UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR TÉCNICO

Developing approaches for continuously monitoring and evaluating integrated remote care interventions

Rafael Alexandre Pires Miranda

Supervisor: Doctor Mónica Duarte Correia de Oliveira
Co-supervisor: Doctor Filipa Freitas de Matos Baptista
Doctor Isabel Garcia Fonseca Faro de Albuquerque

Thesis approved in public session to obtain the PhD Degree in
Engineering and Management

Jury final classification:
Pass with Distinction and Honour

2025

UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR TÉCNICO

Developing approaches for continuously monitoring and evaluating integrated remote care interventions

Rafael Alexandre Pires Miranda

Supervisor: Doctor Mónica Duarte Correia de Oliveira
Co-supervisor: Doctor Filipa Freitas de Matos Baptista
Doctor Isabel Garcia Fonseca Faro de Albuquerque

Thesis approved in public session to obtain the PhD degree in
Engineering and Management

Jury final classification:
Pass with Distinction and Honour

Jury

Chairperson:

Doctor Rui Miguel Loureiro Nobre Baptista, Instituto Superior Técnico, Universidade de Lisboa

Members of the Committee:

Doctor Maria do Céu Caixeiro Mateus, Faculty of Health and Medicine, Lancaster University, United Kingdom

Doctor Luís Miguel Cândido Dias, Facultade de Economia, Universidade de Coimbra

Doctor Mónica Duarte Correia de Oliveira, Instituto Superior Técnico, Universidade de Lisboa

Doctor Ana C. L. Vieira Godinho de Matos, Instituto Superior Técnico, Universidade de Lisboa

Funding Institution: Fundação para a Ciência e Tecnologia (FCT)

2025

AGRADECIMENTOS

Começo por agradecer à Fundação para a Ciência e Tecnologia (FCT) por me atribuir a bolsa de doutoramento 2020.05845.BD, graças à qual este projeto foi possível. Agradeço também ao Instituto Superior Técnico pela atribuição de uma bolsa de investigação no âmbito do projeto 101BP.03394.1.01, que suplementou o período final do meu doutoramento. À Siemens Healthineers Portugal e ao Centro de Estudos de Gestão do Instituto Superior Técnico (CEGIST), instituições de acolhimento do doutoramento, agradeço por me providenciarem um ambiente de investigação com todas as condições para desenvolver trabalho de elevada qualidade. Agradeço também às mesmas pelo apoio financeiro no contexto de divulgação científica, cujo suplemento às bolsas foi fulcral. Deixo também a nota de que a investigação, em diferentes momentos, foi conduzida no âmbito dos projetos MEDIVALUE (bolsa FCT n.º PTDC/EGE-OGE/29699/2017) e SCOPE (bolsa FCT n.º DSAIPA/AI/0088/2020).

Para além das instituições, tenho que agradecer às pessoas cujos contributos, orientação e encorajamento foram inestimáveis. Obviamente, começo pela incansável equipa de orientação, composta por três investigadoras e lideres que moldaram a minha abordagem ao projeto em todos os momentos e trouxeram perspetivas inovadoras quanto à gestão e inovação em cuidados de saúde. Obrigado Professora Mónica Oliveira, Doutora Filipa Baptista e Professora Isabel Albuquerque.

Agradeço à Professora Mónica Oliveira, orientadora científica da tese, pela mentoria e amizade. Quando decidi fazer o doutoramento, tinha ideias difusas quanto à temática de estudo, mas claras quanto à pessoa com quem gostaria de trabalhar. É um privilégio aprender e trabalhar com a Professora Mónica, uma mentora que sempre me incentivou a levar a investigação mais longe, que foi paciente para me ajudar com as minhas lacunas enquanto investigador, que foi incrivelmente disponível para acompanhar o trabalho desenvolvido e sugerir aquela frase, estudo ou método que fizeram toda a diferença. Abriu-me portas para novos desafios e inspirou-me a olhar para este período como mais do que uma tentativa de reforçar o meu currículo profissional. Motivado pela Professora Mónica, espero agora que esta tese de doutoramento não seja um fim, mas um início de uma nova jornada…

Agradeço à Doutora Filipa Baptista, por me abrir as portas da Siemens Healthineers e me integrar plenamente na equipa de Enterprise Services (ES). Foi um privilégio beber da sua criatividade, liderança e ambição. Em ES, sob a sua liderança, aprendi a pensar Saúde fora da caixa, a encarar desafios complexos como oportunidades entusiasmantes, a abordar um negócio como uma parceria que cria valor mútuo e duradouro. E, nesta equipa, estive também inserido num ambiente rico em experiências e perspetivas, reforçando a minha crença em que a multidisciplinaridade é um fator-chave na construção de equipas de alto desempenho. Carlos Parente, David Neves, David Rodrigues, Filipa Carmona, Madalena Simões, Mafalda Neiva, Manuel Eliseu, Mário Viegas, Nuno Reis, Paulina Rocha, Pedro Gonçalves, Rita Silvério e Vera Geraldes, obrigado pelo caloroso acolhimento e apoio durante estes quatro anos, são ESpetaculares! Um agradecimento especial à Filipa Rapazote, que sucedeu à Doutora Filipa Baptista como Head de ES, por me manter as portas abertas e oferecer novas perspetivas sobre a forma como a minha tese poderia contribuir para a Siemens Healthineers.

Ao realizar o doutoramento em ambiente empresarial, tive o privilégio de fazer parte de duas “casas” – a Siemens Healthineers e o CEGIST. Quero agradecer a todos os membros integrados, staff e estudantes de doutoramento do CEGIST, especialmente aos associados à área de DECISion science and management engineerING (DECISING). Um agradecimento especial à Ana Flávia Santos, Edgar Mascarenhas, Francisco Viterbo, Liliana Freitas e Sara Vanelli, colegas de gabinete, que partilharam comigo os altos e baixos inerentes à jornada doutoral.

Como o sucesso de qualquer projeto vem da dedicação dos envolvidos, cabe-me agradecer às pessoas e equipas que contribuíram para os estudos realizados e reservaram tempo das suas exigentes agendas. Sou privilegiado por ter sido sempre recebido com um forte compromisso de colaboração e com abertura à partilha de conhecimento e experiências.

Agradeço a Ana Batista, Joana Tomé Pereira, Marisa Serrano, Miguel Castelo-Branco Sousa e Salomé Azevedo, contribuintes em várias fases do estudo apresentado no Capítulo 5 da tese. Agradeço também ao grupo notável de especialistas portugueses que participou no processo web-Delphi deste estudo. Pelo apoio imprescindível e participação no *workshop* do estudo do Capítulo 6, agradeço à equipa do Centro de Responsabilidade Integrada Cérebro-Cardiovascular do Alentejo.

Em relação ao estudo do Capítulo 7, expresso a minha gratidão à equipa de telemonitorização do Serviço de Cardiologia do Hospital Santa Maria, Doutores Afonso Nunes Ferreira, Joana Rigueira, João Agostinho, Rafael Santos e, particularmente, à coordenadora da equipa, Professora Dulce Brito. À Professora Dulce Brito deixo um reconhecimento especial, não só pelo papel de "champion," sendo uma peça chave em motivar a equipa, mas também pelo seu profissionalismo incondicional. Tenho um imenso respeito pela Professora Dulce, alguém que honra sempre a sua palavra e que transmite paixão pelo desempenho da sua profissão, inspirando quem a rodeia a fazer mais e melhor.

Por fim, resta-me agradecer àqueles cuja gratidão vai além do período afeto. Aos Amigos, que tanto ouviram o desabafo e partilharam das incertezas dos 20s, como me voltaram a encher o copo para mais um brinde “a nós”. À Família, que me acompanha desde sempre e me ensinou a resiliência das gentes do frio Norte, mas também o calor e carinho que são o aconchego nos momentos difíceis. Aos Avós, que estão comigo onde quer que estejam, serão sempre a motivação para seguir o caminho do conhecimento e para contribuir para uma Saúde mais equitativa e mais próxima de quem precisa.

Aos Pais, Céu e Victor, pedras basilares do que sou e força motriz para ir mais além. São um exemplo de que dedicação e ambição, aliadas a humildade e ética, são o caminho certo. São a rede de segurança que permite arriscar, com a certeza de que, mesmo que rasgue, os braços deles me agarram. São o motivo para, salvo situações pontuais e naturais da vida, nunca ter sentido dificuldades ou dor. Sentiram-nas eles por mim. São alegria, são conhecimento, são a palavra dura no momento certo, são amor. São Pais. Obrigado. Por tudo.

À Leonor, o melhor destes quatro anos. Talvez tivesse acabado a tese mais cedo não fosse Aquele jantar… É difícil manter o foco quando se é arrebatado por alguém tão entusiasmante, tão interessante, tão genuíno e tão caloroso! Talvez nunca tivesse acabado a tese… É o colo onde pouso a cabeça no fim de um dia mais difícil, é o abraço sorridente ao chegar a casa, são os olhos atentos que antecipam as necessidades, é o cérebro – mais dotado para investigar que o meu – que potencia debater métodos, sem sair do sofá. Felizmente, acabei a tese e conheci a Leonor. Não posso pedir mais. Nô, amo-te.

ABSTRACT

Remote patient monitoring (RPM), a decentralized care delivery model, gained prominence during the COVID-19 pandemic, enabling patient tracking, assessment, and engagement regardless of location. Implementing RPM programs requires continuous follow-up and evaluation to drive improvements. However, current health technology assessment (HTA) methods and tools need advancement to objectively demonstrate RPM's clinical, social and economic benefits and address user scepticism and investment reluctance.

Addressing the lack of tools for day-to-day RPM program assessment, this thesis contributes to HTA by proposing and implementing a novel approach – the **S**tructuring, **B**uilding and **I**mplementing a **M**ultidimensional **D**ashboard with **S**takeholders, **B**usiness **I**ntelligence and **M**ulticriteria **D**ecision-aiding (**SBI-MD**) – for developing multidimensional management dashboards (MMDs) to enable continuous monitoring and evaluation of RPM programs. By integrating stakeholder engagement, business intelligence, and multicriteria decision analysis, this thesis fills critical gaps in modelling RPM value according to impacts on access to care, clinical quality, stakeholder acceptability, and economic sustainability while clarifying these aspects' relative importance. SBI-MD was validated in Portuguese healthcare institutions, proving its feasibility and replicability in practice.

Contributions to the fields of health policy, decision sciences, and information systems include comprehensively reviewing the RPM landscape in Portugal and international RPM initiatives aligned with integrated care; creating a roadmap on RPM adoption challenges and future directions in Portugal; developing a framework for implementing RPM-based integrated care; producing a consensus-driven list of value aspects for assessing heart failure RPM programs; introducing a novel approach for rapid dashboard prototyping; and building an MMD prototype embedding a multicriteria value model for ongoing HTA.

Deploying MMDs for RPM management equips stakeholders with tailored, accessible, and actionable insights for tactical and strategic decision-making, facilitating improved implementation, scaling, and maintenance. Additionally, generated evidence supports pay-for-value financial models, enables benchmarking, and facilitates policymaking efforts. This contributes to more effective incentives and broader adoption of RPM solutions.

Keywords: Remote Patient Monitoring, Health Technology Assessment, Collaborative Modelling, Multicriteria Decision Analysis, Business Intelligence

RESUMO

O acompanhamento remoto de doentes (ARD) ganhou destaque durante a pandemia por permitir seguir, avaliar e envolver os doentes à distância. A implementação de ARD exige um acompanhamento e avaliação contínuos para gerar melhorias. No entanto, a avaliação de tecnologias de saúde (ATS) carece atualmente de melhorias para demonstrar objetivamente os benefícios do ARD e superar o ceticismo em investir.

Considerando a falta de ferramentas para a ATS diária de programas de ARD, esta tese propõe e implementa uma nova abordagem (**SBI-MD**) para desenvolver dashboards de gestão multidimensionais (DGMs) para a monitorização e avaliação contínuas de programas de ARD. Ao integrar atores relevantes, *business intelligence* e análise de decisão multicritério, esta tese propõe modelar o valor do ARD com base no acesso aos cuidados, qualidade clínica, aceitabilidade e sustentabilidade económica, ao mesmo tempo que esclarece a importância relativa destes aspetos. A SBI-MD foi validada em instituições de saúde portuguesas, comprovando a sua exequibilidade e replicabilidade.

Os contributos para as políticas de saúde, ciências da decisão e sistemas de informação incluem rever o panorama do ARD em Portugal e iniciativas de ARD alinhadas com integração de cuidados; propor estratégias para incrementar a adoção de ARD em Portugal; desenvolver um *framework* para implementar ARD em cuidados integrados; produzir uma lista de aspetos de avaliação de programas de ARD para insuficiência cardíaca; apresentar uma nova abordagem para prototipagem rápida de dashboards; e contruir um DGM incorporando um modelo multicritério para ATS contínua.

A implementação de DGMs para gerir ARD equipa os decisores com insights personalizados e acionáveis para apoiar decisões táticas e estratégicas, facilitando a implementação, dimensionamento e manutenção dos programas. Adicionalmente, a evidência gerada pode apoiar modelos financeiros inovadores, permitir a avaliação comparativa e facilitar esforços de formulação de políticas, contribuindo para incentivos mais eficazes e uma adoção mais ampla do ARD.

Palavras-chave: Acompanhamento Remoto de Doentes, Avaliação de Tecnologias de Saúde, Modelação Colaborativa, Análise de Decisão Multicritério, *Business Intelligence*

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

2HT	High-touch-high-tech
ACES	Portuguese Groups of (Public) Primary Care Centers
ACSS	Central Administration of the Portuguese Health System
ALS	Amyotrophic Lateral Sclerosis
AMI	Acute Myocardial Infraction
B2B	Business-to-business
B2C	Business-to-consumer
BI	Business Intelligence
BP	Blood Pressure
BT	Bluetooth
CDB	Collaborative Dashboard-Building
CEA	Cost-Effectiveness Analysis
CIC	Portuguese Commission for Clinical Computerization
CIED	Cardiac Implantable Electronic Devices
CIEDT	Monitoring Committee of the Strategic Initiative for the Development of Telemedicine in Portugal
CKD	Chronic Kidney Disease
CNTS	Portuguese National Telehealth Centre
COPD	Chronic Obstructive Pulmonary Disease
DataViz	Data Visualisation
DC	Decision Conference
DSS	Decision Support System
e-PROs	Electronic Patient Reported Outcomes
ECG	Electrocardiogram
ED	Emergency Department
EMR	Electronic Medical Record
ETL	Extract, Transform, Load
EU	European Union
FCT	Portuguese Foundation for Science and Technology
GTT	Portuguese Telemedicine Working Group
H2H	Hospital-to-home
HESE	*Hospital do Espírito Santo de Évora*
HF	Heart Failure
HSM	*Hospital de Santa Maria*
HTA	Health Technology Assessment

ICT	Information and Communication Technology
ICU	Intensive Care Unit
KPI	Key Performance Indicator
LoS	Length of Stay
LVEF	Left Ventricular Ejection Fraction
MACBETH	Measuring Attractiveness by a Categorical-Based Evaluation TecHnique
MAST	Model for Assessment of Telemedicine Applications
MCDA	Multicriteria Decision Analysis
MedTech	Medical Technology
MMD	Multidimensional Management Dashboard
NASSS	Nonadoption, Abandonment, and challenges to the Scale-up, Spread, and Sustainability
NGT	Nominal Group Technique
NHS	National Health Service
NYHA	New York Heart Association
NT-proBNP	N-terminal pro-B-type Natriuretic Peptide
OECD	Organisation for Economic Cooperation and Development
PENTS	Portuguese National Strategic Plan for Telehealth 2019-2022
PFP	Protocol-based Follow-up Program
PK	Project Keyholder
PMS	Performance Measurement System
PRISMA-ScR	PRISMA extension for Scoping Reviews
PTSD	Post-traumatic Stress Disorder
QoL	Quality of Life
RHA	Regional Health Administrations
ROI	Return on Investment
RPM	Remote Patient Monitoring
RQ	Research Question
SBI-MD	Structuring, Building and Implementing a Multidimensional Dashboard with Stakeholders, Business Intelligence and Multicriteria Decision-aiding
SELFIE	Sustainable intEgrated chronic care modeLs for multi-morbidity: delivery, FInancing, and performancE
SPMS	Shared Services of the Portuguese Ministry of Health
SQL	Structured Query Language
SUS	System Usability Scale
SVP	Single Ventricle Physiology
TAM	Technology Acceptance Model
TM	Telemonitoring
VC	Videoconferencing

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1. Chapter Summary

This introductory Chapter intends to enlighten the reader on key topics addressed in this thesis – remote patient monitoring (RPM), health technology assessment (HTA), business intelligence (BI) and performance measurement, and participatory methods –, which are essential for framing the research questions, objectives and studies undertaken in this doctoral research.

