treatment, the quality of life could be improved among heart disease patients while the usage of medical services could be decreased.

The third mechanism is *integration*. Simply put, integration brings shattered knowledge together, exploiting all knowledge sources and perspectives to perform a comprehensive analysis of the patient's condition. With the integration, overlapping services can be avoided whereas consistency, continuity, and ultimately the quality of services can be improved from the viewpoint of patients (Haggerty et al., 2003; Vedel et al., 2009).

The fourth mechanism is *coordination*. It describes the means of organizing activities and resources effectively by avoiding waste, according to Lean-philosophy (Hicks, 2007). An

example of coordinating activities effectively is the exploitation of TOC-principle in home care (Groop, 2012).

Evidence-based medicine is a mechanism that stands for performing clinical decisions only based on the evidence that can be gathered. Essentially, the decisions made for the patients can always be justified with scientific evidence, thus considering only those options that aim for the best treatment possible without performing any harmful and unnecessary actions (Chaudhry et al., 2006; Sandelin et al., 2005).

The sixth mechanism is *demand management*. Generally, demand management consists of activities to control patients seeking treatment. More precisely, it controls this demand in terms of volume, timing, cause, and direction. The main goal is to avoid unnecessary appointments and overloading, besides directing patients to correct contact points (Lillrank, 2018).

Finally, the last mechanism is *co-creation of health*. This mechanism leverages patient's own assets by introducing the patient's own role in the treatment process. Increasingly more activities regarding the treatment process are given to the hands of patients, thus not only making them more active considering their treatment as a whole but also saving health professionals resources on more crucial activities. As an example of co-creation in practice, our case company, Klinik, activates patients to perform part of the activities within the clinical pathway.

3.4 Conclusion

As can be seen, various problems can be analyzed by dividing and segmenting them into individual black boxes. These boxes together form a more extensive system with a hierarchy. To understand the mechanisms within each of the black boxes, we can exploit the value formulation model, PROVE-IT illustrated in Figure 14.

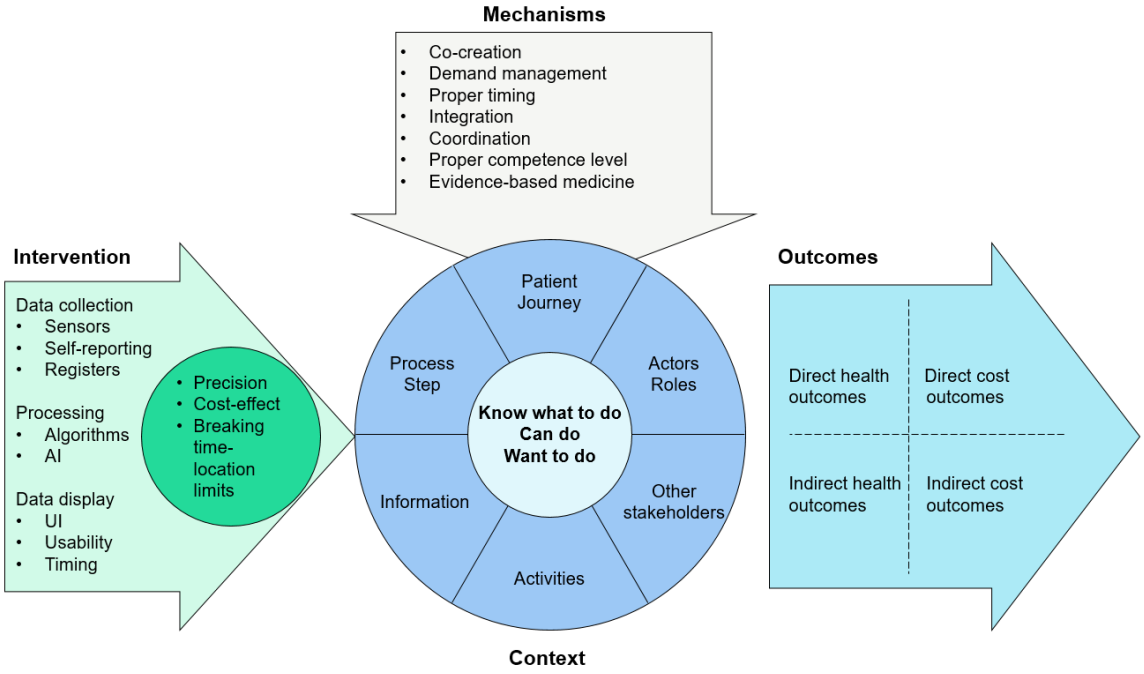

Figure 14 - Illustration of the PROVE-IT Model (Lillrank et al., 2019)

The utilization of this model relies on collecting data regarding intervention, context, and expected outcomes by addressing the incorporated factors in each. The brief checklist of key questions regarding the data collection is presented in Appendix 1. The next step after data gathering is to analyze which mechanisms are apparent in a DHI by analyzing the data and considering the interdependent relations between the parts of CIMO.

We will utilize the PROVE-IT model for our empirical cases in this thesis to collect data to understand Klinik's value formulation. The checklist (Appendix 1) acts as a base for all the interviews conducted in this thesis. Although each step within the PROVE-IT model can be tackled rather comprehensively as presented above, the user of the PROVE-IT model can base the value formulation process to the ultimate key questions presented in the list. Thus, the PROVE-IT model checklist is not all exclusive list of questions that could be asked but rather an effective and brief list of key factors that should at least be addressed in the value formulation process.

4 Empirical Background

In this chapter, we acquaintance ourselves with the empirical context of this thesis beginning with the examination of the case company Klinik Healthcare Solutions. We will then address the expansions Klinik is about to perform in four cases by focusing on the fundamental problems to which it is providing solutions. By the same token, we will explore in more detail the public healthcare systems in these four cases to enlighten ourselves with the empirical environment where the evaluation studies take place later in this thesis.

4.1 Klinik Healthcare Solutions

Klinik Healthcare Solutions is a Finnish health technology company providing condition and urgency recognition tools for patients as well as the intelligent patient flow management solutions for medical care providers. Founded in 2013, the company has over 30 employees, including medical professionals aiming to ease the process of identifying and receiving treatment. Currently, the company operates in over 300 medical units. (Klinik Healthcare Solutions, 2019a)

Klinik provides several services to patients and care providers. The basic free-to-use web version, Klinik.fi, provides an initial diagnostic tool for patients. By collecting the user data regarding reported symptoms and condition, the service aims to identify diseases, suggest treatments, or provide means to find a suitable specialist. The service is in continuous development influenced by its users, physicians, and other health care professionals. In Finland, the service has 150 000 monthly visitors on average (Klinik Healthcare Solutions, 2019b).

Besides Klinik.fi symptom and urgency recognition tool, the company provides an intelligent patient flow management system tool, Klinik Pro (also called Klinik Access), for medical centers. This service includes a similar medical engine and user interface for patients than in Klinik.fi service but additionally provides a digital triage management tool for nurses and doctors. The service suggests initial diagnoses and suitable actions for treatment utilizing the patient data. Based on the case characteristics and suspected diagnoses, the service ranks patients according to their urgency needs. As a result, the service supports nurses' work with an effortless way to receive and handle patient contacts. Furthermore, doctors can prepare for patient appointments as the service provides initial diagnoses and structured patient information. Klinik Pro is the service we are focusing on in this thesis.

Both services, Klinik.fi and Klinik Pro, exploit advanced medical algorithms for performing initial diagnoses. AI-based algorithms take as an input the information the patient provides

from his or her condition. The algorithms then process this data and then deliver it to the healthcare professionals with a suggested initial diagnosis and urgency level. Although the healthcare professionals set the final diagnoses, the AI is inherently beneficial to address emergent conditions that require immediate action.

To illustrate how Klinik is used for seeking of treatment and triage, Figure 15 illustrates the process:

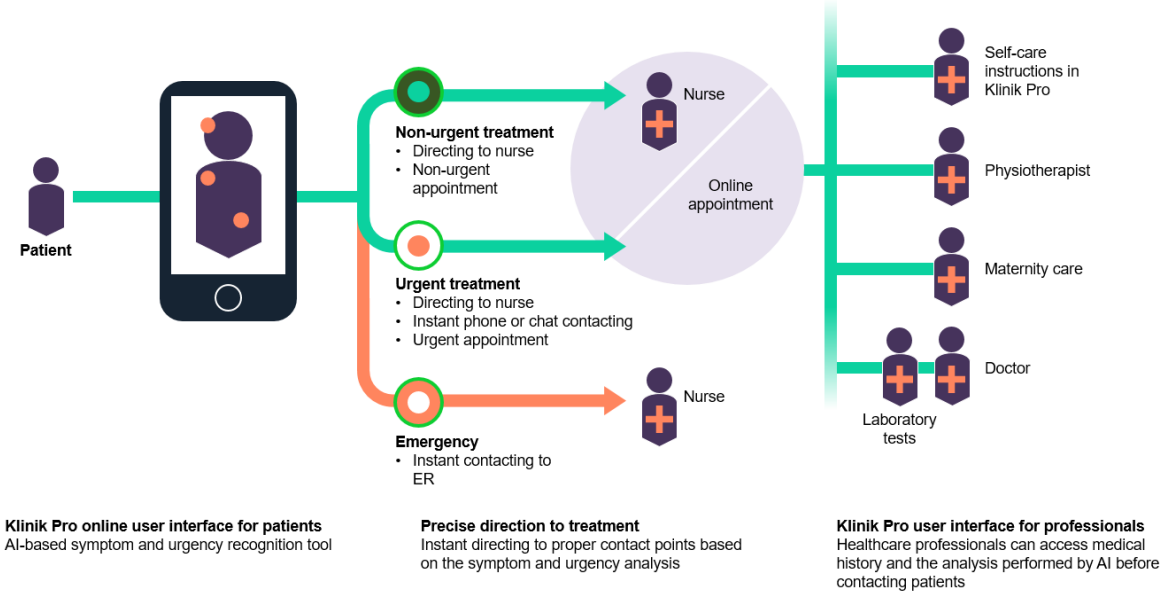

Figure 15 - Functionality of Klinik Pro

4.2 Empirical Case Environments

In this section, we will explore more in detail the contextual environments where the PROVE-IT model is utilized. As mentioned earlier, Klinik is expanding its operations globally. During the first half of the year 2019, Klinik has been expanding its business in two cases within Finland besides its international expansion to Portugal and Mexico. These four expansion operations are our business cases in this thesis. In the following chapters, we will acquaintance ourselves with the contextual environments of each case. Our focus will be on understanding the overall healthcare system and the organizational environment the Klinik Pro solution is implemented case-specifically. Especially, we will examine the critical problem Klinik Pro is meant to solve in each location.

4.2.1 Vantaa - Finland

As a Finnish-based company, Klinik has already implemented its services in numerous primary care centers in Finland. In this thesis, we will focus on a city of Vantaa, where Klinik Pro is planned to be integrated into all of the primary care centers in the city area. Vantaa

is the fourth largest city in Finland with a population of over 220 000 people (Kuntaliitto, 2019; Parviainen, 2019).

In the case of Vantaa, our contextual focus is on the Finnish public primary care. As mentioned earlier in chapter 2.2.1, the primary care addresses the most common health issues in the communities with preventive, curative, and rehabilitative services (Atun, 2004). In Finland, the municipalities or co-operation districts are responsible for organizing primary care (HUS, 2019). According to Kuntaliitto (2018), there are 295 municipalities altogether. From those 78 municipalities organize the health services themselves while 217 of those form 59 co-operation districts. In turn, there are 137 primary care provider organizations across entire Finland, each of them featuring one to multiple primary care units. Besides municipalities and co-operation districts, there are private sector providers and other organizations that can offer health services.

The Klinik Pro service was successfully implemented and demonstrated in Myyrmäki primary care center in August 2017, generating initial evidence of the cost savings (Tenhunen et al., 2018). Besides cost-savings, the service is expected to help nurses to self-manage their work more efficiently, thus relieving stress. Due to its benefits in Myyrmäki, Klinik Pro will also be established in other medical centers of Vantaa city, thus integrating the Klinik Pro service into a broader health system. These centers are Hakurila-Länsimäki (two separate units but coordinated as one entity), Koivukylä, Korso, Martinlaakso, and Tikkurila. The beginning of the expansion is scheduled to the beginning of September 2019. This thesis utilizes PROVE-IT model for this specific case.

4.2.2 FSHS - Finland

Another case located in Finland concerns the Finnish Student Health Service (FSHS - *YTHS in Finnish*). Finnish Social Insurance Institution *Kela* is a significant government agency providing main financial support for FSHS which, in turn, is responsible for providing health services to students (Kela, 2019; Sipilä and Saarikko, 2018). The majority of the services are free for students, whereas secondary healthcare and partially dental services have fees included (FSHS, 2019).

According to an interview with the FSHS informant, Klinik Pro suits very well to improve the existing operations within the FSHS triage process. As FSHS is obligated to perform triage besides having already a relatively considerable customer base, soon both university and college students (Kiuru et al., 2018), Klinik Pro is seen as a great alternative to existing channels to enhance the seeking of treatment and triage altogether. Especially the dental services tend to build up long queues to which Klinik Pro could provide a solution.

FSHS implemented a Proof of Concept (PoC) for Klinik Pro from fall 2018 to February 2019. As the pilot provided positive results and new insight on students' behavioral pattern regarding seeking of treatment, Klinik Healthcare Solutions is interested in continuing the customer relationship with FSHS.

4.2.3 P5 Project - Portugal

In Portugal, Klinik Pro implementation is embedded into a broader P5 Project of the School of Health Sciences at the University of Minho that aims to prove the benefits of digital health solutions (Universidade do Minho, 2019). In total, there are three primary care centers involved with the P5 Project that will utilize Klinik Pro tool. The main idea is to operate Klinik Pro within a single Digital Center located in the University of Minho. The Digital Center would direct all patients needing medical assistance to the primary care centers while managing itself the non-urgent patients that require only self-care.

The Portuguese healthcare system is heavily publicly provided and overseen by the Portuguese Ministry of Health (Expatica, 2019). The system is built on three subsystems: the National Health Services (SNS), special social health insurance schemes as well as private health insurance. Like in Finland, the government is a significant financial supporter for citizens to enable free healthcare services. Our focus is on public primary care.

The reason behind implementing Klinik Pro in Portugal is to establish a suitable tool for triage. Currently, there is no triage in primary care centers, which causes long waiting queues, unnecessary receptions, and unorganized approach to seeking of treatment. As a result, the missing triage system fills the hospitals of people desiring to see a doctor. According to Portuguese informants, the majority of these people are not needing a doctor's appointment and could be easily cured at home. Thereby, Klinik is seen as a solution to help Portuguese primary care centers with this problem.

We are going to apply the PROVE-IT model for an entity of three primary care centers in the area of Braga. The medical units are USF Saúde Oeste and USF Manuel Rocha Peixoto in Braga besides São Miguel-O-Anjo in Famalicão. The respective patient and family doctor numbers for each location are the following: 7 218 patients and four doctors in Saúde Oeste, 14 720 patients and nine doctors in Manuel Rocha, and 12 197 patients and seven doctors in São Miguel-O-Anjo. Thus, in total, we have roughly 34 000 patients with 20 family doctors in the target environment.

4.2.4 Guadalajara - Mexico

In Mexico, Klinik is expanding to Guadalajara, which is in the state of Jalisco. The city of Guadalajara has a population of nearly 1.5 million, while the population of the Guadalajara metropolitan area is approximately 4-5 million people (Cuéntame, 2015).

While in the case of Vantaa, FSHS, and Portugal we will focus mainly on public primary care, in the case of Guadalajara, we need to *au contraire* manage four different healthcare systems: federal social security, state, occupational and private. From these, the two first ones are mainly arranged by the government while the occupational healthcare is divided between public and private players. According to Mexican informants, 75% of the hospitals are considered under the public sector, while 25% of them are private.

There are significant issues with the low number of doctors and nurses in Mexico. According to informants, approximately there are only two doctors per 1000 inhabitants while the average of OECD countries is 3.2. Similarly, there are only four nurses per 1000 inhabitants while there are six nurses on average in OECD countries. As a result, waiting times are long and capacity problems within hospitals are usual.

The general issue Klinik is solving is twofold depending on the healthcare provider. On the public side, the digitalization of healthcare is relatively low. There is only a limited number of electronic records of patients while data management is almost non-existent. As a result, the management of hospitals is performing ineffectively. Thereby, Klinik Pro is aiming to provide an easily approachable system to collect and manage patient data to prove its benefits for the government. Currently, all the data regarding waiting times and patients' diagnoses and issues are rough estimates on the public side. Consequently, Klinik Pro could provide actual statistics with real data, thus providing useful insight regarding the current situation and challenges in public healthcare.

On the contrary, private players are more ahead with collecting and managing patient data. For them, Klinik Pro is a useful tool on top of the existing systems, thus improving the effectiveness and precision of current systems. Besides creating a data infrastructure for public healthcare, as mentioned above, Klinik Pro is also improving the triage system similar to other cases of this thesis.

