Exploring the scalability of a digital health intervention: A value network approach

Pedro Alves Andrade da Silva Brum

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Supervisor(s): Prof. Teresa Sofia Cipriano Gonçalves Rodrigues
Salomé Guedes Sequeira de Pádua Azevedo

Examination Committee

Chairperson: Prof. Mónica Duarte Correia de Oliveira

Supervisor: Prof. Teresa Sofia Cipriano Gonçalves Rodrigues

Member of the Committee: Ana Catarina Lopes Vieira Godinho de Matos

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Declaration

I declare that this document is an original work of my own authorship and that fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

Declaração

Declaro que o presente documento é um trabalho original da minha autoria e que cumpre todos os requisitos do Código de Conduta e Boas Práticas da Universidade de Lisboa.

Preface

The work presented in this thesis was performed at Instituto Superior Técnico, during the period March 2021-May 2022. The thesis was supervised by Prof. Teresa Sofia Cipriano Gonçalves Rodrigues and co-supervised by Salomé Guedes Sequeira de Pádua Azevedo.

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Abstract

Innovative technology has been showing the potential to be an adequate venue for improving the quality of care delivered. Any health service or treatment provided through the adoption and use of innovative technology in healthcare can be seen as a digital health intervention. Thus, understanding conditions that may facilitate their implementation at scale, has been increasingly important.

This dissertation focused on evaluating the potential of using a value network as an aiding tool to assess the scalability of a digital health intervention. For this purpose, this study contributes with a first suggestion of a value network modeling framework.

The value network modeling framework was applied to an illustrative case study in the Portuguese health context. This allowed the demonstration of how the technical component of the framework can be applied in practice.

The final result of the suggested framework is a value network that successfully depicts the dynamics involved in the implementation of the digital health intervention in a healthcare system and the quantified value added by this intervention to each stakeholder. This value network helps in answering whether the digital health intervention is worth it or not, which is a crucial question in assessing its scalability. We suggest that is a way that a value network may be used as an aiding tool to assess the scalability of a digital health intervention.

Keywords: Value Network; Scalability; Digital Health Intervention; MCDA; Framework

Resumo

A inovação tecnológica tem mostrado potencial para ser uma solução adequada para melhorar a qualidade de cuidados de saúde prestados. Qualquer serviço ou tratamento de saúde prestado através da adoção e uso de tecnologia inovadora na área da saúde pode ser visto como uma intervenção de saúde digital. Desta forma, entender as condições que podem facilitar a sua implementação em escala, tem sido cada vez mais importante.

Esta dissertação teve como objetivo avaliar o potencial do uso de uma rede de valor como ferramenta auxiliar para avaliar a escalabilidade de uma intervenção de saúde digital. Para este fim, este estudo contribui com uma primeira sugestão de uma framework de modelação de rede de valor.

A framework de modelação da rede de valor foi aplicada a um caso de estudo ilustrativo no contexto de saúde português. Isso permitiu a demonstração de como a componente técnica da framework pode ser aplicada em prática.

O resultado final da framework sugerida é uma rede de valor que representa as dinâmicas envolvidas na implementação da intervenção de saúde digital em um sistema de saúde e o valor quantificado adicionado por essa intervenção a cada stakeholder. Essa rede de valor ajuda a responder se a intervenção em saúde digital vale a pena, esta que é uma questão crucial na avaliação da escalabilidade. Deste modo, sugerimos que esta pode ser uma forma da rede de valor ser usada como ferramenta auxiliar para avaliar a escalabilidade de uma intervenção de saúde digital.

Palavras-chave: Rede de Valor; Escalabilidade; Intervenção de Saúde Digital; MCDA; Framework

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List of Acronyms

AHP	Analytic Hierarchy Process
EMG	Electromyography
FGD	Focus Group Discussion
IoT	Internet-of-Things
MACBETH	Measuring Attractiveness by a Categorical Based Evaluation Technique
MCDA	Multicriteria Decision Analysis
NHS	National Health System
NGT	Nominal Group Technique
PSM	Problem Structuring Method
SCA	Strategic Choice Approach
SLA	Service Level Agreement
SODA	Strategic Options Development and Analysis
SSM	Soft Systems Methodology

1

Introduction

1.1 Motivation

One of the main goals of the healthcare system is to provide universal health coverage (World Health Organization, 2010; Garret et al., 2009; Reich et al., 2011; Latko et al., 2011; Chuma and Okungu, 2011). In its simplest form, universal health coverage is a system in which everyone in a society can get the healthcare services they need without incurring financial hardship (World Health Organization, 2005). Good health can be achieved at a low cost whenever resources are allocated toward more cost-effective care (Savedoff et al., 2012). Therefore, the commitment to universal health coverage demands a transformation of the healthcare system grounded on appropriate care and efficient use of resources (Savedoff et al., 2012; Abiiro and De Allegri, 2015; White, 2015; Sobel et al., 2016). Despite the rising costs of achieving universal health coverage, improving medical practices through the introduction of technological innovations make it possible to prevent or treat more illnesses (Savedoff et al., 2012). Innovative technology shows the potential to be an adequate venue for improving the quality of care delivered and collecting evidence, supporting decision-making across all levels and stakeholders of the system (Saranummi et al., 2006; Kijl et al., 2010; Murray et al., 2016; Vannieuwenborg et al., 2016).

Any health service or treatment provided through the adoption and use of innovative technology in healthcare can be seen as a digital health intervention (Murray et al., 2016). As with any health intervention, it is needed to be tested first on a small scale and then assess its suitability to be scaled up, i.e., the scalability of the intervention (Milat et al., 2013; Zamboni et al., 2019). The concept of scalability was defined by Milat et al. (2013) as "the ability of a health intervention shown to be efficacious on a small scale and/or under controlled conditions to be expanded under real-world conditions to reach a greater proportion of the eligible population while retaining effectiveness" (p. 289). In this context, understanding conditions that may facilitate their implementation at scale, is increasingly important (Zamboni et al., 2019). However, there is a lack of published research on the impact of certain conditions on the evaluation of the scalability of a health intervention, such as the population reach of programs, associated costs, or external validity (Nutbeam and Bauman, 2006; Glasgow and Emmons, 2007).

Good practices and successful implementations of technological innovations have been identified. However, it has been difficult to understand how these can be scaled up to new contexts (Howard et al., 2021). There is an urgent need for studies assessing mechanisms by which widespread intervention adoption and reach can be achieved (Milat et al., 2011). A policymaker or health decision-maker will not have available all the information about scalability considerations, such as effectiveness, feasibility, acceptability, costs, sustainability, or adaptability, to inform decision-making (Milat et al., 2020; Zamboni et al., 2019). This highlights the importance of building evaluative and performance monitoring systems into any significant health promotion investment so that funds can be withdrawn if it does not meet intended objectives (Milat et al., 2013). Zamboni et al. (2019) say that "Partnerships between researchers and stakeholders are necessary to achieve sound contextual framing of a new intervention and to aid scale-up" (pp. 550-551), calling

for researchers to better incorporate the scalability considerations in pragmatic trials through greater integration of impact and process evaluation, more stringent definition and measurement of scale-up objectives, and outcome evaluation plans that allow for comparison of effects at different stages of scale-up. Some studies (Chesbrough, 2002; Broens et al., 2007; Spil and Kijl, 2009) have been suggesting the use of models from the business management literature to possibly help to assess the scalability of the adoption and use of the innovative technology in a healthcare system.

One of these models, which has been used for many years and across several industries is the value chain (Handfield et al., 1997; Humphrey and Memedovic, 2003; Higgins et al., 2007; Holweg et al., 2009). The value chain concept was developed for the first time by Michael Porter during his studies on competitive advantage (Porter 1985). However, while a value chain has been defined as the entire production chain from the input of raw materials to the output of the final product consumed by the end-user (Porter, 1985), the 'value network' terminology is often used in studies across many sectors, to reflect activities being increasingly spread across many specialized firms, including studies of the healthcare and pharmaceutical sectors (Edwards, 2009; Harrington et al., 2016). The model of a value chain that consists of all the value-generating activities (Porter, 1985) is not enough nowadays to aid in the decision-making of an extended enterprise. In contrast, the model of a value network does (Daaboul et al., 2012). The healthcare system has been characterized as "fragmented processes across payers, providers, and hospitals" (Rai and Sambamurthy, 2006, p.328). Dispersed organizational structures with insufficient information flows can lead to higher costs and inferior quality of care (Cebul et al., 2008). The fragmented nature of the healthcare system makes a network and customer-centric approach such as the value network particularly attractive as an analysis tool (Peltoniemi, 2016). A value network is defined as “a dynamic network of legally independent, collaborating actors who intend to offer a specific service, and in which tangible and intangible value exchanges take place between the actors involved” (de Reuver and Bouwman, 2012, p.347). A healthcare system conceptualized as a value network allows knowing exactly who initiates the exchange, what specific value or product is being conveyed, and who receives it. Thus, value creation can be analyzed from multiple perspectives such as time, goals, resources, results, or costs (Allee, 2000).

This dissertation aims to evaluate the potential of using a value network as an aiding tool to assess the scalability of a digital health intervention. It is necessary to review the literature on existing frameworks to model a value network so that a proper design of a value network was performed. In this dissertation, we aim to suggest a value network modeling framework that is based on and is an enhancement of the frameworks existing in the literature. Furthermore, we aim to use a case study to illustrate how the value network can be modeled and potentially validate that the value network can be used as an aiding tool to assess the scalability of a digital health intervention.

1.2 Objectives

The objectives that were set for this thesis are the following:

- Explore the literature on existing frameworks to model a value network to help in the development of a value network modeling framework.
- Suggest a value network modeling framework to be used in the scalability assessment of a digital health intervention.
- Evaluate the potential of using a value network as an aiding tool to assess the scalability of a digital health intervention.
- Apply the value network modeling framework, using a case study in the Portuguese context.

1.3 Thesis Outline

This thesis is organized into a total of 6 chapters that follow.

Chapter 2 is a contextualization that provides a background on some challenges that this thesis aimed to address, such as the technology adoption challenges in healthcare and the challenges regarding the assessment of the scalability of a digital health intervention.

In chapter 3, a literature review related to the value network concept is performed to provide insight on this topic, understand how it has been used successfully in the past, and most importantly, how it can be used successfully in the context of this work. Moreover, it presents a literature review on the existing methods to model the value network to provide insight into how a value network model can be designed and to understand if any of the methods were appropriate considering the objectives of this work. Additionally, a brief review of the Multicriteria Decision Analysis (MCDA) literature is made to understand how it can be used to quantify the value added by the digital health intervention to each stakeholder of the value network. Moreover, measuring attractiveness through a categorical-based evaluation technique (MACBETH) is introduced, briefly exposing how this method works and how to apply it.

In chapter 4, it is proposed a value network modeling framework that incorporated a detailed description of each step to be carried out, and it is introduced concepts that were used in this framework.

In chapter 5, the proposed value network modeling framework is applied to an illustrative case study to demonstrate how it can be applied in practice and to demonstrate the technical aspects of modeling a value network.

In chapter 6, considering the initial objectives, the results obtained are discussed and the identified limitations are pointed out.

Finally, in chapter 7, the main conclusions of this thesis are drawn, and future work is suggested.

2

Background

2 Background

In this chapter, we introduce the topics of technology adoption challenges in healthcare and the difficulties that arise when assessing the scalability of a digital health intervention. The adoption and use of innovative technology in a healthcare system is a complex and difficult task, therefore in this section, we introduce certain challenges associated with technology adoption. Since any health service or treatment provided through the adoption and use of innovative technology in healthcare can be seen as a digital health intervention (Murray et al., 2016), a digital health intervention is directly linked to innovative technology, and therefore, innovative technology adoption in healthcare is linked to the scalability of a digital health intervention. Thus, we then provide an overview of what comprises the scalability of a health intervention and the challenges that arise when assessing it. Lastly, we briefly address how the challenges introduced could be overcome by suggesting one possible solution, which this work is mainly focused on.

2.1 Technology Adoption Challenges in Healthcare

The healthcare system uses technology innovations to develop new pilot programs and improve service delivery and information systems (Ong et al., 2018). However, the literature has already mentioned several challenges to achieving the adoption of innovative technology in healthcare. Two of the biggest challenges are the healthcare system fragmentation and the value assessment (Vannieuwenborg et al., 2016; King, 2020).

As mentioned before, fragmentation across the healthcare system is one of these challenges. The individual, non-integrated, and stand-alone characteristics of the healthcare landscape make it fragmented and fuzzy for users, both care receivers, and caregivers (Vannieuwenborg et al., 2016). Ong et al. (2018) state that their findings indicate that there is fragmentation among the many actors who operate in their own ways across the healthcare space, have their own goals and objectives to meet, and have different resources, capacities, and capabilities. Additionally, the healthcare landscape is complex, consisting of many actors and barriers, so bringing these innovative technologies to a certain healthcare system is challenging (Vannieuwenborg et al., 2016).

The other challenge lies in the uncertainty in assessing the value that the adoption and use of the technology add to each participant in a healthcare system. King (2020) states that many healthcare implementation projects that struggle to achieve adoption may reflect a lack of attention to the value added and the cost to carry it out. Adoption of any health technology depends on the value it provides. In assessing the value, one needs to remember that innovative technology usually is embedded into a service. Therefore, the contribution of the technology toward the total value of the service may be difficult to assess (King, 2020). Assessment of value requires that we first agree on how the value is to be evaluated since the value is perceived differently by

the diverse actors present in a healthcare system. In other words, value is subjective and contextual (Saranummi et al., 2006; Peppard and Rylander, 2006; Allee and Schwabe, 2015).

2.2 Scalability of a digital health intervention and assessment challenges

There is enormous potential for digital health interventions to be effective, cost-effective, safe, and scalable interventions to improve health and healthcare (Murray et al., 2016). They are typically complex interventions with multiple components and can have multiple aims, such as enabling users to be better informed about their health, change perceptions and cognitions around health or assess and monitor specified health states or health behaviors (Murray et al., 2016). As with any health intervention, it is needed to test first on a small scale and then assess its suitability to be scaled up, i.e., the scalability of the intervention (Milat et al., 2013; Zamboni et al., 2019). The scalability of an intervention may seem an obvious concept, however, before Milat et al. (2013), it was not effectively defined in the health promotion literature and terms were applied in many ways and contexts with little consistency or rigor (Milat et al., in press). Therefore, Milat et al. (2013) defined scalability as "the ability of a health intervention shown to be efficacious on a small scale and/or under controlled conditions to be expanded under real-world conditions to reach a greater proportion of the eligible population while retaining effectiveness" (p.289).

For complex interventions, the consideration of factors associated with 'scalability' is essential since it is vital information that can help policymakers and decision-makers to facilitate the widespread adoption and implementation at scale (Milat et al., 2013; Zamboni et al., 2019). The proven effectiveness of a health intervention on its own cannot be enough to reach widespread adoption. Taking as an example the study by Sud et al. (2020) on meditation programs for chronic pain and depression, they say that "Despite evidence of the effectiveness of meditation programs for chronic pain and depression, this intervention has not been widely implemented in North American health systems" (p. 2) and call for "evidence on how to implement such programs in the context of contemporary health systems" (p. 3). Adding to effectiveness, assessing scalability generally requires an assessment of a range of considerations, including feasibility, acceptability, costs, sustainability, and adaptability (i.e., to suit the needs of the context in which it is to be scaled up), which are often difficult to assess (Milat et al., 2020; Zamboni et al., 2019; Sutherland et al., 2019). Contextually, appropriate evaluative frameworks built into intervention delivery from the outset should have the capacity to produce reliable information on the scalability considerations (Milat et al., 2013).