RPM enables health professionals to effectively monitor patients' health status at a distance, being particularly relevant for chronic patients and underserved populations. While offering notable benefits, challenges remain in transparently, comprehensively, and systematically demonstrating its value. Assessing RPM requires addressing a multidimensional problem (encompassing clinical, social and economic aspects) while engaging diverse stakeholders (e.g., patients, caregivers, providers, payers). Effective assessment depends on approaches and tools that capture this complexity and foster collaboration. Moreover, sparse and unstructured RPM data must be transformed into actionable insights to monitor program performance, identify areas for improvement, and, ultimately, achieve sustained adoption.

Developed within an academia-industry partnership with Siemens Healthineers, this doctoral research is motivated to respond to challenges in advancing RPM solutions and business, seeking to merge actionable, agile approaches with the rigor of the scientific method. Six interconnected studies are proposed to answer four research questions: (*a*) what benefits, risks, costs, and challenges are impactful for RPM adoption, (*b*) which methods and tools can enable continuous RPM program monitoring and evaluation, (*c*) which value aspects need to be considered during the assessment, and (*d*) to operationalise RPM assessment activities, which tool requirements and features are relevant for end-users and other involved stakeholders. A summary of the thesis' main contributions and scientific outreach is presented, along with an outline of the remaining of the document.

1.2. Background and Motivation

1.2.1. Remote Patient Monitoring: Current Context and Opportunities

"The home is where much of the medical care takes place. It is no longer confined to clinicians in the clinic or hospital. The ubiquity of digital communication means that many doctor-patient contacts are now virtual and deliver care to the patient in their home. Specialist hospital treatment is reserved for trauma and emergency surgery; local day care organizations deal with most elective surgery, while chronic and long-term conditions are managed in the community". This prediction constituted a bold and provocative view from Deloitte, reported in a 2014 essay (Deloitte, 2014), about how healthcare delivery systems would look like in 2020, in "the era of digitised medicine". Although much of this vision is yet to be achieved, it is undeniable the impact the COVID-19 pandemic has had on bringing health systems worldwide closer to this perspective of decentralised and digitalised healthcare (Doraiswamy *et al.*, 2020; Kumpunen *et al.*, 2021; Xu *et al.*, 2021). In a period marked by (successive) mandatory confinement and social distancing, remote care provision, which had mostly been conceived as local and small-scale pilot initiatives (Oliveira Hashiguchi, 2020; Azevedo, Rodrigues and Londral, 2021), had to assert itself as a solution to deliver care that otherwise would remain unprovided (Newhouse, Farmer and Whelan, 2020; Kronenfeld and Penedo, 2021). During this period, telehealth applications, especially teleconsultation and RPM, proved reliable and effective in improving access for those confined at their homes or living in underserved geographies, increasing the efficiency of healthcare organisations, and strengthening patient-physician relationships through more recurrent contacts (Gülmezoglu *et al.*, 2020; Hirko *et al.*, 2020; Tersalvi *et al.*, 2020).

RPM can be defined as "a mode of health care delivery that gathers and integrates patient data outside of traditional health care settings, allowing providers to track, assess, and engage patients regardless of location" (Casale *et al.*, 2021), constituting an alternative (but also a complement) to conventional medical care with potential social and economic value for both patients and providers. The latter can follow multiple patients simultaneously, monitoring their vital signs and reported symptoms, providing educational materials to promote health literacy and self-management capabilities, and adapting care delivery to better suit patients' needs. In return, patients can benefit from receiving care in a more comfortable and familiar environment (Castelnuovo *et al.*, 2020; Watson, Wah and Thamman, 2020). Particularly in chronic diseases and multimorbidity settings, RPM allows healthcare professionals to detect early signs and symptoms of decompensation, providing opportunities for preventive intervention, avoiding unnecessary hospitalisations, as well as visits to emergency services (Vegesna *et al.*, 2017; Melchiorre *et al.*, 2018).

In recent years, several studies in RPM implementation have been conducted to assess the clinical and economic impacts of applying this mode of care delivery to patients with chronic conditions or seeking long-term care (McLean, Protti and Sheikh, 2011). Heart failure (HF) (Hernández-Quiles *et al.*, 2016; Schmier, Ong and Fonarow, 2017; Koehler, Koehler, Deckwart, Prescher, Wegscheider, Kirwan, *et al.*, 2018; Lopez-Villegas *et al.*, 2018; Vestergaard *et al.*, 2020), chronic obstructive pulmonary disease (COPD) (Chandra *et al.*, 2012; Reddel, Jenkins and Partridge, 2014; Udsen *et al.*, 2014; Lundell *et al.*, 2015; Lilholt *et al.*, 2017), asthma (Zamith *et al.*, 2009; McLean *et al.*, 2011), diabetes (Clarke *et al.*, 2017; Lee and Lee, 2018; Franc *et al.*, 2019; Randall *et al.*, 2020) and oncology care (Coriat *et al.*, 2012; Frankland *et al.*, 2019; Knegtmans *et al.*, 2020; Daly *et al.*, 2022) are some of the clinical conditions and settings in which the application of telemonitoring (TM) and remote monitoring technologies have shown positive results comparing with conventional care, promoting the reduction of unscheduled hospitalisations and urgent care episodes, greater adherence to drug and physical therapy, and improved mental health, both for the patient and for family members/informal caregivers.

From a comprehensive and integrated care perspective (Leijten *et al.*, 2018), implementing an RPM program should be collaborative and patient-centred, including all relevant stakeholders and allowing for comprehensive, complete, and coordinated healthcare delivery (Donner *et al.*, 2018). This process must address the patient as a complex system, both from a biological and social perspective – involving the patients themselves, their caregivers, their community, and their environment, and not just health professionals and hospital services (Herkert *et al.*, 2020). With this setting in place, technology becomes a facilitator for communicating, for collecting and sharing information, and enables coordination between all the interveners, permitting evidence-informed actions and continuous improvement (Gordon *et al.*, 2020). From this standpoint, the field of RPM is still developing, tending to integrate more complex systems and technologies and to be applied to a broader range of conditions (e.g., obstetrics (Alves *et al.*, 2020), mental illness (Turvey, 2016)).

RPM implementation is possible in many different shapes – a single healthcare organization may provide remote care for several health conditions (e.g., one hospital may have RPM programs for HF, COPD, and diabetes), and a single condition may be remotely monitored within distinct care settings (e.g., HF can be monitored by hospitals, primary care centres or community pharmacies) (Grustam *et al.*, 2017). Although this characteristic of RPM allows for a highly personalized and patient-centred provision, it also increases the degree of variability in care delivery, resulting in operational inefficiencies, wasteful allocation of resources, and lower comparability between RPM interventions (Acheampong and Vimarlund, 2015).

Although emerging literature is addressing RPM as a complex care delivery model and from an integrated care perspective, most evaluation studies still report on single morbidity settings and focus on either health outcomes alone or on the trade-off between costs and benefits of the intervention through the application of traditional HTA economic evaluation techniques, such as cost-effectiveness and cost-utility analysis (Peretz, Arnaert and Ponzoni, 2018). Thus, there is a need to consider more comprehensive assessment approaches that encompass the multiple and dynamic impactful aspects of remote care delivery and the differing perspectives, objectives and needs of involved stakeholders.

1.2.2. Health Technology Assessment: Existing Challenges in Assessing RPM

HTA is a multidisciplinary field involving theoretical and practice-oriented research to assess the direct and indirect consequences of health technology use (e.g., pharmaceuticals, medical devices, health information systems) according to sound evidence and involving health stakeholders, in order to inform decision processes, support policies on the use and coverage of these technologies in healthcare systems, and promoting a value for money spirit in healthcare (Oliveira, Mataloto and Kanavos, 2019). Nevertheless, there are substantial variations in defining and measuring value in health, due to the large heterogeneity in clinical contexts, characteristics of target technology, local policy, and legal contexts (leading to also large methodological heterogeneity), and most existing value assessment frameworks fail to promote patient or public engagement in the framework development process (Zhang *et al.*, 2022). The lack of standardised methods for assessing the value of remote care solutions is a commonly stated obstacle that hinders adoption. Measuring and monitoring clinical quality, social benefit or financial metrics may allow a better appraisal of existing initiatives and assist program coordinators and/or health professionals in decision-making contexts, further contributing to creating awareness of telehealth benefits and incentivising adoption and the development of better reimbursement mechanisms (Takahashi *et al.*, 2022).

Telehealth interventions are intricate and enclose various impactful factors (Kidholm *et al.*, 2012), including clinical, social, and economic costs, benefits, and risks. Furthermore, these interventions involve numerous stakeholders (e.g., patients, caregivers, physicians, nurses, technology providers, and public or private payers), each bringing unique perspectives and value definitions. As conventional HTA methodologies present several shortcomings in addressing such a multidimensional evaluation context, there is a need for new and more comprehensive approaches (Angelis and Kanavos, 2016).

To explore the diverse aspects involved in RPM assessment, multicriteria decision analysis (MCDA) emerges as a likely alternative to overcome the limitations of traditional HTA economic evaluations (Angelis and Kanavos, 2017). MCDA offers a more comprehensive and robust approach to assessing RPM implementations for three main reasons (Angelis and Kanavos, 2016). Firstly, MCDA considers an extended number of value dimensions in an explicit manner, beyond costs and direct clinical benefits. Secondly, it allows for the transparent assignment of quantitative weights to evaluation criteria, clarifying the relative importance of each value dimension. Lastly, MCDA involves stakeholders in the model-building process, promoting legitimacy, accountability, and democratic decision-making.

Nonetheless, applying MCDA for HTA is not without its challenges. Oliveira et al. (Oliveira, Mataloto and Kanavos, 2019) discuss the key issues in and advancing the “MCDA for HTA” debate, stating twelve challenges to be addressed for advancement in providing robust methodologies, procedures and tools to improve the methodological quality of MCDA in HTA studies. Such challenges include (*a*) dealing with evidence and data-related difficulties, (*b*) balancing methodological complexity and resources, (*c*) criteria selection and attribute construction difficulties or (*d*) introducing flexibility features for universal/generalised evaluation models. Furthermore, when conducing HTA for complex health interventions like RPM, even MCDA often fails to capture key aspects of complexity tied with changing perspectives, indeterminate phenomena, uncertainty, unpredictable outcomes and historicity, and time and path dependency (Lysdahl *et al.*, 2017; Sarri *et al.*, 2021). This limitation arises because studies frequently rely on *ex-ante*, short and one-time technology assessments rather than conducting ex-post or ongoing HTA (Hogervorst *et al.*, 2022).

1.2.3. Enabling Evidence-Sharing and Information-Based Tools in Healthcare

Nowadays, healthcare organisations generate and process ever-increasing volumes of data due to the dynamism of the economic environment and continuous developments in information and communications technologies (ICT) and health technology innovation. In recent years, there has been a focus on developing BI tools that allow gathering data from various sources and processing large amounts of structured and unstructured data to produce real-time, actionable information for supporting responsible decision-making in resource allocation and operations management (Rajnoha *et al.*, 2016; Vallurupalli and Bose, 2018). In healthcare contexts, deploying such tools enables effective evidence-sharing and enhanced analytics capabilities in areas such as patient service and satisfaction measurement, marketing management, financial strength, operations analysis and people development (Mettler and Vimarlund, 2009).

Since the primary use of BI tools is to measure performance (Vallurupalli and Bose, 2018), we can often identify relevant literature on the subject through the concept of performance measurement systems (PMS). PMS can be defined as “the set of metrics used to quantify both the efficiency and effectiveness of actions” (Neely *et al.*, 2000), playing a key role in the organizations’ learning processes and knowledge dissemination. According to Demartini and Trucco (Demartini and Trucco, 2017), PMS can be used in strategic and non-strategic ways – the first related to its use for detecting strategic uncertainties associated to changes in competitive dynamics and internal competencies that may create opportunities or threats, thus being mostly directed to its role in decision support; the second related to delivering feedback on the variances between target and actual performance, thus more directed to its formative and informative role. Elg et al. (Elg, Palmberg Broryd and Kollberg, 2013) highlight six activities where these systems can improve decision-making and performance – continuous follow-up in formal arenas and meetings, improvement work, professional efforts, goal deployment, reporting based on external demands, and creating awareness in everyday clinical work.

To operationalise PMS in a quick, user-friendly manner, BI tools (Ain *et al.*, 2019) such as multidimensional management dashboards (MMD) can be implemented to represent performance visually and provide information on demand to support decision-making (Vitacca and Vitacca, 2019), reducing the methodological and technical burden of evidence processing for healthcare professionals, who may be not fully acquainted with PMS concepts, methods, and specificities (Salgado *et al.*, 2022). Ippolito et al. (Ippolito *et al.*, 2022) identify the needs that the implementation of an integrated performance evaluation system responds to in the context of accountability and information provision of a university hospital to regional authorities: (*a*) counteracting the weaknesses of middle management in the implementation phase of the corporate strategy; (*b*) counteracting the weaknesses of operations management; (*c*) avoiding focus imbalance between economic-financial results / authority-defined indicators and key indicators relating to healthcare, teaching and research; (*d*) overcoming a highly fragmented monitoring system; (*e*) issuing the fragmentation of organisations’ information systems from which data for the determination of indicators may be gathered. These systems can thus help synthesise information and deal with large volumes of data; allow all relevant stakeholders to access a common, standardised source of information in decision-making contexts; facilitate and accelerate evidence-sharing among professional groups; and permit access to information regardless of location, as these systems are generally cloud-based and accessible via a web browser.

1.2.4. Engaging RPM Stakeholders and Involved Institutions

In health innovation contexts, as is the adoption of RPM, it is vital that beneficiaries and end-users, including patients, caregivers, clinicians, and other health decision-makers, are included as co-creation partners within creative development efforts. In this way, their knowledge, experiences, and insights can shape solutions and related tools and models, ensuring that the end user's needs are prioritised, ultimately leading to better outcomes, more efficient services, and greater adoption (Bird *et al.*, 2021). Engaging stakeholders in an equitable manner and within a participation degree that goes beyond input gathering and towards collaboration and stakeholder empowerment is considered key to delivering valuable healthcare solutions since individuals' willingness to accept is higher when they contribute both resources and make decisions on aspects that may impact their lives (Hendricks *et al.*, 2018).