Klinik's service will be implemented in some of the medical centers, still not confirmed. The first Proof of Concept (PoC) implementation of Klinik Pro might only be a rather short demonstration of the service. Within this short period of time, Klinik aims to implement the service, collect relevant data, and perform an analysis of the results.

5 Methodology

In the following, we will dive into the methodological foundation of this thesis. We will begin by examining the research design, including the characteristics of this study. Thereafter, we will take a closer observation of the data collection process. Finally, we will conclude with the process of data analysis together with the critical evaluation of the suitability of used research methods.

5.1 Research Design

Considering the suitable research design for this thesis, the nature of the entire study and its objectives need to be taken into account. Primarily, we aimed to gather contextually diverse information to test and develop the PROVE-IT model. We were interested in seeing whether the model provides a valid picture of the functionality of a DHI. Thus our research design was based both on principles of design science and service engineering. Due to utilizing the theoretical model and testing it in an empirical context to make further evaluations of it, the research phenomenon was essentially created artificially. Thereby, we were exploiting the concepts of design science in this thesis (Holmström et al., 2009). Especially, the CIMO-configuration that is in the heart of this thesis was a key design science concept we are utilizing (Denyer et al., 2008; Holmström et al., 2014).

Besides design science, another approach used in this thesis concerns service engineering (Kimbell, 2011; Salvendy and Karwowski, 2010). As we aimed to engineer an evaluation model for formulating value of services utilizing digital health interventions, we were interested in solving a problem of the applicability of this model by testing it in real-life settings. Furthermore, we were especially interested in how well defined each component in the PROVE-IT model was.

In this study, we mainly utilized the CIMO-configuration theory to develop the PROVE-IT model by narrowing the scope with research questions. As a result, we could understand this as an inductive research strategy (Eisenhardt and Graebner, 2007; Ketokivi and Choi, 2014). However, we were first utilizing and testing the PROVE-IT model in empirical cases, and later developing it further. Thus, essentially we were not generating a new theory from the empirical data, but rather elaborating the already identified general logics of CIMO and operations management specifically for the needs of a health technology industry. As a result, the case study in this thesis followed a theory elaboration model (Ketokivi and Choi, 2014).

As we were researching the interpretation and meaning of various components within the PROVE-IT model in the predetermined contexts, this thesis followed a qualitative research

basis (Ketokivi and Choi, 2014). It is worth noting that the factors behind the generation of the PROVE-IT model stemmed from the individual case studies concentrating on the evaluation of DHIs (Lillrank et al., 2019).

Besides the elaboration model, this study exploited the concept of grounded theory to elaborate on the engineered PROVE-IT model with the empirical data (Glaser and Strauss, 2010). According to Glaser and Strauss (2010), for qualitative research, we can be built theories by utilizing the constant comparative method of qualitative analysis, which concentrates on an iterative process of coding, comparing, and verifying results as the theory-building goes forward.

The methodological approaches relevant for this thesis were both a case study and an explorative approach. As mentioned briefly in the objectives of this thesis, the chosen research strategy was in the form of a multiple case study due to several justifications. Eisenhardt (1989) describes the case study to be a research strategy which concentrates on examining the dynamics present within single settings. In our case, we were examining four different cases, thus conducting a multiple case study. Building or elaborating a theory from cases has strengths such as novelty, testability, and empirical validity resulting in a case-study to be a well-suited to research areas with an inadequate theoretical background (Eisenhardt, 1989). Furthermore, Eisenhardt and Graebner (2007) emphasize that case studies are useful to explain complex social processes such as the evaluation of a DHI. Finally, regarding the nature of our research questions, a case study typically responds to questions asking “how” or “why”, thus leaving a little control for the researcher of the occurring events at present (Yin, 2003).

Furthermore, instead of testing a predetermined hypothesis, we were essentially applying and developing the theoretical value formulation model in a real-life context to gain new insight concerning the evaluation of DHIs. Thereby, this thesis followed an explorative approach as well (Kothari, 2004).

5.2 Data Collection

In the following, we take a closer investigation of the data collection. First, we will address the unit of analysis regarding this study. Second, we will go through the sampling process and the choice of information sources for this thesis. Finally, we will take an examination of the chosen methodology of the entire data collection process.

5.2.1 Unit of Analysis

The decision of the unit of analysis for a case study can follow two paths according to Yin (2003): holistic or embedded design. The former proposes building the study based on one

single unit of analysis, while the perspective of embedded design is to exploit multiple units of analysis. In our context, we concentrated on one unit of analysis that is used in all cases, thus utilizing the holistic design approach (Yin, 2003). The chosen unit of analysis concerned the very first parts of the service production system of treating patients. In other words, our unit of analysis comprised the seeking of treatment and triage process within the medical centers in each location. This was the target area that was influenced by Klinik Pro.

The chosen unit of analysis consisted of several parts that were analyzed separately using the PROVE-IT model. The categorization was divided into contextual perspectives as described in chapter 3.2. Although patients are clearly the actors using the DHI, they were left out due to the scope of this thesis. However, they were yet indirectly taken into account based on the experiences and perspectives of healthcare professionals delivering their views on behalf of their patients.

5.2.2 Sample

Considering the objectives of this thesis, we aimed to ultimately develop an evaluation model to provide generalized results. To achieve this objective, we exploited the theoretical sampling for this purpose by choosing particularly suitable but also mutually different case organizations where the influence of the DHI was relatively apparent (Eisenhardt and Graebner, 2007). Additionally, the decision of performing a multiple case study once again supported the sampling as it enabled mutual comparison improving the overall emergent theory (Eisenhardt and Graebner, 2007).

The use of interviews as a source was essential to receive any experience of the valid use of the PROVE-IT model. For each case, the interviewees were chosen based on their background and current role. The main purpose was to maximize the diversity within the interviewees to guarantee a rich and diverse set of perspectives and opinions of the Klinik Pro solution by also avoiding the bias of leaning too greatly on a narrow viewing angle. Besides performing the interviews, I exploited the snowball sampling by asking the interviewees to provide other potential people to be interviewed as well (Goodman, 1961). Table 4 presents the list of interviewed people below:

Table 4 - List of Informants

ID	Purpose of the interview	Organization type	Description of the organization	Informant(s)	Data collection method(s)
1	Background data, primary data	Digital health technology company	Klinik Healthcare Solutions	Chief Medical Officer	Informal discussion, semi-structured interview
2	Primary data	Primary care	Vantaa, Finland	Chief Physician	open interview
3	Primary data	Primary care	Vantaa, Finland	Assistant Head Nurse	open interview
4	Primary data	Primary care	Portugal, Minho medical center	Managing Physician	Semi-structured interview
5	Primary data	Primary care	Portugal, Minho medical center	Physician Intern	Semi-structured interview
6	Primary data	Primary care	Vantaa, Finland	Manager of Health Services	Semi-structured interview
7	Primary data	Primary care	Vantaa, Finland	ICT Service Coordinator	Semi-structured interview
8	Primary data	Venture capital	Athensmed	CEO	Semi-structured interview
9	Primary data	Primary care	FSHS	CIO	Semi-structured interview
10	Primary data	Primary care	Mexico, Guadalajara medical center	MD, CEO	Semi-structured interview

5.2.3 Data Collection Process

Interviews were utilized in the data collection process. They consisted of various discussions from informal to more structured conversations with relevant actors and stakeholders. The formal interviews were semi-structured. The reason to use semi-structured format was based on the nature of this research being an exploratory study, thus benefitting greatly from open-ended and not purely predetermined interview questions (Saunders et al., 2016).

Furthermore, semi-structured interviews are useful when the objective is to discuss predefined themes without predefining the progress of the interview (Metsämuuronen, 2009).

Although the literature review was performed early on the research, part of the interviews were performed simultaneously. According to Ghauri and Grønhaug (2010), the literature review encompasses three main objectives: the framing of the problem, recognition of the relevant concepts and facts, and acknowledgment of the research gap. These objectives were addressed iteratively as the study continued further by receiving increasingly more insight on the topic. Particularly, as the PROVE-IT model was still under formulation during the early stages of this study, the three aforementioned objectives were not "written in stone" so to say. Thereby, besides familiarization with the relevant literature, I conducted several discussions to understand the case company, its digital solution, and the triage process more thoroughly. These meetings included discussions with one of the top managers in our case company Klinik Healthcare Solutions as well as the management personnel from the Myyrmäki medical center.

Once the informal discussions were finished, I began the formal interview process. As mentioned, the interviews followed mostly a semi-structured format due to the nature of this research. Additionally, the research phenomena of utilizing a value formulation model to evaluate digital health interventions is an exceedingly novel research area, the data collection requiring rather open-ended interview questions.

Moreover, as the Klinik Pro implementations in our case environments are yet on very early stages, no direct observations of any quantified outcomes could have been performed. Thus, the data collection had to concentrate on understanding the ontology and dynamics of the DHI. To gather this knowledge of Klinik Pro, the interviews were mainly constructed around the CIMO-logic within the PROVE-IT model with varying customization and emphasis based on the expertise and background of an interviewee (Denyer et al., 2008; Lillrank et al., 2019). Appendix 2 illustrates the used interview protocol.

5.3 Data Analysis

Besides writing notes, the majority of the interviews were also recorded with permission from the interviewees. Thereafter, I transcribed the recordings as early as possible. I then used Atlas.ti software to create coding from the interview notes and transcripts. Generally, the coding was based on both thematic analysis (Guest et al., 2012) as well as the constant comparative method (Glaser and Strauss, 2010). In total, 91 codes were utilized in the analysis built around themes constructed from the CIMO-logic (Denyer et al., 2008).

5.4 Quality of the Chosen Methodology

The evaluation of the quality of this study is crucial, particularly as the topic of this thesis is evaluation. To appraise the credibility and quality of our research, I exploited a four-step evaluation model targeted for case studies by Yin (2003). This model structures evaluation under for factors: *construct validity*, *internal validity*, *external validity*, and *reliability*.

The construct validity measures whether this study is constructed in a way that it tests if the value formulation of a DHI can be accomplished with PROVE-IT (Yin, 2003). This study utilized multiple data sources to test value formulations in varying contexts. First, the informants had significantly diverse backgrounds varying from nurses and doctors to funders and managers. Second, this thesis exploited perspectives from different healthcare systems and cultures by comparing different countries. Third, I explored varying technical stages of the DHIs as Vantaa had already experience from Klinik Pro while it is new to medical centers in Portugal and Mexico. By exploiting these differences to drive conclusions, this thesis aimed to construct validity based on the comparative analysis. Furthermore, Yin (2003) suggests also having key informants to review the draft of the study, which was achieved with regular updates with key informants.

Second measure of credibility is the internal validity, which considers causal logic and inferences performed by the researcher (Yin, 2003). As Yin (2003) emphasizes that internal validity is not relevant in exploratory studies, this measure was not addressed any further. However, internal validity is partially relevant for the CIMO-logic as mechanisms explain the causal relationship between the intervention and its outcomes. Therefore, I briefly took into account a few rival explanations while analyzing the mechanisms.

The third measure is external validity, which deals with the issue of whether the study results can be generalized or not (Yin, 2003). This is considered to be one of the main challenges for case studies. Yin suggests testing the theory in a single-case study following replication in multiple cases (2003). Considering digital health interventions as our domain, we can perceive the PROVE-IT model to be generalizable in multiple instances but only in evaluating digital health technologies. Thus, the evaluation logic cannot be directly generalized for any other industries or fields.

Reliability measures the extent to which data collection and analysis of the *same* case will yield consistent findings when performed, for instance, by another researcher or at a different time (Yin, 2003). Yin (2003) recommends making as many steps of the case operational and explain the procedures as clearly as possible for other researchers to be able to follow it. Thus, reliability has been ensured with a clear description of the methods and PROVE-IT model along with the PROVE-IT checklist that acts as a base for all interviews.

Besides the four-step evaluation model (Yin, 2003), we can address the quality of this thesis from the perspective *strengthening*, thus considering whether other studies provide a similar result. Despite being a rather novel study to utilize CIMO-logic for evaluation purposes, a previously conducted study by Väljä et al. (2019) provides a similar idea of the utilization of CIMO-logic to examine a DHI for headache purposes.

6 Findings

In these following chapters, we will examine the key findings from the interviews by mapping the collected information into the PROVE-IT model. Based on the collected information from the interviews and external sources, we will address the research sub-question 1.1. First, we will present the planned intervention for each case. Second, we will explore more in detail the contextual setting where the intervention is implemented. This will be followed by the description of the expected outcomes. Thereafter, we aim to understand the context-intervention and context-mechanisms relationships to address the research sub-questions 1.2 and 1.3. Finally, by exploiting our earlier findings, we aim to discover the actual mechanisms to respond to the first research questions as a whole.

6.1 PROVE-IT - Intervention

We will begin by comparing the intervention for our cases by addressing the specific questions related to the intervention in the PROVE-IT model. For all cases, the planned intervention is Klinik Pro, a triage and urgency level analysis tool. In each case, it is a tailored, yet essentially the same solution addressing problems it is meant to solve in each contextual environment. Table 5 illustrates the descriptions of the intervention for each case:

Table 5 - Summary of Intervention Features

	Vantaa	**FSHS**	**Portugal**	**Mexico**
What data is collected?	Health conditions, patient information			
How is data processed to information?	Structural questions for patient, AI generated diagnosis and urgency-need analysis			
How is the information presented?	Diagnosis and urgency-need presented in a well-structured format copied to existing systems	Diagnosis and urgency-need presented in a well-structured format copied to existing systems	Diagnosis and urgency-need presented in a well-structured format copied to existing systems	Diagnosis and urgency-need presented in a well-structured format
What information becomes more precise?	Patient's condition, behavioral patterns, frequency of sensitive diseases	Patient's condition, behavioral patterns, frequency of sensitive diseases	Patient's condition, behavioral patterns, need of appointments	Patient's condition, behavioral patterns, general statistics of medical needs
To whom is the information provided?	Nurses and doctors in medical centers	Nurses and doctors in medical centers	Healthcare professionals in Digital Center	Nurses, secretaries, and doctors in medical centers

In Vantaa, Klinik Pro is separately running service linked to the web sites of Vantaa medical centers regarding the triage process. As patients seek guidance concerning their medical condition, they are directed to Klinik service. According to informants, the typical response

time is two days at maximum. The process of accessing Klinik is mostly similar to the case of FSHS except for the additional integration to student information databases to confirm whether the patient is a student or not. If permission is accepted, the patient is directed to Klinik interface. In turn, patients in Portugal can access Klinik similarly to Vantaa, but it is meant to be used for acute instances where an appointment is needed in a day. For the case Mexico, the Klinik Pro implementation is a planned to be a simplified version of that in Finland.

The Klinik user interface (UI) for patients is similar in all cases. The UI provides a body part map for patients to target the location of their pain. With the support of medical questions, the AI asks additional information aiming to gather as much data from the patient to process it further. In all cases, the collected data is focused on factors explaining the health condition received directly from the patients themselves. Thus, we may consider Klinik Pro as a DHI where data is self-reported by patients.

After the data collection, the AI then makes an urgency analysis and initial diagnosis of the patient's condition. This information is then sent to the Klinik UI for healthcare professionals to be further utilized. Healthcare professionals can then log in to their Klinik accounts to handle contact requests by patients. In the cases of Vantaa and FSHS, the initial diagnosis and urgency-analysis are presented to nurses as they are the contact points for patients besides confirming whether the analysis performed by AI is appropriate. The confirmation is vital as in some instances the AI performed incorrect deductions regarding the patient's condition. The similar approach is implemented in the digital center in Portugal, except doctors are the main responsible ones for diagnoses. In Mexico, both nurses and secretaries are first contact points while doctors mainly support with diagnoses and treatment further on.

According to informants, the information regarding the patient's condition is more precise with Klinik Pro as patients have to structure, ponder, and write their conditional information themselves besides the support of the AI. The informants considered this to be superior to phone calls that are typically rambling in nature. More importantly, the ability to apply for treatment without time and location restrictions was seen greatly beneficial. Table 6 presents informants' quotations regarding the intervention.

Table 6 - Intervention Features

Feature	Vantaa	FSHS	Portugal	Mexico
Data collection	*"Patient submits the data directly to the service."* [6]	*"First, the patient inputs the data to the system."* [9]		*"In question, simplified version of Klinik Pro that is*

Data processing	*"AI makes an urgency analysis […] in two working days nurse handles the analysis and responds to the patient."* [2]	*"Klinik Pro helps to perform a triage with body-pain-map and detailed questions."* [9]	*"…we would be […] receiving the patients' requests and redirecting only the patients who need medical assistance."* [4]	*running in Finnish medical centers."* [1]
Data presentation	*"…data is copied directly to patient episodes, now to graphical Finstar, and later to Apotti. Patient information does not change."* [6]	*"Healthcare professional checks the patient data from her own professional Klinik Pro user interface."* [9]		
Improved precision in information	*"…patient may or should structure her issue at her own pace. […] phone call is rambling in its nature."* [6]	*"Consistent quality in diagnoses, machine-like […] doesn't forget to ask relevant questions."* [9]	*"…roughly 20-30% of all medical appointments that day are for acute problems. Most of these […] do not need to be seen by doctor but can be self-cured. With Klinik this can be diminished."* [4]	*"…urgent cases will be recognized more precisely. […] Also, we are able to achieve increase in visibility of processes as reporting and statistics will be digitalized and in real-time."* [1]
Changes in time-location-constraints	*"Klinik's solution is not time or location bound. […] No need to visit physically or queue in phone."* [7]	*"Klinik form can be filled at own pace, no time-limited."* [9]		

6.2 PROVE-IT - Context

Next, we will explore more in detail the contextual factors and differences between our cases. As the general description of each case environment is presented in chapter 4.2, in this chapter, we will focus on contextual perspectives of the PROVE-IT model.