2.3 Overcoming the challenges

Over the last section, we discussed how there is fragmentation across the health system and uncertainty surrounding the assessment of the value that the adoption and use of the technology add to each of the participants of a healthcare system. Integrating digital health services demands

an intensive collaboration of several actors (Vannieuwenborg et al., 2016). All actors and stakeholders need to be engaged in the strategy formulation, implementation processes, and the respective evaluation (Saranummi et al., 2006). Additionally, there is a need for tools that can produce reliable information on scalability considerations. To assess the scalability of health interventions with proven efficacy, it is crucial to answer the following two questions (Haynes, 1999): "*Does it work in practice? Is it worth it?".* If all the actors and stakeholders could see the value that the digital health intervention adds, then the innovative technology associated with it would be more adopted, and therefore the digital health intervention would have more potential to be scaled up.

Following this reasoning and considering the nature of the challenges presented, one possible solution to overcome these challenges, which is the main focus of this work, is the design of the value network model and the exploration of its potential to be used as an aiding tool to assess the scalability of a digital health intervention.

3

Literature Review

3 Literature Review

To fulfill the objectives of this work, it was necessary to perform a review to identify and analyze the existing literature on 'value network'. It is important to highlight that the literature on this topic is sparse and dispersed. Additionally, little research exists on its application in the context of healthcare settings. Consequently, the literature review was crucial to gather all the definitions and perceptions of this concept to make us understand the variations between them, giving us a wider perspective on what comprises a value network and how we can model it.

First, in this chapter, a brief overview of the research method used to perform the literature review on 'value network' is presented in Section 3.1. Section 3.2 focuses on the literature regarding the transition from the value chain to the value network concept and gives an insight into the several definitions used for this concept through the years (3.2.1), the literature on the reason for the increasing adoption of a value network approach by organizations and companies (3.2.2) and the literature on the purposes and uses that a value network model can have (3.2.3). Lastly, section 3.3 focuses on the literature that involves what is needed to effectively model a value network. This includes the studies that propose the components, with their terminology associated, that should be modeled to constitute the value network (3.3.1) and the studies where a value network was successfully modeled and applied (3.3.2 and 3.3.3). In section 3.3.2, we present studies in which the authors focused on applying the value network resulting in the absence of a clear and structured methodology to model the value network. We will be referring to them as the ad-hoc processes to model a value network. In section 3.3.3, we present studies in which the aim was to propose a structured methodology to model a value network. We will be referring to them as the value network modeling frameworks.

3.1 Research Method

To cover the existing literature as complete and accurate as possible and build upon existing knowledge, it was carried out a keyword search on the following databases: PubMed, Science Direct, Scopus, and Web of Science. The following queries were used for the search: ("Value network*"); ("Value network*" AND ("design*" OR "model*" OR "evaluat*") AND ("framework" OR "method*"); ("Value network*" AND ("health*" OR "medic*)); ("Value network*" AND ("scale up" OR "scalability" OR "scalable")). There were no timeframe restrictions. However, only articles in English were considered. A title and abstract analysis were performed on the articles to select the ones that were relevant to the context of this review and the achievement of this work's goal. In this title and abstract analysis, selection criteria were applied to the titles and abstracts identified in the literature search.

An article was included if one of the following criteria was met:

- Studies focusing on the concept of value network and how it can be used.
- Studies presenting the evolution from value chain to value network.

- Studies that apply the modeling of a value network in their methodology.
- Studies proposing a networked approach to value creation in healthcare.
- Studies proposing a value network modeling language.
- Studies proposing a value network modeling framework.

This selection resulted in 27 articles that were considered for a full-text review and the respective detailed analysis.

3.2 Value network

Before exploring how a value network can be modeled, it was necessary to understand the value network concept. Likewise, before defining the value network concept, it was important to introduce the value chain concept and find out the motivations that drove certain organizations to adopt a value network approach.

So, in this section, we start by introducing the value network concept by presenting the evolution from value chain to value network, showing how this concept started being used and its definitions present in the literature. Next, we explore the reasoning behind the use of a value network approach by certain companies or organizations. Lastly, we provide an overview of the purposes and uses that a value network model can have.

3.2.1 What is a value network?

The value chain concept was developed for the first time by Michael Porter during his studies on competitive advantage (Porter 1985). This is a model to think strategically about business activities (value activities) in terms of costs and contribution. It is also useful to understand how firms can create, sustain, and maximize value for their customers. It is formed by several strategic activities, which are useful to deliver valuable products or services to the market (Ricciotti, 2019).

However, even though the value chain concept initiated the first steps, a wider and deeper thought about value creation was shaped, into the concept of value network (Ricciotti, 2019). While in the value chain, there is a sequential and linear logic to the process organization to reach value creation, in the more fluid value network, the process does not have a rigid order but works at the same time in a network within which there are also external organizations (Peppard and Rylander 2006). According to Fjeldstad and Ketels (2006), the value chain does not adequately represent business flows that create value from intangible solutions. In the value network logic, there are, as well as the fundamental activities, also the concepts of stakeholders, open innovation networks, and relationships (Allee, 2000).

The value network concept has been progressively more used across several diverse industries due to the increasingly connected economy and connected inter-organizational relationships, making it an adequate method to visualize inter-organizational exchanges and relationships (Biem and Caswell, 2008). The increased globalization, widespread use of new technology, and

pressure to be online, flexible, and efficient have resulted in the formation of strategic alliances, joint-ventures, and partnerships, and a steadily increasing flow of inter-organizational knowledge (Westergren and Holmström, 2012).

Since the first use of the value network concept, there have been used many definitions of this term through the years in studies regarding multiple sectors, including the health sector. Allee (2003) defined a value network as a "web of relationships that generates tangible and intangible value through complex dynamic exchanges between two or more individuals, groups, or organizations" (p.606). Alternatively, Peppard and Rylander (2006) defined a value network as a "set of relatively autonomous units that can be managed independently but operate together in a framework of common principles and service level agreements (SLAs)" (p.132). Casey et al. (2010) state that "we understand a value network as a set of interlinked (business) actors and technical (or more generically functional) resources that work together to create economic value through services and products" (p.3). More recently, Fjeldstad et al. (2020), a study in a health setting, states that "a value network is a configuration that facilitates flexible interaction among people, places, and things (e.g., patients, clinicians, researchers, organizational entities, and databases)" (p.2). Despite this being the most recent definition found and being the only one used in a health context, this is an incomplete definition that does not comprise all the elements that describe a value network, which can be obtained from all of the other definitions. It should be clear that a value network is comprised of multiple stakeholders that exchange tangible or intangible value between them with a common goal, which is to create value whether by offering services or products. Following this reasoning, in this work, we will adopt the definition of de Reuver and Bouwman (2012). This is the most recent definition found that contains all the characteristics to accurately describe a value network. They state that "a value network is defined as a dynamic network of legally independent, collaborating actors who intend to offer a specific service, and in which tangible and intangible value exchanges take place between the actors involved" (p.347).

3.2.2 Why use a value network approach?

As mentioned in the previous sections, today's organizations need above all to have flexibility and agility. They must have a light structure to deal with different types of problems and must be capable of doing this quickly.

Networked organizations rely less on hierarchy or matrix structures to control and coordinate work and more on peers and self-organization among the participants of a network. This type of structure and the mechanism to promote self-organizing behavior enable a value network to respond quickly and nimbly to a variety of needs because resources can be reconfigured as needed (Fjeldstad et al., 2020). A value network helps to operate sustainably since the organizations that are part of it share standards and policies, it can convert intangible assets into marketable assets, and it increases the flexibility and agility of organizations thanks to its self-organizational structure (Ricciotti, 2019). A value network has also structural integrity, and its actors are kept together

because each organization makes available competencies and relationships, therefore they can benefit from shared information (Lusch et al., 2010).

By adopting a value network approach there is no focus on only one organization but on the system of value creation (Daaboul et al., 2012). Value is formed through dynamic exchanges by actors who are directly or indirectly connected to each other. Value is created for customers as well as for provider actors themselves (Myllärniemi and Helander, 2012).

Since healthcare systems are one of the primary cases of organizations that need to be agile and flexible, where quick responses to different types of problems with limited resources are required, the value network approach is suitable and has been increasingly used in recent years. A good example of this is while a healthcare service is being created or being provided: combinations of nodes, linkage relationships, and activities for controlling and coordinating the combinations emerge, making the value network the appropriate approach (Fjeldstad et al., 2020). The collaboration in the network can be used to improve the efficiency without an original intention to change the service offering, or it can be used to create additional value and differentiation in the service offering, without affecting the internal logic of the service delivery (Laya et al., 2018).

3.2.3 Why model a value network?

A value network model can have multiple and diverse purposes in its use. In the last section, we discussed why organizations such as healthcare systems should adopt a value network approach, which consists of multiple stakeholders connected and exchanging tangible and intangible value, instead of the more traditional value chain approach. In this section, we discuss the benefits of effectively modeling all the stakeholders and the value exchanges between them.

A value network model is an adequate tool that allows the definition of actors' roles and understanding of their main functions (Allee, 2003; Allee, 2011). It also allows knowing how all the actors are linked together and what are their value exchange mechanisms to produce economic and social value (Allee, 2000; Allee, 2003; Grudinschi et al., 2015; Liu et al. 2020). In the case of the health sector, a value network model leads to the understanding of how organizations such as service providers, physicians, and hospitals are linked together and how they co-operate to produce value for the patient (Peltoniemi, 2016).

Additionally, a value network model can be used as a performance measurement tool (Daaboul et al., 2014) and as a strategic tool (Allee, 2000; Allee, 2011; Grudinschi et al., 2015; Kage et al., 2016). There is a need to analyze the performance of a network of organizations and include the customer-perceived value in the strategic decision-making process (Daaboul et al., 2014). Performance measurement is a process of collecting information relating to performance and reporting it. According to Moullin (2003), performance measurement is "evaluating how well organizations are managed and the value they deliver for customers and other stakeholders". Therefore, the performance of a network can be measured through the assessment of the value that each actor generates and receives.

Regarding its use as a strategic tool, a value network model can help to determine the best way to handle tasks and challenges while all the actors are working together to achieve their goals (Allee, 2011). A value network model aids in the analysis of a given situation in a way that provides useful guidance in developing feasible alternatives (Fjeldstad and Ketels, 2006). This all contributes to the value network to be a great tool that can be used to support decision-making (Daaboul et al., 2014; Grudinschi et al., 2015; Vesselkov et al., 2018; Fjeldstad and Ketels, 2006).

As mentioned in section 2.1, one of the key problems with healthcare systems is fragmentation. Dispersed organizational structures with poor information flows can lead to higher costs and poorer quality of care. Consequently, Peltoniemi (2016) defends that a network and customer-centric model such as the value network is particularly attractive as an analysis tool. It enables the identification of bottlenecks and information gaps that impact a healthcare system's performance (Peltoniemi, 2016). An analysis of the value network model right from the beginning of a project may improve the success rate of health services development and deployment, and lead to substantial savings in costs and resources (Nieuwenhuis, 2010).

3.3 Modeling a value network

To use the value network as a tool that possibly can help in the assessment of a digital health intervention, it is necessary to know first how exactly a value network can be successfully modeled.

First, it must be known what comprises a value network, i.e., its components. On this topic, throughout the literature review, we discovered that three studies have suggested that a value network is comprised of a certain set of components and have proposed a certain terminology for each component. We will refer to these suggestions as value network modeling languages. Therefore, in the literature review performed, we found three different modeling languages for value networks proposed in three different studies. Therefore, we start by introducing in section 3.3.1 each of the modeling languages found in the literature.

After that, it was needed to explore the literature where a value network was modeled and applied. The review of this literature was fundamental to understanding what the existent frameworks are to model a value network and if any of them are, in fact, suitable for the objectives of our study. However, most of the studies only focused on applying the value network for a certain purpose, without providing a clear and structured methodology to accomplish it. Therefore, we consider that these value networks were modeled through an ad-hoc process. These studies are presented in section 3.3.2.

Nevertheless, three frameworks to model a value network were found in this review. In section 3.3.3, we discuss each of this framework's strengths and weaknesses to conclude whether any can be applied in its entirety, or used by making some enhancements, to a work of this context, the exploration of the potential of using the value network model as an aiding tool in the assessment of the scalability of a digital health intervention.

3.3.1 Value network modeling languages

In the literature, we found that three studies propose different value network modeling languages (Gordians and Akkermans, 2003; Biem and Caswell, 2008; Allee, 2011). They present different ways in which a value network is comprised, with differences in the components proposed to be modeled or the terminology used for a certain component. In other words, there is not a universal modeling language for value networks. So, in this section, we go through the proposed components of each study and provide their corresponding definitions. Then, there is a grouping of the components that we think can be considered as the same component through our interpretation of their definition, despite different terms being used to denominate them.

Allee (2011) proposes the value network to be constituted by the following components: participants, transactions, and deliverables. Allee (2011) defines a participant as an individual or group of people (organization, business units, communities, etc.), and transactions as a unidirectional transfer of a deliverable from one participant to another. She considers transactions to be of primary importance in the model as drivers of value. Additionally, defines a deliverable as the asset that moves between the two participants. The deliverables can be tangible such as goods, services, and revenue, or intangible such as knowledge and benefit.

Gordians and Akkermans (2003) propose that a value network can have the following components: actors, value exchanges, value objects, value ports, value interfaces, and value activities. An actor is an economically independent entity representing a company, an organization, or a customer. It is not necessarily a legal entity. A value object is what is being exchanged between actors with the exchange done through a value port, which is a connection point between the actor and the outside world. The value object could be a service, good, or money that has an economic value to at least one of the actors. A value exchange connects to a value port and represents a pipe through which a value object could be potentially traded. A value interface is a group of value ports. A value activity is performed by an actor motivated by a potential profit.

Lastly, Biem and Caswell (2008) propose that a value network should be constituted by the following components: economic entities, offerings, transferables, financials, and an end-consumer. An economic entity is an entity whose activities are separated from the activities of its owner. In this model, economic entities may be firms, business units, or individuals. Offerings can be any transferable or financial from one economic entity to another. Offerings are transferred through unidirectional links. A transferable could be a manufactured product, a service, knowledge, or a brand. Financials correspond to the flow of revenue between economic entities. An end-consumer is a special node in the network. It is the "sink" whose role is to consume and appreciate the value proposition of the overall network.

As we can see, each of them proposes different components to be modeled and use different terms to refer to the same type of value network component. So, in each row of table 1, we group all the terms that we think are being used to describe the same type of value network component.

It is important to mention that the end-consumer can be considered as a subcategory of the actor/participant/economic entity component.

Allee (2011)	Gordians and Akkermans (2003)	Biem and Caswell (2008)
Participant	Actor	Economic Entity
-	-	End-Consumer
Transaction	Value Exchange	Offering
Deliverable	Value Object	Transferable + Financials
-	Value Activity	-
-	Value Port and Value Interface	-

Table 1 - Value network components proposed in each of the three studies

3.3.2 Ad-hoc processes to model a value network

In this section, we present some studies where the value network model was a beneficial tool and examples of accomplishments through its use. On the other hand, this section also intends to demonstrate how the majority of studies modeled their value network through an ad-hoc process. We present in table 2, examples of works where we considered that the value network was modeled through an ad-hoc process. As mentioned before, we consider them to be ad-hoc because they do not provide a clear and structured methodology to model the value network.

Study	Objective	Application Area	Accomplishments
Peppard and Rylander (2006)	Analyze the value network to explore the provision of innovative mobile content and services to customers through mobile devices.	Mobile industry	With this analysis, they were able to identify the diverse players in the mobile ecosystem and understand that this ecosystem was a set of firms that co-create value. They conclude that “the players who understand the sources of value in the network and can exploit them will be the winners” (p.139).