According to Woudstra et al. (Woudstra *et al.*, 2022), by involving stakeholders in medical device development, alignment with people's needs with vested interests is ensured, device usability and functionality are improved, and the overall productivity of the development process is increased. These authors conducted a scoping review to identify the participatory approaches used in medical device development and their characteristics and challenges. Papers were categorised into three levels of the spectrum of public participation (International Association for Public Participation, 2022) – collaboration (i.e., stakeholders participate in decision-making, e.g., co-design, co-creation), involvement (i.e., stakeholders are involved so that decisions align with their concerns, e.g., user-centred design), and consultation (i.e., obtain stakeholders' feedback on analysis, e.g., focus groups and interviews). Patients and healthcare professionals were frequently engaged in all approaches. Workshops constitute the most used method in collaboration papers and interviews in involvement and consultation papers. The topics addressed in all approaches were related to the problem, device requirements, design choices, testing, and procedural aspects of involvement. The challenges included sampling, analysis, social dynamics, and feasibility issues. The main finding of this study was that collaboration, involvement and consultation have similar methodological characteristics and, thus, researchers should flexibly and independently determine the degree of participation, stakeholders, methods, and topics to be addressed rather than adhering to a pre-determined participatory approach.

When analysing complex problems and evaluating strategic decisions, stakeholder participation and collaboration through facilitated value modelling proves to be particularly suitable (Franco and Montibeller, 2010). Numerous studies have documented the use of participatory approaches and methods in value modelling tasks, including problem framing, defining metrics, evaluating options, and prioritising actions (Aubert, Esculier and Lienert, 2020; Cadilhac *et al.*, 2020; Mentzakis, Tkacz and Rivas, 2020; Bana e Costa, Oliveira, Vieira, *et al.*, 2023; Haig *et al.*, 2023). Within value measurement, Vieira et al. (Vieira, Oliveira and Bana e Costa, 2020) proposed a new integrated socio-technical setting that enhances multicriteria decision conferencing with an ex-ante web-Delphi participatory process, combining the technical soundness and meaningfulness of MCDA with social processes that promote shared understanding around key evaluation issues while capturing multiple stakeholders' values and perspectives. The authors state that incorporating the views of an enlarged number of stakeholders contributes to reducing the distance between the research teams and the research users and enhancing the commitment of the actors involved in the modelling process towards the acceptance and dissemination of developed models.

1.2.5. Motivation From Industry

Integrating scientific methods into agile enterprise workflows can be burdensome, especially when balancing methodological complexity with business objectives. It is a challenging task that requires close collaboration between researchers and business professionals (Gagnon, 2011). However, these two groups often present significant differences in knowledge backgrounds and experiences that may result in differences in “language” and logic regarding the applied methods (de Wit-de Vries *et al.*, 2019). Thus, incorporating data-driven decision-making processes within industry settings poses significant challenges as it often requires a cultural shift and can be resource-demanding and time-consuming – even when developed approaches are sound and evidence-informed, companies’ clients may not be willing to engage (Rybnicek and Königsgruber, 2019). Therefore, to foster the adoption of developed scientific approaches, proposed methodologies must be easily explainable, applicable and transferable. The latter characteristic is fundamental as it enables the company to use existing models in different contexts, reducing costs and resource usage associated with developing models from scratch (Oliveira, Mataloto and Kanavos, 2019).

In this thesis, the challenges of transferring knowledge between university and industry acquire increased importance since the research was developed in close collaboration with Siemens Healthineers. Siemens Healthineers is a multinational medical technology (MedTech) company headquartered in Germany, specialising in the development, manufacturing, and distribution of medical devices, healthcare software, and services, providing these solutions to healthcare providers, including hospitals, clinics, and laboratories – the company’s portfolio includes several imaging systems and laboratory diagnostics equipment, as well as digitalisation and automation solutions and operational and strategic healthcare consulting services (Siemens Healthineers, 2023a). To face the most pressing challenges in healthcare and create opportunities for its customers, Siemens Healthineers bases its value proposition on four pillars: expanding precision medicine, transforming care delivery, improving patient experience and digitalising healthcare (Siemens Healthineers, 2023b). According to company reports, 75% of all critical clinical decisions are influenced by Siemens Healthineers solutions, and 90% of leading hospitals work with the company, which is present in more than 70 countries (Siemens Healthineers, 2023c).

Siemens Healthineers Portugal is the company's branch host institution in this doctoral project. However, there was constant contact with Siemens Healthineers headquarters in terms of following ongoing RPM programs, knowing and using applied technologies (for RPM and data acquisition, processing or visualisation), and alignment with the company's strategic objectives. In the context of RPM, Siemens Healthineers was a valuable partner due to its portfolio of clients and public and private partnerships and experience in implementing RPM initiatives in conditions such as HF, diabetes or oncology care. Regarding Siemens Healthineers' strategy towards RPM, these projects were perceived as promising solutions to improve healthcare delivery – even prior the COVID-19 pandemic outbreak –, particularly in contexts of diminished access to healthcare and for underserved geographies, as is the case of rural and isolated populations. However, several challenges hampered the dissemination of RPM initiatives in Portugal and other Siemens Healthineers territories, limiting the expected significant increase in adoption suggested by the COVID-19 pandemic. One major obstacle identified by Siemens Healthineers stakeholders was demonstrating the value of RPM to potential clients (e.g., healthcare providers and insurance companies), as the expensive setup costs inhibit adoption. Both public and private clients often hesitated to invest in these solutions as they were unsure about their effectiveness and long-term benefits for their patients, the provider itself (in the form of return on investment), and the health system.

Another identified area for improvement in Siemens Healthineers' RPM value proposition was developing standardised approaches for implementing, monitoring, and evaluating these initiatives. The lack of standards creates inconsistency in designed care pathways and protocols and hinders the ability of healthcare managers to monitor and evaluate program performance. In turn, the lack of standards, guidelines and frameworks makes it challenging to implement novel pay-for-performance and pay-for-value reimbursement models, which have the potential to lower upfront investments and reduce the risk for the client. In a pay-for-performance or pay-for-value model, providers are reimbursed based on the value they deliver, as determined by the evaluation model (Grustam *et al.*, 2017). It incentivises providers to adopt and effectively utilise new technologies proven to deliver value. It also encourages technology suppliers like Siemens Healthineers to invest in developing solutions that deliver significant value to patients and providers. By sharing the risk of implementing new technologies, providers and suppliers are better positioned to achieve their goals and improve the quality of care for patients.

To overcome these challenges and align with Siemens Healthineers objectives for enhancing the company's RPM business model, within this 4-year collaboration, we aimed to develop an actionable and flexible (yet robust) approach for continuously monitoring and evaluating deployed Siemens Healthineers RPM projects. The developed tools and models were expected to drive actionable insights regarding the value generated by the RPM program at every moment and help identify improvement areas. Using objective metrics to measure outcomes, the developed tools and models may help mitigate the risk of implementing RPM initiatives, allowing for assessing the program's impact on various aspects, namely patient outcomes, resource utilisation, patient experience, and cost, adequately addressing RPM as a complex, multidimensional evaluation context. By promoting collaboration between all relevant stakeholders throughout model-building phases, Siemens Healthineers and their clients can establish clear and mutually agreed value definitions, leading to more accurate and consistent evaluations. In turn, such a co-creation spirit ensures that providers may only pay for program features and interventions that deliver high value and meet patients' expectations and needs.

1.3. Objectives and Research Questions

This doctoral research was conducted in collaboration with Siemens Healthineers and partner healthcare institutions, focusing on developing innovative approaches to support continuous monitoring and evaluation in remote patient care interventions. The expected outcomes include new literature and knowledge in HTA, health policy, and information and decision-support systems (DSS). These contributions aim to create methodologically sound frameworks and practical assessment tools to support decision-making and strategic planning in real-world settings. Ultimately, this work seeks to promote the widespread adoption and delivery of high-quality, cost-effective remote care services.

In this research context, this thesis aims to answer four research questions (RQ):

RQ1: Which benefits, risks, costs, implementation issues and challenges should be considered for RPM successful adoption?

RPM has been extensively presented as a main trend in chronic and long-term care, but its widespread adoption is not yet a reality. Most existing RPM initiatives are pilot projects, with restrictions on covered conditions/populations, geographic reach, and patient numbers. Thus, the first objective of this thesis was to understand the general context of RPM implementation, its evolution over time, the main socio-economic, legal, and political barriers imposed to adoption, and which good practices should be considered to enable successful implementation, both in Portugal and abroad.

RQ2: Which measurement and decision-aiding methods and tools can enable continuous monitoring and evaluation of RPM initiatives?

Traditional HTA techniques often fail to address RPM assessment complexity and perspectives' multiplicity. Beyond clinical and economic impacts, RPM assessment must consider organisational, sociocultural, ethical, legal, and experiential aspects. As many initiatives are in their early stages, periodic impact evaluation and operations monitoring are critical for continuous improvement. Data processing, knowledge dissemination, and collaborative decision-making challenges must also be addressed. Therefore, the second thesis objective was to align actionable and continuous RPM program monitoring with HTA processes, exploring the role of participatory methods, MCDA, and BI – particularly, MMDs – towards innovative approaches and tools for effective and comprehensive RPM program management.

RQ3: Which value dimensions, indicators and costs should be considered when monitoring and evaluating RPM programs?

Numerous value dimensions and performance indicators may be relevant for monitoring and evaluating RPM programs. Selected indicators must align with program objectives and diverse stakeholder perspectives and preferences. Moreover, indicators should be operational, transparent, and consensual to support user-centred visualisation and decision-support tools. Thus, the third thesis objective was to identify key value dimensions and indicators for actionable, context-specific RPM monitoring and evaluation, while engaging stakeholders to align assessment aspects with their perspectives regarding the problem domain and scope.

RQ4: Which requirements and features should an actionable BI tool incorporate for ongoing monitoring and evaluation of RPM programs, accounting for user needs and stakeholder views?

The last RQ relates to how the identified indicators and developed models may be embedded and presented to end users through interactive and user-friendly visualisations. Knowledge from BI tool design, decision sciences, and human perception combined with recurring feedback and co-creation from potential users should guide the tool's development. Consequently, the thesis's fourth, and last, objective was understanding stakeholder preferences for value measurement and decision-aiding tools for building a functional and validated MMD for ongoing monitoring and evaluation of a real-world RPM initiative.

Figure 1.1 depicts a graphical conceptual framework summarising the main research objective, RQs and conducted studies. This doctoral thesis consists of six studies, each addressing an RQ to varying extents:

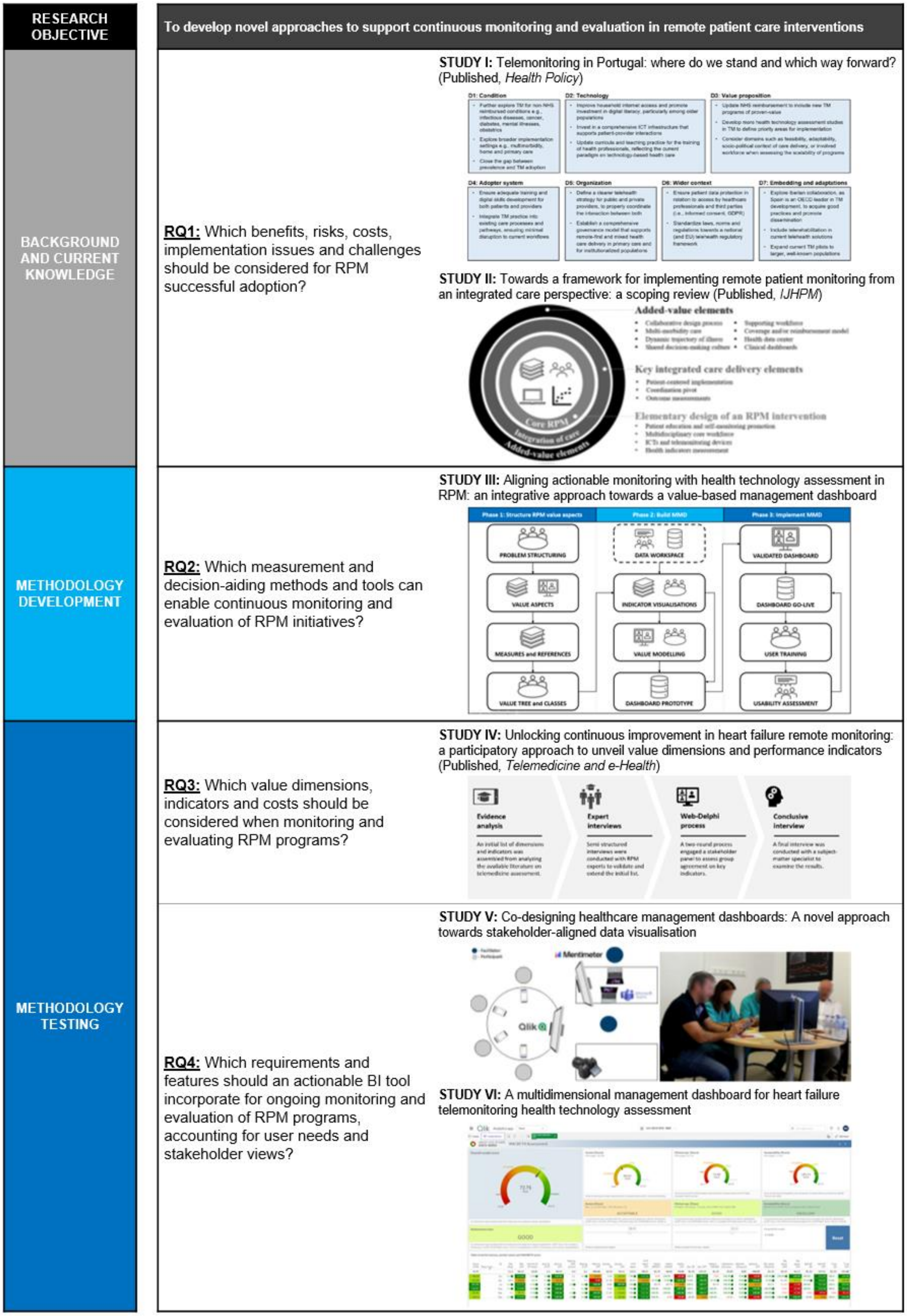


Figure 1.1. Graphical conceptual framework of the doctoral thesis.

- **Studies I and II** address **RQ1**: Study I explored the current state, challenges, and priority actions for RPM implementation and adoption in Portugal. As Study I identified integration with existing care pathways as a significant barrier to adoption, Study II examined RPM implementation from an integrated care perspective.
- **Study III** (core thesis contribution) addresses **RQ2** by proposing an integrative approach, **SBI-MD** (**S**tructuring, **B**uilding and **I**mplementing a **M**ultidimensional **D**ashboard with **S**takeholders, **B**usiness **I**ntelligence and **M**ulticriteria **D**ecision-aiding), to develop an MMD that assists decision-makers in continuous RPM program monitoring and evaluation.
- **Study IV** addresses **RQ3**, focusing on HF RPM indicator identification and selection, which required broad stakeholder engagement for enlarged consensus. Employed steps are encompassed in SBI-MD's *Phase 1: Structuring value dimensions and indicators*.
- **Studies V and VI** address **RQ4**: Study V focused on defining data visualisation (DataViz) formats for HF RPM key performance indicators' (KPIs) (in collaboration with Hospital do Espírito Santo de Évora (HESE) in Évora, Portugal), following a novel rapid dashboard prototyping approach which required validation before integrating into SBI-MD's *Phase 2: Building the multidimensional management dashboard*. Study VI then implemented and validated the SBI-MD approach within a real-world non-invasive TM program for HF management (in collaboration with Hospital Santa Maria (HSM) in Lisbon, Portugal).