First, the target area on the clinical pathway is essentially the same in all cases: seeking of treatment and triage as presented in Table 7. In the cases of Vantaa and FSHS, Klinik Pro provides an alternative to calls or physical visits. As patients may seek treatment besides receiving initial diagnosis and urgency-analysis, Klinik Pro is targeted at the very beginning

of CPW. In turn, there is no triage process in Portugal, forcing all the patients to visit a doctor even when it is unnecessary. Consequently, Klinik Pro introduces a new practice; a digital triage. In Mexico, Klinik Pro does provide not only a digital triage system but also a broader tool to collect and analyze patient data. We will get back to this later in chapter 6.4. For the private sector, which has already partially digitalized, Klinik Pro acts as a supporting triage system.

Table 7 - Target Area on the Clinical Pathway

Feature	Vantaa	FSHS	Portugal	Mexico
Target area on the CPW	*"Previously, the patient either calls or visits physically [to apply for treatment]. Klinik becomes a third alternative."* [3]	*"As we are acting under care warranty law, triage is a compulsory activity to which Klinik Pro is a useful tool. It takes a lot of nurses' time."* [9]	*"No, no triage in any of the cases."* [5] *"Only triage is when you walk in and say you need a medical appointment today. […] You can lie and get the appointment. […] triage is given to the hands of patients."* [4]	*"Klinik supports current triage systems."* [10] *"For private sector, Klinik can be built on top of the existing systems."*[10]

Second, the stakeholders are mostly similar in all cases with a few exceptions. Although briefly presented in this chapter, it is worth mentioning that we will discuss the expected outcomes and claims of the stakeholders more in detail in chapter 6.3. First and foremost, informants pointed without saying Klinik Healthcare Solutions to be one of the stakeholders. Moving on to doctors, the informants emphasized that Klinik Pro provides more structured patient information to plan appointments and treatment process. As this is the case in Vantaa, FSHS, and Mexico, Portuguese interviewees also raised the fact that Klinik saves doctors' and secretaries' time to concentrate only to those patients who truly need appointments.

Other relevant stakeholders are the decision-makers. According to informants, primary care center managers expect Klinik to improve the effectiveness of demand management. In Vantaa, the informants raised the interest of Klinik improving productivity by lowering stress levels among nurses. Furthermore, informants in Portugal highlighted the stake of Regional Health Administration and their interest in cost-savings. Under decision-makers,

we will consider also the government in each country that has a role in each case as we are mainly considering public care. Especially in Mexico and Portugal, a successful Klinik Pro implementation could have a high impact on the government.

Investors are one group of stakeholders in all cases. They see Klinik as a useful service that can be sold with a reasonable price for the public sector, thus making it a great investment opportunity. Informants raised the importance of global expansion as the Finnish market is not sufficient as its own. The interest of investors actualizes in the pay-back time of their initial investment in Klinik.

Besides other stakeholders, IT administration is one important stakeholder group as they need to manage the IT infrastructure for Klinik Pro. Although being one of the stakeholders, informants did not consider IT administration having a clear stake or interest toward the DHI as Klinik is mostly an additional digital service without substantially modifying the current work of IT administration.

One relatively important group of stakeholders is the communications team. Informants emphasized their role as ensuring the Klinik is communicated clearly enough to the patients as a new alternative to existing phone calls and physical visits.

Finally, Mexican informant highlighted that there are needs for various skills to achieve a successful implementation of Klinik Pro. Notably, the informant emphasized such roles as expert on machine learning and AI, project manager, and designer.

After stakeholders, the third perspective encompasses actors, the actual users of the DHI. Clearly, patients form one group of actors in all cases. In the cases of Vantaa and FSHS, the other actors are nurses. Informants emphasized the ease-of-use regarding Klinik, which is why there are no specific competency requirements to use the service, except for the initial training provided to users. On the contrary to nurses, as the use of Klinik Pro concentrates on the centralized Digital Center in Portugal, the doctors are mainly the active users there as they are only permitted to perform the medical diagnosis. However, secretaries support them with the booking of appointments. Table 8 illustrates the quotations regarding both stakeholders and actors.

Table 8 - Stakeholders and Actors

Feature	Vantaa	FSHS	Portugal	Mexico
Stakeholders	*"IT administration, communications, Klinik."* [3]	*"IT administration to manage infrastructure. […] In the end,*	*"The university, digital center […]. Regional health*	*"There's got to be someone who is expert on IT, also […] a project*

	"Consulting physician possibility but they are not using the service." [6] *"Communicating through Vantaa website […] inhabitant magazines. […] no larger impact on IT administration."* [7]	*important for decision-makers how Klinik benefits functionally and qualitatively […] customer satisfaction"* [9] *"Communications team take care of social media and FSHS website to market Klinik"* [9]	*administration."* [5] *"…people in P5 units: nurses from Klinik, health coaches and psychologists, nutritionists."* [4]	*manager of teams. Then there normally has to be a person managing the side of medical things. Because of the cultural differences, it is good to have a designer (UI etc), Also, it's good to have a person looking for analysis."* [10]
Actors	*"Mainly actors are nurses. […] Also there are experienced medical center assistant-labeled practical nurses."* [6]	*"Nurses and patients."* [9]	*"Main ones are doctors, secretaries."* [5]	*"On the actual user end is the patient, nurse or front desk person. And obviously the physician."* [10]

Moving on to the activity perspective, informants recognized many relevant activities as presented in Table 9. Essentially, the processing of AI's urgency-level analysis together with the self-reported facts of the patient's symptoms form the core activities that provide more knowledge and discovery of the patient's medical condition. Additionally, confirming the diagnosis and contacting the patient are also following activities which are same in all case instances. Being a self-reported service, Klinik Pro is a DHI that gathers Patient Reported Outcome Measures (PROM) while aiming to improve Patient Reported Experience Measures (PREM) with a more effortless media to access treatment (Nilsson et al., 2015). The informants highlighted Klinik Pro's ability to positively affect PREM by not only being time-location free service but also speeding up the process of receiving treatment.

The Finnish or Mexican informants did not recognize any major changes in current activities except arranging the daily tasks differently due to the handling of Klinik's contact requests by patients. In Vantaa, the transfer of nurses to the centralized call center could be seen as a new activity. Similarly, the establishment of a digital center in Portugal could also be considered a new activity, but more importantly, the use of Klinik as a triage tool was considered absolutely new activity. Also, in Mexico, Klinik Pro would be an additional task

besides the existing ones. In general, informants did not see Klinik Pro make any existing activities obsolete.

Table 9 - Activity Perspective

Feature	Vantaa	FSHS	Portugal	Mexico
Changes in the existing activities	*"Nurses that answer calls rearrange their tasks so that there is time for Klinik."* [6]	*"Without saying Klinik affects how professionals rearrange their work to respond contact requests."* [9]	*"...scheduling of appointments would be changed to Klinik."* [5] *"We would love that the appointment would only be made by triage [with Klinik]."* [4]	
New activities	*"No directly new activities."* [6]	*"We did not need any new activities, no new personnel."* [9]	*"Digital Center, [...] we are talking about a single center where all the digital platforms will be managed."* [4]	*"Klinik will be more of an add on to the existing tasks."* [10]
Obsolete activities		*"Apparently there are no obsolete activities."* [9]	*"For now there will be no activities that become obsolete."* [5]	

Related to activities is the information perspective, which considers what information is provided to actors to perform activities. Generally, the diagnosis and urgency-level information regarding patients was considered to be more structured, and thus more useful for healthcare professionals. This is partly due to forcing patients to logically answer health-related questions with the help of an AI. According to informants, with this information, doctors can easier prepare for upcoming appointments by receiving a more structured understanding of patients' symptoms.

Portuguese informants highlighted a great deal of additional control information Klinik provides to both actors and stakeholders. First, the use of Klinik would provide information regarding how many of patients stop visiting Emergency Rooms (ER) when not necessary, how patients feel when they perform appointment bookings online without visiting their doctor, and how do patients seek medical help when they have similar symptoms later in

the future. All this information is useful for planning and coordinating treatment activities. Mexicans considered Klinik Pro to be ultimately an assistant in the daily tasks due to is the ability to provide more precise information that can be further utilized. Table 10 presents the quotations regarding the information perspective.

Table 10 - Information Perspective

Feature	Vantaa	FSHS	Portugal	Mexico
Provided information	*"Klinik helps patient to structure her symptoms which are printed in black and white. […] Doctor gets patient information through Klinik, and can better prepare for appointments."* [3] *"Information is compiled wisely and structurally."* [6]	*"Klinik diagnosis helps work, no need to ask again same questions."* [9]	*"If you think you are sick, there is nothing preventing you to go to the ER. And people come to hospitals for all different reasons (sore throats, cough etc.). We would like to see if with Klinik this can be improved in different units, because there is a way for us to see how many of these people go to another clinic and how many go to hospital, and we want to see if we can diminish that."* [4]	*"For public health sector, Klinik Pro creates digital health records […] for private sector, more accurate diagnoses. Klinik will be a partner for any clinician increasing the accuracy and prediction."* [10]

Finally, we will compare the process-step perspective that is also related to activities and information. As described in chapter 3.3, the DHI may touch single or multiple areas within the individual process. As Table 11 presents, Klinik Pro affects the overall knowledge regarding the medical condition of a patient, which is why this DHI touches and concerns the preparation stage in the process-step perspective.

Table 11 - Process-Step Perspective

Feature	Vantaa	FSHS	Portugal	Mexico
Process-step target	*"In acute cases, Klinik Pro directs*	*"Klinik Pro can direct patients to*		

to call to emergency." [6]	*self-treatment. Or then there is an acute case that suggests calling immediately to ER."* [9]		

"After Klinik's digital assessment, healthcare professionals perform triage." [8]

6.3 PROVE-IT - Outcomes

The observation of expected outcomes is divided into three categories: direct health outcomes, indirect health outcomes, and cost outcomes. As presented earlier, the value in healthcare is defined as a relation of health outcomes to cost outcomes (Porter, 2010). When the outcomes are not directly but indirectly related to health benefits, we consider them as indirect health outcomes or enablers. As informant provided limited information on cost outcomes, we do not separate them between direct and indirect costs.

The informants recognized many pertinent health outcomes. First, most of the informants emphasized Klinik Pro to result in the faster seeking of treatment and triage, thus causing shorter throughput times. This allows patients to get medical guidance to their diseases faster. We can perceive this to be a particularly important health outcome as the aging population increases the demand for treatment, thus presumably making queues longer (Howdon and Rice, 2015). Furthermore, an apparent health outcome is also the opportunity to improve productivity measured in the number of patient cases completed per resource unit.

Generally, Klinik Pro was seen as a tool to improve the overall quality of treatment. The quality can be understood here as a reduction on complications besides improved patient experience. This is especially vital during the time of aging populations, while the quality of treatment should also be maintained at least. Informants also raised that Klinik Pro could enable putting more effort on particularly mental and cardiovascular diseases.

What is more, informants highlighted a possible health outcome to be an increase in the number of recognized and treated sensitive diseases (e.g., mental or sexual). This was especially the outcome for cases of Vantaa and FSHS, in which they observed an increase in these diseases during the already completed Klinik Pro demonstrations.

As the implementation of Klinik Pro in Mexico is yet in the very planning stage, the health outcomes were not directly addressed by the informants other than mentioning broad statements about increased quality and speed. However, informants emphasized indirect

outcomes, from which it is possible to deduce the health outcomes as well. Table 12 illustrates the health outcome related quotations.

Table 12 - Expected Direct Health Outcomes

Feature	Vantaa	FSHS	Portugal	Mexico
Expected direct health outcomes	*"Intimate and mental things have been relatively more usual with Klinik. […] Overall quality has been improving."* [3] *"If Klinik frees workload, more time would be used for preventing cardiovascular diseases."* [6]	*"If we recognize mental issues early on before larger challenges, it affects the rest of the students' life! […] Mental diseases are on focus in FSHS strategy."* [9] *"Klinik form can be filled whenever patient wants. […] Diagnoses speed up the process."* [9]	*"For [medical] units themselves, if they manage patients better, they can give better care and appointments."* [4]	
	"Most important health outcomes are improvements in quality […], faster treatment process, […] and positive effect on health in general." [8]			

Although mechanisms, which will be covered later, explain the dynamics behind all outcomes, we also need to consider the indirect health outcomes, which account for several direct health outcomes. Table 13 illustrates these below. As described above, Klinik Pro results in the faster seeking of treatment and triage process. This a result of a decrease in waiting times on queues (physical or phone). Consequently, less time is spent on unnecessary waiting, which shortens the throughput time for patients. In turn, nurses and doctors will also encounter productivity improvements. Additionally, one of the informants mentioned the ability of digital supporting non-digital services. The idea is that patients using Klinik Pro free up the queues in phone calls or physical visits for those patients who are not using any digital services, thus resulting in reduced waiting times.

Another indirect outcome for improved productivity could be the decrease in patients visiting medical centers. Portuguese informants landed hopes that Klinik Pro would reduce the number of unnecessary and trivial contacts. Furthermore, with fewer people in medical centers, more time and effort can be spent on actual medical issues.

Informants also raised the indirect outcome of reduced workload. This results in increased productivity besides the possibility to put more effort into severe diseases. Another indirect outcome improving productivity concerns reduced stress levels. As nurses and secretaries need to respond less stressful calls while doctors can help mainly those patients who are actually in need of an appointment, productivity is affected positively.

An indirect health outcome supporting quality as a health outcome is a more structured understanding of a patient. The well-structured description of the patient's condition enables increased quality of treatment by using proper resources with a well-planned CPW. Thus, fewer complications and unnecessary activities can be accomplished.

Finally, FSHS considered Klinik Pro to have an impact on the government regarding the digitalization of healthcare services. This was also mentioned by Portuguese informants. In Mexico, Klinik Pro could disrupt the way government collects digital services and electronic health records. Even further, Klinik Pro implementation was thought to inspire to bring public and private players together to improve health services co-operatively. Thereby, we can consider an indirect outcome to be an impact on decision-makers that could result in further development and investments in health services, which affects patients positively.

Table 13 - Expected Indirect Health Outcomes

Feature	Vantaa	FSHS	Portugal	Mexico
Expected indirect health outcomes	*"Call queues will be shorter. […] Essential to give 24/7 access to treatment."* [6] *"Information is compiled wisely and structurally."* [6] *"Finally, there is a system to reduce stressing calls for nurses. […] Klinik might decrease workload but not necessarily."* [2]	*"Klinik may decrease workload…"* [9] *"FSHS may be the forerunner in developing digitalized health and social services."* [9]	*"We want to prove that a digital medical center is effective, it is possible, better, and with less time and other people. […] Doctors will benefit with less complications and less unnecessary appointments. Secretaries will have less people to see, and have more time to back-office work (there is a lot of it)."* [4]	*"Catapult to connect private incentives with public healthcare sector to do collaboration."* [10] *"Government looks for benefits of gathering data of different issues, statistics, and predictive analysis. Klinik supports in this, as there is no infrastructure and servers."* [10]
	"…more efficient triage process, 24/7 access for patients, saves professionals work." [8]			

Now, concerning the cost outcomes, informants did not generally consider any major costs resulting from implementing Klinik Pro except the service cots for the company itself. A few informants raised the costs stemming from changes as one cost factor. More specifically, these costs relate to such activities as changing processes, reallocating resources, and management of change in general. Moreover, another cost factor that was mentioned by the informants was all the activities to tender out service providers, which is obligatory in the public sector investments. Besides costs related to Klinik Pro, informants also raised a few cost-saving factors. Table 14 illustrates the quotations relating to cost outcomes.