Sun and Ren (2013)	Construct a mobile business value network model.	Mobile industry	This paper presented a new model of mobile commerce value network. They say that this model would enrich the perspective of research on mobile business value networks and provide scholars with theories for reference for further research.
Fjeldstad and Ketels (2006)	-Address the uncertainty surrounding the use of value configurations as effective analytical tools in companies' decision-making. -Address the way that the choice of the value network instead of the value chain as a conceptual tool affected the analysis.	Insurance business	This article improves the understanding of how companies' activity configurations can be represented in ways that support effective decision-making by company executives. They have made the argument that in certain situations the value network configuration may prove a more appropriate analytical tool than the value chain configuration.
Hartel et al. (2020)	Analyze the structure of the value network related to scattered trees and investigate how the removal of individual values influences the value network.	Ecologic sector	This study highlights three ways by which a value network approach may help towards a better understanding of the traditional multifunctional landscapes as social-ecological systems. They also propose three approaches to how a value network perspective can improve their understanding of the importance of values in maintaining wood pastures and, broadly, multifunctional landscapes as social-ecological. In this way, they show that a value network approach is promising for understanding human-nature systems.
Nieuwenhuis (2010)	Present a business modeling approach to early-stage business model and value network development for Myotel, a wireless rehabilitation service	Healthcare	The author states that improving the viability and feasibility of business model and value network designs in an early deployment stage may lead to substantial savings in costs and resources. Business modeling and designing the related value network are

			seen as a solution to bring technological innovations to successful deployment.
Myllärniemi and Helander (2012)	Approach the challenging question of balancing the different kinds of needs and expectations around the healthcare system through a systematic value network analysis.	Healthcare	They argue that value network analysis can be a tool to reveal the different kinds of actors within the healthcare system and their role in the network and this kind of understanding of the network is a necessary step to further elaborate the overall functionality and successfulness of a healthcare system.
Peltoniemi (2016)	Examine the potential of digitalization in healthcare and the medication market through the conceptualization of the medical and healthcare value network	Healthcare	The value network model highlighted the information asymmetries between actors. Therefore, they argue that digitalization can be beneficial for the management of incomplete information and information asymmetries.
Vesselkov et al. (2018)	Model a value network of the telehealth industry at the time and suggest a potential future value network of telehealth	Healthcare	The suggested value network provides stakeholders with greater awareness of the potential changes in the industry structure and allows for more informed decision-making on their future telehealth strategies.

Table 2 - Objective, application area, and accomplishments of each study

All these studies provide evidence on how a value network model can be valuable and that it is used across all kinds of industries. However, they do not present a clear and structured methodology to model the value network. This can hinder subsequent researchers that are trying to replicate the process to reach similar accomplishments and hinder subsequent researchers that are trying to advance the value network model of the study or adapt it to other research areas. The absence of a structured methodology can also raise questions about the validity of the value network designed (Leung, 2015). Therefore, these studies should not be a reference point when modeling the value network.

3.3.3 Value network modeling frameworks

Since the ad-hoc processes to model a value network do not provide reasonable guidance to effectively model a value network, we searched in the literature for studies that propose frameworks with this aim. We identified three studies that effectively propose a value network modeling framework. We describe in this section, the Allee (2011) value network modeling framework, the Daaboul et al. (2014) value network modeling framework, and the Grudinschi et al. (2015) value

network modeling framework. These three frameworks provide significant and structured guidance to model a value network. Additionally, they were validated through their application in case studies. In this section, we compared the three frameworks between them, pointing out their strengths and their limitations, and deciding if there is one that can be modified and enhanced to suit the context of this study.

Allee's (2011) value network modeling framework

The Allee (2011) value network modeling framework highlights the importance of including intangible exchanges and intangible value in a value network model. Moreover, her framework can be applied to all business contexts, so it was a good starting point for other frameworks to be based on (Grudinschi et al., 2015). Contrastingly, this framework has limitations such as the fact that it focuses on exchanges without assigning a purpose to the value network, therefore the added value that every participant earns from the network cannot be identified and quantified. Despite providing outlined steps, they are not sufficiently detailed, making it difficult for anyone who wants to model the value network by reproducing its steps. Allee describes the basics of value network modeling but provides no details on identifying the participants' resources and assets or on identifying the challenges involved in the activity of partnership of the value network in question.

Daaboul et al. (2014) value network modeling framework

Daaboul et al.'s (2014) value network modeling framework shows a significant advance when compared to Allee's (2011) value network modeling framework. This framework assigns a purpose to the value network by defining a strategic decision to be made so that it can be used as a support tool for decision-making. It allows performing a simulation to choose the best scenario between a bundle of alternative scenarios, therefore supporting the decision-making. This simulation can be performed since this framework includes, in the value network model, variables that can measure and impact the performance of each participant and the value network as a whole. As a result, the value for each participant in each one of the possible scenarios can be assessed. On the other hand, this is a framework that was proposed for Mass Customization Design. It is targeted to be used in an organization that offers a product instead of a service, being more focused on the production processes' strategic decisions. Thus, the performance variables used in this framework are variables that are most used in a mass-production context, such as the idle cost, usage cost, utilization rate, order delivery time, etc. Moreover, its utilization is coupled to the use of proprietary software with a value network simulation library, and each step to model the value network is not exposed with the necessary detail, which can make the process of a subsequent researcher that tries to model a value network through this framework a very difficult task. This framework also proposes the use of the analytical hierarchy process (AHP) for a "analyze results and identify best-fitting scenario" step which is a method that has some criticism. In 2021, based on an empirical investigation and objective testimonies by 101 researchers, a study found at least 30 flaws in the AHP and found it unsuitable for complex problems, and in certain situations even for small problems (Munier and Hontoria, 2021).

Grudinschi et al. (2015) value network modeling framework

Grudinschi et al.'s (2015) value network modeling framework turns out to be an enhancement of Allee's (2011) framework. Hence, this is a generic modeling framework that can also be used in all contexts. They start from Allee's (2011) framework and overcome some limitations that it had. Contrastingly to Allee's (2011) framework, this framework consists of detailed steps and provides guidance on the kind of questions that should be asked in the interviews or workshops of experts. Therefore, it makes it much easier to understand the value creation and the value network modeling process. Additionally, it emphasizes the identification of participants' assets, as well as the challenges encountered in collaboration activities. They state that "a particular challenge can best be solved by the partner who has the most competencies in the most relevant area. In this way, new value can be created in the network" (p.6). Therefore, they go one step further because it does not simply focus on the modeling process of the current value network, but it can also be used to enhance these networks. The division of the value network into two different stages (i.e., the current value network and the potential value network) in this study, provides all collaboration participants with an understanding of the value creation process by comparing current and potential value networks. This understanding is seen as a factor in motivating organizations to collaborate. However, just like Allee's (2011) framework, it does not assign a purpose to the value network, therefore the added value that every participant earns from the network cannot be quantified. Furthermore, contrastingly to Allee's (2011) framework, this framework does not include a step that focuses on the identification of the participants of the value network. It assumes that the participants are known from the start, which is not always the case.

Value network modeling frameworks: Summary

In table 3, it is presented a summary of the features of each framework to compare them.

Framework	Objective	Det	Part	Pur	Ser	Res	Val	Chal
Allee (2011) modeling framework	Generic framework to be used in all contexts		X		X			
Daaboul et. al (2014) modeling framework	Framework constructed for decision-support for Mass Customization design		X	X		X	X	
Grudinschi et al. (2015) modeling framework	Generic framework that can be used in all contexts	X			X	X		X

Table 3 - Features of each framework

Note: Det=Each step is detailed; Part=Identifies the participants Pur=Assigns a purpose to the value network; Ser=Can be applied to a service provision context; Res=Considers resources and assets of each participant; Val=Identifies the value that each participant earns from the value network; Chal=Identifies the challenges of each actor.

Daaboul et al.'s (2014) value network modeling framework has some strong and appealing features. By observing the table above, we can see that it is the only of the three that assigns a purpose to the network and identifies the value that each participant gains from it. However, there is a big barrier to its use in the context of this work. As mentioned before, it is a framework that is targeted to be used in an organization that offers a product instead of a service, being more focused on the production processes' strategic decisions. Despite being the only framework with performance variables associated, these are variables that are most used in a production context. This work intends to explore the use of the value network as a possible aiding tool to evaluate the scalability of a digital health intervention and not the value network as an aiding tool to assess the best strategy to produce the technology to be implemented in a health system. Considering this, we have to exclude the use of this modeling framework, since its utilization does not apply to the context of this work.

Based on our introduction of the strengths and limitations of each framework and on the observation of the table that summarizes the features of each framework, it can be noticed that the Grudinschi et al. (2015) value network modeling framework is more complete and is an enhancement of the Allee (2011) value network modeling framework. Therefore, we can exclude the use of Allee's (2011) framework in its entirety.

Despite the limitations that we discussed when introducing the Grudinschi et al. (2015) framework, this is a framework that can be used in all contexts, provides a structured guide of clear and detailed steps to follow when modeling the value network, considers both the tangible and intangible value, identifies the resources and assets of each participant of the network and identifies the challenges of the activity of partnership of the value network under consideration. Therefore, we conclude that this framework can be further explored and enhanced to be suitable for our work's goal.

Grudinschi et al. (2015) developed a framework for value network modeling that helps to increase the understanding of how new value can be created in cross-sector collaborations. Cross-sector collaborations can be defined as "people and organizations from some combination of public, business, and civil constituencies (non-profits) who engage in voluntary, mutually beneficial, innovative relationships to address common societal aims through combining their resources and competencies" (Gribben et al., 2001, p.8). This value network modeling framework helps managers and experts understand how to get a complex value network model, how new value can be created, and how to get the full potential of collaboration. This value network modeling framework is based on two premises: identifying the perception of each participant regarding his own added value as well as his received value from the other participants in the network. The idea of this framework is to first model the value network of the current state of collaboration. Then, by trying

to enhance the value network model and creating value for all participants in the collaboration, the potential value network is modeled. One of the key motives in successful collaboration is a shared desire to solve a challenge. Therefore, while aiming to enhance the value network, a starting point has to be finding solutions for particular challenges. Furthermore, when taking on the various necessary roles for solving these challenges, each participant's assets (i.e., strength and resources) must be considered. They state that "a particular challenge can best be solved by the partner who has the most competencies in the most relevant area. In this way, new value can be created in the network" (p.6). This modeling process can produce two different models: the current value network model and the potential value network model. The first model (of the current value network) demonstrates the exchange of values among participants in the current state of collaboration. The second model (of the potential value network) shows what additional value can be created if the collaboration is properly managed and existing challenges are solved. The authors state that "new value is created by trying to find optimal solutions for specific challenges and by assigning roles based on each partner's assets (strengths and resources)" (p. 7). By comparing these two models, the process of value creation can easily be assessed.

This work describes, step by step, through the use of a case study of a collaboration among the public, private, and non-profit sectors for elderly care, how the proposed value network modeling framework can be applied in practice to help managers and experts understand how to develop complex value network models, how new values can be created, and how to maximize the potential of a collaboration. The modeling steps are presented in figure 1.

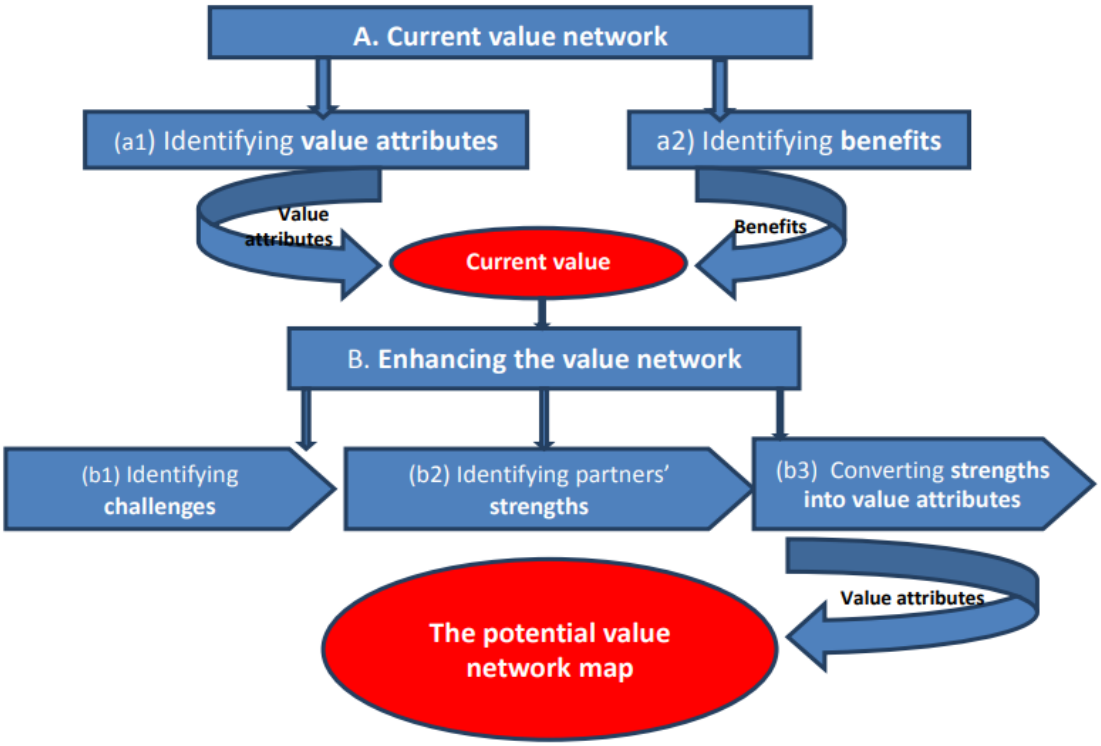

Figure 1 - Value network modeling framework by Grudinschi et al. (2015)

Additionally, table 4 introduces each modeling step of this framework along with the corresponding questions to be asked and the explanations of each step.

Step	Questions	Explanations
1. Modeling the current value network		**Determining what kind of value everyone brings to the collaboration**
A1. Identifying perception related to added value in the network (value attributes)	• What could you offer to service customers? • What could you offer to every participant in collaboration?	• The perception of the types of value that every partner offers to customers, as well as to all other participants. • The question should be asked separately to each participant. • After this step, the value attributes are introduced to the model.
A2. Identifying perception related to perceived benefits from collaboration.	• What kind of benefits do you get from every other participant?	• New types of value may be identified; the perceptions of benefits received from the collaboration may be different. • After this step, new value attributes (perceived as benefits) will be added to the model.
2. Modeling the potential value network		**Enhancing the value network to determine the full potential of collaboration**
B1. Identifying challenges in the activity of the partnership.	• What kind of challenges are involved in providing the services to customers? • What kind of challenges are involved in collaboration?	• The outcome is a list of challenges regarding the specific service domain that needs to be procured.
B2. Identifying strengths and resources of every participant.	• What are your organization's specific assets? • From the perspective of service providing? • From the perspective of collaboration?	• The outcome is a table delineating every participant's assets (core abilities and specific resources)
B3. Converting strengths and resources into values to respond to challenges.	• How every challenge could be solved so that it creates value for customers and other participants?	• Every challenge discovered in step B1 will be analyzed separately, also

	• Who has the best ability and resources to solve the challenge? • What type of value could be created to network participants by solving the challenges in a specific way?	using information gathered in step B2. • The results of this step will be put into a table that specifies what actions (tasks) are required to solve the challenge. • The table will also specify who creates the value and who is offered. • The information from the table will then be added to the value network model.