Studies IV, V, and VI targeted HF management because (*a*) Studies I and II confirmed HF as an RPM priority with legislative, financial, and guideline support, (*b*) HF RPM aligned with Siemens Healthineers' business strategy and partnerships (Siemens Healthineers, 2023c), and (*c*) it maintained research continuity, despite different partner institutions in Studies IV–V and Study VI.

1.4. Thesis Contributions and Scientific Outreach

This thesis has generated significant contributions to research and practice in the fields of health policy, decision sciences, and information systems. The primary outputs and achievements include:

- A comprehensive identification of existing and historical RPM programs in Portugal (detailed in Chapter 2, Tables 2.1 and 2.2).
- A roadmap addressing the challenges and future directions for RPM adoption in Portugal (visually summarised in Chapter 2, Figure 2.4).
- A three-tier framework outlining the structural elements for RPM-based integrated care implementation (visually summarised in Chapter 3, Figure 3.2).
- An integrative, step-by-step approach for developing decision-support MMDs for RPM program management, in the form of **SBI-MD** (elaborated in Chapter 4).
- A stakeholder-informed and consensus-driven list comprising five value dimensions, 43 indicators, and six case-mix parameters for monitoring and evaluating HF RPM programs (presented in Chapter 5, Table 5.5).
- A novel approach for rapid dashboard prototyping, in the form of the Collaborative Dashboard-Building (CDB) workshop (briefly introduced in Chapter 4 and elaborated in Chapter 6).

- An MMD prototype embedding a multicriteria value model for ongoing monitoring and evaluation of an HF RPM program in a real hospital setting (full development described in Chapter 7).

Several other supporting techniques and analyses were developed or employed, including:

- Social procedures for eliciting individual and group preferences in selecting value aspects, designing DataViz, value modelling, and refining dashboard aesthetics (methods outlined in Chapter 4 and applied in Chapters 5-7).
- Enhancing the DataViz decision table originally developed in (Ignatenko, Ribeiro and Oliveira, 2022), expanded to incorporate additional alternatives from recent literature and addressing novel communication purposes (Chapter 6, Table 6.2).
- Aggregated measures and reference values for the 43 indicators, consolidating findings from diverse sources on HF performance measurement (described in Chapter 7).
- Validation of unpublished methods to reconcile value functions, facilitating the transition from individual to unified group value models (addressed in Chapter 4 and explored in Chapter 7).
- An analysis of interrelations among identified indicators, highlighting preference dependencies, overlaps, and inseparable indicators, and contributing to establishing evaluation criteria from RPM KPIs (outlined in Chapter 4 and applied in Chapter 7).

Regarding scientific outreach activities, this thesis led to the publication of three scientific articles in top-tier peer-reviewed journals, with three more under preparation for submission. Additionally, thesis results were presented at national and international conferences and meetings through oral and poster presentations. These outputs are detailed as follows.

Articles published in peer-reviewed journals

- Miranda, R. *et al.* (2023) ‘Telemonitoring in Portugal: where do we stand and which way forward?’, *Health Policy*, 131, p. 104761. doi: 10.1016/j.healthpol.2023.104761.
- Miranda, R. *et al.* (2023) ‘Towards A Framework for Implementing Remote Patient Monitoring From an Integrated Care Perspective: A Scoping Review’, *International Journal of Health Policy and Management*. doi: 10.34172/ijhpm.2023.7299.
- Miranda, R. *et al.* (2024) ‘Unlocking Continuous Improvement in Heart Failure Remote Monitoring: A Participatory Approach to Unveil Value Dimensions and Performance Indicators’, *Telemedicine and e-Health*, 30(7), pp. e1990–e2003. doi: 10.1089/tmj.2023.0560.

Articles under preparation for submission

- Miranda, R., Baptista, F.M., Albuquerque, I., Oliveira, M.D. ‘Aligning actionable monitoring with health technology assessment in remote patient monitoring: an integrative approach towards a value-based management dashboard.’
- Miranda, R., Rodrigues, D., Baptista, F.M., Oliveira, M.D. ‘From predefined indicators to a management dashboard for heart failure telemonitoring: a modified nominal group technique approach in Portuguese hospitals.’
- Miranda, R., Brito, D., Oliveira, M.D. ‘A Multidimensional Management Dashboard for Health Technology Assessment of Heart Failure Telemonitoring.’

Oral presentations at conferences/scientific meetings

- Miranda, R., Oliveira, M.D., Nicola, P., Baptista, F.M., Albuquerque, I. (2021) 'Remote patient monitoring: A scoping review of models and initiatives from an integrated care perspective', *17ª Conferência Nacional de Economia da Saúde*, Lisbon, Portugal
- Miranda, R. (2023) 'Developing approaches for continuously monitoring and evaluating integrated remote care interventions', *7ª Conferência Anual da redeSaúde da Universidade de Lisboa*, Lisbon, Portugal
- Miranda, R., Oliveira, M.D., Baptista, F.M., Albuquerque, I. (2023) 'Aligning continuous monitoring with value-based remote care services assessment: an integrated approach for building a multidimensional management dashboard', *49th Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services*, Graz, Austria
- Miranda, R., Oliveira, M.D., Baptista, F.M. (2023) 'Aligning ongoing performance measurement with RPM assessment: an integrative approach towards a value-based management dashboard', *5th International Conference on Health Care Systems Engineering*, Lisbon, Portugal
- Miranda, R., Silvério, R., Baptista, F.M., Oliveira, M.D. (2023) 'Which value aspects to consider when monitoring and evaluating remote patient monitoring programs in heart failure contexts: A collaborative approach', *18ª Conferência Nacional de Economia da Saúde*, Lisbon, Portugal
- Afonso, F., Miranda, R., Oliveira, M.D. (2023) 'Moving forward in the incorporation of uncertainty within Time-Driven Activity Based Costing in value-based healthcare', *18ª Conferência Nacional de Economia da Saúde*, Lisbon, Portugal
- Miranda, R., Baptista, F.M., Albuquerque, I., Oliveira, M.D. (2024) 'Aligning actionable monitoring with HTA in remote care management: combining BI, MCDA and participatory approaches to build a multidimensional management dashboard', *XXIII Congresso da Associação Portuguesa de Investigação Operacional*, Viseu, Portugal
- Miranda, R. (2024) 'Telemonitoring in Portugal: Where do we stand and which way forward?', *HealthTech Horizont: Inovando o Bem-estar na Era Digital*, Lisbon, Portugal
- Miranda, R., Baptista, F.M., Albuquerque, I., Oliveira, M.D. (2024) 'A collaborative dashboard-building approach combining BI and socio-technical MCDA: a tool to assist decision-makers in health settings', *98th meeting of the European Working Group on Multiple Criteria Decision Aiding and 5th meeting of the Euro Working Group on Behavioural OR*, Catania, Italy
- Miranda, R. (2024) 'Developing approaches for continuously monitoring and evaluating integrated remote care interventions', *8ª Conferência Anual da redeSaúde da Universidade de Lisboa*, Lisbon, Portugal – **Winner of the ULisboa - redeSAÚDE 2024 prize for Best Doctoral Work in the field of Health Systems / Entrepreneurship / Digital Transition**

Poster presentations at conferences/scientific meetings

- Miranda, R., Oliveira, M.D., Nicola, P., Baptista, F.M., Albuquerque, I. (2021) 'Remote patient monitoring: A scoping review of models and initiatives from an integrated care perspective', *5ª Conferência Anual da redeSaúde da Universidade de Lisboa*, Lisbon, Portugal
- Miranda, R. (2023) 'Developing approaches for continuously monitoring and evaluating integrated remote care interventions', *7ª Conferência Anual da redeSaúde da Universidade de Lisboa*, Lisbon, Portugal

During the doctoral thesis, research collaborations were conducted as part of the study titled "A Novel Policy Dialogue to Build Sustainable and Resilient Health Systems: Findings from PHSSR-Portugal," that has been recently submitted to publication, and of Project SCOPE (DSAIPA/DS/0115/2020), aiming to developing collaborative approaches to building dashboards that facilitate the transition from data and maps to DSS. Furthermore, two master's theses were co-supervised in collaboration with Mónica D. Oliveira (Afonso, 2023; Mexia, 2024).

1.5. Thesis Outline

The doctoral thesis is structured as a book, with Chapters 2 through 7 interconnected and building upon one another. Figure 1.2 outlines the main contributions of each chapter and illustrates their interconnections and mutual influences. Chapters 2 and 3 provide an overview of the background and current knowledge on the implementation and management of RPM programs. Chapter 4 presents the main contribution of the thesis, focusing on the central methodological study. Chapters 5 and 6 involve studies where the proposed generic approaches were tested and validated in specific contexts, leading to their refinement. Finally, Chapter 7 is the primary implementation study, applying the methods developed in Chapter 4 in a real-world care provision context. Notwithstanding, Chapters 2-7 are intended for independent publication, therefore some content overlap is inevitable. However, this does not disrupt the logical flow of the thesis nor impact its readability. Finally, Chapter 8 concludes the thesis with an overarching discussion, summarising lessons learned, conclusions, and suggestions for future research. Below is a brief summary of the remaining Chapters of the thesis.

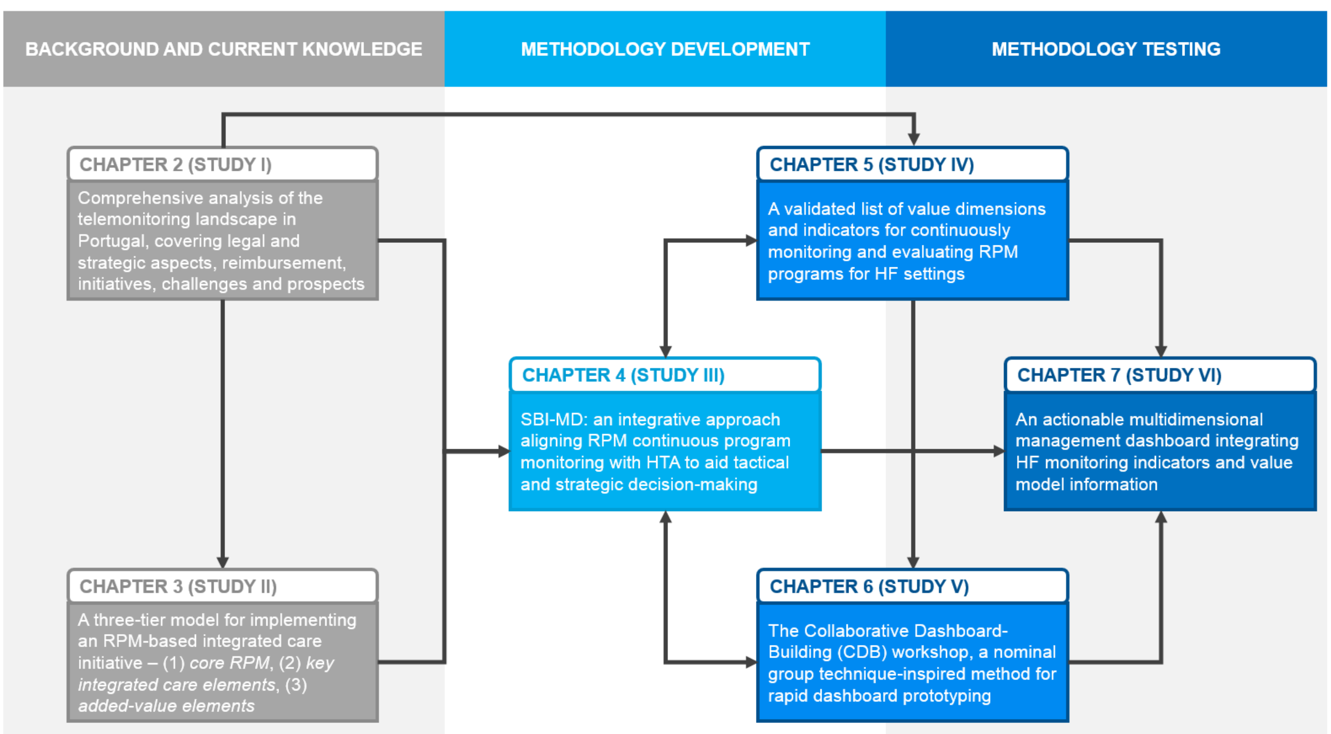


Figure 1.2. Relationship graph illustrating how the contributions of each Chapter influence one another.

Chapter 2: Telemonitoring in Portugal: Where Do We Stand and Which Way Forward?

Chapter 2 comprehensively analyses the TM landscape in Portugal, first examining the underlying conditions for telehealth development and then describing the governmental TM strategy and financing priorities – the Portuguese National Strategic Plan for Telehealth (PENTS) development and National Health Service (NHS) reimbursement opportunities for TM. To understand TM implementation, adoption, and dissemination in Portugal, 46 reported initiatives and adoption studies focusing on providers' perspectives were analysed. Finally, a structured reflection on current challenges and the way forward is provided, according to the seven domains of the Nonadoption, Abandonment, and challenges to the Scale-up, Spread, and Sustainability (NASSS) framework.

Chapter 3: Towards a Framework For Implementing Remote Patient Monitoring From An Integrated Care Perspective: A Scoping Review

Chapter 3 examines the structural elements that are considered relevant for implementing RPM according to an integrated care logic. A scoping review was conducted in PubMed, Scopus, and Web of Science, leveraging terms relative to (*a*) conceptual models and real-life initiatives; (*b*) RPM; and (*c*) care integration. 28 articles were included, covering nine conceptual models and 19 real-life initiatives. Eighteen structural elements were identified among conceptual models, defining a structure for assessing real-life initiatives. Such assessment was the basis for defining a three-tier model for implementing an RPM-based integrated care initiative, which is the main contribution of this Chapter.

Chapter 4: Aligning Actionable Monitoring with Health Technology Assessment in Remote Patient Monitoring: An Integrative Approach Towards a Value-Based Management Dashboard

Aiming to help RPM decision-makers, who lack tools for day-to-day HTA, Chapter 4 proposes a novel integrative and step-by-step approach – **SBI-MD** – combining BI, MCDA and stakeholder participation to build an MMD to facilitate continuous improvement of deployed healthcare interventions and promote value creation for all involved stakeholders. Making use of a collaborative value modelling framework, the proposed approach combines participatory methods, value measurement and decision-aiding tools for involving stakeholders in (*a*) selecting KPIs that are aligned with producing RPM value and achieving managerial targets; (*b*) building a flexible multicriteria value model and a classification model to help decision-makers understanding which RPM areas need corrective actions; and (*c*) integrating information from (*a*) and (*b*) into a user-friendly MMD. SBI-MD configures the main contribution of this Chapter and this doctoral thesis in general. Thus, the Chapters ahead contributed to testing the novel approach and validating the adequacy of employed methods and tools.

Chapter 5: Unlocking Continuous Improvement in Heart Failure Remote Monitoring: A Participatory Approach to Unveil Value Dimensions and Performance Indicators

Chapter 5 tests the methods and tools from Phase 1 of SBI-MD, focusing on problem structuring, stakeholder identification, and selecting value dimensions and indicators for an MMD aiding continuous RPM program monitoring and evaluation for a specific condition or patient population. The application case centred on HF management, as explained in Section 1.2. A bibliographic review was conducted, followed by two participatory processes (expert interviews and a web-Delphi process with an enlarged stakeholder group). A final expert interview concluded the approach, resulting in five value dimensions (*Acceptability*, *Access*, *Clinical aspects*, *Costs* and *Technology*), 43 indicators, and six case-mix parameters. The study reported in this Chapter references a master's thesis (Silvério, 2022) conducted alongside this doctoral research, with shared supervision (Mónica D. Oliveira and Filipa M. Baptista) and host entity (Siemens Healthineers). Rita Silvério is a co-author of the published article.