Table 14 - Expected Cost Outcomes

Feature	Vantaa	FSHS	Portugal	Mexico
Expected cost outcomes	*"Indirect costs mainly."* [3] *"Contract fees, no need to perform additional acquisitions. Only service fee."* [6]	*"Service fee for using Klinik Pro. […] Other costs related to integration to authorization system."* [9]	*"Regional Health Administration want to reduce costs because they will pay for all of this [experiment with Klinik]."* [5] *"Not-urgent, 40% of all hospital admissions. We want to decrease that. Government would save a lot of money."* [4]	

Besides direct and indirect health and cost outcomes, there may be other outcomes not directly related to the three categories presented above. FSHS emphasized that the data gathered and analyzed by Klinik Pro could be beneficial for developing other services. Furthermore, the PROVE-IT does not directly ask for adverse outcomes or risks. However, during the data collecting process, these were perceived to be important additional questions to understand each case more thoroughly. Table 15 presents the risks gathered from the informants:

Table 15 - Recognized Risks

	Vantaa	FSHS	Portugal	Mexico
Highlighted risks	*"…number of calls didn't decrease in Myyrmäki but*	*"Patients might also call besides Klinik Pro, thus*		*"It must be affordable and prove value with*

using multiple channels might have an impact." [6] *"Cybersecurity could be a risk but there has been no issues so far."* [2]	*causing negative load."* [9] *"Public imago risk. Entire digitalization would take hit if cybersecurity fails. […] Also, a hacker could overload the servers."* [9]		*low costs. Cannot take too long."* [10]

"Klinik could direct patients incorrectly, technical risks (if the service does not work), public imago." [8]

6.4 Context-Intervention and Context-Mechanisms Relationships

After utilizing the PROVE-IT model to collect data from intervention, context, and outcomes, we are interested in their interdependent relationships to discover further mechanisms that explain the dynamics of Klinik Pro. There are two types of relationships we are particularly interested in. First, we will analyze how the context modifies the implementations of Klinik Pro. This is relevant to understand if the context even supports the proper use of the intervention to actualize any of the mechanisms. Second, our observation focuses on how the context modifies mechanisms. This is an important step to exclude those mechanisms that are not suitable in a given context. After performing the analysis of the two presented relationships, we can discover the actual mechanisms of Klinik Pro.

6.4.1 Context-Intervention Relationship

Beginning with the context-intervention relationship, we want to understand how the context in different cases affects the intervention and implementation of Klinik Pro. As we can recall from Table 5, the intervention and its functionality are very similar in each case. The main differences thus regard the implementation. First, in Portugal Klinik Pro is operated by exterior Digital Center which then transfers urgent cases to medical centers. In all other cases, Klinik Pro is operated directly within the medical centers. Second, in Vantaa and Portugal, the integration of Klinik Pro to the existing systems was not considered as much as in cases of FSHS and Mexican private players. Third, we can perceive differences in actors based on their legal permissions to perform diagnoses; in other cases excluding Portugal, nurses are more active on utilizing Klinik Pro, while in Portugal doctors are needed to perform diagnoses.

Furthermore, the actual problem Klinik Pro is solving is relatively different in each case. Klinik Pro supports stress management in Vantaa while for FSHS, it is a more efficient way of dealing with students besides gathering valuable data. In Portugal, Klinik Pro introduces a new digitalized triage system whereas in Mexico the DHI improves the efficiency but also acts as an example of collecting and managing electronic health records to analyze medical statistics of the public sector.

As a deduction, we can understand that the context modifies the implementation on four levels. First, the decision of centralizing or decentralizing the implementation may affect the dynamics of Klinik Pro. Second, whether the DHI is integrated into the existing systems could significantly affect the utilization of data. Third, there are legal differences between the cases accounting who can analyze and decide on gathered patient data on a professional level. Finally, a major contextual factor regards the available patient information infrastructure, which is vital for a successful implementation of Klinik Pro.

6.4.2 Context-Mechanisms Relationship

Now, moving on to the context-mechanisms relationship, we need to consider how the context modifies mechanisms in any of the cases. We will perform the analysis by considering each contextual perspective. Beginning with the patient journey, Klinik Pro is meant to support already existing processes of seeking of treatment and triage in the cases of Vantaa, FSHS, and Mexico (Table 7). In turn, Klinik Pro introduces a new practice in Portugal, where the triage process is completely non-existent (Table 7). Thus, the adoption of this new practice affects the activation of any mechanisms.

The second perspective on context is the actor and stakeholder perspective. Due to the utilization of self-reporting patients, Klinik Pro clearly activates the co-creation healthcare mechanism. The constraint in the actor perspective could be the lack of skill or motivation to use the DHI. This is especially important in Portugal. We will examine whether this is the case in the next chapter.

The third perspective concerns activities. Informants did not consider Klinik Pro to remove or create activities (Table 9). Mainly, the use of Klinik Pro requires a rearrangement among the existing tasks to have time for using the DHI. Finnish informants emphasized the risk of patients using existing channels besides Klinik Pro (e.g., call or physical visits), which could practically constrain the demand management mechanism due to uncontrolled demand spike in patient contact inquiries. This could be the case in other cases as well.

Moving on to information perspective, the informants clearly emphasized Klinik Pro to provide useful information and analysis regarding patients' condition (Table 10). Regarding

the clinical decision-making based on this information, the AI of Klinik Pro could be considered to activate the evidence-based medicine mechanism as it provides an initial diagnosis. However, many of the informants emphasized that the AI is not yet sophisticated enough to provide accurate diagnoses besides being prone to a few errors. Thereby, due to missing of scientifically proven nearly optimal diagnoses, the evidence-based mechanism is not activated by Klinik Pro. However, as the AI is yet on a relatively early technological stage, this mechanism is likely to be activated as the technology of the DHI improves. Moreover, Klinik Pro introduces the management of electronic health records for Mexican public care. The extent of its adaptability to the existing infrastructure could constrain the activation of mechanisms.

Finally, the process-step perspective of Klinik Pro focuses on setup, thus focusing on planning the CPW for patients. Generally, this is similar to the first contextual perspective. Primarily, this is critical in Portugal due to the missing triage process.

As a conclusion, we can observe that in each context main constrains to mechanisms concern evidence-based medicine and demand management. A few healthcare mechanisms may not be actualized depending on the tide of events. In Portugal, Klinik Pro introduces a new practice, which means that the willingness of people to adopt it determines the activation of any mechanisms. We will explore this in the next chapter. In turn, the ability to manage electronic health records in Mexico constrains the ability to integrate information effectively.

6.5 PROVE-IT - Mechanisms

In this final chapter, we will dive deeper into mechanisms. We will first consider the three mechanisms of the intervention. Second, we will examine the three defining conditions for action. Finally, we will explore the typical healthcare mechanisms that are apparent in each case using the understanding from our previous findings. It is noteworthy that while indirect health outcomes may lead to direct health outcomes as enablers, they also act as mechanisms due to causing other outcomes to occur. As we have covered them in chapter 6.3, we do not concentrate on them in this section.

Intervention Mechanisms

Beginning with the precision mechanism of the intervention, it is relatively distinct that all informants found Klinik Pro to increase the precision (Table 6 and Table 10), which is also a typical characteristic of any DHI as described in chapter 3.3. Regarding the second intervention mechanism of performing data collection and analyzing cost-effectively, it is rather apparent that Klinik Pro addresses this as the utilization of patient's self-reported

data besides the initial analysis by AI require none to very few resources from medical centers, thus minimizing costs. Finally, regarding DHIs' ability to break time and location boundaries, many informants emphasized this to be the case as well with Klinik Pro (Table 6). The intervention mechanisms influence the purposeful action, which will be covered next.

Context Mechanisms

In this section, we will observe the context-related mechanisms, which are the prerequisites for purposeful action. Beginning with the "can do" condition, the informants did consider Klinik Pro to provide a few new capabilities. Although being a rather easy-to-use software, Klinik Healthcare Solutions arranged training sessions for healthcare professionals to give them competences to use the software. Informants from Vantaa gave a thought of Klinik Pro's AI to improve the capabilities of nurses and doctors to learn to recognize patients' symptoms in novel ways. Furthermore, the informants emphasized the possibility of AI to develop more efficient methods to plan CPWs. FSHS emphasized the capability of developing new services with the collected data. In Portugal, Klinik Pro introduces a new practice, thus providing a new capability in the form of digital triage. In Mexico, Klinik Pro provides competencies for public healthcare to manage electronic health records.

Considering the patient side, informants highlighted Klinik Pro to not only teach patients about diseases and symptoms but also enable lower threshold to seek medical assistance in more sensitive diseases such as mental issues or sexually transmitted diseases as described in chapter 6.3. This occurs due to the anonymity of the user interface. Table 16 presents the quotations regarding "can do" prerequisites.

Table 16 - Can Do Perquisites

Prerequisite	Vantaa	FSHS	Portugal	Mexico
Can do	*"Initial training sessions were organized. Generally the software is easy to assimilate."* [2] *"Klinik AI might teach nurses to see diagnoses from new perspective. […] It is possible that planning*	*"Klinik trained the personnel by showing the practicalities."* [9] *"Klinik Pro AI gathers interesting data to develop other services."* [9]	*"The main problem, there is no triage. No matter what is the issue, you get the appointment. […] We would like to see if with Klinik this can be improved in different units."* [4]	*"Klinik Pro's functionality can be disrupting as a way for public healthcare to start running digital data on servers."* [10]

CPWs gets more efficient with the AI." [6]		*"First thing that will be generated, is the amount of progress to consultation and amount people are waiting."* [5]	

The second defining condition is the "know what to do", the control information that is derived from the increase in information precision and well-structured display. Table 17 below illustrates the relating quotations. As mentioned previously, informants highlighted Klinik Pro to provide more detailed and structured information on patient's symptoms, which supports more precise and personalized care plans. Additionally, Klinik Pro helps to understand how Portuguese patients relate to online triage and booking system besides the knowledge of the waiting times to get treatment. Similarly, other informants considered Klinik Pro to provide insightful knowledge on patients' behavior of seeking and contacting medical professionals. Interestingly, there were differences between the hours of using the service among various patient groups. According to FSHS, students tended to use Klinik service during the evening while patients in Vantaa scheduled their use of the service to the small hours. Furthermore, with Klinik FSHS learned whether patients preferred mobile or desktop UI.

The "know what to do" mechanism also works on the patient side by improving their understanding of diseases and providing guidelines when self-care is possible. This was especially the case in Portugal where health literacy is a mechanism to reduce the number of unnecessary contacts. In Mexico, the informant described Klinik Pro to visualize and improve the understanding of problems in healthcare with increased precision.

Table 17 - Know What to Do Prerequisites

Prerequisite	Vantaa	FSHS	Portugal	Mexico
Know what to do	*"Information is compiled wisely and structurally."* [6] *"In Vantaa, people had a tendency to use Klinik Pro in the small hours.*	*"There is a tendency to use the software during the evening on average."* [9] *"Receive information with what kind of*	*"With information we gain from Klinik […] we can do some activities to improve general knowledge and diminish the illiteracy of patients."* [4]	*"Klinik provides digital triage and also gives visuals to the problem. In the public healthcare they have their timings of waiting times, ER, they have estimation but*

	Perhaps the idea was to use the software before the actual reception." [9]	*devices people use Klinik. Surprisingly more desktop than mobile users although we had assumption that default user would be mobile."* [9]	*"We want to see how many people see their doctors, how many people stop going to ER because they don't have a medical appointment, how comfortable people feel when they don't see physically managing their case, and how comfortable they feel for future cases when have same symptoms."* [4]	*no actual visual data of these inputs while private already has it somewhat."* [10]

The third defining condition, "want to do", concerns the motivation to use the DHI. All the informants raised the ease of use, which along with the personnel's openness to using Klinik Pro ensured relatively high motivation and engagement to their work. Although we have no data regarding patients' motivation, Finnish informants described that patients were also motivated to use the DHI during its demonstration phase. Table 18 describes the quotations regarding "want to do" condition.

Table 18 - Want to Do Prerequisites

Prerequisite	**Vantaa**	**FSHS**	**Portugal**	**Mexico**
Want to do	*"Klinik has increased job satisfaction, nurses are very motivated to use it. Managers never need to ask who responds Klinik contact requests."* [6] *"It has remarkably engaged nurses to their tasks."* [3]	*"Acceptance to use Klinik Pro has been positive among nurses and patients."* [9]	*"Doctors will be happier to see patients who are in fact sick and can manage schedules better to patients."* [5] *"When people see it [online booking] is working, they start using it. I work at countryside, and strangely I have*	

			lots of people who don't know how to read but they have family members who make appointments to them. That's why we see Klinik would be interested in, people could fill the form for their relatives." [4]

Healthcare Mechanisms

Next, we will proceed to the actual healthcare mechanisms presented in chapter 3.3. While data regarding the intervention and its mechanisms, the context and its respective mechanisms, as well as the outcomes, are all possible to collect from informants, the healthcare mechanisms are different in nature. During the data collection phase, it appeared challenging for informants to think of healthcare mechanisms without a clear understanding of the theoretical background. As a result, the discovery of healthcare mechanisms needs to be deduced based on the collected data.

Generally, we can deduce that healthcare mechanisms rely mainly on three factors. First, both intervention and context related mechanisms act as enablers of healthcare mechanisms. From these mechanisms the essential part regards the adaptability among actors to ensure their capabilities and willingness to use Klinik Pro in the first place to activate any further mechanisms. Second, the ability to manage the information collected and analyzed by Klinik Pro is another necessity to achieve efficiency improvements. Third, Klinik Pro introducing a new channel to the existing ones might also cause the negative impact that needs to be taken into account.

The first healthcare mechanism recognized in all cases is the co-creation. It is the foundation for all the other healthcare mechanisms. If users of Klinik Pro have willingness and capabilities to use the software, co-creation is activated. This is relatively self-explanatory due to a patient's active role in self-reporting his or her symptoms to the AI, which is then utilized by nurses and doctors (Table 6). This was seen beneficial as it leads to more structured patient stories besides increasing the ability to provide information more openly regarding sensitive diseases as described earlier. Although we have no data from patients, many of the informants emphasized that both patients and healthcare

professionals were willing to use the software or had experience of using similar tools earlier.

The second mechanism at least partially responsible for Klinik Pro's outcomes is proper timing. As the AI processes the data by providing an urgency analysis initializing the CPW for the patient, especially urgent cases get the signal to contact ER immediately, thus ensuring proper timing for them to be treated as soon as possible (Table 11). From the operations management point of view, Klinik Pro does not generally ensure optimal timing of arrivals as patients need first to use the service. However, Klinik Pro supports the scheduling and routing of patients assuming the data is managed correctly. This is likely to be the situation in Finnish cases, whereas in Mexico, the low level IT infrastructure may hinder proper scheduling and directing of patient-related activities. In turn, the decentralized Digital Center in Portugal may be a barrier to this. Generally, informants emphasized in Table 12 an opportunity of ensuring proper timing for sensitive diseases if patients are directed to the treatment as early as possible due to the lower threshold to seek help. As a conclusion, proper timing is likely to be apparent in Finnish cases whereas we will consider it more of a question mark for Portugal and Mexico.

As described in chapter 6.3, Klinik Pro improves productivity and results in lower waiting and throughput times. These are results of improved efficiency, which can be explained with three mechanisms: integration, coordination, and proper competence level. These mechanisms can be perceived as a black box in a sense that it is difficult to interpret which of the mechanisms actually causes specific outcomes even we aim to analyze them separately. Beginning with the integration, an apparent mechanism in Klinik Pro caused by the increase in precision of information which is then brought together. The DHI brings together the patient's reported symptoms, the diagnosis and urgency analysis performed by AI besides the contact information and booking of appointments. As all these essential parts affecting the planning of CPWs are compiled together, it is possible to plan and implement treatment more effectively with optimal resources unless the complexity and integration of other systems within medical centers diminish these benefits (Goodhue et al., 2019). Finnish informants desired even further integration of Klinik Pro to existing systems used in medical centers (such as to Apotti in Vantaa). In turn, the activation of integration in Mexico is dependent on the IT infrastructure, which is yet under development in the public sector. Regarding Mexican private sector, integration is more comfortable to accomplish due to existing infrastructure. Concerning the case Portugal, Klinik Pro implementation is decentralized, which might cause challenges to integrating information effectively. Thus, for Mexico and Portugal, we consider integration as a question mark.

Coordination is the second mechanism for improving efficiency. It can be perceived in all cases due to similar reasoning. As Klinik Pro produces more detailed information to design more comprehensive treatment plans, coordination is the following mechanism to allocate resources and implement treatment effectively. Coordination comprises more effective resource allocation, including work-flow management and work-time utilization. As a result, productivity might increase, which allows putting more effort into severe diseases.

Finally, with proper competence level, as also presented in the previous study (Tenhunen et al., 2018) concerning Klinik's solution, Klinik Pro makes it possible to utilize the lowest sufficient level of competence to create cost savings. This is likely to be the case as well in the rest of Vantaa's medical centers. For FSHS we can expect a similar effect as it performs under the same healthcare system with similar dynamics as Vantaa medical centers. As Portuguese informants emphasized in Table 6, Klinik Pro helps to diminish the use of doctor on unnecessary appointments by exploiting diagnosis and urgency analysis of Klinik Pro instead. Regarding Mexico, Klinik Pro enables more extensive use of electronic health records, which has been proven to create cost savings (Wang et al., 2002). Together with coordination, proper competence level results in utilizing Klinik Pro to act as a contact point for patients, which results in utilizing less healthcare personnel with stressful calls. Thus, stress levels can be reduced, which enables an increase in productivity.