Table 4 - Detailed steps of the value network modeling framework by Grudinschi et al. (2015)

However, despite being the most appropriate of the three, this is not entirely the framework to generate the appropriate tool to be used in the context of this study, to aid in the assessment of the scalability of a digital health intervention. This is due to the limitations that were mentioned in the introduction of this framework. This framework does not include a step that focuses on the identification of the participants of the value network. Additionally, it does not assign a purpose to the value network and does not identify the goals of its participants. Consequently, the added value that the digital health intervention adds to each participant cannot be quantified.

Therefore, the focus of this work was centered on suggesting a new value network modeling framework by trying to enhance the Grudinschi et al. (2015) modeling framework in order to generate a value network model that may help to answer the question of whether a digital health intervention has scalability or not. In general, we aimed to use the suggested framework to model a value network that can be used as a tool that may help future researchers to assess the scalability of a digital health intervention. A major step in this direction would be the addition of a phase of quantification of the value added by the adoption and use of the digital health intervention in a healthcare system to each participant through the use of multicriteria decision analysis (MCDA) (Marsh et al., 2014). Hence, in the next section, we made a brief introduction to MCDA and its increasing use in the healthcare context.

3.4 Multicriteria decision analysis (MCDA)

In this section, we provide an overview of multicriteria decision analysis (MCDA) to understand how we can use it to quantify the value added by the digital health intervention to each participant of the value network. We will go through its definition, its growing use in the health context, especially its use to assess the value of health interventions, and the major steps in its application. In this work, we chose to use the measuring attractiveness through a categorical-based evaluation technique (MACBETH). Hence, this technique is then introduced, briefly exposing how it works and how to apply it.

3.4.1 Multicriteria decision analysis (MCDA): overview

Multicriteria decision analysis, or MCDA, is an umbrella term used to describe a collection of formal approaches that seek to incorporate multiple criteria and objectives into a single evaluation to help individuals or groups in decision-making (Belton and Stewart, 2002). It is most applicable to solving problems characterized as a choice among alternatives (Regier and Peacock, 2017). However, MCDA can also be implemented into the decision-making process to support the deliberate process, objectively examining the thorough value of a new health intervention (Jakab et al., 2021). It has all the characteristics of a helpful decision support tool, helping to focus on what is essential, logical, consistent, and what is easy to use (Regier and Peacock, 2017). Furthermore, MCDA can be seen as a sociotechnical approach, as it is necessary to consider not only its technical component but also the social component, such as the decision-maker and possible experts involved (Marsh et al., 2016).

Defining the value of healthcare is a challenging task and depends heavily on the decision context and stakeholders involved (Jakab et al., 2021). However, appropriate value estimation in healthcare is crucial for various purposes, such as allocating scarce resources efficiently across innovative healthcare technologies (Regier and Peacock, 2017). For instance, it is necessary to judge whether a healthcare technology at a specific price is a good value for a specified society. Innovative medical devices, while effectively responding to the population's growing needs in terms of disease diagnosis and treatment, need to be evaluated through a decisional process capable of considering a broad range of criteria, such as clinical value, safety, potential and operational effectiveness, economic, and organizational impact (Tallarico et al., 2021).

Healthcare decision-making can often be considered an MCDA problem. Hence, the importance and use of MCDA in healthcare decision-making have increased in the past few years (Yang et al., 2021). MCDA has been gaining popularity in the past decade as a method for healthcare value assessment and to improve the consistency and transparency of policy decisions (Thokala et al., 2016). In this regard, MCDA, for instance, was used to develop disease classifications concerning critical criteria (Johnson et al., 2014), to support hospital purchasing (van Til et al., 2008), to understand the value of the options for pricing, reimbursement and coverage purposes (Miot et al., 2012; Schmitz et al., 2016), to develop a ranking of choices to treat patients (Tervonen et al., 2015; Marsh et al., 2017), to prioritize health interventions (Peacock et al., 2007; Baltussen et al., 2010; Mobinizadeh et al., 2016), and so forth. In addition, using MCDA can help suppliers clarify what factors hospitals value and help them focus on providing the most necessary data to decision-makers (Yang et al., 2021).

A proper MCDA methodology focused on value measurement must contain three general stages: structuration, evaluation, and analysis (Drake et al., 2017).

Structuration involves identifying criteria and organizing them to have a complete, understandable, and accepted model. Criteria must be operational, which is assured by defining a descriptor

of performance for each of them, an ordered set of performance levels (Bana e Costa et al., 1999). Each option to be evaluated is represented by a set of performance levels, with each element of the set representing the performance level on one criterion. Additionally, criteria must be exhaustive, non-redundant, non-overlapping, and independent of preference (Von Winterfeldt and Edwards, 1986). Moreover, we can choose a high and a low reference level within each performance descriptor to ensure commensurateness between criteria, which means that we can compare any performance on one criterion with any performance on any other criterion (Grabisch, 2004). When establishing the decision criteria in health-related MCDA, subjective and objective data can be shaped into measurable descriptors to value health or healthcare directly. In the case of health technologies, many outcome parameters are considered, such as mortality, morbidity, and quality of life, as well as benefit dimensions in terms of improvement of health status, reduction of side effects and disease duration, life extension, and improvement of the process (Mühlbacher and Kaczynski, 2015).

The evaluation phase involves building value functions for each criterion, attaining weights, and calculating the global score for each option to be evaluated using an aggregation function. These value functions allow transforming performance on value scores. A value score represents performance attractiveness, considering two reference levels. By convention, the low reference level is valued at 0, and the high reference level is valued at 100 (Angelis and Kanavos, 2017). As mentioned previously, using references ensures commensurateness or trade-off requirements between criteria, meaning that one should be able to compare any performance on one criterion with any performance on any other criterion (Grabisch, 2004).

The most prevalent aggregation function is the simple additive model or simple weighted sum, which consists in adding weighted partial performance values of options on each criterion (Marsh et al., 2014), with weights consisting in scaling constants that “harmonize” the value functions. For this to be applicable, as previously mentioned, criteria must be exhaustive, non-redundant, non-overlapping, and independent of preference (Von Winterfeldt and Edwards, 1986). Additionally, the weights must be obtained considering the references since they must reflect the relative importance of each criterion based on their performance ranges and not only their notion of importance by itself (Thokala and Duelas, 2012), which has been described as the most common critical mistake in value analysis by Keeney (1992).

Having a set of criteria N with n elements and a set of options X, the global score of $x \in X$ using the simple additive model is given by:

$$V(x) = \sum_{i=1}^{n} w_i v_i(x) \ (1)$$

$$v_i(P_{i+}) = 100 \ (2)$$

$$v_i(P_{i-}) = 0 \ (3)$$

$$w_i > 0, \forall i \epsilon N \ (4)$$

$$\sum_{i=1}^{n} w_i = 1 \ (5)$$

where $V(x)$ represents the overall value score of an option x, n the finite set of choice alternatives, w_i the weight of a criterion i and v_i the partial value score of option x in criterion i. Each criterion must have a positive weight, and, by convention, the weights of all criteria must sum to 1. P_i represents a performance or impact of criterion i, with P_{i+} and P_{i-} representing superior and inferior references within the descriptor of performance, respectively.

There are several methods represented in the literature for building additive models. Two of the most used in healthcare are AHP and MACBETH (Marsh et al., 2016). However, AHP has methodological problems that compromise its use (Bana e Costa and Vansnick, 2008; Adunlin et al., 2015; Munier and Hontoria, 2021) and therefore cannot be a choice.

It is necessary to ask for value judgments to determine the weights and value functions through robust, transparent, but as simple as possible protocols that allow decision-makers to be involved in the decision process. Thus, it seems to us that the option for a method that only asks for qualitative value judgments can facilitate this task, as is the case with MACBETH.

Applications of the MACBETH approach encompass a broad range of evaluation contexts, such as helping an individual select his future career from several self-imposed possibilities (Bana e Costa and Chagas, 2004); helping an important rural development program build a project evaluation tool considering cross-cutting issues (Sanchez-Lopez et al., 2012); helping to solve facility layout selection problems (Karande and Chakraborty, 2014); assessing the ecological value of wetlands (Lavoie et al., 2016); designing and building a value risk-matrix for evaluating health and safety risks (Lopes et al., 2015); used to build a population health index (Rodrigues, 2014); and so forth.

3.4.2 MACBETH

MACBETH is an interactive multicriteria decision support methodology that allows evaluating options through qualitative judgments assessment about differences in attractiveness (or value) between options (Bana e Costa and Vansnick, 1994; Bana e Costa et al., 2012). It assists the decision-maker in obtaining value functions and weights for each criterion and the overall score of various options (Bana e Costa et al., 2012).

Value functions are attained by asking the decision-maker to judge the difference in attractiveness between the different performance levels of each descriptor of performance, using one (or a combination of several) of the six MACBETH categories (Very Weak, Weak, Moderate, Strong, Very Strong, and Extreme). Indifference judgments are also allowed, which are represented by the category Null. The judgments concerning one descriptor of performance allow obtaining the value function for the respective criterion, as represented in figure 2. Moreover, the judgments are asked using matrixes, which support the decision-maker in the visualization of the several options in

comparison (figure 2). To obtain a global score of each option, it is also required to “harmonize” the value scales, i.e., to assign a weight to each criterion, according to its performance range. The importance of a criterion depends on how much one can improve on that criterion and how relevant this improvement is, considering the specific performance level. Once the value functions and the weights are defined, the global score of each option is obtained through the simple additive model, which was already introduced.

The MACBETH approach was implemented in M-MACBETH, a multicriteria decision support system that solves an optimization problem to attain a MACBETH numerical scale (Bana e Costa and Vansnick, 1999; Bana e Costa et al., 2005). For each matrix, M-MACBETH uses a linear programming model to attain a numerical scale from the semantic judgments. Further details on the linear programming model of M-MACBETH can be consulted in Bana e Costa and Vansnick (1999) and Bana e Costa et al. (2005).

	300	400	500	600	700
300	no	very weak	weak	moderate	extreme
400		no	very weak	weak	extreme
500			no	very weak	extreme
600				no	extreme
700					no

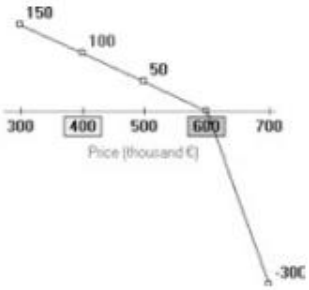

Figure 2 – Building a value function on a criterion (Bana e Costa and Oliveira, 2012)

For this model to be solvable, at least $w - 1$ pairwise comparison judgments must be provided (w being the number of elements defined in the matrix). This can be achieved, for instance, by pairwise comparing only each option with the option that has the next lower performance level, which results in populating the “diagonal” of the upper diagonal matrix. It can as well be achieved by pairwise comparing the option that has the most attractive performance level with the remaining options.

This is a sociotechnical process that combines the technical elements of MACBETH with the social aspects of decision conferencing (Bana e Costa et al., 2012). Since only qualitative judgments based on differences in value between options are asked to the decision-maker makes the MACBETH approach and, thus, M-MACBETH an advantageous tool to use with decision-makers with different backgrounds, who may not be used to numerical estimations and or do not like to provide numerical judgments (Bana e Costa and Vansnick, 1999).

In the course of the use of the M-MACBETH tool, the eliciting of the decision maker’s judgments and perspectives is a crucial step of the social component that constitutes this sociotechnical process (Bana e Costa et al., 2012). The decision-maker body usually is a group of people with different values, priorities, and interests (Mühlbacher and Kaczynski, 2015). There is a commit-

ment to ensure the transparency of decisions and an attempt to facilitate the understanding between the decision-maker and other possible involved stakeholders, by leading them to think through all the key factors and share their rationale. This enhancement in communication should ease the identification of gaps in data and prioritize data generation, as well as reveal different perspectives, facilitating discussion and consensus generation (Marsh et al., 2014). Some of the methods used for the initial eliciting of points of view and values are Focus Group Discussion (FGD), Interviews, Q methodology, Nominal Group Technique (NGT), Delphi, Decision Conference, Surveys, and Questionnaires (Mukherjee et al., 2018). Overall, the most appropriate elicitation methods are the ones not too cognitively demanding that may lead to the manifestation of unrealistic feedback, are not excessively time-consuming, and are fairly intuitive to understand (Riabacke et al., 2009).

4

Methodology

4 Methodology

In this work, we built upon the value network modeling framework developed by Grudinschi et al. (2015), adapting it and overcoming some of its limitations to reach our goal of achieving a framework to model a value network that may be used as an aiding tool to evaluate the scalability of a digital health intervention. In this chapter, based on the literature review of chapter 3, we start by presenting our chosen definition for concepts that are fundamental in modeling a value network. Afterward, we provide a brief introduction to the characteristics that a modeling framework should have to generate a value network that can help in the assessment of the scalability of a digital health intervention. Lastly, we present the proposed value network modeling framework, providing a detailed description of each step. In the next chapter, the framework is then applied to an illustrative case study in the Portuguese context, to demonstrate how it can be applied and to detect improvements and future research that must be carried out.

4.1 Fundamental concepts

The value network modeling framework developed by Grudinschi et al. (2015) uses the three components proposed in the Allee (2011) modeling language: participants, transactions, and deliverables, which are represented in figure 3. In this case, the value networks that are developed using the framework will be composed of three basic components that are based on the ones proposed in Allee (2011) 's modeling language, adapting them to be more suited for the health context. As an alternative to using the term participants, we will use the term stakeholders, as we think this term is more appropriate to the context of this work. In this enhancement of the framework, each transaction is associated with two types of stakeholders, the "donor stakeholder" and the "recipient stakeholder". The terms and correspondent definitions of the components of the value network are summed up in table 5.

Term	Definition
1. Stakeholder	Any naturally occurring entity that is affected by organizational performance (Reed et al., 2009), e.g., hospitals, patients, or medical device manufacturers.
1.1 Donor stakeholder	The stakeholder that "donates" the tangible or intangible asset. In the example provided in figure 3, the donor stakeholder would be the hospital.
1.2 Recipient stakeholder	The stakeholder that "receives" the tangible or intangible asset. In the example provided in figure 3, the recipient stakeholder would be the patient.
2. Transaction	Consists of the flow of tangible and intangible assets. They are represented as arrows between stakeholders. A transaction can

	be tangible or intangible. A tangible transaction is expressed as a green arrow, while an intangible transaction is expressed as a red arrow (Allee, 2011).
2.1 Tangible transaction	Transactions that are contracted, mandated or expected by the recipient stakeholder as part of the delivery of a product or service (Allee, 2008), e.g., telemonitoring the heart rate, blood oxygen saturation, and blood pressure.
2.2 Intangible transaction	All the unpaid or non-contractual transactions that make things work smoothly and help build relationships (Allee, 2008), e.g., transfer of knowledge in the treatment of heart diseases.
3. Deliverable	The assets that are delivered from one stakeholder to the other (Allee, 2011). A deliverable can be tangible (e.g., pacemaker) or intangible (e.g., knowledge and expertise on heart diseases).

Table 5 – Terms used for components of a value network and corresponding definition

Additionally, the concept of value that is adopted when applying this framework also needs to be introduced. Therefore, value is defined as the amount of satisfaction created by fulfilling a certain goal of a beneficiary party. It is subjective, it is dependent on the circumstances, and it is tied to the specific goals of the beneficiary party (Daaboul et al., 2015).