Chapter 6: Co-Designing Healthcare Management Dashboards: A Novel Approach Towards Stakeholder-Aligned Data Visualisation

Chapter 6 introduces a novel collaborative approach for engaging dashboard users in designing prototype reports based on selected KPIs. Suitable DataViz format sets are literature-informed for each KPI based on its communication properties. The CDB workshop follows, using a modified nominal group technique (NGT) allowing participants to select and review formats for integration into the dashboard. In collaboration with HESE, six HF RPM experts participated in a hybrid-format workshop to analyse 17 *Access* and *Clinical aspects* KPIs and six case-mix parameters, achieving consensus on DataViz formats. The process produced two co-created, validated dashboard pages tailored to user needs, with post-workshop surveys showing high satisfaction with the approach. The study reported in this Chapter references a master's thesis (Rodrigues, 2023) conducted alongside this doctoral research, with shared supervision (Mónica D. Oliveira and Filipa M. Baptista) and host entity (Siemens Healthineers). David Rodrigues will be included as a co-author of the published article.

Chapter 7: A Multidimensional Management Dashboard for Health Technology Assessment of Heart Failure Telemonitoring

Chapter 7 reports the structuring and building process of an MMD for tactical and strategic management of the HSM HF RPM program, engaging five stakeholders between December 2023 and August 2024. The project covered the first two phases of SBI-MD, with the main deliverable being a functional MMD prototype to be validated by HSM stakeholders before implementation. During these eight months, the decision analysis and facilitation team conducted six participatory processes – a group interview, three workshops (including a CDB workshop and an online decision conference [DC]), a questionnaire, and individual decision interviews. The developed MMD include seven dashboard reports for analysing program case-mix, evaluation, and monitoring, featuring monitoring KPIs organised by value dimension, a multicriteria value measurement model, colour-coded achievement classification, target and minimum performance reference lines per KPI and criterion, and interactive, user-adjustable weighting.

Chapter 8: Overarching Discussion and Conclusions

This final Chapter discusses the lessons learned over the four-year doctoral project, examining the implications of its contributions and findings through key messages of the thesis. Chapter 8 (1) explores the extent to which the research questions have been addressed, (2) reflects on the evolution of RPM adoption over the four years of the thesis, (3) assesses the methodological implications and key messages for researchers, and (4) provides key recommendations for the industry and suppliers of RPM services and technology, reflecting the research collaboration with Siemens Healthineers. The Chapter concludes by suggesting directions for future work and further developments in research.

CHAPTER 2

TELEMONITORING IN PORTUGAL: WHERE DO WE STAND AND WHICH WAY FORWARD

2.1. Chapter Summary

Following the pandemic, there was growing pressure in Portugal to adopt new practices that promote more efficient, sustainable, and equitable healthcare. Among remote care solutions, TM has been identified as a valuable alternative, particularly for chronically ill, long-term or socially isolated patients. Several initiatives have since emerged. Thus, Portuguese stakeholders recognised the need to reflect upon TM's current state and prospects.

This Chapter aims to provide a comprehensive analysis of the TM landscape in Portugal. We begin by analysing the underlying conditions for telehealth development. Then, we describe the governmental strategy and priorities towards TM – PENTS and NHS reimbursement opportunities for TM. To understand TM implementation, adoption, and dissemination in Portugal, we analyse 46 reported initiatives and adoption studies focusing on providers' perspectives.

A structured reflection on current challenges and the way forward is provided, according to the seven domains of the NASSS framework. The telehealth governance model, public reimbursement mechanisms and the pandemic were identified as the main drivers for TM growth in Portugal, but monitored patients and scaling-up programs are still few. Barriers include low digital literacy, fragmented care integration, and monetary and technological resource constraints, hindering the scale-up of pilot initiatives.

This Chapter's main contributions consist on the identification of a comprehensive list of existing and past TM programs in Portugal, both in the NHS and private providers, and the development of a roadmap addressing challenges in adopting remote care in Portugal and future directions. Chapter's conclusions guided subsequent studies, shaped proposed approaches and tools, and informed case studies.

2.2. Introduction

Over the past four decades, Portugal has made significant progress in improving health care coverage and quality, translating to better outcomes, such as reduced mortality rates and increased life expectancy at birth (Simões *et al.*, 2017). Nonetheless, in the last decade, two severe economic and social crises – the sovereign debt crisis (2009–2014) (Simões, Augusto and Fronteira, 2017; Nunes and Ferreira, 2019) and the COVID-19 pandemic (Duarte *et al.*, 2020) – sorely affected the Portuguese healthcare system, jeopardising the sustainability of the NHS, aggravating access inequalities and leading to the exhaustion and demotivation of health professionals (Crisp, 2015; Amorim *et al.*, 2021). Like other western countries, Portugal also experiences underfunding, scarcity of human resources, population ageing, and low levels of mental well-being (Crisp, 2015). A high prevalence of patients with multimorbidity; low investment in disease prevention and active lifestyle promotion; and high fragmentation, incoordination and discontinuity of services are other hampering issues (Sakellarides, 2020).

The use of telehealth solutions, in particular TM, can be a means to overcome some of these challenges, improving access, increasing infrastructure efficiency and strengthening patient-physician relationships, albeit at a distance (Guilcher *et al.*, 2013; Hirko *et al.*, 2020). Particularly in chronic diseases and multimorbidity settings, TM allows the detection of early signs of decompensation, providing opportunities for preventive action and avoiding unnecessary hospitalisations (Centro Nacional de TeleSaúde, 2019).

In Portugal, although the first telehealth initiatives date back to 1998 (Castela *et al.*, 2005), it was in the post-austerity period that a commitment to its use was reinforced (particularly in the NHS), with institutions, norms and legislation set to support and regulate telehealth adoption within a coordinated, national strategy (Centro Nacional de TeleSaúde, 2021a; Martins and Amorim, 2022). Although several studies have analysed distinct components of telehealth in Portugal, and there is information regarding this ecosystem spread across institutions acting within the Ministry of Health, to our knowledge, no former study focused on the TM state-of-art and reflected upon future developments. This Chapter aims to provide a comprehensive analysis of TM adoption in Portugal, aggregating sparse information from multiple sources, covering legal, strategic and reimbursement aspects and synthesising existing projects in the area to enable an informed reflection.

2.3. Materials and Methods

This Chapter explores relevant publicly available sources in the Portuguese telehealth context, including legislative and policy documents, national and European Union (EU) reports, public contracts, scientific literature and media articles, providing sound evidence on the current TM landscape. First, the historical background and applicable political-legal framework, the strategic frame and the financing context of TM in Portugal are described based on existing data, information and evidence. Then, TM implementation, adoption and dissemination in Portugal are addressed by a review of implemented projects, for two groups of initiatives – NHS-covered and non-covered – and by analysing providers' perspectives on adoption in recent years. NHS-covered initiatives were identified through a review of contracts (available in (Administração Central do Sistema de Saúde, 2024)) signed between public hospital entities (Ministério das Finanças, 2013) (which include hospitals, hospital centres, oncology institutes and local health units integrated into the NHS) and the NHS in 2021. We gathered information about (*a*) provider institution, (*b*) target condition, (*c*) prospective number of patients and (d) total predicted expenditures. For other TM initiatives, we searched the scientific literature, official national/EU reports, media articles and other available sources (e.g. company websites, healthcare blogs). From the reports identified as relevant (i.e. reports describing a TM-based care delivery setting, implemented in the past or ongoing), the following information was gathered: (a) provider institution, (b) city or region, (c) date (month and year) of the beginning of activities, (d) target population or condition, (e) number of patients, and (f) partner institutions involved. Lastly, we synthesised information from the Portuguese Association of Hospital Administrators' two editions of the Portuguese telehealth barometer (2019 (Associação Portuguesa de Administradores Hospitalares, 2019) and 2022 (Associação Portuguesa de Administradores Hospitalares, 2022)) to understand the current status, barriers and challenges to telehealth adoption and dissemination in Portuguese hospitals.

Finally, the gathered analyses are used as a starting point to perform a structured appraisal of current challenges and prospects for remote care in Portugal. This appraisal is organised along the NASSS of health technologies framework (Greenhalgh *et al.*, 2017), which makes available 13 questions in seven domains – Condition, Technology, Value Proposition, Adopter System, Organization, Wider Context and Embedding and Adaptations Over Time – as used by James et al. (James *et al.*, 2021). Accordingly, we use the NASSS framework to synthesise findings regarding TM adoption in Portugal along the seven domains, while benchmarking against other EU experiences and discussing current challenges and prospects. Figure 2.1 summarises the proposed approach, defining the sections to be addressed throughout the article.

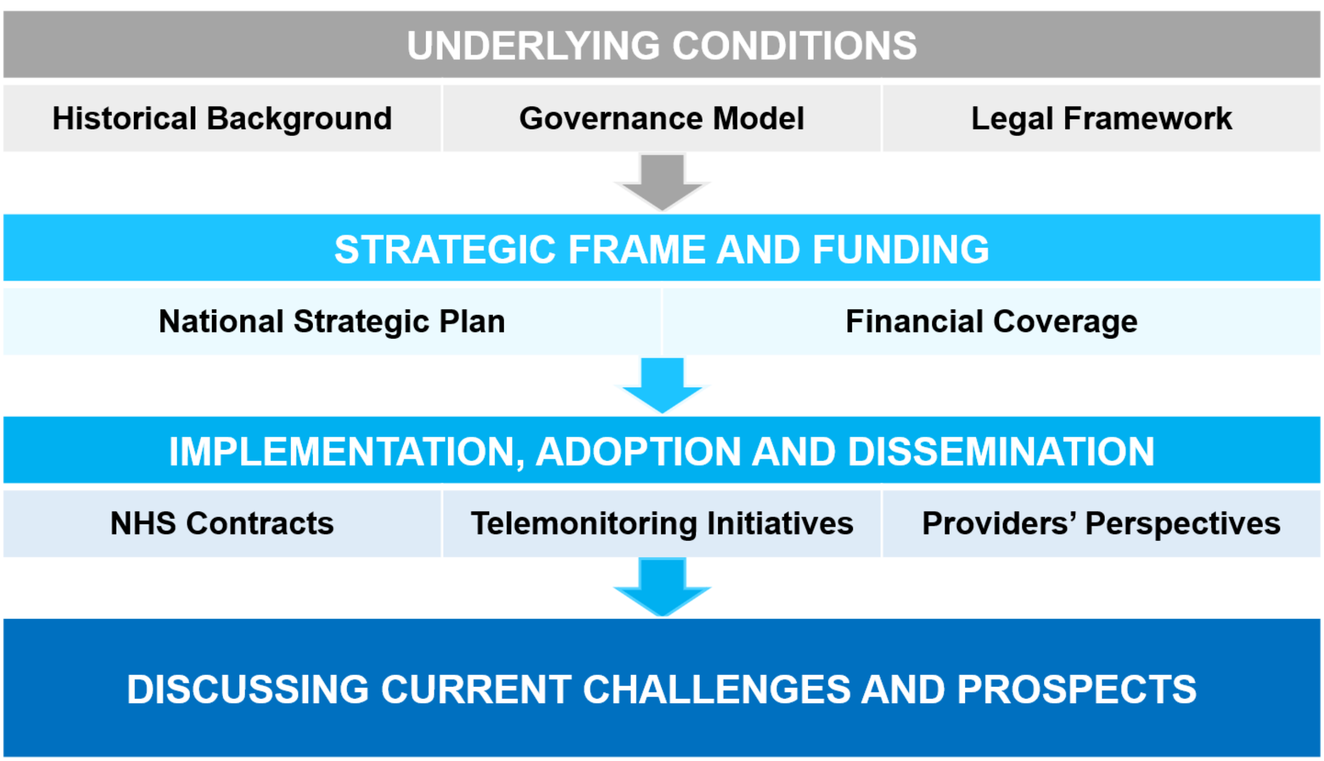


Figure 2.1. Approach adopted to describe and discuss the status quo and future prospects of TM in Portugal.

2.4. Results

2.4.1. Historical Background and Legal Framework of TM in Portugal

2.4.1.1. General Context of Telehealth and TM

A historical retrospective on TM inevitably intersects with the history of telehealth, as the latter includes the former (Centro Nacional de TeleSaúde, 2019; Velayati *et al.*, 2022). As defined in PENTS (Centro Nacional de TeleSaúde, 2019), telehealth constitutes the 'use of ICTs to remotely support health in the aspects of care provision, service organisation and training of health professionals and citizens, not restricted to medical activity (i.e. telemedicine).' In the absence of a specific TM frame in Portugal, this is defined by the telehealth frame.

Figure 2.2 summarises the historical context of telehealth in Portugal, identifying the main milestones in its development and legislation in place (Centro Nacional de TeleSaúde, 2017, 2021a; Gonçalves, Castelo-Branco and Nando Campanella, 2018; Botrugno and Zózimo, 2020; Martins and Amorim, 2022).

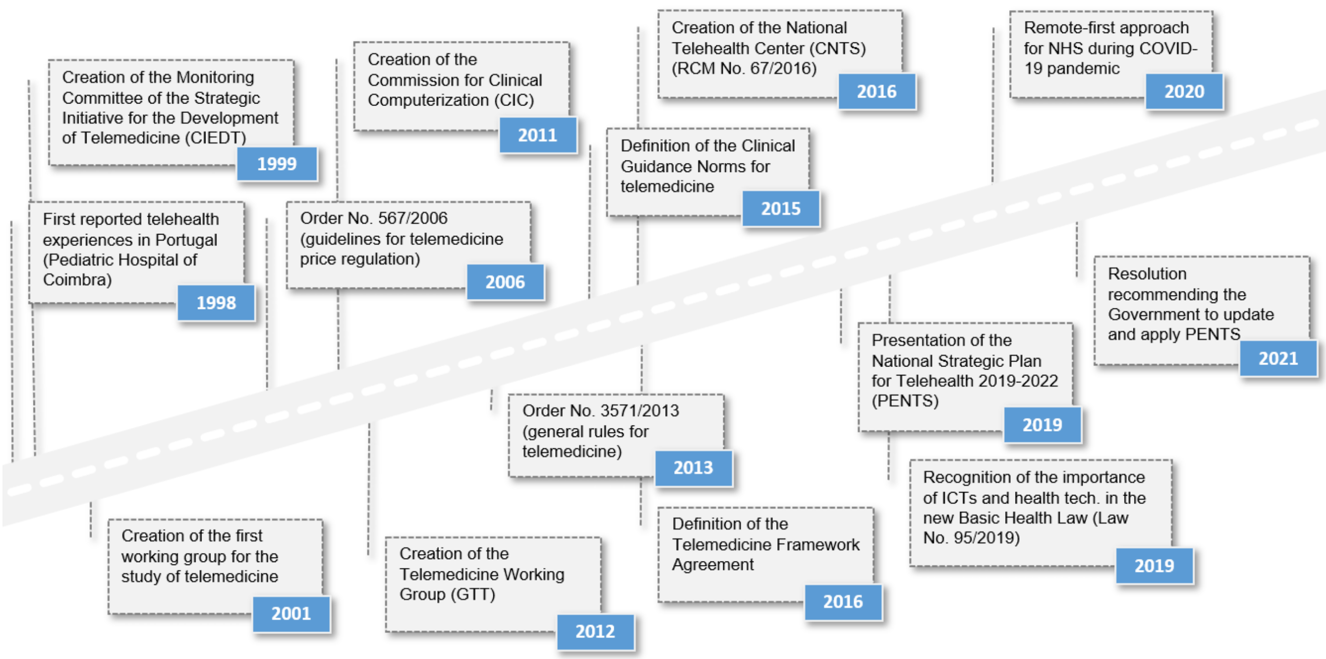


Figure 2.2. Telehealth evolution in Portugal (adapted from (Centro Nacional de TeleSaúde, 2021a)).