As described in Table 6 and Table 13, Klinik Pro allows more controlled contacting and directing possibilities for healthcare professionals, thus ensuring tools for demand management to reduce the workload of contacting patients. Especially in the case of Portugal and Mexico, Klinik Pro would act as a tool to control overcapacity in medical centers (Table 10). However, in the cases of Vantaa and FSHS informants highlighted a possibility that the intervention could also be just an additional channel besides the existing ones resulting in uncontrollable demand in terms of volume and timing. As this is possible in all cases, we will consider demand management as a question mark as we are not sure of its outcomes. To sum up all the findings, Figure 16 below illustrates all recognized healthcare mechanisms of each case. Question marks indicate an unclear connection.

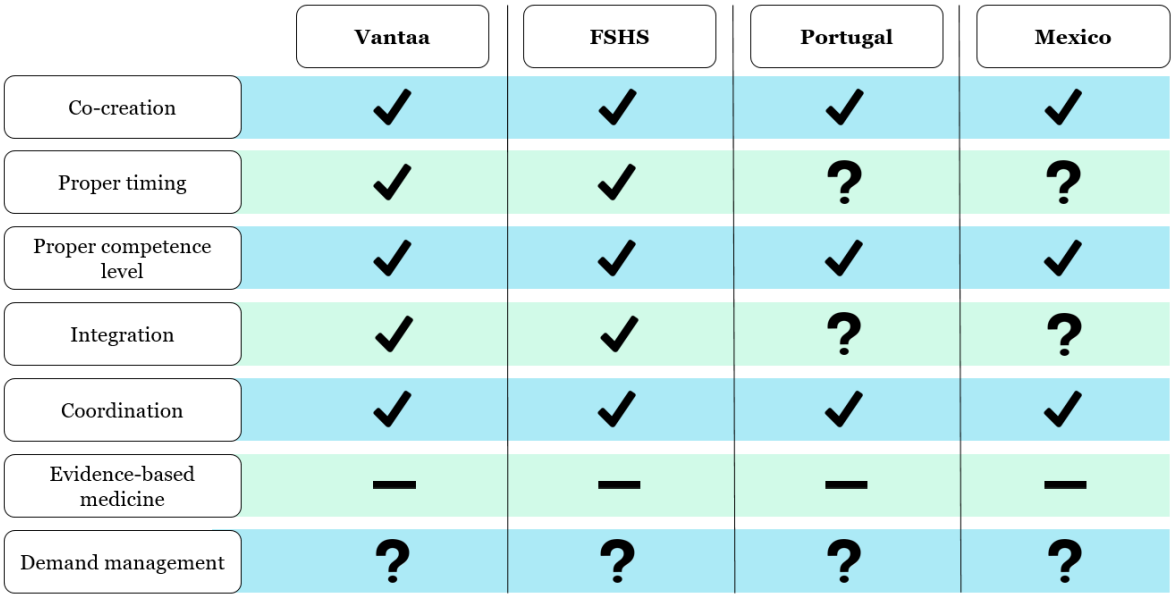

Figure 16 - Healthcare Mechanisms of Klinik Pro

As we can see from Figure 16, the healthcare mechanisms are interestingly similar for all cases. Although the contextual environments vary, these findings show that Klinik Pro acts very similarly in all cases regardless of the environment. However, it is worth mentioning that healthcare mechanisms are relatively general in terms. Thus, it is no wonder that they are similarly present in each case. It is also vital to notice that the reasons whether a mechanism is activated may vary significantly. In Mexico, the low-level infrastructure of patient records of public care may hinder the activation of integration, whereas in Portugal, the decentralization may be the root cause. Thereby, the discovery of mechanisms needs to be performed on a very detailed level by opening the smallest black box in each case. Another observation is that the magnitude these mechanisms affect outcomes is unknown. To understand this, we need to determine metrics to be measured as presented later in chapter 7.2. Finally, the activation of mechanisms relies mainly on the adoption of the DHI among its users. Thus, it is very much dependent on the healthcare organizations and patients how much Klinik Pro is utilized.

To conclude, we have used the PROVE-IT model to understand the value formulation of Klinik Pro in several market expansion cases. The CIMO-configuration supports the perception of how the DHI creates value by structuring it into four logical segments. Generally, PROVE-IT model is a useful model for understanding the expected outcomes and, more importantly, why a DHI could produce them in a given context with certain mechanisms. This knowledge forms the fundamental base for determining the value of a DHI that can be then further quantified and tested empirically. In the following chapter, we will discuss our findings and draw conclusions.

7 Discussion

In this chapter, we will utilize our findings to address the research questions. We will begin by concluding our first research question by presenting entire PROVE-IT configurations for each case indicating the discovered mechanisms that can cause expected outcomes. Next, we will address our second research question by analyzing the previously constructed configurations to understand the evidence that is needed to test the mechanism-outcome relationships in reality. Our discussion then continues to the third research question of developing the model in general. After responding to the research questions, our focus progresses to both theoretical and managerial implications of this thesis. Finally, we will discuss the limitations of this study besides addressing the suggestions for future research possibilities.

7.1 PROVE-IT Configurations

In this section, we will recapitulate the findings from the previous section to present the entire PROVE-IT configuration for each case. The PROVE-IT configurations summarize the value formulation of Klinik Pro. These configurations will be then utilized later to discuss the evidence gathering requirements to prove the value formulation.

Vantaa

In Vantaa, the implementation of Klinik Pro ultimately aims to reduce stress levels among nurses. The key benefits stem from the intervention mechanisms of Klinik Pro breaking time-location limitations besides improving the precision of information. These are the key factors influencing all the rest of the mechanisms.

The earlier demonstration in Myyrmäki provided positive expectations of patients and nurses adopting Klinik Pro, thus activating the co-creation mechanism. Klinik Pro then produces well-structured data of patients' conditions. With this information, we can expect medical centers to be able to integrate it to other systems leading to utilization of coordination and proper competence level. As a result, Klinik Pro improves productivity and quality of care. Patients are directed to use Klinik Pro, which allows nurses to focus more on treatment activities and avoid stressful calls.

We can perceive proper timing is likely to be activated regarding the scheduling and routing due to functional IT infrastructure and centralized management. In turn, demand management mechanism is a question mark in Vantaa as Klinik Pro could be only seen as an additional channel besides the existing (call or physical visits), thus leading to an overload of capacity to contact patients. The evidence-based medicine is not considered to be active due to the early stage of the DHI. However, it is likely that once the AI is developed

further, the accuracy of diagnoses might lead to the activation of this mechanism. Figure 17 presents the PROVE-IT configuration[3] for Vantaa below.

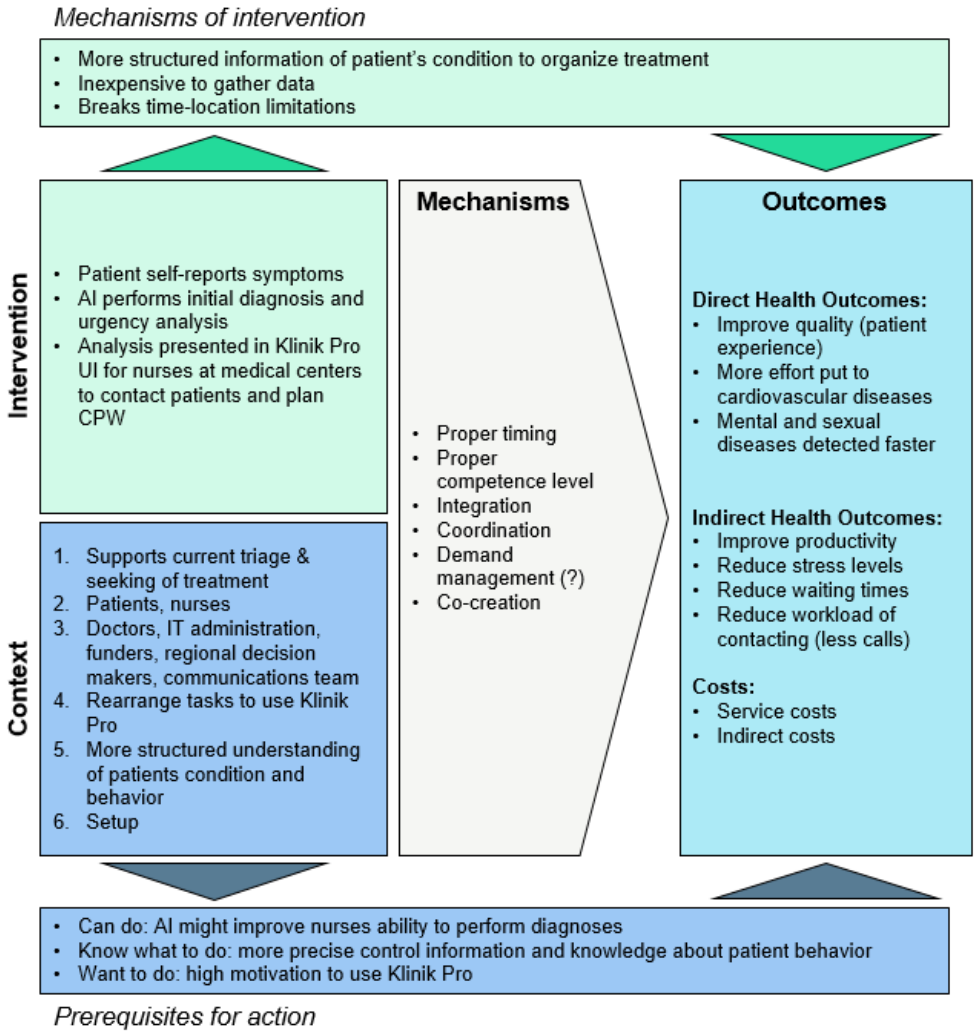

Figure 17 - PROVE-IT Configuration for Vantaa

FSHS

Next, moving on to case FSHS, Klinik Pro provides tools for the efficient handling of numerous students. Similar to Vantaa, intervention mechanisms act as a base for all the other mechanisms.

The earlier demonstration of Klinik Pro provided positive signs of actors adopting the use of service, thus activating co-creation. Informants found Klinik Pro to improve efficiency,

[3] Numbering in context indicates respective contextual perspectives: *1. Patient journey 2. Actors 3. Other stakeholders 4. Activities 5. Information 6. Step-process*

which is a result of integration to the existing systems, coordination of activities, and proper competence level.

FSHS emphasizes the treatment of sensitive, particularly mental, diseases in their strategy as these are common health issues among students. Proper timing mechanism is likely to be activated due to the same reasons than in Vantaa. However, the demand management mechanism is considered a question mark due to a possibility of resulting in an uncontrolled demand as Klinik Pro can be perceived just as an additional channel to seek treatment. Similar to Vantaa, evidence-based medicine is not considered being active due to same reasons. Figure 18 illustrates the PROVE-IT configuration for FSHS:

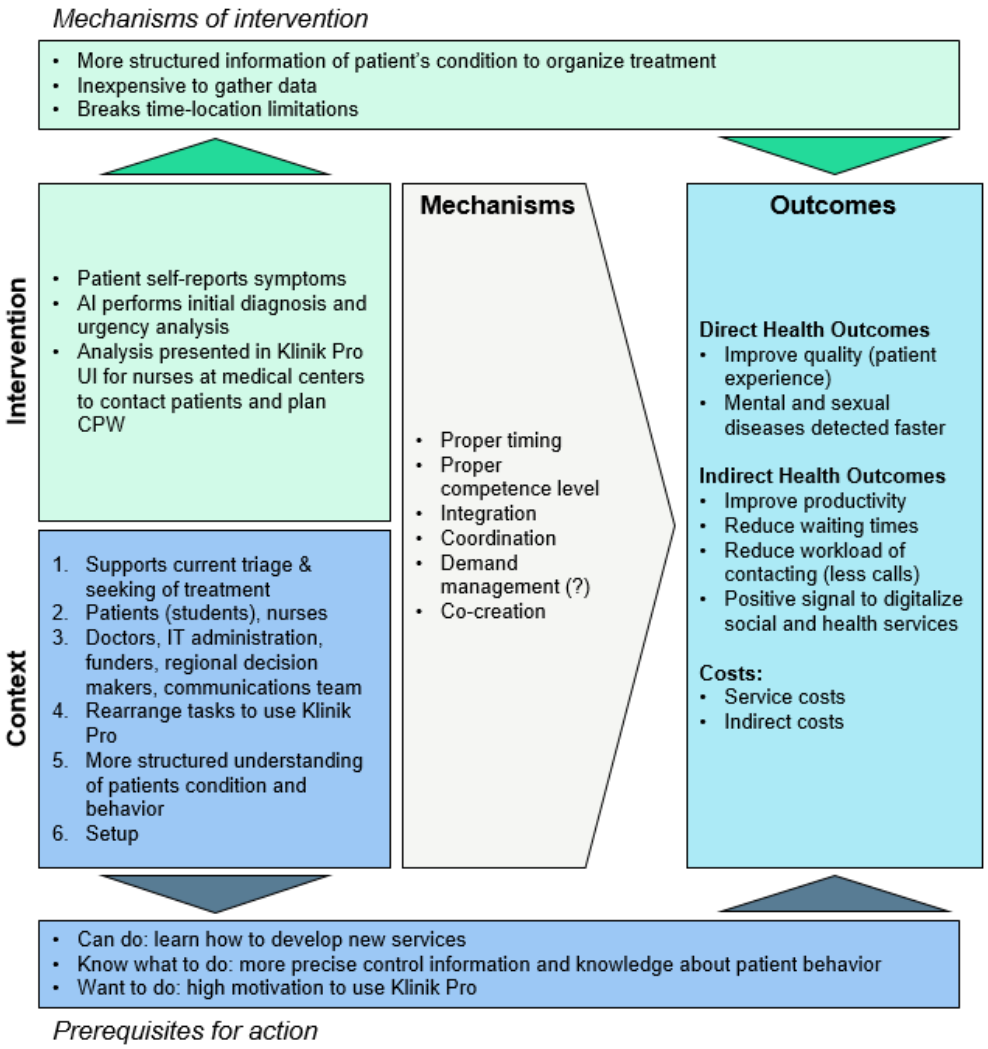

Figure 18 - PROVE-IT Configuration for FSHS

Portugal

Our third case concerns the implementation in Portugal illustrated in Figure 19. The situation there differs from Finnish cases due to a non-existent triage system. Thereby,

Klinik Pro is a way to implement it digitally. Once again, the intervention and context mechanisms act as crucial factors for activating other mechanisms. Notably, the adoption of Klinik Pro among users is a critical factor.

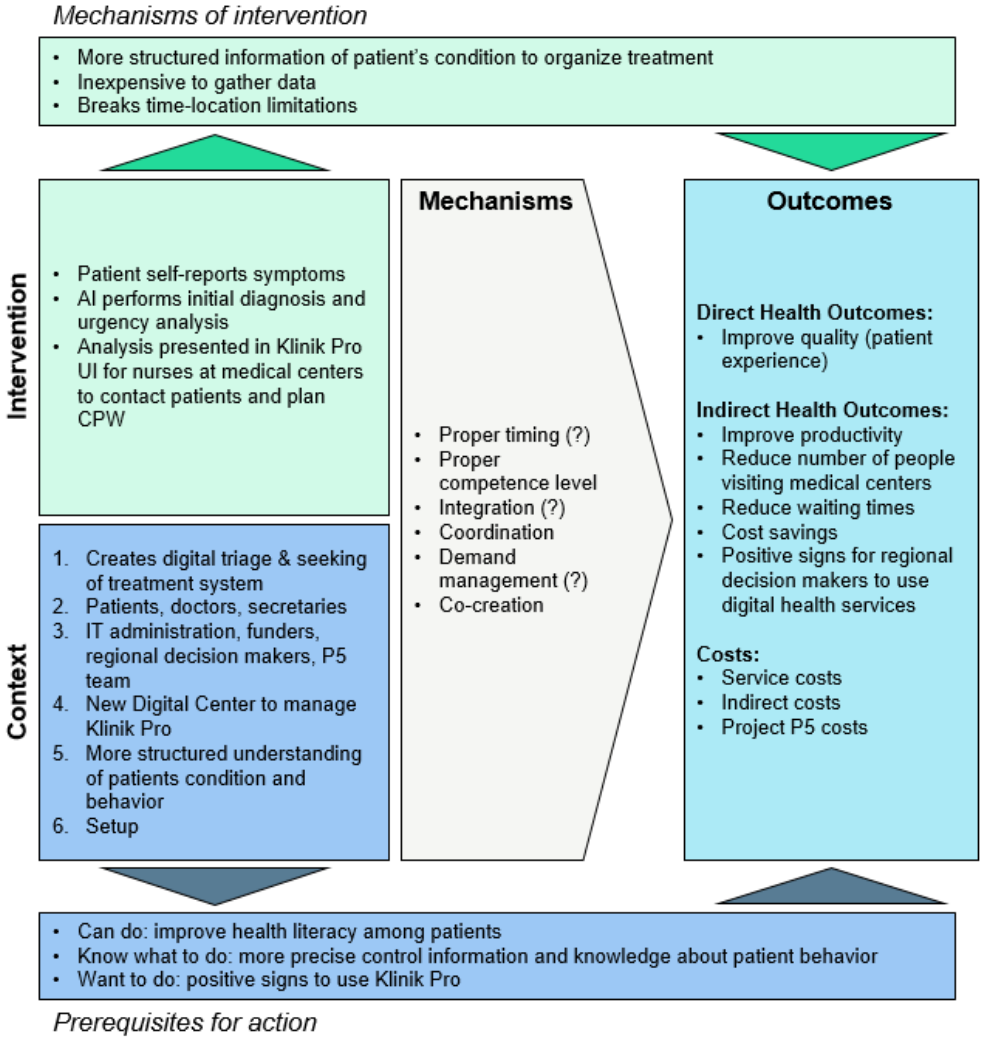

Figure 19 - PROVE-IT Configuration for Portugal

Klinik Pro can be expected to reduce the number of people visiting medical centers due to improved demand management. As the DHI increases the health literacy among patients, this leads to less unnecessary visits to medical centers besides decreasing waiting times to treatment. However, as with Finnish cases, we might perceive the channel-effect of people utilizing Klinik Pro just as an additional channel to seek treatment. Due to this uncertainty, we consider demand management as a question mark.