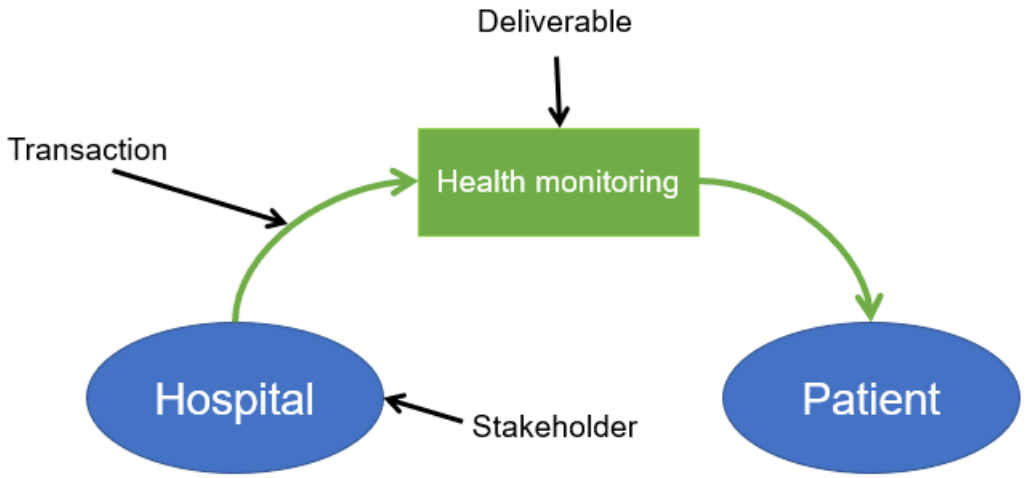

Figure 3 – Basic components used when modeling a value network

4.2 Value network modeling framework

Our value network modeling framework must be one where each step is depicted and where the steps follow a logical sequence to the value network designer. One of the key aspects of the framework must be its reproducibility. According to a U.S. National Science Foundation (NSF) subcommittee on replicability in science (Bollen et al., 2015), “reproducibility refers to the ability of a researcher to duplicate the results of a prior study using the same materials as were used by

the original investigator. That is, a second researcher might use the same raw data to build the same analysis files and implement the same statistical analysis in an attempt to yield the same results. Reproducibility is a minimum necessary condition for a finding to be believable and informative" (p.3-4). This means that anyone who applies the modeling framework to a specific problem using the same data should obtain similar value networks, i.e., value networks with the same stakeholders, transactions, and deliverables. Moreover, the value network resulting from this framework should correctly depict all the players involved in the implementation of a digital health intervention in a certain healthcare system, as well as all the transactions between each one of them that are fundamental to the success of the intervention. It should be plainly represented what is being transacted, to whom the transactions are directed, and whether they are tangible or intangible. Additionally, the goals of each stakeholder should be identified since they are crucial to making the designed value network a proper input to a value measurement approach, which must be also part of the framework.

Overall, we need to have a framework that produces a value network model that can be considered requisite. A requisite decision model is defined as a model whose form and content are sufficient to solve a particular problem (Phillips, 1984). In this case, the value network can be considered a requisite model when its form and content are sufficient to appropriately depict the dynamics involved in the implementation of a certain digital health intervention in a healthcare system and sufficient to be a good input to a value measurement approach.

Following this logic, the value network modeling framework proposed in this work can be implemented using specific steps in a certain order and logic. The idea is to identify and model the three principal components of the value network, the stakeholders, the transactions, and the deliverables. Furthermore, this framework aims to identify and quantify the value that the digital health intervention adds to each stakeholder. This framework can be considered a sociotechnical process since it combines the technical elements of modeling a value network with the social aspects of conducting interviews with the stakeholders (Baxter and Sommerville, 2011). This framework can also be considered interactive and iterative. Interactive since, in this framework, the value network is modeled with the support of the stakeholders that are part of it, and iterative since the network designer is able to repeat steps of the framework to improve the value network model.

Figure 4, it is represented a scheme with all the steps of the framework to be taken, presented succinctly and appealingly. This framework consists of four distinct phases: context definition, value network structuring, value network refining, and value analysis. The first three phases are mostly based on the Grudinschi et al. (2015) value network modeling framework with influences from the Daaboul et al. (2014) and Allee's (2011) modeling frameworks. The suggestion of the addition of a value analysis phase, where the value that the digital health intervention adds to each stakeholder is planned to be identified and quantified is one of the contributions of this framework.

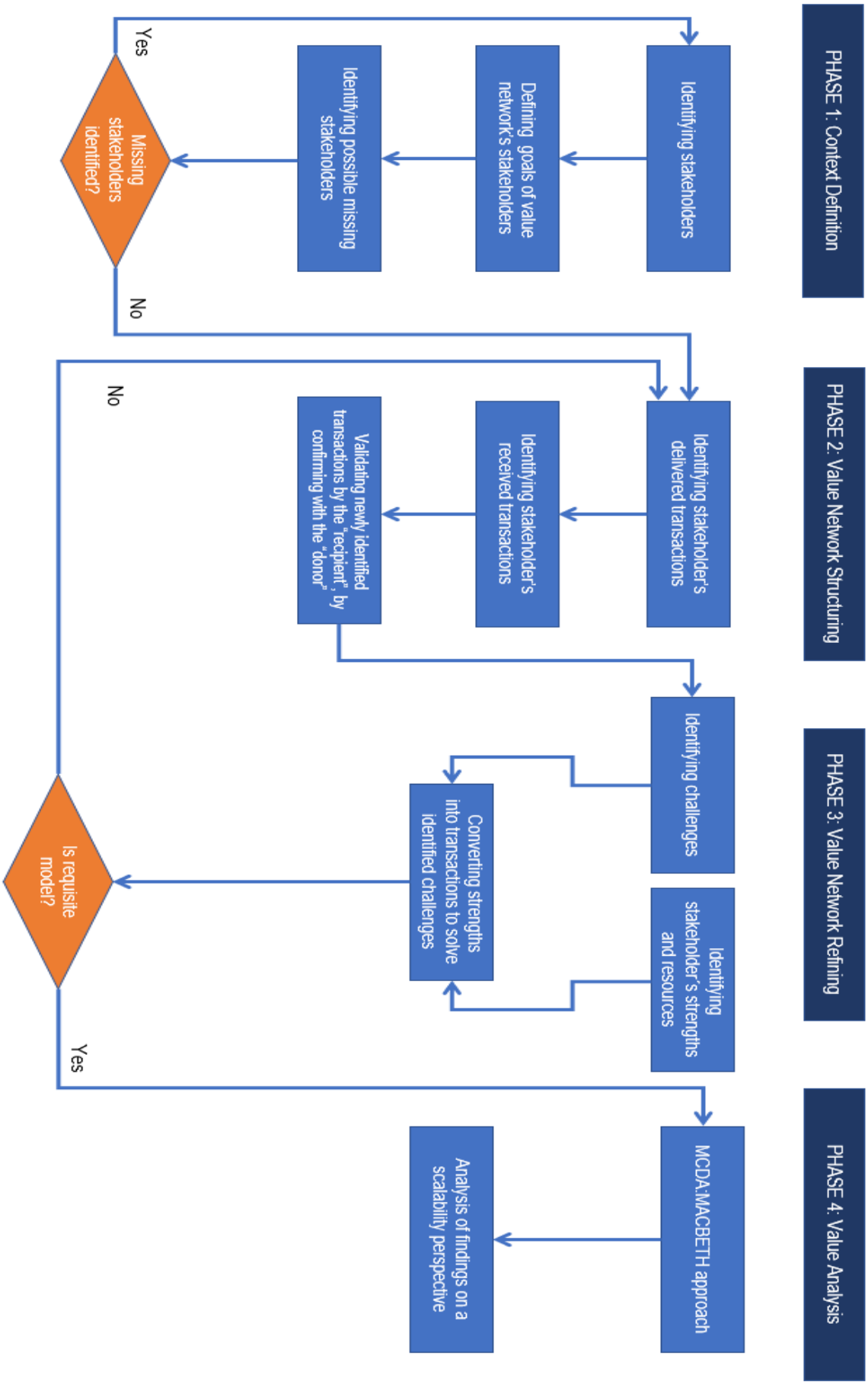

Figure 4 – Framework to model the value network

PHASE 1: Context definition

The first phase of this framework consists of the definition of the context of the value network. In this phase, the network designer should identify the stakeholders and their respective goals.

The first step of this phase consists of the identification of the stakeholders involved in the digital health intervention under consideration.

- This step is not part of the Grudinschi et al. (2015) value network modeling framework. However, we should have a step dedicated to the identification of the stakeholders of the value network (Reed et al., 2009; Lienert et al., 2013 Ferretti, 2016). Stakeholders are often identified and selected on an ad hoc basis. This has the potential to marginalize important groups, bias results, and jeopardize long-term viability and support for the process (Reed et al., 2009). All the stakeholders that are clearly confirmed to take part in the digital health intervention, i.e., that are mentioned in the description or documentation of the intervention, should be identified.
- This step gives us the list of stakeholders that will posteriorly be interviewed.

Afterward, we proceed to the identification of the network stakeholder's goals. It consists of understanding what are the main goals that each stakeholder intends to achieve through the digital health intervention under consideration.

- Like the previous, this is a step that is not present in the Grudinschi et al. (2015) value network modeling framework. However, it is a feature suggested in the Daaboul et. al (2014) modeling framework. Daaboul et. al (2015) defined value as dependent on the circumstances and tied to the specific goals of the beneficiary party. Therefore, it is necessary to define the goals of each stakeholder of the value network to understand how to identify and quantify value.
- This step can be done through a combination of two approaches. The goals should be defined from the description or documentation of the digital health intervention and should be identified through interviews or surveys with the stakeholders.

After the stakeholder's goals have been identified, it should be attempted to identify if there are any missing stakeholders that are crucial to that specific value network based on the response of the previously identified stakeholders.

- This works as a way to prevent the network designer from missing any stakeholder, thus preventing its validity from being called into question (Reed et al., 2009).
- This step may give us some potential stakeholders that are involved in important transactions and are fundamental to the success of the digital health intervention, despite not being clearly part of it.

As it can be seen from the scheme on figure 4, if any missing stakeholders are identified, the network designer should go back to the first step, adding these stakeholders to the list of identified stakeholders. Then, as before, it will be necessary to identify this new stakeholder's goals. This is an iterative process that should be executed until no more new stakeholders are identified. Only then, it can be proceeded to phase two.

PHASE 2: Value network structuring

The second phase of this framework consists of the structuring of the value network. As suggested by Grudinschi et al. (2015), the first step of this phase is based on identifying the perception of each stakeholder regarding its own added value to the network through the use of interviews.

- Based on their answers, transactions between stakeholders can start being modeled. It is important to understand what is the deliverable involved in each transaction, whether the transaction is tangible or intangible, and to who is the transaction directed.
- This step generates a first value network model consisting of each stakeholder's delivered transactions.

The next step, as also suggested by Grudinschi et al. (2015), consists of identifying the perceptions of each stakeholder's received value from other stakeholders in the network through the use of interviews.

- This step essentially consists of the identification of the transactions from other stakeholders that add value to each stakeholder, from the perspective of the recipient stakeholder, i.e., each stakeholder's received transactions.
- This step acts as a validation of the transactions that were previously identified by each stakeholder and it may add transactions that were not mentioned in the latter step.
- The transactions that are not validated should be removed from the value network.
- This step generates a value network without the unvalidated transactions that were added in the last step.

Then, if a new transaction is identified in the last step by the recipient stakeholder, it should be validated through confirmation with the donor stakeholder.

- The transactions that are validated should be added to the value network model.
- This step generates a value network with the addition of the validated transactions identified in the last step.

Afterward, it can be proceeded to phase three.

PHASE 3: Value network refining

Phase three consists of the refinement of the value network. This phase consists of three steps that combined, refine the value network model by adding transactions to solve existing challenges in the implementation of the intervention by the stakeholder with the more appropriate resources, if possible. The next three steps are all based on steps suggested by Grudinschi et al. (2015).

Firstly, the challenges and stakeholders' strengths and resources are identified. The network designer should identify the challenges in the activity of partnership that still exist, i.e., the challenges in the activity of partnership that have not been resolved through the previously identified transactions.

If any challenge is identified, the network designer should then identify the strengths and resources (intangibles and tangibles assets) of every stakeholder.

Subsequently, these strengths and resources (intangibles and tangible assets) may be converted into transactions to respond to the challenges.

- In this step, the network designer must explore how every challenge could be solved, so that it creates value for the patients and other stakeholders. It must be identified who has the best ability and resources to solve the challenge, and what type of value could be created to network stakeholders by solving the challenges in a specific way.
- These three steps work to readjust and improve the value network previously modeled. If a challenge could be solved by a certain stakeholder, a new transaction can be added to the value network.
- These steps generate a refined value network model with the addition of new transactions.

Before going into phase four, the network designer should deliberate on whether the value network model is satisfactory or not. In other words, the network designer should analyze whether the model can be considered requisite, and therefore adequate to be a good input to phase four or whether it still needs to be revised. If the model can be considered requisite, it can be proceeded to phase four, the value analysis. Otherwise, phase two and phase three should be repeated until the model can be considered requisite. This iteration helps the model to improve its quality and legitimacy.

PHASE 4: Value analysis

Finally, the last phase of the framework consists of value analysis. In this phase, the value that the digital health intervention adds for each stakeholder is identified and quantified.

As can be seen in figure 4 and as has been mentioned previously, in this phase it is used multicriteria decision analysis (MCDA). To be more precise, the MCDA technique that is used is MACBETH.

The value of healthcare depends on a multiplicity of criteria, such as the decision context and the stakeholders involved, therefore its definition is a very difficult task to accomplish (Jakab et al., 2021). However, the quantification of this value of healthcare is necessary for the assessment of the scalability of a digital health intervention (Haynes, 1999). Hence, this healthcare decision-making problem can be regarded as an MCDA problem. MACBETH was proposed since it is an interactive multicriteria decision support methodology that assists the decision-maker to obtain the value function and weights for each criterion and, in this case, obtaining the overall value score for each stakeholder of the previously modeled value network (Bana e Costa et al., 2012).

Since the main goal of this phase is to quantify the value added for each stakeholder, a set of criteria has to be identified and organized to achieve an acceptable model for each stakeholder. To achieve this, the interviews with the stakeholders in the preceding phases are truly crucial to understand what they really value in a digital health intervention and what they want to achieve from it. The goals identified in the interviews are fundamental to structuring the problem of the MCDA process. These interviews with the stakeholders are the basis to select the criteria, build the value functions for each criterion, and for the assessment of their respective weights. Therefore, they are crucial to calculate the value score of the digital health intervention to a certain stakeholder. The final result of this step should be a value network in which each node of the network, i.e., each stakeholder has a value score, which corresponds to the value that the digital health intervention adds to each stakeholder.

After the value has been quantified for each stakeholder, the network designer should analyze the findings from a scalability perspective. As previously mentioned, to assess the scalability of health interventions with proven efficacy, it is crucial to answering the following two questions (Haynes, 1999): "*Does it work in practice? Is it worth it?*". Therefore, the value network modeled through the use of this framework that has the value score added by the digital health intervention on each node helps to answer whether this intervention is worth it or not. This is a first suggestion of how the value network can aid in the assessment of a digital health intervention.

5

Case study

5 Case Study

In this chapter, we applied the value network modeling framework presented in the last chapter to an illustrative case study (Jackson, 1991). Our main goal was to demonstrate how it can be applied in practice. The case study was provided by VOH.CoLAB and consists of a project that they are involved in, EasyHealth4Covid. All the steps of the modeling framework are observed one by one, followed by the main results of each step. Despite this being a real-life case study, we consider this case study illustrative (Jackson, 1991) since there were some limitations when applying the framework to this case study, mainly in terms of conducting interviews with stakeholders of the value network. We tried to get the results as close to reality as possible by researching the project documentation, researching the stakeholders involved, and reviewing the literature on digital health interventions similar to this one. Nevertheless, the most important is to demonstrate how the technical component of the framework can be applied and identify how it could be improved in future research rather than to seek to provide a thorough and "accurate" exposition of the real data that one would obtain from the interviews with the stakeholders.