2.4.1.2. Portuguese Governance Model for Telehealth

The evolution of institutions, norms and legislation, as summarised in Figure 2.2, contributed to developing a governance model that provides guidance and support for telehealth development (Oliveira Hashiguchi, 2020). Within the Shared Services of the Ministry of Health (SPMS), the CNTS was created (Presidência do Conselho de Ministros, 2016) to promote innovation and the use of ICTs, supporting the regular practice of telehealth. Besides coordinating, regulating and providing services at the national level, the CNTS also oversees the Telehealth Promotion Network, composed of Regional Telehealth Coordinators from Regional Health Administrations (RHAs) and Internal Telehealth Promoters responsible for telehealth adoption coordination at the local level (Oliveira Hashiguchi, 2020). The use of telehealth is further enabled through strategies, documents and technologies developed in collaboration between the Ministry of Health, SPMS and CNTS, such as the PENTS (Centro Nacional de TeleSaúde, 2019), which will be further analysed.

2.4.1.3. Legislation and Regulations Applicable to TM

Due to the detail on TM-specific provisions, it is meaningful to closely analyse some legislative documents (Ministério da Saúde, 20AD, 2013, 2018; Assembleia da República, 2021) to better understand the regulations and guidelines applicable to TM practice.

The telemedicine 'tool' (Ministério da Saúde, 2013) (which includes teleconsultations and TM) 'allows the observation, diagnosis, treatment and monitoring of users as close as possible to their area of residence, work or even at home'. It is portrayed as a 'rapidly growing practice' that contributes to 'the reduction of distances between health services and users, reduction of unnecessary travel, faster response in some specialities and greater support for those who work and live in more distant areas'.

The Ministry of Health (Ministério da Saúde, 2013) outlines measures for establishing a 'telemedicine network' in the NHS, where hospitals must implement remote care in articulation with the groups of (public) primary care centres (ACES) of their area of influence (which, in turn, must articulate with their respective RHA). Priority implementation areas are identified – dermatology, physiatry, neurology, cardiology, paediatric cardiology and pulmonology – and it is determined that the Central Administration of the Health System (ACSS), together with the GTT and the SPMS, must establish reimbursement rules that promote the use of teleconsultation and TM (described in Section 3.2.2.), as well as monitor and support their effective implementation. In complementary documents, the improvement of care provision through remote care in both HF (Ministério da Saúde, 20AD) and home hospitalisation units (Ministério da Saúde, 2018) constitute clear examples of how integrating TM technologies into current practice can positively impact care quality.

The last document (Assembleia da República, 2021) is a call for action to the government to implement a revised version of PENTS, revealing awareness from political decision-makers towards telehealth development and adoption in the post-pandemic period. Twenty-eight action points are proposed to intensify its dissemination, highlighting two points in the scope of TM: (*a*) no. 7 recommends attributing to NHS services and units the necessary means to implement teleassistance programs; (*b*) no. 10 recommends home hospitalisation programs to integrate telehealth services and to ensure access to TM and teleconsultation, safely and effectively (in line with (Ministério da Saúde, 2018)).

2.4.2. Strategic Frame and Funding Context for TM

2.4.2.1. PENTS: the National Strategic Plan for Telehealth Development Between 2019 and 2022

In 2019, SPMS and CNTS presented PENTS (Centro Nacional de TeleSaúde, 2019), a strategic document dedicated to the development of telehealth in the Portuguese health system during the 2019–2022 quadrennium. According to the then president of SPMS, 'the document manages to identify and validate the main challenges, but also needs and future trends', with the ambition 'to create more opportunities for the Portuguese through telehealth to guarantee more access, equity and quality in health.' Teleconsultation, teletriage, telediagnosis, telescreening and TM are subareas of telehealth in which ongoing initiatives exist.

The objectives of the PENTS are (*a*) to elaborate an updated vision of telehealth in Portugal, (*b*) to characterise a value proposition for telehealth sustainable growth, (*c*) to define strategic axes and action measures for telehealth development during the 2019/2022 quadrennium and (*d*) to design a roadmap for operationalising the recommended plan. These objectives are outlined in the definition of six strategic lines and 12 measures, complemented by a set of proposed activities.

TM is considered highly valuable in promoting mobility and portability in care provision, enabling access regardless of location or immediate availability. In this context, TM adoption is encouraged under Measure 1 'Ensuring a sustainable model for telehealth', where the need to develop and test valuable and cost-effective models is underlined.

In 2021, the Operational Plan 2021–2022 (Centro Nacional de TeleSaúde, 2021b), which updates the objectives and strategic lines of the PENTS in light of the impacts of the COVID-19 pandemic, was introduced. The principles of mobility and portability are reinforced, in consideration of the paradigm shift towards a greater adhesion to digital, remote-first care.

2.4.2.2. Financial Coverage for TM Services in the NHS

The current Portuguese payment system for NHS hospitals reflects a contract-based approach, where budgets are defined and allocated through the ACSS, according to 1-year contracts, signed with the Ministry of Health, defining the hospital's predicted overall expenditure and production by lines of activity. The primary care payment system is also contract-based, where RHAs receive funds from the Ministry of Health and, in turn, fund the activity of each ACES (Simões *et al.*, 2017). The available lines of activity for NHS reimbursement are defined in the ACSS terms of reference for contracting healthcare services (Administração Central do Sistema de Saúde, 2021b).

In 2014, a line of activity for TM programs for COPD patients was introduced, followed in 2016 by the addition of two new ones – post-acute myocardial infarction (AMI) and chronic HF – these being the three TM programs currently available within NHS contracts. According to 2022 contracting rules (Administração Central do Sistema de Saúde, 2021b), the following prices apply:

COPD TM program. The price consists of two instalments – TM elements (€1,361 per patient, one time) and the comprehensive price for treatment of a COPD patient (€179.67 per month).

Post-AMI TM program. Two prices per treated patient per month are defined, one for new and another for previously enrolled patients. The former is only applied once for each new patient, up to a limit of 15 patients per institution. Prices are €3,561 for TM elements (per patient, one time), and €117.42 per month for treatment.

Chronic HF TM program. Two prices per treated patient per month are defined –if the patient is new and if already enrolled. Prices are €1,702 for TM elements (per patient, one time), and €117.42 per month.

Payment per treated patient covers setup (i.e. installation of TM devices in the patient's home), home visits, teleconsultations, and data transmission (Oliveira Hashiguchi, 2020). For each program, a list of eligibility criteria for inclusion of new patients and provider tasks to be performed under program scope are also defined (Administração Central do Sistema de Saúde, 2021a).

2.4.3. Implementation, Adoption, and Dissemination of TM in Portugal

2.4.3.1. NHS Public Contracts for TM

Table 2.1 shows the 18 (out of 42 at the national level) public hospital entities that contracted NHS TM services in 2021 (Administração Central do Sistema de Saúde, 2024). For each institution, the expected production level for the three above-mentioned lines of activity (HF, post-AMI, COPD; see Section 3.2.2) is expressed as the prospective number of enrolled patients (*Treated patients*) and predicted expenditure (*Total expenditure (€)*). One can read that *Treated patients* in the HF program at Centro Hospitalar Universitário do Algarve (Centro Hospitalar Universitário do Algarve, 2021) is given by the number of patients undergoing treatment, indicated in the institution's contract (i.e. 3). In turn, *Total expenditure (€)* corresponds to the sum of the two instalments considered for an HF program, where the instalment price is multiplied by the number of contracted instalments (i.e. €10,212 for TM elements + €4,227 for treated patients).

According to these contracts, there are 32 programs – 15 in COPD, 13 in HF and 4 in post-AMI TM –, corresponding to a total reimbursement of approximately €2.3 million, agreed upon for monitoring 721 patients in 2021. The program type with the highest number of treated patients is COPD (412 treated patients), also having the highest predicted expenditure (approximately €1.3 million); the HF program has 258 prospective patients and costs around €780,000; the post-AMI program has 51 patients and approximately €200,000 in total expenditure.

The Lisbon and Tagus Valley RHA is the region with the largest share of public contracts for 2021 – 14 programs, €1.2 million in total expenditure and 322 treated patients. The largest program is the Alto Minho local health unit's COPD program, with 113 prospected enrolled patients (and €284,458 in total expenditure). Still, Centro Hospitalar Universitário Lisboa Norte is the hospital entity with the largest number of patients (132, 100 in COPD, 32 in HF). In turn, the entity that predicted spending the most on TM in 2021 was Centro Hospitalar do Oeste – €377,600 for 20 COPD and 20 HF patients. In contrast, 10 of the 18 public hospital entities considered contracted less than 40 patients, with the average number of patients treated per program being 27 for COPD, 20 for HF and 13 for post-AMI.

Table 2.1. TM lines of activity on NHS contracts for the year 2021.

Healthcare provider	Program type	Treated patients	Total expenditure (€)	Avg. price (€)
Centro Hospitalar Universitário do Porto	HF	15	29,645	1,976.33
Unidade Local de Saúde do Alto Minho	COPD	113	284,458	2,517.33
	HF	10	27,706	2,770.60
	Total	123	312,164	2,537.92
Centro Hospitalar Universitário S. João	COPD	10	35,170	3,517.00
	Post-AMI	5	24,850	4,970.00
	HF	30	67,800	2,260.00
	Total	45	127,820	2,840.44
Centro Hospitalar Universitário Cova da Beira	HF	32	99,552	3,111.00
Centro Hospitalar Universitário de Coimbra	COPD	26	66,944	2,574.77
	Post-AMI	15	21,135	1,409.00
	HF	30	50,780	1,692.67
	Total	71	138,859	1,955.76
Centro Hospitalar do Baixo Vouga	COPD	15	52,755	3,517.00
	Post-AMI	20	63,790	3,189.50
	HF	20	45,200	2,260.00
	Total	55	161,745	2,940.82
Hospital Distrital da Figueira da Foz	COPD	10	35,170	3,517.00
Unidade Local de Saúde da Guarda	COPD	12	42,204	3,517.00
Centro Hospitalar Universitário Lisboa Norte	COPD	100	242,820	2,428.20
	HF	32	62,108	1,940.88
	Total	132	304,928	2,310.06
Centro Hospitalar Universitário Lisboa Central	HF	10	14,090	1,409.00
Centro Hospitalar Universitário Lisboa Ocidental	COPD	10	62,390	6,239.00
	Post-AMI	11	86,719	7,883.55
	HF	21	63,629	3,029.95
	Total	42	212,738	5,065.19
Hospital Distrital de Santarém	COPD	10	35,170	3,517.00
	HF	15	46,665	3,111.00
	Total	25	81,835	3,273.40
Hospital Fernando Fonseca	COPD	12	44,926	3,743.83
Centro Hospitalar Médio Tejo	COPD	11	38,687	3,517.00
Centro Hospitalar de Setúbal	COPD	30	105,510	3,517.00
	HF	20	62,220	3,111.00
	Total	50	167,730	3,354.60
Centro Hospitalar do Oeste	COPD	20	179,220	8,961.00
	HF	20	198,380	9,919.00
	Total	40	377,600	9,440.00
Unidade Local de Saúde do Norte Alentejano	COPD	12	25,872	2,156.00
Centro Hospitalar Universitário do Algarve	COPD	21	73,857	3,517.00
	HF	3	14,439	4,813.00
	Total	24	88,296	3,679.00
Total		721	2,303,861	3,195.37

Source: Authors elaboration based on the contracts of each public hospital entities, available on the ACSS website (Administração Central do Sistema de Saúde, 2024).

As these agreements are prospective, there is no guarantee that the presented values reflect the actual dimension of NHS-covered TM initiatives.

2.4.3.2. Review of TM Initiatives

The previous section presented the institutions contracting TM public provision. Nevertheless, other remote monitoring initiatives have been implemented in Portugal without articulation with the NHS (Martins and Amorim, 2022).

Table 2.2 presents the information collected on the 25 TM programs identified. Although 11 were already reported in Table 2.1, we retained them in Table 2.2 (identified with an asterisk following Target population) since additional information is provided.

Table 2.2. Main characteristics of the identified TM programs implemented in Portugal.

Region / city	Healthcare provider	Kick-off date	Target population	Patient number	Partner institutions	References
Alto Minho	Unidade Local de Saúde do Alto Minho	April 2014	COPD (*)	130	VitalMobile	(Filipe, 2019; Tomé, 2020)
Vila Real	Centro Hospitalar de Trás-Os-Montes e Alto Douro	Dec. 2019	Chronic kidney disease (CKD) (on home peritoneal dialysis)	>40	-	(Agência Lusa, 2019a)
Porto	Centro Hospitalar Conde de Ferreira	2021	Dementia	2	-	(*Centro de dia do Conde Ferreira tem projeto pioneiro de telemonitorização*, 2021)
	Unidade Local de Saúde de Matosinhos (Hosp. Pedro Hispano)	Jan. 2018	HF	39	-	(Cruz *et al.*, 2021)
Aveiro	Centro Hospitalar do Baixo Vouga	Feb. 2020	HF and post-AMI (*)	40	-	(Filipe, 2020)
Guarda	Sabugueiro, Seia	2012	Multimorbidity	>17	Vodafone Portugal	(Pinto Saraiva, Castelo-Branco and Nunes, 2017)
Covilhã	Centro Hospitalar Universitário Cova da Beira	July 2017	HF (*)	37	NOS Comunicações, HopeCare, Axa Assistance, Fundação EDP	(Agência Lusa, 2019b; *Vigiado 24 Horas por dia, José ajuda os médicos a tratar a sua doença*, 2020)
Coimbra	Centro Hospitalar Universitário de Coimbra	May 2017	HF and post-AMI (*)	30	-	(Agência Lusa, 2021b)
Castelo Branco	Unidade Local de Saúde de Castelo Branco	2016	CKD (on home peritoneal dialysis)	5	Baxter Portugal	(*ULS de Castelo Branco inicia projeto de telemonitorização em diálise peritoneal domiciliária*, 2019)
Santarém	Hospital Distrital de Santarém	Feb. 2021	HF (*)	10	-	(Agência Lusa, 2021a)
			COPD (*)	10	-	(Sistema Nacional de Saúde, 2022)
Lisboa	AFID Diferença's nursing home	Dec. 2020	COVID-19 infection	-	Saúde@Home, Siemens Healthineers	(*Lares portugueses recebem nova plataforma de telemonitorização*

						da COVID-19, 2020)
	Centro Hospitalar Universitário Lisboa Norte	Feb. 2008	COPD (*)	38	Vodafone Portugal	(Gonçalves, 2009; Zamith *et al.*, 2009)
		Dec. 2017	HF (*)	40	Linde Saúde	(*A telemonitorização como auxiliar ao tratamento da IC*, 2020)
		2019	Sleep apnoea	21	-	(Fernandes *et al.*, 2019)
		Mar. 2020	Post-COVID-19 infection	-	Vodafone Portugal	(Vodafone Portugal, 2020)
	Centro Hospitalar Universitário Lisboa Central	2018	HF (*)	80	-	(*Hospital Santa Marta. Na hora de medir corações, estar perto é estar longe*, 2020; TSF Rádio Notícias, 2020)
		May 2021	Post-COVID-19 infection	10	Altice Portugal (SmartAL)	(Cristino, 2021; Inácio, 2021)
Almada	Hospital García de Orta	Mar. 2020	Post-COVID-19 infection	-	Vodafone Portugal	(Vodafone Portugal, 2020)
		April 2020	Home care	-	Vodafone Portugal, Lean Health Portugal, ThinkDigital	(Fernandes, 2021)
Setúbal	Centro Hospitalar de Setúbal	2020	HF (*)	17	-	(*Hospital de Setúbal "quebrou barreiras". "O mais importante é o doente"*, 2020)
Évora	HESE	Feb. 2008	Asthma	21	-	(Zamith *et al.*, 2009)
			COPD	13	-	(Zamith *et al.*, 2009)
		April 2021	HF (due to aortic valve stenosis)	52	Saúde@Home, Siemens Healthineers	(Meyer, 2022)
Faro	Centro Hospitalar Universitário do Algarve	Jan. 2014	COPD (*)	15	-	(*Algarve integra projeto de telemonitorização de doença pulmonar obstrutiva crónica*, 2014)

Legend: (*) stands for TM projects already reported in Table 2.1.