With the expected increase in efficiency, Klinik Pro could result in cost savings that were expected by the informants. Additionally, successful implementation of Klink Pro might result in a positive sign for the government of utilizing digital tools in terms of healthcare.

As the DHI is implemented in a decentralized way, it is a question whether the integration of information or proper timing of routing and scheduling can be adequately proven.

Mexico

Finally, Figure 20 illustrates the PROVE-IT configuration for Mexico. Klinik Pro provides different solutions for public and private players. For the public sector, the DHI aims to establish a manageable way to create and analyze electronic health records, whereas, for the private medical centers, Klinik Pro is a supporting tool to improve efficiency.

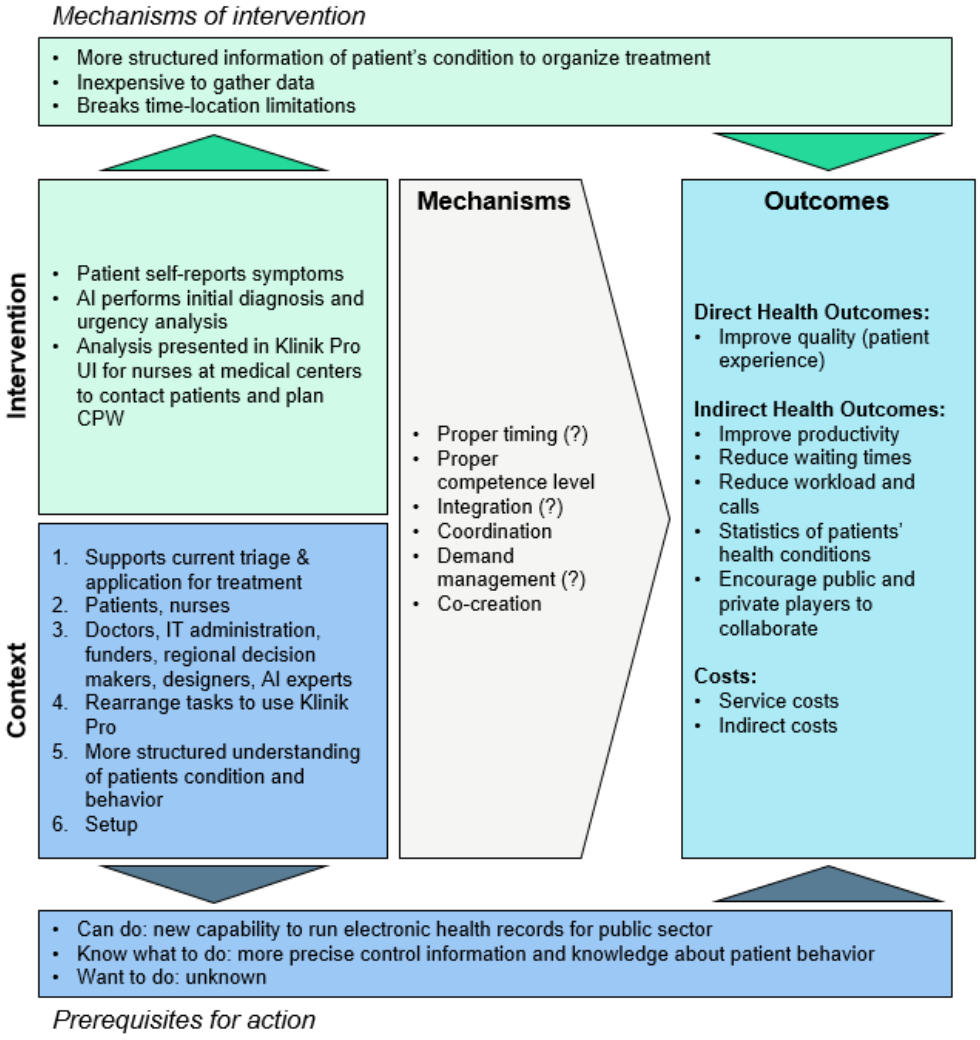

Figure 20 - PROVE-IT configuration for Mexico

Klinik Pro creates new capabilities to manage and analyze data for public medical centers. The adoption of the DHI is the critical success factor. The activation of integration is a question mark for the public sector as the infrastructure of patient data is on a rather low level whereas for private sector it seems to be more likely.

The efficiency improvements stemming from integration, coordination, and proper competence level are expected to lead to cost savings and better quality of treatment while also addressing the overloaded medical centers. Furthermore, Klinik Pro can encourage the public sector to act more actively with private sectors.

Similarly to earlier cases, proper timing and demand management are question marks. Proper timing of routing and scheduling patients requires functional IT infrastructure which can be questioned in Mexico. In turn, demand management may be uncontrollable if Klinik Pro is utilized as an extra channel besides the physical visits to medical centers.

Conclusion

As we can perceive, the functionality of Klinik Pro is similar in all cases despite contextual differences. While there are similar mechanisms, the different intentions and priorities among stakeholders result in diverse outcomes responding to the actual problems Klinik Pro aims to solve. Thus, the same DHI can be used for very different purposes.

By analyzing and comparing each case, it is possible to discover general patterns in Klinik Pro's functionality to understand its value formulation on a more general level. In short, Klinik Pro's ability to function correctly relies on the co-creation mechanisms to engage patients to report their symptoms to a digital system. Consequently, the practices regarding triage (e.g., whether it even exists) and the existing IT-infrastructure are the critical factors. As perceived above, any issues with these factors result in uncertain activation of any healthcare mechanisms (Figure 19 and Figure 20).

Depending on the willingness of actors, Klinik Pro produces a more precise understanding of the patient's condition, which forms a foundation for a better access, planning, and implementation of treatment. Klinik Pro improves not only the knowledge of the patient and healthcare professionals but also enables optimization of resources, thus leading to potential costs savings, enhanced productivity, and improved quality of care. Consequently, more effort can be put to actual tasks. This is the value that decision-makers are looking for. Additionally, Klinik Pro could even provide new competences for its users. However, a critical factor in realizing all the mechanisms rely on the users' adaptability and willingness to use Klinik Pro in the first place. Figure 21 illustrates this value creation process of Klinik Pro on the general level below:

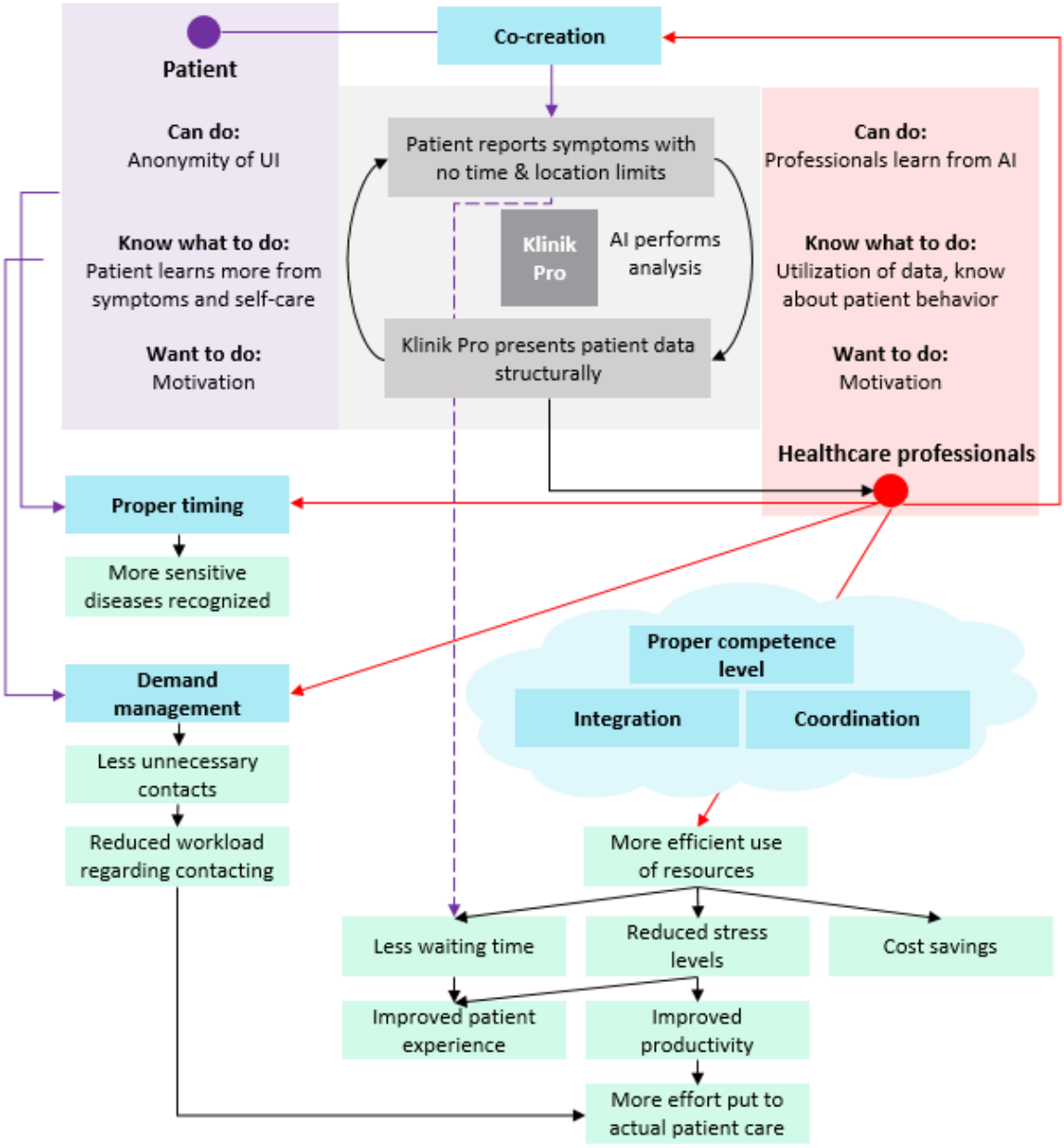

Figure 21 - Klinik Pro Value Formulation on the General Level

In the figure above, the purple color indicates patient while the red color illustrates healthcare professionals. Klinik Pro and its activity is described with gray. Healthcare mechanisms are illustrated with blue while the outcomes are highlighted with green. The arrow indicate the interdependent relationships between the factors.

7.2 Testing of Mechanism-Outcome Relationships

In this section, we will consider the testing of mechanism-outcome relationships to answer the second research question. More specifically, we will explore the evidence that needs to be gathered in each case to show the value realization by Klinik Pro. Thus, the evidence-gathering is the following step after constructing the value formulation with the PROVE-IT

model. What follows is the utilization of earlier perceived mechanisms to deduce relevant phenomena that encounter variation due to Klinik Pro. Additionally, we need to determine quantified metrics to measure these factors. We will begin with the shared evidence gathering needs and then proceed to the case-specific ones. To support deduction, we will also exploit the previously presented evaluation models to ensure broader and more comprehensive viewing angle to the evaluation of suitable measures (Murray et al., 2016; World Health Organization, 2016).

Shared Evidence Gathering Needs

For all cases, there are several common mechanism-outcome relationships that are presented first to avoid repetition in each case later. First, as marked in Figure 21, the co-creation mechanism is the fundamental starting point for all other outcomes as Klinik Pro relies solely on patient's self-reporting to accomplish any further activities. If it is not activated, none of the other mechanisms are active either. As the name co-creation implies, also the other side of actors, that is healthcare professionals, need to have the willingness and capabilities to use the DHI to activate any further mechanisms.

Besides activating all other mechanisms, co-creation leads to better access to seek treatment. As mentioned earlier, this is not only due to breaking the time and location boundaries but also due to providing an additional channel alongside the existing calls and physical visits. Better access was perceived as more flexible use of the service. This can be measured with user satisfaction queries, for instance, to measure functionality, usability, acceptability ("want to do"), and accessibility of the DHI (Bertot et al., 2006; Murray et al., 2016). These metrics regard all actors who are using the DHI. Additionally, we are interested to define the potential of even using Klinik Pro as a channel for seeking treatment. Thus, we can measure the availability of whether the service is available around the clock besides response times of contact requests toward healthcare professionals. If the response times are, say, very long, the chances are rather minimal that patients begin to utilize Klinik Pro as the channel of choice to seek treatment.

Another common outcome that is caused directly by co-creation and "know what to do" is improved precision in information among actors. Although it also acts as an enabling mechanism for other outcomes, we can also measure it as an outcome itself. The improved precision of information appears as an accuracy of diagnostic processes and precision in patient's root cause to seek treatment in the first place. The former can be measured with the number of errors made, particularly regarding the urgency analysis performed by the AI. Also, the number of revisits to the medical centers is a metric that can exploited. The precision in patient's root cause to seek treatment can be measured based on the structural

consistency and clarity of reported symptoms. These are particularly important to measure as they affect the extent of how well Klinik Pro can be utilized in the diagnoses and urgency-analyses.

A generally perceived mechanism of Klinik Pro was demand management. As described in chapter 3.3, it is a mechanism to control volumes and timing of patients seeking treatment and direct them to correct contact points. This, together with the better access of treatment account how well the workload caused by the contact inquiries can be controlled with given resources. As a result, informants emphasized the possibility of decreasing the number of unnecessary contacts caused by patients excessively calling or visiting medical centers. To test this relationship of demand management and better access leading to reduced workload, we can emphasize several factors. We are mainly interested in how the utilization of each contact point changes. This can be measured by analyzing how many users are actually using Klinik Pro, how many stop calling or visiting physically, and how many will use multiple channels. Another factor is that encounter variation is the workload of contacting and performing triage processes. A suitable metric could be the change in the working hours that are spent on the tasks related to seeking of treatment and triage when Klinik Pro is in use besides benchmarking the average workload on these activities to those medical centers that are not using Klinik Pro (Aaltonen-Määttä, 2019).

The latter part of demand management regards how optimally patients can be directed to treatment with the least amount of unnecessary visits and activities in the patient episode. It regards performing sufficient activities that match with the patient's urgency level (Lillrank, 2018). This is basically what Klinik Pro does in its urgency-analysis. We can test how many contact points were used in getting the patient to treatment and how well the urgency analysis by AI was utilized. Especially, it would be useful to benchmark these results to the average results before using Klinik Pro or to medical centers that are not using Klinik Pro at all.

Furthermore, three interdependent mechanisms were all present in all cases. These are integration, coordination, and proper competence level. These all are resulting mechanisms of improved precision of information among users of Klinik Pro. As an outcome, all three mechanisms result in more efficient use of resources, cost savings, and productivity improvements.

To test integration, we can measure the utilization of information gathered and analyzed by Klinik Pro in relation to the other knowledge. For instance, we may ask how much faster and more accurate performing of diagnoses and planning of treatment become with Klinik Pro. Thus, the relevant metric is the amount of potentially relevant information that can be

utilized to make a clinical decision. Generally, benchmarking these metrics to other medical centers with no Klinik Pro could produce a useful comparison. Also, before and after comparison might be possible to utilize. Furthermore, rating the level of integration and adaptability of Klinik Pro to the existing systems is an important factor to understand how well the DHI can be utilized for other systems. This can be measured with metrics such as consistency of integrated information besides the adaptability to other systems.

Coordination regards to the efficient management and utilization of resources. While there are multiple metrics on evaluating the performance of human resources (Fitz-Enz, 2009), we will present only a few key factors. First, Klinik Pro changes the utilization of each resource in the seeking of treatment and triage processes. The utilization ratio defines how much each resource was utilized in a given time frame (Modig and Åhlström, 2016). Thus, we can measure the time spent on actual tasks in relation to all the tasks and waiting that occurred. The second phenomenon Klinik Pro affects is the duration of diagnostic process. A suitable metric suggested by Modig and Åhlström (2016) is the flow efficiency. It can be measured by how much time in total a patient spent on seeking of treatment and triage activities and what percentage of that time was spent on actually value-adding activities (e.g., not queueing). Additionally, we could calculate the throughput time regarding the entire process from contacting to receiving diagnostic decision. Further, Bush (2019) suggests utilizing Lean philosophy in general in measuring the number of waste in healthcare. Therefore, it would be essential to measure how much processes can be improved due to Klinik Pro by considering mainly which activities produce value and is it possible to remove any unnecessary and non-value adding processes due to the DHI.