5.1 Case Description

The COVID-19 pandemic has imposed extraordinary measures on nursing homes causing there to be reduced access to National Health System (NHS) health services, reduced access to monitoring for infection and other complications, and adaptation of the healthcare providers in the adoption of telecare means. Hence, EasyHealth4COVID is a project that aims to develop telecare solutions that are easy to implement for the elderly population and that complement the NHS, creating value for all citizens and the healthcare delivery systems. It aims to develop a telehealth solution to monitor the population at risk for COVID-19 infection, promote their safety, and facilitate communication with clinical teams. It consists of a platform for interaction between a population residing in a nursing home and healthcare providers, in order to maintain and optimize the healthcare provided. It allows continuous or punctual telemonitoring of parameters such as blood pressure, heart rate, O2 saturation, and electrocardiographic recording allows access to video consultations and programmed clinical follow-up and allows access to telemonitoring results and other specific assessments. This telehealth solution was developed by VOH.CoLAB in partnership with PLUX, Future Healthcare, and Healthy Systems (VOH CoLAB, 2020). Despite this being a real-life case study, we consider this case study illustrative (Jackson, 1991) since we were limited and, therefore, the interviews with the stakeholders were not conducted. Hence, in this illustrative case study, we focused on demonstrating the technicalities involving the modeling of the value network, using data from the research of the project documentation, the research of the stakeholders involved, and the review of the literature on digital health interventions similar to this one.

5.2 Results

After this brief introduction of this project, we started by applying the value network modeling framework.

PHASE 1: Context definition

As previously mentioned, the first phase of this framework consists of the definition of the context of the value network. In this phase, the stakeholders and their respective goals must be identified.

Through the analysis of the documentation of the EasyHealth4COVID project (VOH.CoLAB, 2020), we identified four major players in this project which must be included in this value network. These four stakeholders are VOH.CoLAB, PLUX, Future HealthCare, and Healthy Systems, and the main goal of the collaboration was to scale up a telehealth solution for a nursing home. The telehealth solution included patient-remote monitoring using Internet-of-Things (IoT) devices and video-based clinical appointments (VOH.CoLAB, 2020).

VOH.CoLAB is a non-profit private association whose mission is to measure value in health. The founding partners have centralized expertise and resources to accelerate the essential restructuring of healthcare delivery for the paradigm shift towards value-based health, in which active citizen Involvement is essential (VOH.CoLAB, 2019).

PLUX develops innovative products for monitoring and analyzing biosignals that integrate wearable sensors such as electromyography (EMG), electrocardiography, breathing, and accelerometers combined with wireless connection (VOH.CoLAB, 2020).

The Future Healthcare group is a private international group specializing in the management of health and life insurance. Its mission is to provide its customers with access to the best conditions of health, life, and well-being through the development of technology solutions, operations, and innovative services for its corporate customers (VOH.CoLAB, 2020).

Health Systems is an HLTSYS spin-off of Universidade do Porto, which has professionals with experience in several areas of informatics, such as cybersecurity, data protection, integration of health information systems (Mirth Certified Professionals), National Standards Body (IPQ members), ISO 9001:2015 Certification, ITIL® 2011 Foundations in IT Management and members of the HL7 Portuguese Affiliate Chapter (VOH.CoLAB, 2020).

We started by adding these four stakeholders to our value network, as depicted in figure 5.

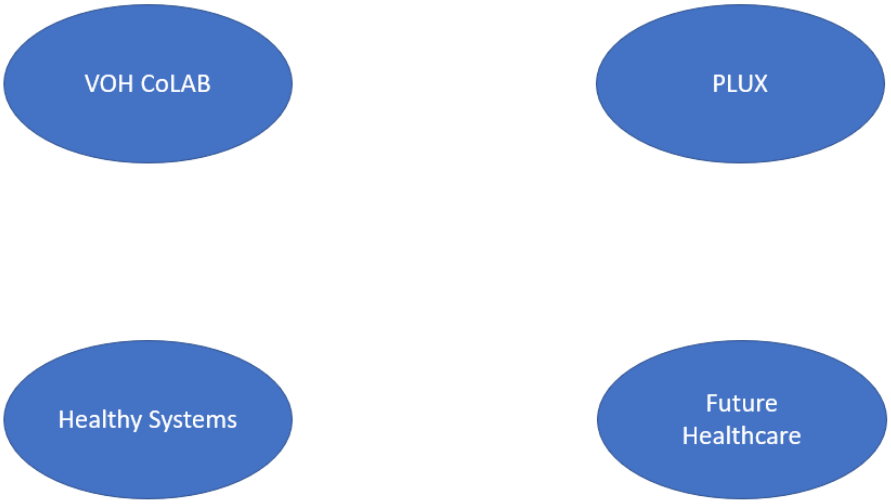

Figure 5 - Stakeholders of EasyHealth4COVID (First iteration)

Afterward, we proceeded to the identification of the value network stakeholder's goals. This step can be done through a combination of two approaches. The goals should be defined from the description or documentation of the digital health intervention and should be identified through interviews or surveys with the stakeholders. Since we were limited when applying the modeling framework to this case study, we solely defined the goals through the consultation of the documentation and research on the stakeholders of the digital health intervention identified. However, conducting interviews or surveys with the stakeholders is highly recommended and preferable. The goals of the stakeholders are presented in table 6.

VOH CoLAB	• Validate innovative methodologies to objectively measure health outcomes and costs to create scientific evidence on the principles of Value-based Healthcare • Assess the value of healthcare delivery
PLUX	• Provide solutions that are usable, interoperable, secure, and compatible with the regulation of medical devices
Future Healthcare	• Provide its customers with access to the best conditions of health, life, and well-being • Improve remote digital healthcare delivery
Healthy Systems	• Promote health, security, and robustness for their customer's Information Systems and Networking Infrastructures

Table 6 - Stakeholder's goals (First iteration)

Following the identification of the stakeholder's goals, the stakeholders should be asked if there is any missing stakeholder in the value network. In this case, we considered and added the COVID-19 risk population and the nursing home as important players in the success of this project. We considered these two as stakeholders, since, as mentioned in the last chapter, in the

context of the adoption of a digital health intervention in a health system, the key stakeholders are the patient and the healthcare provider where the intervention is to be implemented. In this illustrative case study, the patient of the digital health intervention corresponds to the COVID-19 risk population and the healthcare provider is the nursing home (VOH.CoLAB, 2020). Hence, they can be considered stakeholders of the value network of this digital health intervention.

Following the scheme of the framework (Figure 4), since missing stakeholders were identified, we needed to go back to the first step, the stakeholder's identification, and, therefore, these new stakeholders were added to the list of identified stakeholders. Thus, the two new stakeholders were added to our value network, as depicted in figure 6.

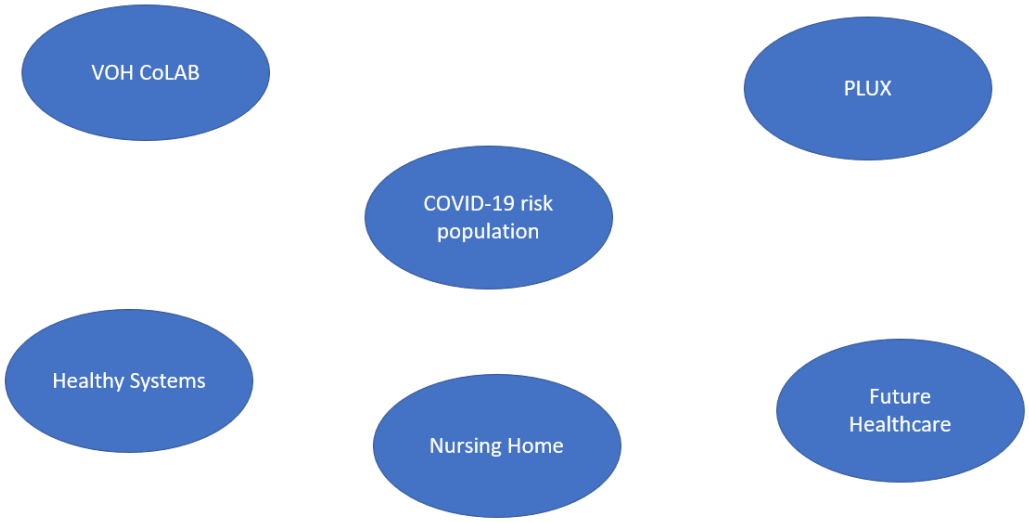

Figure 6 - Stakeholders of EasyHealth4COVID (Second iteration)

The next step consisted of identifying the new stakeholder's goals. Once more, we identified them only through the research on the documentation of the project regarding the nursing home and the COVID-19 risk population (VOH.CoLAB, 2020). Thus, we will consider their goals as the following:

Nursing Home	• Promote the health of the patients and prevent illness • Provide a high standard of care and support to the patients
COVID-19 Risk Population	• Increase their security • Maintenance of health, well-being, and quality of life

Table 7 - Stakeholder's goals (Second iteration)

Finally, it should be reflected if there are missing stakeholders of the value network through the interviews with the new stakeholders. In this case, we considered that no more stakeholders were identified. Consequently, we proceeded to phase two of the value network modeling framework.

PHASE 2: Value network structuring

The second phase of this framework consists of the structuring of the value network. In the first step of this phase, it must be identified the perception of each stakeholder regarding its own added value to the network through the use of interviews. Once again, we had to rely on researching documentation associated with the project and its stakeholders to obtain appropriate illustrative results of this step (VOH.CoLAB, 2020). The results of this illustrative case study are grouped by stakeholder and presented in table 8. We specified the deliverable that is being exchanged and who is the recipient stakeholder, the stakeholder that "receives" the tangible or intangible asset. Additionally, we specified if the transaction is tangible or intangible. Tangible transactions are the ones that are contracted, mandated, or expected by the recipient stakeholder as part of the delivery of a product or service. On the other hand, intangible transactions are all the unpaid or non-contractual transactions that make things work smoothly and help build relationships.

VOH CoLAB	• Contribute with knowledge in digital literacy (Intangible) ->COVID-19 Risk Population, Nursing Home • Contribute with health knowledge (Intangible) -> COVID-19 Risk Population • Apply disruptive scientific methods and transfer scientific knowledge (Tangible) ->Nursing Home • Collect and analyze health data (Tangible) -> Nursing Home • Implementation and monitoring of the telemonitoring service (Tangible) -> Nursing Home
PLUX	• Develops digital health products for patient monitoring (Tangible) -> Nursing Home • Provides specific services (Tangible) -> Future Healthcare
Future Healthcare	• Management of the contracting process, negotiating and maintaining financial relationships with the Nursing Home (Tangible) -> Nursing Home • Integral management of all operational and clinical processes necessary for managing Health and Life Insurance. (Tangible) -> COVID-19 Risk Population • Provision of a platform for teleconsulting (Tangible) -> Nursing Home
Healthy Systems	• Cybersecurity (Tangible) -> COVID-19 Risk Population • Data protection (Tangible) -> COVID-19 Risk Population

	• Integration of Health Information Systems (Tangible) ->Nursing Home
Nursing Home	• Health Monitoring (Tangible) ->COVID-19 Risk Population • Provision of healthcare (Tangible) ->COVID-19 Risk Population
COVID-19 Risk Population	• Generation of evidence on the added value of the telemonitoring service (Tangible) -> VOH CoLAB • Quality assessment and feedback for design improvement (Tangible) -> PLUX • Feedback on the platform for teleconsulting (Tangible) -> Future Healthcare • Generation of evidence of the quality of services provided (Tangible) -> Healthy Systems • Quality assessment and impact on reputation (Tangible) -> Nursing Home

Table 8 - Perceptions of each stakeholder's added value to the network

Based on the information that was gathered in table 8, we can start modeling a first value network. The perceptions of each stake stakeholder's added value were represented as transactions and, therefore, represented in the form of arrows. The direction of each arrow indicates for whom the deliverable was "donated" by a specific stakeholder or, in reverse, from which stakeholder a specific deliverable was received. The value network obtained from the first step of this phase is represented in figure 7.

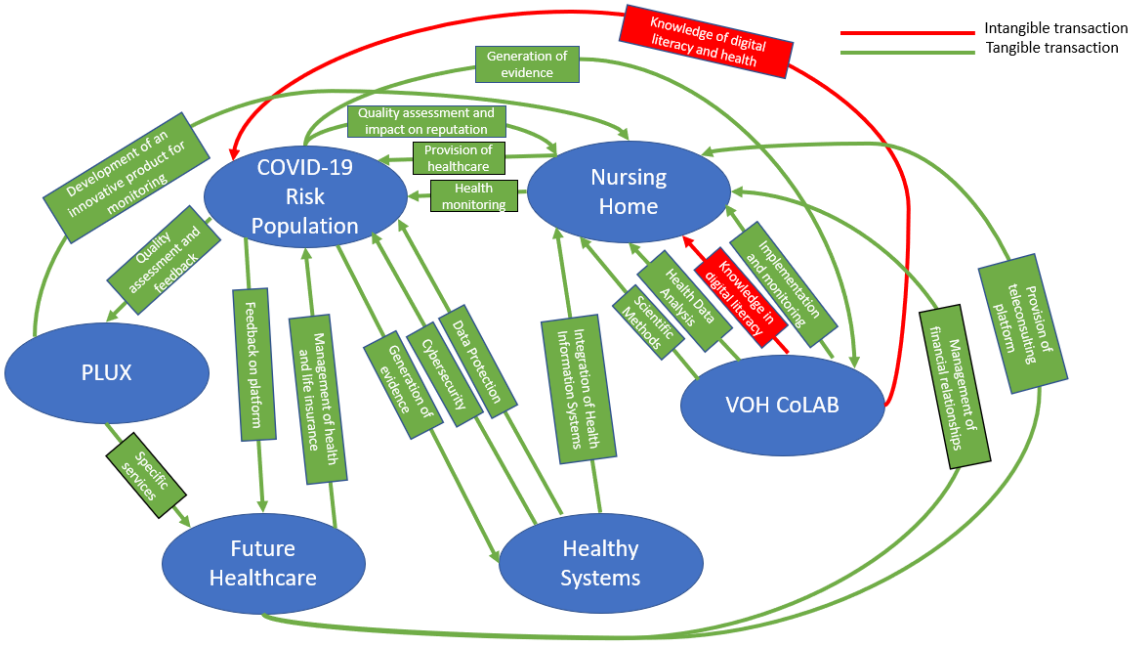

Figure 7 - Value network consisting of transactions related to the perceived added value of each stakeholder

In the next step of this phase, it has to be identified the perception of each stakeholder's received value from other stakeholders in the network through the use of interviews. As it was not possible to carry out the interviews, to demonstrate how to apply this step, we used a hypothetical and merely illustrative situation as an example. Thus, we considered the results of this step as presented in table 9.