Reported initiatives present a wide national coverage, with at least one program run in 13 of the 18 districts of mainland Portugal. These programs are implemented in 17 health institutions, mostly regional hospitals. Most programs have been implemented since 2015 – with only six programs reported before this year and 11 programs in 2020 and 2021 alone.

The focus has been on cardiovascular and respiratory diseases (20 of 25), predominantly in conditions such as HF (9 programs, around 310 patients), COPD (5 programs, 206 patients) and COVID-19 infection (4 programs). About 670 patients (an average of 27 patients per program) are reported to have been enrolled – the largest program is the COPD program of the Alto Minho local health unit, with a total of 130 registered patients; by contrast, 15 initiatives report enrolling less than 40 patients.

2.4.3.3. Providers' Perspectives Towards Remote Care Adoption

In this section, we analyse both the 2019 (Associação Portuguesa de Administradores Hospitalares, 2019) and 2022 (Associação Portuguesa de Administradores Hospitalares, 2022) editions of the Portuguese telehealth barometer, which entails two parts – one on reported adoption by health institutions and another on stakeholder perspectives on telehealth importance and barriers. Given that the first barometer edition was conducted immediately before and the second after the COVID-19 pandemic, comparison between editions provides insights about the impact of the pandemic on remote care dissemination in Portugal (aggregated data and comparisons are available in Table 2.3).

Table 2.3. Portuguese telehealth barometer: comparison between 2019 (Associação Portuguesa de Administradores Hospitalares, 2019) and 2022 (Associação Portuguesa de Administradores Hospitalares, 2022).

	2019	2022	Δ
% of institutions that provide telehealth	75.0%	83.6%	↑ 8.6%
Number of telehealth areas in use by institution (Local Health Units)	3.6	6.0	↑ 2.4
Number of telehealth areas in use by institution (Public hospital > 500 beds)	2.3	6.0	↑ 3.7
Number of telehealth areas in use by institution (Public hospital ≤ 500 beds)	1.8	7.0	↑ 5.2
% of telehealth projects: Teleconsultation (Synchronous + Asynchronous for 2019)	53.0%	96.1%	↑ 43.1%
% of telehealth projects: TM	17.0%	62.7%	↑ 45.7%
% of telehealth projects in hospitals: Teleconsultation	75.0%	97.7%	↑ 22.7%
% of telehealth projects in hospitals: TM	25.0%	69.8%	↑ 44.8%
% of TM areas in NHS hospitals			
HF	13.0%	57.1%	↑ 44.1%
COPD	8.0%	53.6%	↑ 45.6%
Post-AMI	4.0%	35.7%	↑ 31.7%
Diabetes Mellitus	13.0%	17.9%	↑ 4.9%
COVID-19	-	10.7%	-
Others	-	17.9%	-
% considering/believing telehealth (% totally agree + % agree):			
Promotes the user-health professional relationship	47.0%	51.0%	↑ 4.0%
To be priority for their institution	53.0%	56.0%	↑ 3.0%
Helps to fill the lack of response from health institutions	75.0%	68.0%	↓ 7.0%
Allows for a reduction in hospital readmissions	75.0%	77.0%	↑ 2.0%
Promotes adequate guidance and therapeutic adherence through data sharing	87.0%	75.0%	↓ 12.0%
Promotes improved access to care of health	96.0%	83.0%	↓ 13.0%
Plays a very important role in remote monitoring of chronic patients	96.0%	90.0%	↓ 6.0%
Promotes better disease self-management	96.0%	85.0%	↓ 11.0%
Barriers to the adoption of telehealth (% of agreeing respondents)			
Inadequate technological infrastructure	61.0%	31.3%	↓ 29.7%
Low literacy in telehealth	53.0%	60.9%	↑ 7.9%
Lack of motivation in the adoption of telehealth by professionals	44.0%	48.4%	↑ 4.4%
Reduced broadband coverage / Limited internet access	42.0%	23.4%	↓ 18.6%
Scarcity of financial resources	31.0%	28.1%	↓ 2.9%
Lack of training of professionals in telehealth	19.0%	32.8%	↑ 13.8%
Non-existent reference architecture/process and change management	17.0%	17.2%	↑ 0.2%
Little evidence on the benefits of telehealth	14.0%	10.9%	↓ 3.1%
Lack of disclosure / little information about ongoing telehealth projects	-	17.2%	-
Difficulties in integrating the telehealth technological tool in the institution	-	15.6%	-

Adoption data confirms that the pandemic produced a rapid proliferation of telehealth, with all 2022 indicators registering a remarkable improvement over 2019. TM showed significant growth, with 45.7% more institutions reporting initiatives in 2022, mainly in HF and COPD, and more than half of respondent institutions reporting initiatives in these conditions. Conditions covered by NHS reimbursement (i.e. HF, COPD, and post-AMI) revealed significant growth (44.1%, 45.6% and 31.7%, respectively), whereas diabetes (↑ 4.9%) and other conditions (↑ 17.9%) grew more modestly.

However, stakeholders' perspectives on the importance of telehealth for care provision are not as bright. Although the perceived influence of telehealth in strengthening patient-physician relationships (↑ 4.0%) and in reducing hospital readmissions (↑ 2.0%) has improved, as has the percentage of respondents considering telehealth a priority in their institutions (↑ 3.0%), the other indicators worsened. Nevertheless, in 2022, the statement 'Telehealth plays a very important role in remote monitoring of chronic patients' was the one with the highest percentage of 'totally agree' + 'agree' responses (90%), with an increase in 'totally agree' responses (48%, in 2019, to 57.6%, in 2022), confirming the positive trend of TM adoption in Portugal. Regarding barriers to telehealth adoption, there was a significant decrease in the percentage of responses denoting technology-related barriers (i.e. inadequate infrastructure, poor broadband coverage, and poor internet access), which are no longer the main barriers to adoption in Portugal. In contrast, responses regarding user-related barriers (i.e. low literacy, lack of motivation towards adoption and lack of training) presented growth, with low telehealth literacy currently being the main barrier to adoption (60.9% of agreeing respondents).

Other studies confirm similar tendencies in telehealth adoption in Portugal. In 2021, Batista conducted (Batista, 2022) an online questionnaire to identify the factors that influence telehealth implementation from the perspective of Portuguese health professionals. In all, 55.7% of respondents are aware of ongoing telehealth projects in their employing institution, 35.1% reported providing telehealth assistance in the past, and only 23.7% reported using telehealth daily – 22.6% of the latter report providing home TM to their patients. A lack of organisational support, leadership, resources (e.g. ICTs, technical infrastructure, human resources) and adequate training, the need for skills development, and poor adaptation of telehealth solutions to current workflows are the main barriers identified by respondents.

2.5. Discussion of Current Challenges and Prospects

This section assesses the *status quo* and challenges associated with TM adoption according to the seven domains proposed by the NASSS framework (Greenhalgh *et al.*, 2017; James *et al.*, 2021).

Domain 1: The Condition. Earlier we identified 46 TM programs developed in Portugal since 2008. TM is common and proliferating in conditions covered by NHS reimbursement (i.e. COPD, HF and post-AMI) (45.6%, 44.1% and 31.7% between 2019 and 2022, respectively, according to data from Section 3.3.3). Nonetheless, we were also able to identify programs targeting COVID-19 recovery, sleep apnoea, asthma, CKD, dementia and in multimorbidity, home and primary care settings. Regarding home care, although there is a lack of public financial incentives for TM adoption, some legal documents have stated that TM shall be fostered by home hospitalisation units whenever the acute condition state is attenuated, or clinical/therapeutic procedures are perceived to be performed by other levels of care (Ministério da Saúde, 2018).

Even for health conditions in which TM is covered by public funding, although the percentage of adopting institutions is high, the number of treated patients is still reduced. For instance, analysing Table 2.1 for HF, we observe that 13 public hospital entities (31% of total) contracted TM services for this condition in 2021. However, only 258 patients are enrolled in these programs, an average of 20 per institution, compared with approximately 400,000 people suffering from HF in Portugal (Fonseca *et al.*, 2022). Estimation is that about 120,000 have class II HF (New York Heart Association [NYHA] classification) (Fonseca *et al.*, 2018), the class for which the European Society of Cardiology considers TM beneficial (McDonagh *et al.*, 2021).

Domain 2: The Technology. Under the governance model in force to support telehealth development in Portugal, SPMS are the primary technology providers supporting TM implementation within the NHS (Ministério da Saúde, 2013; Oliveira Hashiguchi, 2020). Aiming to foster public TM adoption, SPMS launched, in November 2021, the *Telemonit SNS 24* platform (Sistema Nacional de Saúde, 2021), a mobile application that allows beneficiaries enrolled in NHS TM programs to record measurements of biometric parameters and self-assess their symptoms through health questionnaires. The platform includes programs for HF, COPD and post-COVID-19 recovery, with more than 10,000 downloads, according to data available on Google Play (Serviços Partilhados do Ministério da Saúde, 2022). In the absence of articulation with the NHS, private partner institutions are responsible for providing the necessary ICT infrastructure. In Table 2.2, under the column *Partner institutions*, there can be found companies specialised in TM services, pharmaceutical, MedTech, telecommunications, and insurance companies supporting the implementation and provision of TM platforms and devices, mimicking the action of SPMS.

Wearable devices are another example of innovative technologies with growing interest among the Portuguese population (Sá and Lopes, 2019), allowing users to monitor vital signals and provide real-time health feedback. These devices, such as smartwatches and fitness trackers, can monitor various health metrics, including heart rate, activity levels, and sleep patterns (Hilty *et al.*, 2021). While the growth of wearable device adoption may foster TM adoption, that is not without concerns. Data privacy and security, lack of clinical accuracy and regulation, over-reliance by patients, and inequity in access are some issues in using wearable devices as health technologies (Liao *et al.*, 2019). Although there are no concrete guidelines in Portugal or a national strategy for the adoption of wearables in TM contexts, in 2021, the president of the SPMS stated that "more important than waiting or looking for new technologies is to potentiate and encourage the use of existing ones", considering fundamental the "development of a hub that integrates with different technologies, mobile applications, and wearables for gathering vital parameters" for enhancing remote care and health monitoring (Oliveira, 2021).

According to van Kessel et al. (van Kessel *et al.*, 2022), Portugal follows a trend of geographical inequalities regarding access to technological infrastructure and digital skills, specifically between urban and rural populations, with some aggravated issues compared to other EU member states. The overall household internet connectivity in the country is much below the EU average, the normalised prices of standalone internet are the fifth highest in Europe, and digital skills are still underdeveloped, especially when compared with those in Northern European countries (as represented in Figure 2.3), factors that limit the potential for remote care adoption.

In the face of these findings, van Kessel et al. consider that healthcare digitalisation may amplify inequalities in access, thus recommending investment in digital literacy and capacity for the general population, in a comprehensive ICT infrastructure (arguing that these should represent public goods in European context), and in updating the curricula and teaching practice to reflect the new conceptual framework for digital literacy.

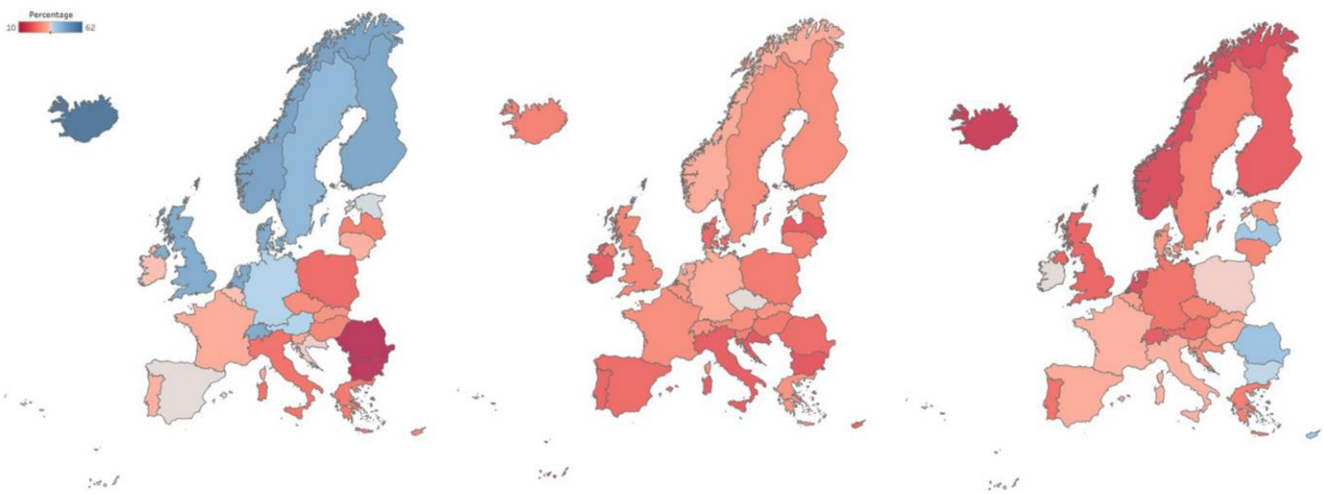


Figure 2.3. Geographical heatmap of the distribution of digital skills (adapted from (van Kessel et al., 2022), left shows above basic skills, centre shows basic digital skills, and right shows low digital skills).

Domain 3: The Value Proposition. Resource scarcity in healthcare is a recurring theme, and the context of TM is no exception. Establishing a technology-based solution entails high costs, especially in setup, where considerable initial investment is required to configure access (Acheampong and Vimarlund, 2015). Additionally, the continuous treatment of patients involves human resources in medicine, nursing and administrative and social work, and the continuous transmission of data. To foster adoption, it is essential to ensure funding across the different stages of these programs.

In this context, the reimbursement mechanisms established by the Portuguese Ministry of Health are highly relevant, guaranteeing coverage of incurred costs. As stated in Section 3.3.3, adoption of TM programs in conditions covered by NHS reimbursement (i.e. HF, COPD and post-AMI) grew significantly compared to non-covered ones. Nonetheless, existing ACSS lines of activity are only available for public contracting and limited to three conditions, posing barriers to an identical TM development in other conditions (e.g. diabetes, cancer, or infectious diseases such as COVID-19), particularly in the private sector, where initiatives struggle to scale-up from pilot to established projects. Although experience in Portugal points to potential benefits of TM programs in promoting care mobility and portability, since 2016 no new programs have been included in NHS contracts.