The third mechanism, proper competence level ensures the utilization of the least sufficient resource. This mechanisms thus regards the total service costs. One way to measure this is to analyze utilization and costs of different types of contacts (phone calls, Klinik Pro, physical appointments) (Tenhunen et al., 2018). Besides potential cost savings, with a proper competence level medical centers can more efficiently use their resources (e.g., a nurse can spend more time on curing than being in phone unnecessarily), thus reducing unnecessary activities, which further enables to put more effort on actual tasks.

The efficiency and productivity improvements together with the outcomes of demand management, the entire process of seeking of treatment and triage is faster and thus more pleasant to patients. Thereby, the outcomes that can be perceived from the patient's perspective are reduced waiting times and improved experience of diagnostic processes. Reduced waiting times appear as a change in the duration of the whole process or as a time

spent on queueing. As mentioned above, the flow efficiency ratio could be a suitable metric (Modig and Åhlström, 2016). Also, we could just simply calculate the total waiting time.

Regarding improved patient experience and satisfaction, it is possible to use surveys, before-and-after observations, or even Randomized Controlled Trials (RCTs). By measuring the PREM of the whole process of seeking of treatment and receiving triage could reveal whether Klinik Pro actually improves it (especially when compared to cases where Klinik Pro is not used).

To put our operationalization and suggested quantified metrics together, Figure 22 below illustrates all mechanism-outcome relationships that are common in all cases. The presented phenomena and respective metrics to measure them are suggestions based on the knowledge gathered from the interviews. Thus, it is likely that there are more factors to add to the ones that are presented here. We will get back to this in the discussion of future research avenues in chapter 7.7. In the following sections, we will analyze further the case-specific mechanism-outcome relationships and suitable measures for them.

Expected Outcomes	Contributing Mechanisms	Examined Phenomena Encountering Variation	Potential Metrics
Better access to seek treatment	Can do, co-creation, want to do	• Flexibility of using the service • Potential of using Klinik Pro to report symptoms and seek treatment	• Functionality, usability, accessibility, acceptability • Availability of service, response time of contacting
Improved precision in information	Co-creation, know what to do	• Accuracy of diagnostic process • Precision in patient's root cause to seek treatment	• Number of revisits, errors • Structural consistency and clarity of patient reported data
Less redundant contacts, reduced workload of contacting	Demand management, better access to seek treatment	• Utilization of each contact channel (visits, calls, Klinik Pro) • Workload of contacting & performing triage • Improved directing of patients	• Number of patients using the channel • Total working hours spent • % of decisions based on AI, number of contact points used
Improved efficiency, cost savings, and improved productivity	Integration, improved precision of information	• Time and accuracy to perform diagnoses and planning of treatment • Level of integration	• Benchmarks, before-after comparisons • Consistency, adaptability to other systems
	Coordination, improved precision of information	• Utilization of resources within application for treatment and triage processes • Duration of diagnostic process • Improving processes	• Time spent on actual tasks vs unnecessary tasks/waiting • Flow efficiency, throughput time • Number of unnecessary activities removed
	Proper competence level, improved precision of information	• Total service costs	• Benchmarks to other medical centers, before-after comparisons, episode groupers
Less waiting time	Improved efficiency, better access to seek treatment	• Duration of diagnostic process • Duration spent on queueing	• Flow efficiency, throughput time of entire process • Waiting time
Improved patient experience	Less waiting time	• Patient experience of seeking of treatment and triage	• Surveys, before-after comparisons, RCTs measured with PREM

Figure 22 - Common Evidence Gathering Needs

Vantaa Specific Evidence Gathering Needs

Regarding the Vantaa specific measures, the first mechanism mentioned was proper timing together with intervention related mechanisms that could lead to detecting sensitive diseases faster than currently. Particularly, Klinik Pro could affect the overall number of

observations besides also influencing the timing of detection. The overall number of detections could be measured by benchmarking the quantity of these diseases on average to medical centers without Klinik Pro. Furthermore, evaluating the average stage of the disease when it was detected and benchmarking this to other medical centers could reveal whether sensitive diseases are detected earlier with Klinik Pro or not. What is more, Klinik Pro likely affects the patient's threshold to inform about sensitive diseases digitally compared to physical visits or calls. This could be measured with surveys, for instance.

Another reason Klinik Pro is implemented in Vantaa is the ability to reduce nurses' stress levels caused by rambling and tiring calls. Due to more efficient resource allocation, Klinik Pro is utilized more in contacting, thus saving nurses' time on treatment activities. As a result, Klinik Pro likely affects job satisfaction. These can be measured by analyzing how many patients can be directed to contact nurses via the DHI besides the stressful calls. In turn, surveys are a sufficient tool to measure job satisfaction besides exploiting benchmarks to other medical centers. Figure 23 illustrates the evidence gathering measurements and needs for Vantaa.

Expected Outcomes	Contributing Mechanisms	Examined Phenomena Encountering Variation	Potential Metrics
Sensitive diseases detected faster	Proper timing, Can do, better access to seek treatment	• Number and stage of detected sensitive (mental, sexual) diseases • Threshold to seek help	• Benchmarks to other medical centers, before-after checks • Surveys and questionnaires toward patients
Reduced stress levels among nurses	Improved efficiency	• Utilization of Klinik Pro in contacting • Job satisfaction among nurses	• % of contacting occurring via Klinik Pro • Surveys and benchmarks to other medical centers

Figure 23 - Evidence Gathering Needs of Vantaa

To supplement the previously presented evidence gathering needs, we can also utilize the WHO evaluation model (World Health Organization, 2016). In the case of Vantaa, the stage of maturity is already in the advanced level regarding the scale-up from one medical center to the rest of the medical centers within that area (Table 1). The stage of evaluation is thus implementation science. We can perceive that the claims are relatively similar to those we have gathered with the PROVE-IT model, emphasizing cost savings and effectiveness besides also highlighting the technological feasibility. As Vantaa implementation is yet in the beginning, we can perceive it to match with process evaluation type (Table 2). Consequently, the model suggests collecting evidence both with focus group discussions and in-depth interviews besides analyzing the data generated by Klinik Pro itself. Murray et al.

(2016) also emphasize very similar factors with an additional mention of risks that should be considered regarding the mechanisms and unexpected outcomes.

FSHS Specific Evidence Gathering Needs

Concerning FSHS related mechanism-outcome relationships, proper timing, and intervention related mechanisms were also mentioned in this case. As mental and other sensitive diseases are part of their strategy, Klinik Pro was expected to improve the ability to detect these diseases in a proper time. This can be measured similarly to the case Vantaa presented above.

FSHS also considered Klinik Pro to cause two high-level outcomes. First, the proof of better efficiency, speed, and quality caused by Klinik Pro might encourage the government to consider more of investing and developing digital services within the social and healthcare sector. Although this is a positive outcome, it is difficult to measure directly. One possibility is to measure this outcome by analyzing the change in the level of digitalization and compare it to that of other sectors (Kotarba, 2017). As any successful DHI might encourage further investments despite of the level of digitalization, also the amount of investments into similar projects to Klinik Pro could be measured. The second higher-level outcome is Klinik Pro's ability to collect data which can be then further exploited by FSHS to develop other services. The mechanisms behind this are precision in information, and co-creation to gather data in the first place. Generally, we can measure this service development activity by observing the utilization of Klinik Pro data besides calculating the number of projects initiated. Figure 24 presents the evidence gathering needs for case FSHS.

Expected Outcomes	Contributing Mechanisms	Examined Phenomena Encountering Variation	Potential Metrics
Sensitive diseases detected faster	Proper timing, Can do, better access to seek treatment	• Number and stage of detected sensitive (mental, sexual) diseases • Threshold to seek help	• Benchmarks to other medical centers, before-after checks • Surveys and questionnaires toward patients
Forerunner in digitalizing social and health sector	Positive health and cost outcomes of Klinik Pro	• Level of digitalization • Investment activity	• Comparison of the IT infrastructure and its utilization • Amount of money invested in similar projects to Klinik Pro
Benefits of collected user data from Klinik Pro	Information precision, co-creation	• Development of other services • Exploiting Klinik Pro data in other services	• Number of new services created • Amount of Klinik Pro data utilized in development processes

Figure 24 - Evidence Gathering Needs of FSHS

As with the previous case, we can utilize WHO's model (2016) to case FSHS as well. The stage of maturity is integration while the stage of evaluation is implementation science as well (Table 1). Whereas the Klinik Pro implementation in Vantaa case is already beginning, the FSHS implementation is yet under consideration, thus regarding the needs assessment type (Table 2). As we can perceive, the model does not provide much support in this situation by providing the exploitation of descriptive studies to measure contextual adaptation. This regards mostly to addressing the needs and expectations in the context of FSHS, which are already covered in the PROVE-IT model. Regarding the adaptation, Murray et al. (2016) emphasize the risk aspect but also the ability to tailor the DHI over time for its users. Thus, the ability and level of customization should definitely be thought of as the needs of Klinik Pro might change, especially once it is integrated to FSHS.

Portugal Specific Evidence Gathering Needs

The first mechanism-outcome relationship specific to the case Portugal was Klinik Pro's ability to decrease health illiteracy among patients by utilizing co-creation, demand management, and intervention-related mechanisms. As Klinik Pro provides information on diseases and symptoms based on the user input, the DHI can influence the level of illiteracy among patients. Typical measures to test this include various surveys and tests of how well people understand different symptoms and diseases (Peerson and Saunders, 2009). Further, we can measure the willingness and capabilities to learn about diseases by using user satisfaction surveys.

Similar to the higher-level outcomes in FSHS, Portuguese informants also expected Klinik Pro to have a positive influence towards decision-makers to perceive the added value of DHIs in healthcare as Klinik is part of the P5 project of proving the benefits of digitalization in healthcare. Much like the impact of Klinik Pro on social and healthcare sector is challenging to measure for FSHS. However, we can similarly to FSHS analyze the change in the level of digitalization (Kotarba, 2017). Figure 25 illustrates the evidence gathering needs for Portugal.

Expected Outcomes	Contributing Mechanisms	Examined Phenomena Encountering Variation	Potential Metrics
Improved health literacy regarding diseases	Co-creation, intervention mechanisms, demand management	• Average illiteracy among patients • Willingness and capabilities to learn	• Surveys and other tests to measure illiteracy • Motivation to use Klinik Pro, user satisfaction
Positive signal to exploit DHIs	Positive health and cost outcomes of Klinik Pro	• Level of digitalization • Investment activity	• Comparison of the IT infrastructure and its utilization • Amount of money invested in similar projects to Klinik Pro

Figure 25 - Evidence Gathering Needs of Portugal

Regarding the WHO model (2016), the stage of maturity of Portugal implementation is yet in the demonstration stage with effectiveness emphasis on evaluation (Table 1). Thus, the model suggests descriptive analysis for contextual adaptation (Table 2), which is once again already covered in the PROVE-IT model. As there is no triage in Portugal yet, the question of reaching the intended users by Murray et al. (2016) is relevant, thus supporting our reasoning to test co-creation whether patients even begin to use the DHI.

Mexico Specific Evidence Gathering Needs

Regarding Mexico, a specific outcome of Klinik Pro is to establish a system to gather and analyze digital health records in general mainly for the public sector. This is possible due to co-creation and information precision. Generally, we could test this relationship by analyzing the use of electronic health records by measuring the rate of digitalization. Also, the utilization of Klinik Pro data in these analyses can be measured with, for instance, calculating how much this data is used to perform larger-scale statistics of the patients' health condition in general.

Furthermore, Mexico also had a higher level outcome of Klinik Pro's benefits to encourage the public sector to work more with the private sector in digitalizing healthcare. Although being an important outcome, it is difficult to test directly. One possibility is to measure the change in the number of shared projects besides all the investments and subsidies provided to these. Figure 26 illustrates evidence gathering needs related to only Mexico:

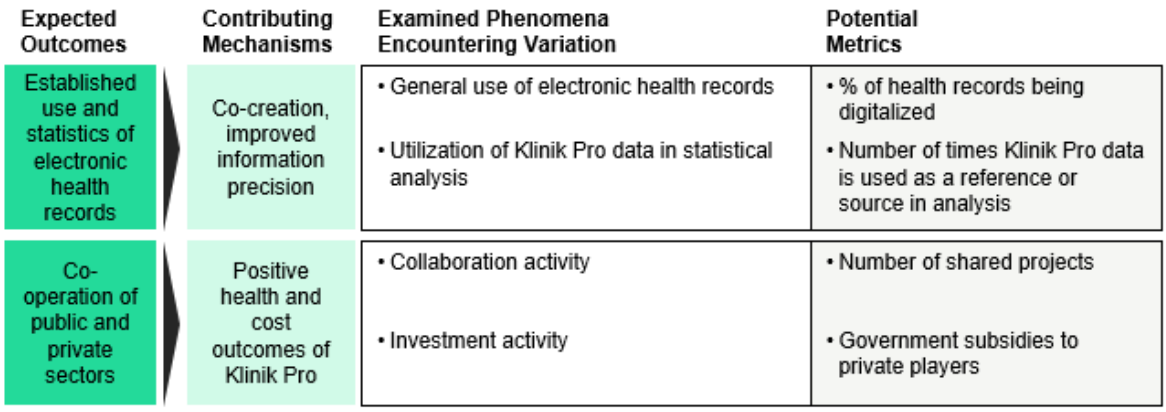

Figure 26 - Evidence Gathering Needs of Mexico

Similar to Portugal, case Mexico can also be considered to be a demonstration with the focus on needs assessment (World Health Organization, 2016). Thus the emphasis on testing mechanism-outcome relationships should be given to contextual adaptation, especially for the public sector where digitalization is on a low level.

Conclusion

As a conclusion, we have utilized our earlier discoveries of the mechanisms to deduce quantified metrics to test their relationship to the expected outcomes. While these metrics provide a suitable starting point for empirically test Klinik Pro's value creation in a real-life setting, it is once again essential to notice that the mechanisms are rather general in nature. Therefore, they are partially overlapping and it is relatively impossible to distinguish which mechanisms are *de facto* producing certain outcomes. Consequently, the causality should be tested with quantified measures. A comprehensive tool to measure the impact of Klinik Pro is to benchmark the situation when it is used to the one when it is not active. Especially, it would be beneficial to benchmark the tests between the cases. As an example, after testing whether demand management leads to reduced workload in a single case, it could be more firmly ensured if the same occurs in other cases as well. However, the circumstances vary significantly in different contexts which is why benchmarking the cases does not necessarily guarantee causality or correctness of our measures.

7.3 How to Develop the Model?

As we can perceive, the current PROVE-IT model is not perfect. There are several issues with the model that need to be addressed. We will first consider the suitable modifications that could develop it further. Thereafter, we will proceed to the integration of other evaluation models.

7.3.1 Potential Modifications

Before using the PROVE-IT model itself, it is essential to clarify to whom PROVE-IT is actually targeted. Although initially meant for companies to communicate the value of their DHIs, it is likely that not all parts of the model, especially those stemming directly from the research, are clear enough for people within health technology companies. This concerns particularly the healthcare mechanisms that were too complicated for informants to think of. Based on the understanding comprised from the interviews and literature review, the use of the PROVE-IT model seems to be most effective when it is divided for both company stakeholders and researchers. Thereby, a suggested use of this model can be divided into the following steps:

1. *The health technology company gathers information regarding the intervention, context, and expected outcomes through discussions with relevant stakeholders besides other external sources*
2. *The collected information is handled to a researcher familiar with healthcare management literature to discover relevant healthcare mechanisms and evidence gathering requirements for a given DHI*
3. *The company conducts the evidence gathering to prove the mechanisms to be actualized in reality, thus proving the value formulation of the DHI*

Proceeding to our modifications, we will begin with the several existing overlaps between the factors in different parts of CIMO configuration. Although CIMO aims to separate factors into four logics, occasionally it can be challenging to recognize in which part a particular factor should be included (e.g., mechanism or outcome).

Regarding the stakeholders, the original model suggests also considering the claims of the stakeholders within the contextual factors. Although this is reasonable, in this thesis, we have examined the claims in the outcomes section as they will appear there in any case. Thus, to avoid repetition, I suggest dealing claims as expected outcomes, and concentrate only on relevant stakeholders and actors in the context section. This is especially important as different informants may consider stakeholders and expected outcomes from different viewpoints and varying precision than others (e.g., Mexican vs. Finnish informants).

Considering the information perspective, it partially overlaps with two mechanisms: intervention's precision mechanism and context's "know what to do" mechanism. To keep the framework consistent and user-friendly, I would consider removing the information perspective from the context. The intervention's precision mechanism already explains what information gets more precise while the "know what to do mechanism explains how it affects the actors in a specific context.

Regarding the process-step perspective, it was perceived mostly informative factor among context but also overlapping with the patient journey perspective. Presumably, the separation might provide more benefits with other types of DHIs other than Klinik Pro. My recommendation is to deal with these two perspectives as one entity but further research should be conducted to experiment how the PROVE-IT configuration functions with very different DHIs. This could provide more insight how to handle the overlaps of these perspectives.