VOH CoLAB	• COVID-19 Risk Population -> Generation of evidence on the added value of the telemonitoring service (Tangible)
PLUX	• COVID-19 Risk Population -> Generation of evidence on the added value of the telemonitoring service (Tangible)
Future Healthcare	• COVID-19 Risk Population -> Generation of evidence on the added value of the telemonitoring service (Tangible)
Healthy Systems	• PLUX ->Transfer funds (Tangible) • COVID-19 Risk Population -> Generation of evidence on the added value of the telemonitoring service (Tangible)
Nursing Home	• VOH CoLAB -> Contribute with knowledge in digital literacy (Intangible) • VOH CoLAB -> Apply disruptive scientific methods and transfer scientific knowledge to healthcare organizations (Intangible) • VOH CoLAB -> Collect and analyze health data (Tangible) • VOH CoLAB -> Implementation and monitoring of the telemonitoring service (Tangible) • PLUX -> Develops digital health products for patient monitoring (Tangible) • Future Healthcare ->Management of the contracting process, negotiating and maintaining financial relationships with the Nursing Home (Tangible) • Future Healthcare -> Provision of a platform for teleconsulting (Tangible) • Healthy Systems -> Integration of Health Information Systems (Tangible) • COVID-19 Risk Population -> Generation of evidence on the added value of the telemonitoring service (Tangible)

COVID-19 Risk Population	• VOH CoLAB -> Contribute with knowledge in digital literacy and health (Intangible) • Future Healthcare -> Integral management of all operational and clinical processes necessary for managing Health and Life Insurance (Tangible) • Healthy Systems -> Cybersecurity (Tangible) • Healthy Systems -> Data protection (Tangible) • Nursing Home -> Health Monitoring (Tangible) • Nursing Home -> Provision of healthcare (Tangible)

Table 9 - Perceptions of each stakeholder's received value from other stakeholders in the network

This step should act as a validation of the transactions that were previously identified by each stakeholder and possibly add transactions that were not mentioned in the latter step. To do this, we compared the table with the perceptions of each stakeholder's added value to the network (Table 8) and the table with the perceptions of each stakeholder's received value from other stakeholders in the network (Table 9). Through this comparison, in this illustrative case, we noticed that Future Healthcare did not identify the transaction of specific services from PLUX, which was identified in the first step of this phase, presented in table 8. Hence, this transaction was not validated and was removed from the value network. We then obtained the value network without the unvalidated transaction represented in figure 8.

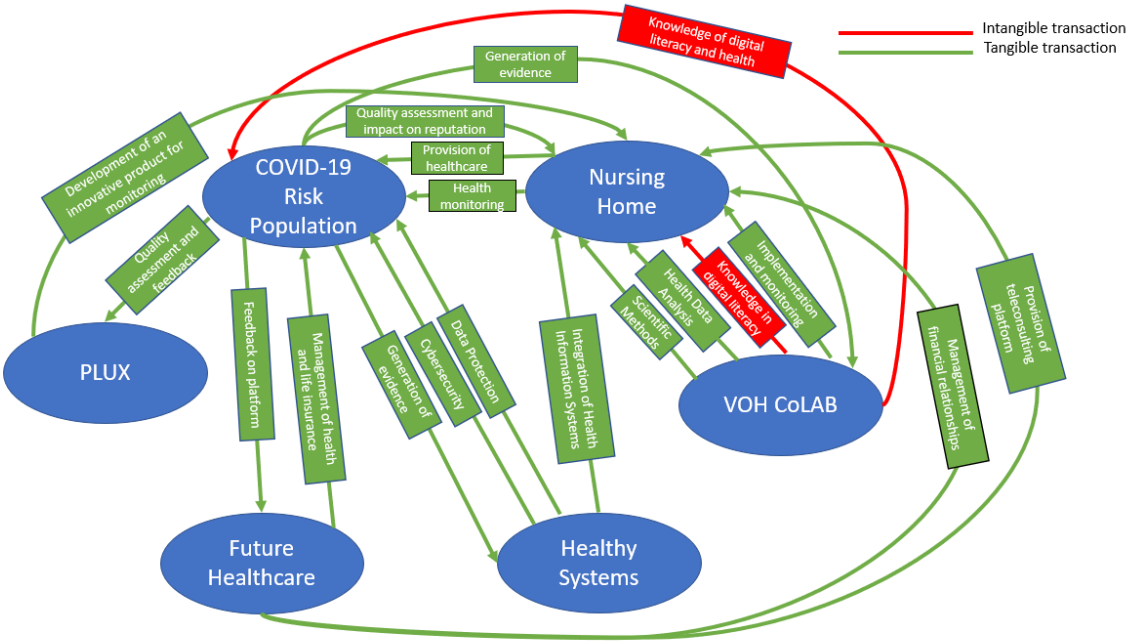

Figure 8 - Value network without the unvalidated transaction

Additionally, from the comparison of the tables, we noticed that from the data presented in table 8, PLUX does not transfer funds to Healthy Systems. However, from the data retrieved from table 9, Healthy Systems receive funds from PLUX. This took us to the next step of this framework.

In the case that a new transaction is identified in the last step by the recipient stakeholder, it should be validated through confirmation with the donor stakeholder. As a merely illustrative scenario, we considered that PLUX indeed confirmed that they transferred funds to Healthy Systems. Therefore, this transaction was added to the value network. This resulted in the value network presented in figure 9.

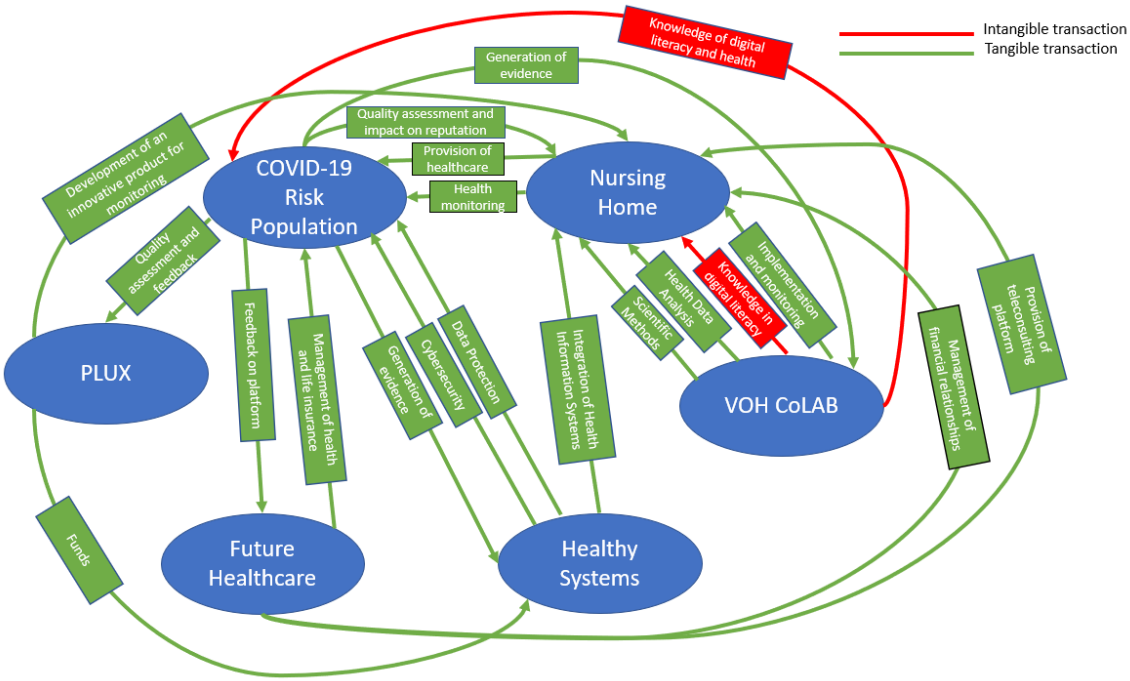

Figure 9 - Value network with the added transaction

In Figure 9 it is presented the final value network of our first iteration of phase two of the framework. Therefore, we proceeded to phase 3.

PHASE 3: Value network refining

Phase three consists of the refinement of the value network. This phase consists of three steps that combine to refine the value network model by adding transactions to solve existing challenges in the implementation of the digital health intervention by the stakeholder with the more appropriate resources, if possible.

Despite this being an illustrative case study (Jackson, 1991), we tried to get the results as close to reality as possible by researching the project documentation, researching the stakeholders involved, and reviewing the literature on digital health interventions similar to this one. Nevertheless, the most important is to demonstrate how the technical component of the framework can be applied. Initially, we needed to identify existing challenges in the implementation of the digital health intervention. This can be done through the use of interviews and by reviewing the literature

on digital health interventions similar to this one. In our case, it was solely done through the literature review. Examples of challenges to implementing this digital health intervention are presented in table 10.

Challenges to implementing EasyHealth4COVID
• Nursing Home resistance to change/lack of interest • Additional work to the Nursing Home (changes in work routines) • Lack of patient education regarding the use of technology • Lack of technology skills from the Nursing Home • Lack of acceptance from the patients

Table 10 – Challenges to implementing the digital health intervention

Additionally, we needed to identify the stakeholder's strengths and resources. It is preferable to do this step through the use of interviews, however, we have done it through research on the stakeholders of this value network and the documentation of the project (VOH.CoLAB, 2020). The stakeholder's strengths and resources can be found in table 11.

In this illustration of the framework application, we only focused on showing how to solve a certain previously identified challenge. So, we considered the challenge of the lack of population education regarding the use of technology, which was retrieved from table 10. By observing the table of the stakeholder's strengths and resources (table 11) we noticed that VOH CoLAB has knowledge of digital literacy, which is a strength that is appropriate to solve this challenge. Therefore, we refined the value network by adding a tangible transaction such as technology use training from VOH CoLAB to the COVID-19 Risk Population, as it is represented in Table 12. The refined value network which resulted from the addition of this transaction is depicted in figure 10.

Before going into phase four, we had to deliberate on whether the value network model obtained could be considered requisite or not. As mentioned previously, a requisite model is a model whose form and content are sufficient to solve a particular problem (Phillips, 1984). In this case, the value network can be considered a requisite model when its form and content are sufficient to appropriately depict the dynamics involved in the implementation of a certain digital health intervention in a healthcare system and sufficient to be a good input to a value measurement approach. In this illustrative demonstration, we considered the value network model achieved as a requisite model. Hence, we then proceeded to phase four. Otherwise, since this is an iterative framework, phase two and phase three would have been repeated until this model could be considered requisite.

VOH CoLAB	• Knowledge in digital literacy and health • Ability to define the most relevant clinical results for a specific disease or health system, reported by patients, social and economic. • Ability to analyze health data and paths in Health to accurately characterize and design inpatient and outpatient paths that enable the provision of better healthcare. • Ability to use cost analysis methodologies to measure costs along paths in healthcare. • Ability to applicate disruptive scientific methods
PLUX	• Ability to develop new sensor solutions for the specific needs of your applications • Ability to develop customized wearable solutions to meet sensor and signal processing requirements. • Ability to convert raw data into meaningful information to support decisions. • Ability to build your digital health solution from a wearable device to cloud and mobile applications.
Future Healthcare	• Ability to provide integrated solutions for the digitization of care. • Ability to provide a technological platform where the entire process of contracting, negotiating, and maintaining financial relationships with healthcare providers is based. • Capability to manage all operational and clinical processes necessary in managing Health and Life Insurance. • Knowledge of the behavior of its customers and providers, as well as trends in the evolution of healthcare costs.
Healthy Systems	• Cybersecurity • Data protection • Integration of Health Information Systems

Table 11 – Stakeholder's strengths and resources

Challenges	Using an Asset to Respond to a Challenge	Converting an Asset Into a Value
Lack of patient education regarding the use of technology	VOH CoLAB: Knowledge in digital literacy	Technology use training (tangible) VOH CoLab -> Patient

Table 12 – Conversion of strengths and resources into transactions to respond to the challenges

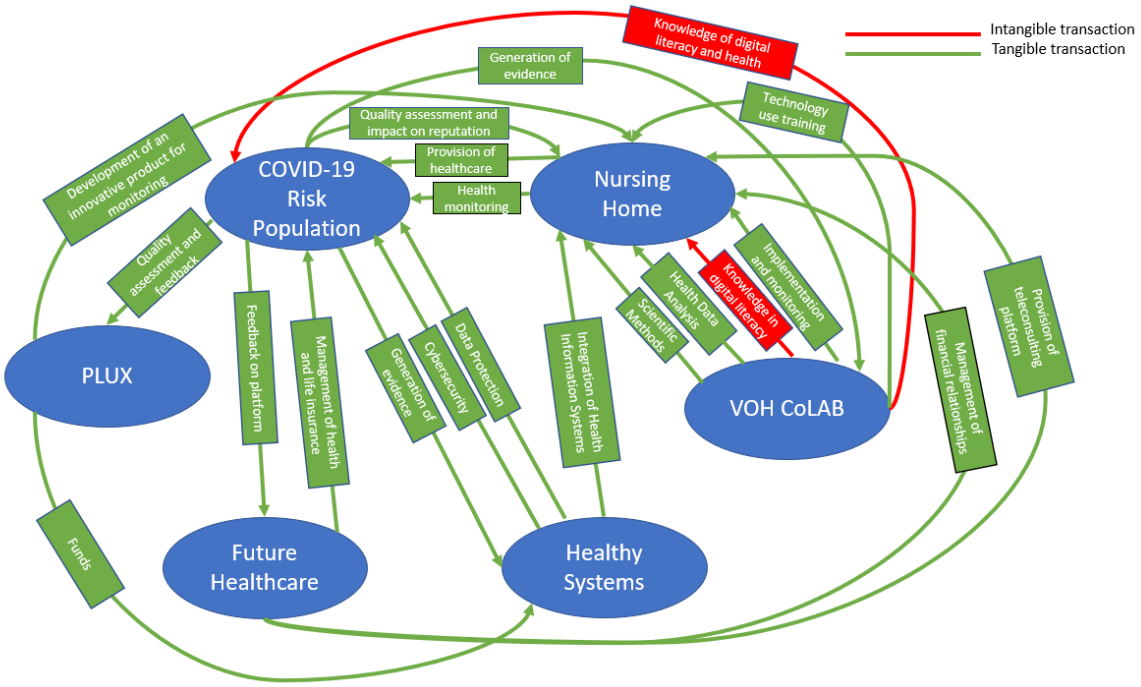

Figure 10 – Refined value network with the added transaction

PHASE 4: Value analysis

Finally, the last phase of the framework consists of the value analysis. In this phase, the value that the digital health intervention adds for each stakeholder should be identified and quantified.

As mentioned before, the value in healthcare depends on a variety of criteria, such as the decision context and the stakeholders involved. To quantify the value added for each stakeholder, a set of criteria has to be identified and organized to achieve an adequate value quantification model for each stakeholder. Since the interviews with the stakeholders are crucial to the choice of the criteria, the building of value functions for each criterion, and the assessment of their respective weights and we were not able to perform them, we have not explored further phase four in this illustrative case study.

6

Discussion

6 Discussion

In the beginning of this work, objectives were outlined. We aimed to explore the literature on existing frameworks to model a value network to help in the development of a value network modeling framework; suggest a value network modeling framework to be used in the scalability assessment of a digital health intervention; evaluate the potential of using a value network as an aiding tool to assess the scalability of a digital health intervention; and apply the value network modeling framework, using a case study in the Portuguese context. Therefore, in this chapter, we discuss each one of these objectives, going through if this objective was fully accomplished, what was really achieved, the limitations encountered and future research that should be carried out to accomplish these objectives.