Finally, regarding the contextual environments which are described now in chapter 4.2 should be included more directly to the PROVE-IT model. Thus, besides other contextual perspectives, one addition could be the descriptions of the environment where the DHI is planned to be implemented.

7.3.2 Integration to Other Models

To further develop the PROVE-IT model, integration with other evaluation models could accomplish a few benefits. Although apparent but yet not emphasized in PROVE-IT model, a brief clarification of the problem the DHI aims to solve should be present in the model as it is the starting point for Murray et al. (2016).

Second, the stage of maturity and evaluation (World Health Organization, 2016) are relevant starting points for examining the DHI further as they outline the technological state and suitable evaluation methods regarding that. Thereby, it is suggested that the PROVE-IT model would be adjusted to the maturity level of the DHI.

Another addition to the model could be the evaluation of its customizability over time (Murray et al., 2016). Murray et al. (2016) suggest a system identification methodology to address suitable strategies to consider tailoring of DHI during its lifecycle. Thereby, the ability of an intervention to adapt to the possible changes in the context should be an essential integration to the PROVE-IT model as a link between intervention and context.

The PROVE-IT model could also benefit from a partial integration with the NASSS model (Greenhalgh et al., 2017). Although there are many similarities, the adaptation over time from the viewpoint of actors and stakeholders could be addressed as well in the PROVE-IT model. This could be done in a similar fashion Murray et al. (2016) recommend the customizability of the DHI over time.

Regarding another study which similarly exploits the CIMO-logic for DHIs to discover contextual perspectives emphasizes IT infrastructure, which is the only perspective that cannot be directly mapped to the current PROVE-IT model (Väljä et al., 2019). As it is essential for affecting the mechanisms of DHIs as we have perceived in the case Mexico, it

would be suggested to integrate this to the added environment perspective in the improved PROVE-IT model.

Furthermore, one relevant addition to the model concerns risks. Currently, the model does not emphasize the risk aspect too much. Yet, during the interviews, it appeared a relevant addition among expected outcomes to ask also the unexpected outcomes as was presented in chapter 6.3. Also, Murray et al. suggest in their study (2016) to consider risks when evaluating DHIs. This is especially important as it provides the means to perform a risk analysis for any given DHI. By considering the risk aspect together with outcomes, it is more comprehensive to consider the dynamics of mechanisms as they might result in both positive and negative outcomes.

7.3.3 Suggested PROVE-IT Model

We have now presented potential modification and integration possibilities to develop further the PROVE-IT model. Besides these additions and modifications, a particular emphasis should be given to the operationalization of the model. A typical issue in design science is the quantification of qualitative and abstract concepts (Anwar et al., 2015). To effectively use PROVE-IT, quantification should be taken into account to compare multiple cases for the same DHI.

Quantification can occur on two levels. First, the contextual environments besides the actors and stakeholders should be presented with numbers and ratios to allow comparison (e.g., number of nurses or doctor-to-nurse ratios). Second, the quantification should be exploited in constructing the evidence gathering needs as presented in chapter 7.2. As the mechanism-outcome relationships here are Klinik-specific, it is challenging to develop general metrics for each relation. This is especially the issue as we have yet only limited understanding of these mechanisms. However, this challenge could be overcome by utilizing the existing models such as the WHO evaluation model (World Health Organization, 2016) and operational logics of healthcare (Lillrank, 2018). We will discuss the operational further in the future research discussion in chapter 7.7. Figure 27 illustrates the improved PROVE-IT model based on the modifications and integrations presented above.

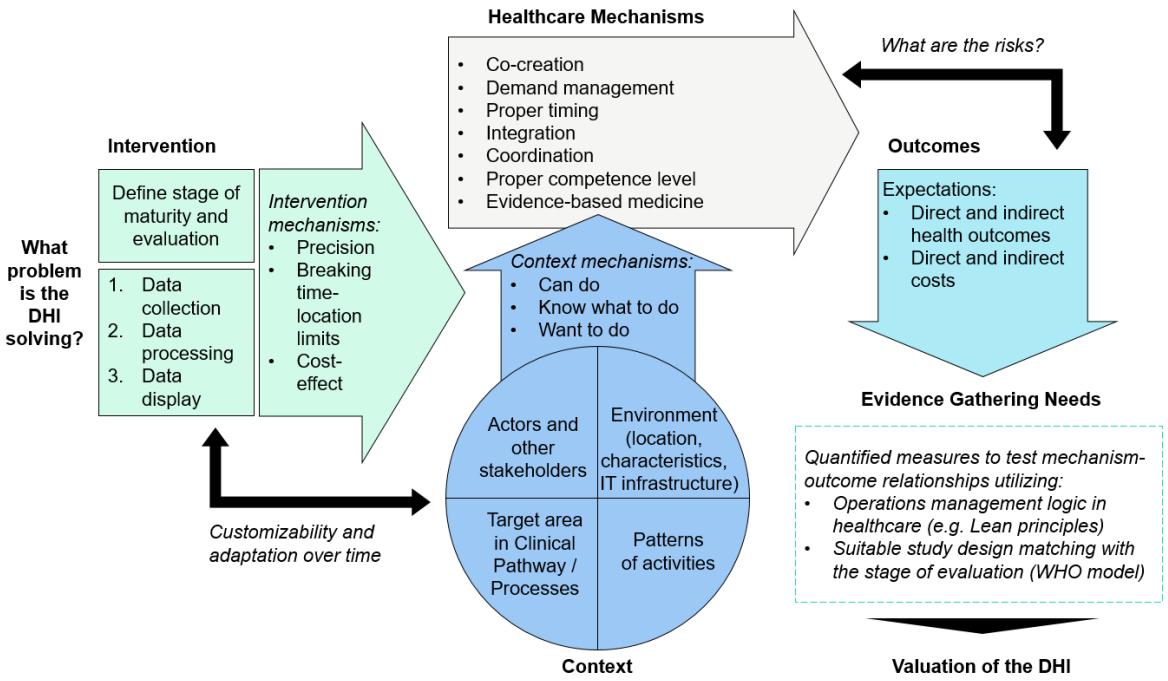

Figure 27 - Improved PROVE-IT Model

In general, the improved PROVE-IT model takes into account each part of the CIMO-configuration to construct the value formulation of the DHI besides providing the following steps to gather evidence whether the value can be realized in a real-life setting. To move one step further, once the quantified measures have been tested, a logical next move would be a valuation. By utilizing the quantified results from evidence gathering and comparing them to the actualized costs, a monetary value of the DHI could be approximated. This would be the ultimate evidence needed to prove the value of any DHI.

7.4 Theoretical Contribution

This thesis contributes to multiple streams of literature. First, it strengthens the utilization of concepts from the field of operations management in the area of digital healthcare by emphasizing the use of specific operational metrics to evaluate DHIs and understand their value formulation.

Second, this research elaborates the existing CIMO-logic by Denyer et al. (2008) in a more nuanced and comprehensive form of the PROVE-IT model (Lillrank et al., 2019). Thereby, the thesis provides new insight into discovering the mechanisms of DHI's value creation by considering the interdependent relationships between the intervention, its context, and its expected outcomes. Furthermore, this study contributes to understanding how such value formulations can be measured empirically with mechanism-outcome relationships.

Third, this study contributes to the existing literature of evaluation models in two ways. The thesis provides a new perspective on evaluation by suggesting the consideration of mechanisms explaining the dynamics of value formulation among DHIs. Furthermore, this study considers the already perceived benefits of existing models by recommending an integration between various evaluation models to accomplish even more practical and comprehensive framework for evaluation purposes. Thereby, this study provides a new and more precise perspective on the existing evaluation models that tend to be rather broad and general or, conversely, concentrate too specifically on single digital health technologies.

7.5 Managerial Implications

The managerial implications of this thesis influence several parties internationally. First, for health technology companies, this thesis has not only tested but also clarified and improved a value formulation model to be utilized in a real-world setting to test the value of any given DHI. Consequently, this value formulation model should be exploited to enhance sales narratives. The implication of the PROVE-IT model is similar to the exploration of Lean philosophy in Toyota Production Systems to understand the company's ability to produce value with minimal waste (Krafcik, 1988).

Additionally, this thesis supports the customers of the health technology companies (e.g., medical centers) to understand the value formulation of various DHIs provided to them, which in turn supports decision-making. With this information, it is possible to concentrate on activities to maximize value creation while also detecting unnecessary activities.

Finally, the utilization of the PROVE-IT model and its development can be considered as an inspirational framework to segment the value formulation of basically any digital technological solution. Consequently, the model can be utilized as a groundwork for creating similar models in different industries.

7.6 Limitations

Considering the limitations, it is apparent that the study concentrates merely on DHIs directed on triage and seeking of treatment. Additionally, the development of the model was heavily influenced by Klinik Pro and the interviews. As a result, it is not certain whether the PROVE-IT model can be similarly utilized on a general level or with very different DHIs although the model as a whole seems to be somewhat generalizable for any DHI.

The original PROVE-IT model was mainly built around the initial experiences of Klinik Pro implementation in Myyrmäki. As a result, the contextual perspectives of the model are heavily based on this environment, thus questioning whether the description of the context is genuinely sufficient capturing the issues of implementing DHIs in general terms.

Nevertheless, the majority of the contextual perspectives in the model have also been recognized in other studies, thus strengthening their validity.

Moreover, the patients, the most important stakeholder group, were not studied which narrows the possibilities to truly evaluate Klinik Pro's ability to produce value as patients might behave differently in various contexts. It is essentially up to patients whether they begin to utilize Klinik Pro or not, thus making patient perspective vital to study in future studies.

Although being a multiple case study, the number of interviews in total was relatively limited, thus causing a possible bias of informant views in some cases. Also, there were necessarily not enough interviews to perceive saturation among responses. Moreover, as the PROVE-IT model is yet under development, the informants might have had challenges to interpret or evaluate various parts of the model within a given context resulting in possibly inconsistent responses between the cases. However, the interviews itself were conducted with the key persons in each market expansion and were comprehensive in nature to gather as clear understanding of each case as possible.

7.7 Suggestions for Further Research

This thesis provides a groundwork for an elaborated value formulation model for digital health interventions. Regarding the future research directions, the following studies should consider further clarification and operationalization of each section in the suggested PROVE-IT model. Strictly speaking, further research should produce comparable quantified measures for each factor within the parts of the model in a similar fashion that was achieved in chapter 7.2. This is particularly relevant not only to make the model comparable between similar DHIs in varying implementations and contexts but also to provide actual measures to quantify the value in healthcare as presented by Porter (2010).

For the intervention part, the definition of the stages of maturity and evaluation could be researched further as a continuum to the WHO model (2016) to explore whether the currently presented stages are well-defined. Future research could study whether the three general intervention characteristics could be presented in a generalizable format to allow comparison between any DHIs. Intervention mechanisms require further work to accomplish relevant measures for each. Additionally, it would be beneficial to see if there are any other intervention mechanisms that are currently not present.

The second part of the model regards the context that itself is very descriptive in nature. Future studies could explore the generalizability of presenting contextual environments in a systematic way to enable comparisons. Additionally, future work could analyze whether

there are missing parts or further modification needs among the contextual perspectives. For the contextual mechanisms, further research could explore suitable metrics for each mechanism, such as motivational measures for “want to do” mechanism. Further, the linkage between intervention and contextual mechanisms could be studied more in-depth to understand their interdependent linkages more comprehensively.

The third part of the model concerns healthcare mechanisms, which requires a great deal of further research. First, besides the groundwork of this thesis, more analysis of discovering the mechanisms and their activation should be performed to eventually accomplish a precise and systematic way of detecting them. Second, more emphasis should be given to the metrics of these mechanisms to be able to test them properly by developing the idea of chapter 7.2. Third, it would be essential to study if there are any missing mechanisms. Regarding these three research avenues, the ultimate goal of future work would make these mechanisms mutually exclusive and collectively exhaustive, which they are not currently as there are overlaps between them.

Concerning the outcomes, more clarification should be given to the indirect outcomes and their relation to the mechanisms to create a clear separation between these two concepts if that is considered necessary. The outcomes also require more research on quantified measures, but this is to be performed together with the future research concerning all mechanisms as these two are linked together as well.

Furthermore, two extensions could make the PROVE-IT model more valuable and useful. First, it would be interesting to study whether the assessment of evidence gathering needs could be performed more systematically using quantified measured discovered with the future research as suggested above. To clarify, future studies could provide practical guidelines for gathering evidence needs that apply to every DHI.

The second interesting future research avenue concerns the valuation in the PROVE-IT model. Especially for companies and other organizations, it could be essential to study whether the quantified metrics achieved with the evidence gathering process could be utilized to form a valuation of the DHI as also suggested in chapter 7.3.3. Along with the first extension, the valuation would provide more accurate quantified value for the examined DHI, thus making the entire framework truly practical and insightful for future use. This is especially important for companies to be able to utilize PROVE-IT in sales narratives. Without valuation, the model can still enhance sales narratives by explaining the dynamics of the DHI although the valuation could take the narrative even further.

As we are exploring digital health interventions, the digitalization of the PROVE-IT model could be an interesting avenue for future research, particularly after researching the aforementioned clarification and operationalization opportunities. One possibility is to study whether the model could act as a digital tool which takes all the necessary data as an input and then outputs recognized mechanisms and respective evidence-gathering needs with the support of an AI, thus acting as an automated digital tool to produce value formulations and guidelines to test them in reality. As a result, companies could enter the data regarding the intervention, context, and expected outcomes to the automated PROVE-IT model before the actual implementation. The PROVE-IT model would then provide measurable factors and metrics concerning the potential mechanisms, which the company can then test empirically.

One further research possibility is to utilize PROVE-IT model as a benchmarking tool. As presented in chapter 7.2, benchmarking was a suggested tool to compare multiple cases to test the validity of mechanism-outcome relationships. However, when the PROVE-IT model has been developed further with operationalization and quantification, it would be interesting to study whether such a model could be used to benchmark various implementations of the same DHI. With such a tool various organizations could peer evaluate the benefits of the DHI in their own organizations, and thus perform actions to reach the benchmarks if needed. For instance, once the installed base of Klinik Pro is large enough, the medical centers using the DHI could benchmark their performance to each other with PROVE-IT.

Finally, there are yet two additional perspectives on future research directions. First, it would be interesting to utilize the suggested PROVE-IT model, or preferably the improved version according to the suggestions above, to test the historical value formulation. As the model is now utilized to predict future expectations, it would be essential to see if the model also works backward to explain the value formulation of already occurred DHI implementations as intended originally. For example, this could enable analyzing the already implemented Klinik Pro installations to discover which mechanisms caused the specific outcomes.

Second, it would be beneficial to utilize the PROVE-IT model for other DHIs or even in industries other than healthcare to study whether the model can be exploited more generally. As an example, the model could explain the dynamics behind the value formulation of a social media platform. At best, PROVE-IT could act as a general value formulation model for any instance.

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Appendices

Appendix 1. PROVE-IT Model Checklist

Appendix 2. Interview Protocol

Appendix 1. PROVE-IT Model Checklist

Intervention: Describe the Digital Health Intervention

- ☐ What data is collected and how?
- ☐ How the data is processed to information?
- ☐ How the information is presented?
- ☐ In what information can precision be improved?
- ☐ To whom new, more precise information is offered?

Context: Describe the context where the DHI is implemented

- ☐ General description of the context (e.g. geographical or organizational)
- ☐ Target area in the clinical pathway or patient journey
- ☐ Stakeholders and their claims
- ☐ Actors and their required competences to use the DHI
- ☐ Activities
    - ☐ What new activities are generated?
    - ☐ What changes occur in the existing activities?
    - ☐ What activities become obsolete
- ☐ To which part of the process does the DHI touch (setup – processing – monitoring)?

Outcomes: Describe the outcomes of the DHI

What are the expected outcomes for stakeholders and actors?

- ☐ Health outcomes and their measures
- ☐ Costs used to achieve health outcomes
- ☐ Indirect outcomes that are connected to health and/or cost outcomes
- ☐ How management needs to act to actualize outcomes?

Mechanisms: Describe the mechanism that leads to outcomes in a given context

- ☐ What competences the DHI brings (Can do)?
- ☐ What information the actors need to have (Know what to do)?
- ☐ What motivational factors are in the DHI (Want to do)?
- ☐ What are the mechanisms? (proper timing, proper competence level, integration, coordination, evidence-based medicine, demand management, and/or co-creation of health)

Appendix 2. Interview Protocol

Interview request

1. Introduce the topic and the objectives of the research
2. Request the possibility to interview
3. Declare a confidential use of gathered information and anonymity

Before the interview

4. Present a concise introduction to the thesis
5. Enquire a permission to record the interview

During the interview

6. Start the recording
7. Ask a brief presentation of the interviewee's background
8. Go through of the interview questions
    a. Seize other questions emerging during the discussion

After the interview

9. Thank the interviewee
10. End the recording
11. Request whether it is possible to contact the interviewee later to get additional information if needed
12. Ask about other suitable informants that could be interviewed
13. Transcribe the interview
14. Perform the coding and grouping of the interview in Atlas.ti