6.1 Discussion of 'value network' literature review

In this work, we aimed to explore the literature on existing frameworks to model a value network to help in the development of our value network modeling framework. Firstly, the literature on the 'value network' concept was sparse and dispersed. Moreover, there was still little research on the application of this concept to healthcare settings. Therefore, one of the first contributions of this thesis was the summary and agglomeration of the value network literature. The performed literature review helped us to gather all the definitions and perceptions of this concept to make us understand the variations between them, giving us a wider perspective on what comprises a value network. The literature review also extended to the studies that involved what is needed to effectively model a value network. These are studies that proposed the components that should be modeled to constitute the value network model and the studies that modeled and successfully applied a value network. However, we found two types of studies that modeled and successfully applied a value network. There were studies in which the authors focused on applying the value network resulting in the absence of a clear and structured methodology to model the value network, which are the ad-hoc processes to model a value network. These types of studies have associated problems since the absence of a clear and structured methodology to model the value network can hinder subsequent researchers that are trying to replicate the process to reach similar accomplishments and hinder subsequent researchers that are trying to advance the value network model of the study or adapt it to other research areas. Additionally, the absence of a structured methodology can also raise questions about the validity of the value network designed (Leung, 2015). Since the ad-hoc processes to model a value network comprised the majority of the value network modeling literature, there was a gap in this literature that should be overcome. Nevertheless, the literature review provided three studies with the aim of proposing a structured methodology to model a value network, which we called the value network modeling frameworks. These three studies were the Allee (2011) value network modeling framework, the Daaboul et al. (2014) value network modeling framework, and the Grudinschi et al. (2015) value network modeling framework. These three frameworks provided significant and structured guidance to model a value network. Additionally, they were validated through their application in case studies. After

a thorough analysis of each of these modeling frameworks, it was concluded that none of them was entirely the appropriate framework to model a value network suited to be used in the context of this study, to aid in the assessment of the scalability of a digital health intervention. Therefore, the next objective was to suggest a value network modeling framework that could be used in this context. In general, this objective was successfully accomplished. Nevertheless, further review of the value network literature is encouraged to better summarize and agglomerate this sparse and dispersed literature.

6.2 Discussion of suggested value network modeling framework

This work aimed to suggest a value network modeling framework to be used in the scalability assessment of a digital health intervention. This suggested framework should model a value network that could be used as an aiding tool in the assessment of the scalability of a digital health intervention.

As mentioned previously, by carrying out the literature review, we were able to identify the existing value network modeling languages and value network modeling frameworks. Through them, we suggested a value network modeling framework, by trying to enhance the Grudinschi et al. (2015) modeling framework, that could generate a value network model that may help to answer the question of whether a digital health intervention has scalability or not. This framework can be considered a sociotechnical process since it combines the technical elements of modeling a value network with the social aspects of conducting interviews with the stakeholders (Baxter and Sommerville, 2011).

Technically, since the components that constitute the value network were specified, and since the proposed value network modeling framework consisted of clear steps that followed a logical sequence, in other words, a step-by-step guideline, the value network modeling process is easy to understand and follow. By having these characteristics, we ensured that this framework had reproducibility. As mentioned previously, according to a U.S. National Science Foundation (NSF) subcommittee on replicability in science (Bollen et al., 2015), “reproducibility refers to the ability of a researcher to duplicate the results of a prior study using the same materials as were used by the original investigator. That is, a second researcher might use the same raw data to build the same analysis files and implement the same statistical analysis in an attempt to yield the same results. Reproducibility is a minimum necessary condition for a finding to be believable and informative” (p.3-4). This means that anyone who applies the modeling framework to a specific problem using the same data should obtain similar value networks, i.e., value networks with the same stakeholders, transactions, and deliverables. Hence, this modeling framework counters one of the major problems of the value network literature, the lack of step-guided and reproducible methods to model a value network, which compromises the use of this model as a tool to support the resolution of problems of various natures (Leung, 2015).

However, despite this being a concrete step-by-step guideline, there is a big social component in the value network modeling process, which is dependent on interviews with the stakeholders. The interviews with the stakeholders are the bigger source of data that is used to model the value network. Therefore, a lack of collaboration, misalignment, and lack of understanding of the stakeholders can hinder especially, phase 2 of this framework, which consists of the value network structuring. Therefore, it should be explored how problem structuring methods (PSMs) can aid the structuring of the value network. PSMs are a broad group of model-based problem handling approaches whose purpose is to assist in the structuring of problems rather than directly derive a solution (Rosenhead, 2013). The over-arching emphasis which the methods share is on helping groups of stakeholders to identify what problem they could usefully work on together and to assist them in making progress with that task (Rosenhead, 2013). The outcomes of a successful application of a PSM will be a group of stakeholders who have gained a deeper insight into their problem area and a group of stakeholders whose shared experience has led to improved relations with each other (Rosenhead, 2013). The foremost PSMs are Soft Systems Methodology (SSM), Strategic Choice Approach (SCA), and Strategic Options Development and Analysis (SODA) (Gomes Júnior and Schramm, 2021). Additionally, in future work, it should be explored and tested the use of other methods to gather the data from the stakeholders to model the value network. Methods such as Focus Group Discussion (FGD), Q methodology, Nominal Group Technique (NGT), Delphi, Decision Conference, Surveys, and Questionnaires (Mukherjee et al., 2018).

The output of this modeling framework is a value network that effectively depicts all the stakeholders involved in the implementation of the digital health intervention in a healthcare system. Moreover, the value network model produced depicts the transactions that are fundamental in this process between each of the stakeholders. It shows what is involved in the transaction, to whom the transactions are directed, i.e., the recipient stakeholder, as well as the stakeholder responsible for carrying out the transaction, i.e., the donor stakeholder, and if it is tangible or intangible. The value network model can be a visual tool not only to show the stakeholders how they are all connected when collaborating but also to help the stakeholders to better understand easier the benefits of the collaboration, thereby motivating them to be engaged in it (Grudinschi et al., 2015).

We also highlight the importance of having a phase such as phase three of our framework, the value network refining, which was only present before in Grudinschi's value network modeling framework (Grudinschi et al., 2015). This phase can contribute to the addition of transactions to the value network that the stakeholders themselves could not identify on their own as important to a successful implementation of the intervention in the healthcare system. It provides new insights for determining how the collaboration between the stakeholders can be enhanced. Therefore, enhancing the collaboration in the network by adding new transactions can improve the probability of a digital health intervention being successful in the healthcare system in which it was implemented, reinforcing the value network as a great support tool. Thus, our framework

goes beyond the objective initially set and also helps to improve the probability of a digital health intervention to be scaled up.

Despite not being represented in the value network model, the identification of the goals of the stakeholders is a crucial step of this framework since they are fundamental to making this value network model a suitable input to a value measurement approach. The suggestion of the addition of a value measurement approach to be applied in a value network, which is critical to the assessment of the scalability problem, is one of the improvements of this modeling framework since it clearly distinguishes this one from the previous frameworks that were found in the performed literature review. This is the first value network modeling framework that could be used in a healthcare context that goes beyond the value network design and suggests that the value added for each stakeholder, in this context by the implementation of the digital intervention, should be quantified through the application of an MCDA method. However, this study only focused conceptually on the result final that the MCDA value measurement approach should generate. There is still a big gap in our framework, which is the absence of a step-by-step guide to applying this value measurement approach. Therefore, this phase of the framework is still at a very initial stage and future research needs to focus on the technical component of the value measurement approach.

In summary, we were able to provide a first suggestion of a framework that models a value network that may be used as an aiding tool to evaluate the scalability of a digital health intervention, and, additionally, that helps to improve the probability of a digital health intervention to be scaled up. However, it is crucial to highlight that this modeling framework, is still at an early stage. Thus, it is crucial for future research to be carried out to improve and validate this modeling framework. It should be explored how problem structuring methods (PSMs) can aid the structuring of the value network, it should be explored and tested the use of other methods to gather the data from the stakeholders to model the value network such as Delphi and Decision Conference, and it is critical that future research focuses on the technical component of the value measurement approach since this study only focused conceptually on the result final that the MCDA value measurement approach should generate.

After the value added for each stakeholder by the digital health intervention has been quantified, the next step of the framework (figure 4) is to analyze the findings from a scalability perspective. This takes us to the next objective, evaluate the potential of using a value network as an aiding tool to assess the scalability of a digital health intervention.

6.3 Discussion of the value network as an aiding tool to assess the scalability of a digital health intervention

This thesis aimed to explore the potential of using the value network as an aiding tool to assess the scalability of a digital health intervention. Even though this study did not focus on the technicalities of the value measurement approach, this study contributed with a description of the results

that should be obtained from this approach and how they should be analyzed to aid in the scalability assessment. The final result of this framework is a value network that successfully depicts the dynamics involved in the implementation of the digital health intervention in a healthcare system, including the value score added by this intervention to each stakeholder. This value network helps in answering whether the digital health intervention is worth it or not, which is a crucial question in assessing its scalability (Haynes, 1999). This is a first suggestion of how the value network can aid in the assessment of a digital health intervention.

Nevertheless, scenario analysis emerges as a possibility to further explore how the value network may be used as an aiding tool to assess the scalability of a digital health intervention. March et al. (2012) defined scenario analysis as internally consistent stories about ways that a specific system might evolve in the future. Depending on the results obtained from the value measurement approach, there are alternative outcomes, i.e., scenarios. Scenarios are plausible accounts of the future rather than forecasts (March et al., 2012). Using scenario analysis, it may be provided different options for future development paths resulting in varying outcomes and corresponding different scalability implications.

6.4 Discussion of case study

This work aimed to apply the value network modeling framework, using a case study in the Portuguese context. However, one big limitation of this study was the fact that the modeling framework was only applied to an illustrative case study (Jackson, 1991) since we were limited in terms of conducting interviews with stakeholders of the value network, and so, these were not carried out. Therefore, when applying this sociotechnical approach to this case study, we were able to only demonstrate the technical component of the framework. Nevertheless, this illustrative case study was important to demonstrate how the framework can be applied, despite not using data obtained from the interviews with the stakeholders, and, therefore, contributing to the reproducibility of this framework, i.e., anyone who applies the modeling framework to a specific problem using the same data should obtain similar value networks, i.e., value networks with the same stakeholders, transactions, and deliverables. The case study that was provided by VOH.CoLAB, consisted of a project that they were involved in, which is EasyHealth4Covid. By applying this modeling framework to an implementation of a digital health intervention problem, such as the EasyHealth4COVID, we were able to show that this framework can produce a value network that effectively depicts all the stakeholders involved in the implementation of the digital health intervention in a healthcare system. Moreover, the value network model produced depicted the transactions that are fundamental in this process between each of the stakeholders. It showed what is involved in the transaction, to whom the transactions are directed, i.e., the recipient stakeholder, as well as the stakeholder responsible for carrying out the transaction, i.e., the donor stakeholder, and if it is tangible or intangible. The value network model can be a visual tool not only to show the stakeholders how they are all connected when collaborating but also to help the stakeholders to better understand easier the benefits of the collaboration, thereby motivating them to be engaged in it (Grudinschi et al, 2015). Additionally, and most importantly, by applying this modeling

framework to this case study, we were able to show how the technical component of modeling a value network can be performed, which helps a subsequent researcher that may have to model a value network that represents their specific problem.

However, since we were limited in conducting interviews and the interviews with the stakeholders are crucial to the choice of the criteria, the building of value functions for each criterion, and the assessment of their respective weights and we were not able to perform them, we have not explored phase four of the framework in this illustrative case study. The absence of the social component of this framework, which compromised the data sample to model the value network and the assessment of phase four, made it not possible to validate this framework.

Therefore, it is important to underline once again that the value network modeling framework that was suggested in this study is still in a very early stage and it is crucial for it to be applied in its fullness without any restraints, such as conducting interviews, to a real-world case study to fully validate it.

7

Conclusion

7 Conclusion

The main focus of this thesis, manifested in Chapter 1, was to evaluate the potential of using a value network as an aiding tool to assess the scalability of a digital health intervention. To do so, a literature review was carried out to determine what are the existing methods to model a value network. It was found a gap in the value network modeling methods literature since most of the studies that modeled and used the value network did not provide a clear and structured methodology to model it. Nevertheless, the literature review carried out resulted in three studies that effectively propose value network modeling frameworks: the Allee (2011) value network modeling framework, the Daaboul et al. (2014) value network modeling framework, and the Grudinschi et al. (2015) value network modeling framework. However, none of these frameworks generated a value network that could be used as an aiding tool to assess the scalability of a digital health intervention. Hence, the focus of this work also shifted towards suggesting a value network modeling framework that generated a value network that could be used in the context of this work.

This work made a first suggestion for a value network modeling framework. The proposed value network modeling framework consisted of clear steps that followed a logical sequence, which makes the value network modeling process much easier to understand and follow. By having these characteristics, we ensured that this framework had reproducibility. The first three phases of this framework are focused on the modeling of the value network. So, they can be used as a guideline for any researcher that needs to model a value network as a supporting tool, and therefore, adapted and used for any type of problem. It is not exclusive to the scalability of a digital health intervention problem. This modeling framework adds value to the value network literature since it gathers more information on and presents in more detail the value network modeling process. Hence, this modeling framework tackles one of the major problems of this literature, the lack of step-guided and reproducible methods to model a value network. Additionally, we also need to highlight the importance of having a phase such as phase three of our framework, the value network refining, since, with this phase, our framework goes beyond the objective initially set and also helps to improve the probability of a digital health intervention to be scaled up.

This thesis aimed to evaluate the potential of using the value network as an aiding tool to assess the scalability of a digital health intervention. For this purpose, it was suggested to add a value measurement approach to be applied in the value network to quantify the value added to each stakeholder by the digital health intervention. This is one of the contributions of this modeling framework since it separates this one from the previous frameworks that could be used in a healthcare context. This value network helps in answering whether the digital health intervention is worth it or not, which is a crucial question in assessing its scalability (Haynes, 1999). This is a first suggestion of how the value network can aid in the assessment of a digital health intervention.

This work also aimed to apply the value network modeling framework, using a case study in the Portuguese context to validate it. However, one big limitation of this study was the fact that the

modeling framework was only applied to an illustrative case study (Jackson, 1991), since interviews with stakeholders were not carried out. Therefore, when applying this sociotechnical approach to this case study, we were able to only demonstrate the technical component of the framework. Nevertheless, this illustrative case study was important to demonstrate how the framework can be applied, despite not using data obtained from the interviews with the stakeholders.

7.1 Future Work

In chapter 6, the future work that must be carried out was discussed and pointed out. In this section, a summary of this future work is provided.

As mentioned previously, further review of the value network literature is encouraged to better summarize and agglomerate this sparse and dispersed literature. Additionally, since the interviews with the stakeholders are the bigger source of data that is used to model the value network and there could be a lack of collaboration, misalignment, and lack of understanding of the stakeholders, which could hinder especially phase 2 of this framework, in future research it should be explored how problem structuring methods (PSMs) can aid the structuring of the value network. Moreover, it should be explored and tested the use of other methods to gather the data from the stakeholders to model the value network. Methods such as Focus Group Discussion (FGD), Q methodology, Nominal Group Technique (NGT), Delphi, Decision Conference, Surveys, and Questionnaires (Mukherjee et al., 2018). The value network modeling framework proposed is on a very early stage, so future developments and improvements concerning this framework, especially in phase four, are encouraged and should be carried out. The value quantification process that is part of the proposed framework should be further explored, as it should have a step-by-step guide to applying the MACBETH approach to obtain the value scores needed for the analysis on a scalability perspective, just as there is a step-by-step guide to model the value network. Furthermore, scenario analysis emerges as a possibility to further explore how the value network may be used as an aiding tool to assess the scalability of a digital health intervention. Using scenario analysis, it may be provided different options for future development paths resulting in varying outcomes and corresponding different scalability implications. Finally, we underline that it is crucial for the framework to be applied and tested in its fullness, without restrictions on conducting interviews with the stakeholders, in a case study so that it can be fully validated in a real-world case.

8

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8 References

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