The cost-effectiveness of most TM initiatives is yet to be explored. Nonetheless, there are some examples of clinical studies conducted in Portugal in HF (Nunes-Ferreira *et al.*, 2020; Cruz *et al.*, 2021), sleep apnoea (Fernandes *et al.*, 2019), COPD (Filipe, 2019) and asthma (Zamith *et al.*, 2009), evaluating program impacts (mainly on clinical outcomes). Results show that TM of chronic conditions can reduce the number of admissions to emergency departments (ED) (Cruz *et al.*, 2021) and hospital admissions, reduce condition-related and all-cause mortality, reduce the number of days lost due to unplanned admissions/death (Nunes-Ferreira *et al.*, 2020), improve the patient's quality of life (QoL), contribute to patients feeling more supported (Zamith *et al.*, 2009), and reduce costs (compared to usual care) (Filipe, 2019). However, Fernandes et al. (Fernandes *et al.*, 2019) suggest that TM use in patients with sleep apnoea showed no benefit concerning compliance and efficacy, compared to conventional care. Thus, it is necessary to develop more HTA studies, in a greater diversity of clinical conditions and involving clinical, economic, and social criteria, to better understand which conditions can benefit the most from TM, making them priority implementation areas.

Regarding TM scalability under real-world conditions, Azevedo et al. (Azevedo, Rodrigues and Londral, 2021) conclude that policy-makers and practitioners are overly focused on intervention-related domains (i.e. clinical effectiveness and costs) when assessing project scalability. Domains related to feasibility, adaptability, and other contextual, technological, and environmental factors, such as the socio-political context of care delivery or the involved workforce, are mostly overlooked by decision-makers. According to these authors, rigorous study designs and robust methods to assess scalability should be established to better inform stakeholders regarding the potential of technology-based care to configure an established, standard practice.

Domain 4: The Adopter System. The vast majority of Portuguese healthcare stakeholders consider the application of TM technologies to chronic disease management to be highly relevant, as shown by 2022 Portuguese telehealth barometer (Associação Portuguesa de Administradores Hospitalares, 2022) data (90% of 'totally agree' + 'agree' responses). However, while the percentage of 'totally agree' responses increased between 2019 and 2022 (48% to 57.6%), the combined rate dropped from 96% to 90% between editions. Considering the significant increase in TM adoption during the pandemic period, these results can be interpreted as follows: (a) respondents who, in 2019, already believed in the potential of TM (innovators and early adopters), confirmed their expectations in a period marked by social distancing and confinement, justifying the increase in 'totally agree' respondents; on the other hand, (b) respondents who recognised the potential, but were sceptical about the responsiveness and preparedness of these solutions for large-scale application, saw their concerns confirmed during the pandemic and lost confidence, justifying the drop in the combined answer.

In fact, between barometer editions, the main barriers to telehealth adoption shifted from technology- to user-related barriers (particularly, low telehealth literacy). This transition seems to indicate that, although the supporting infrastructure is improving and implemented solutions are technologically more robust, end users still lack the digital skills to enable widespread adoption of remote care models. In this regard, van Kessel et al. (van Kessel *et al.*, 2022) point out that, among European countries, younger, highly educated, consistently employed, and urban region-living people report higher internet access and digital skills than other demographic groups. Also, only 34.65% of 2019 respondents report having 'above basic' digital skills. Lack of integration with clinical workflows, lack of telehealth training for professionals, and lack of support (organisational and technological) are some of the common barriers identified among health professionals, hampering adoption and scale-up of projects (Palacholla *et al.*, 2019; Azevedo, Rodrigues and Londral, 2021; Batista, 2022).

To overcome the limitations of TM associated with a lack of (*a*) integration with existing care pathways, (*b*) coordination between involved actors and (*c*) continuous digital skills education of both patients and providers, the concept of RPM has gained popularity over recent years. RPM constitutes a mode of care delivery that allows providers to track, assess and engage patients regardless of location, combining telehealth modalities such as TM, teleconsultation or collection of electronic patient-reported outcomes (Casale *et al.*, 2021). To address in more detail the complexity of integrating RPM into current care pathways, Chapter 3 will present a three-tier model for implementing RPM-based integrated care initiatives: the core RPM intervention consists of four structural elements, i.e. *patient education and self-*

monitoring promotion, *multidisciplinary core workforce*, *ICTs and TM devices* and *health indicators measurement*. Further adding the *patient-centred implementation*, *coordination pivot*, and *outcome measurement* elements outline an integrated RPM intervention. The outer layer of the model includes elements that, although constituting value-added contributions, may not be fundamental to consider in implementing integrated care RPM initiatives.

Domain 5: The Organization. Regarding remote care delivery in the post-pandemic future, Amorim et al. (Amorim *et al.*, 2021) point to the need for a more organised approach to telehealth in Portugal, the role of the government being to define clearer and more adjusted rules for both public and private providers, since the two systems are not directly interrelated and lack coordination. Patient groups and technological companies, in addition to health professionals, should also be involved in the coordination loop. Additional future directions stated by these authors are (*a*) establishing organisation models that allow remote-first and mixed healthcare delivery and (*b*) improving health for institutionalised populations through telehealth systems. Garattini et al. (Garattini, Badinella Martini and Mannucci, 2021) point in the same direction, arguing that telemedicine adoption in primary care settings in Europe appears to be more a matter of labour organisation and funding than of technology and ethics. The authors suggest (*a*) merging all existing health and administrative services into single local primary care centres, as well as health and non-health professionals, and (*b*) weighing local per-capita budgets according to region demographics, with costs and performance of provided services regularly monitored through modern reporting systems.

Domain 6: The Wider Context. Among the various issues hampering remote care implementation, ethical and legal concerns are some of the most complex and diverse. Nittari et al. (Nittari *et al.*, 2020) showed that informed consent, data protection, confidentiality and telemedicine regulations are relevant aspects to be considered when implementing telehealth. The authors point to the need for standardised laws to increase the global adoption of telemedicine. Ensuring maximum protection of patient data during acquisition, transmission, or access by health professionals and third parties, guaranteeing appropriate training and professionalism of those carrying out telemedical activity, and reinforcing patient-centred care by respecting patients' preferences and rights are other highlighted concerns. Negligence and malpractice (Petrazzuoli *et al.*, 2021) may also significantly impact telehealth adoption since, compared to face-to-face care provision, remote care lacks standard, detailed and universal statutory clauses in the presence of clinical malpractice. Thus, developing new mechanisms for ensuring care quality and preventing liabilities from a legal standpoint is critical.

Besides the legal and regulatory framework for telehealth practice (and specific TM provisions) presented in Section 3.1, Portuguese healthcare providers must also consider and comply with the sparse EU regulations and norms applicable to remote care provision, as there is still no common telemedicine framework for EU countries (Raposo, 2016). In 2018, Botrugno (Botrugno, 2018) analysed the most relevant EU acts applicable to healthcare to assess their suitability for telemedicine services. Conclusions pointed to the necessity of establishing an adequate and exhaustive EU regulatory framework for telemedicine, able to (*a*) overcome inconsistencies in adapting current practice rules to remote care delivery, (*b*) guide professionals towards the best use of these services, and (*c*) have a positive impact on EU cross-border healthcare development.

Domain 7: Embedding and Adaptations Over Time. Compared with other member countries of the Organisation for Economic Cooperation and Development (OECD) (Oliveira Hashiguchi, 2020), Portugal presents a national-level dissemination and mostly pilot project scale for TM adoption, aligned with countries like Denmark, Greece, Israel and Lithuania. Few programmes are at an ‘established’ level and with national or higher dissemination (the only examples are in Japan, Spain and Sweden), with most corresponding to small-scale pilot projects. Selected good practices from the most developed countries in TM that may enable successful implementation and dissemination in Portugal include: (*a*) Japan allows provider-to-patient telemedicine only after an initial face-to-face meeting, with the physician solely responsible for determining remote care safety and appropriateness; (*b*) in Spain, the Ministry of Health has issued detailed guidance on implementing and evaluating telemedicine, as well as commissioned a study on the impact of expanding such services; (*c*) in Sweden, telemedicine services are allowed under existing healthcare laws, with a "no-fault" compensation system, based on proof-of-cause. Additionally, collaboration across Nordic countries promotes initiatives such as the VOPD priority project, which targets improving access to healthcare, regardless of location.

When comparing TM adoption with that of other telehealth areas (i.e. teleradiology and teledermatology) in Portugal, the former is still underdeveloped. Teleradiology is already established in Portugal and most OECD countries, often at a national level. Concerning teledermatology, adoption is also extensively established as Portuguese primary care physicians must, by law, attach pictures of any skin lesion when referring a patient to a first dermatology consultation, fostering national, established adoption of teledermatology in the country (Oliveira Hashiguchi, 2020).

When analysing the country’s response during the COVID-19 pandemic, Amorim et al. (Amorim *et al.*, 2021) consider that, although Portugal responded rapidly during the early days of the pandemic (mainly through phone-based services), this reaction should have been followed by upgrading to more comprehensive telehealth technologies. Examples include promoting telerehabilitation and expanding remote assistance pilot programs to larger populations of well-known chronic patients. These authors state that telephone consultation was a convenient, economical, and simple means to respond, as the infrastructure of Portuguese health institutions was not fully prepared for more complex telehealth applications i.e., most public hospitals and primary care units did not have an organised telehealth plan and their computers did not have web camera.

In a broader context, the 2022 Sustainability and Resilience in the Portuguese Health System report (Oliveira *et al.*, 2022) presents 43 agreed policy recommendations generated through a collaborative participatory process involving 40 (top-level) Portuguese health stakeholders who discussed and analysed recommendations with high potential to improve sustainability and resilience of the Portuguese health system following the COVID-19 pandemic. Several recommendations directly or indirectly relate to TM adoption. We highlight those recommendations, namely enabling a structure leading to care integration at various levels and by different sectors (public, private, and social) (recommendation 1B), improving intersectoral coordination and continuity of care (1E), adopting multi-annual budgets in the NHS (2B), ensuring evidence-based health technology adoption (4B), strengthening HTA (4E), investing in domiciliary care and associated digital health (5B), advancing local health care delivery (5D) or implementing electronic medical records (EMR) across the health system (5E). These recommendations align with our findings regarding TM’s lack of care integration and coordination, financial restrictions and tardiness in innovation adoption, highlighting the need for further digital and decentralised care development.

Figure 2.4 synthesises the main challenges and future directions identified in adopting TM in Portugal along this Chapter, organised along the seven domains proposed by the NASSS framework (Greenhalgh *et al.*, 2017).

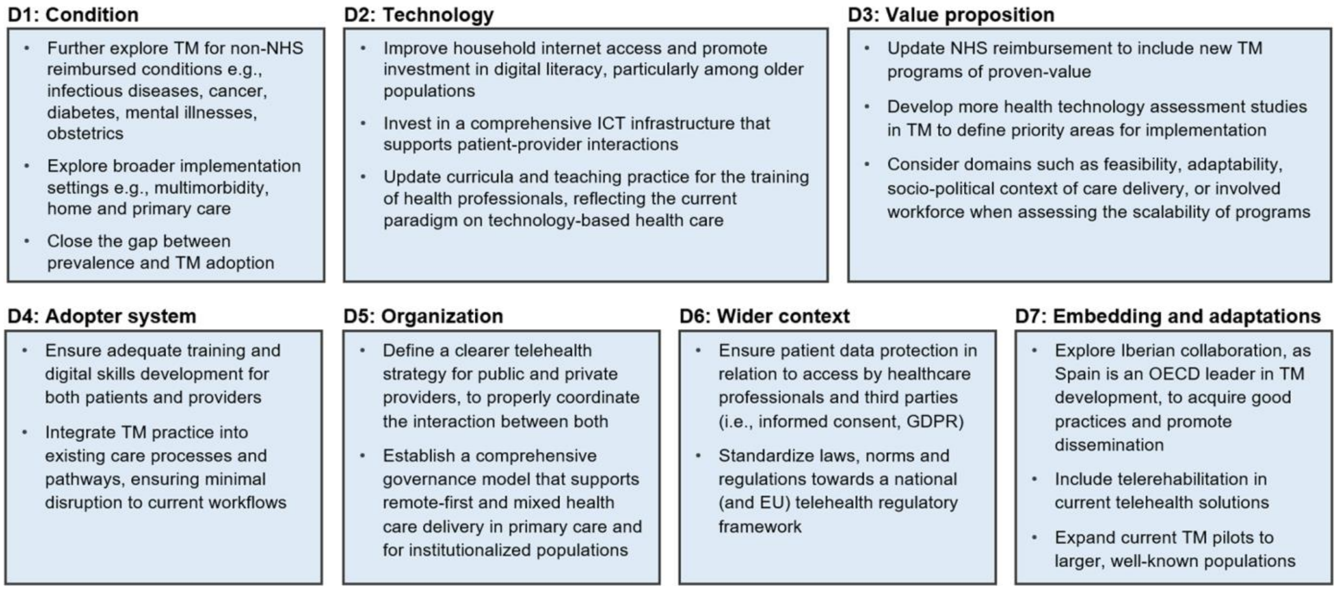


Figure 2.4. Key challenges and future directions in the adoption of TM in Portugal.

2.6. Conclusions

TM adoption in Portuguese healthcare institutions has been multiplying in recent years, leveraged by the governance model established in the NHS, the public reimbursement mechanisms for TM and, above all, by the COVID-19 pandemic period, which constituted a time of unparalleled proliferation for telehealth. Nevertheless, although the percentage of institutions with TM initiatives is already substantial, the number of patients benefiting from TM is considerably low when one account for the prevalence of patients with these diseases.

Lessons on TM adoption in Portugal and the way forward, useful for policymakers in the telehealth context and beyond, can be drawn from this Chapter. Providers have been acknowledging the potential of such services to enhance patient-centred care and reduce costs. However, they recognise the need for more training and organisational support to enable the effective adoption of digital capabilities; and healthcare organisations need to invest in equipping professionals with the necessary digital skills and integrating technology-enabled solutions with existing care pathways to reduce the burden of adaptation and enhance adoption. The next Chapter will delve into the theme of RPM-based integrated care through a comprehensive scoping review of RPM models and initiatives successful in bridging this gap.

This Chapter also highlights the critical role of government support in promoting the digitalisation of healthcare organisations. Government-approved reimbursement mechanisms provide financial support, incentives, and a "stamp of approval" for the benefit of novel interventions, encouraging acceptance among health professionals and enhancing the likelihood of successful implementation. Nevertheless, although the governance model for Portuguese telehealth constitutes an example among the OECD community (Oliveira Hashiguchi, 2020), the country is still in the early stages of TM adoption, presenting a fragmented strategy for national dissemination. Collaboration and resource-sharing between healthcare institutions can help overcome barriers posed by underfunding, resource scarcity, and technical infrastructure limitations. Learning from successful initiatives in other countries, such as Spain, can also boost the development of TM in Portugal.

More knowledge on TM implementation, adoption and dissemination is still needed to inform decision-makers on how to scale up and establish remote interventions as standard practices in chronic, recovery or continued care settings. Future research on TM should focus on analysing and promoting technology integration in current care pathways; developing new care delivery and business models; creating tools to monitor and evaluate the benefits, risks and costs of these initiatives; and investigating new settings where TM can promote improved access and quality (e.g. institutionalised populations, wellbeing and healthy lifestyle promotion, and community health care). Some of these future work avenues are explored in the remaining Chapters of this thesis, namely care integration and technology development for impact assessment.

To further explore and validate our findings and appraisal of TM adoption in Portugal, future work could engage relevant health stakeholders and experts (e.g. patients, physicians, nurses, hospital administrators, technology providers, and policymakers) in a discussion to complement the diagnosis of the current state of adoption. A Delphi process can be developed to involve an enlarged number of stakeholders and experts (Vieira, Oliveira and Bana e Costa, 2020) and promote an agreement on which policies and actions may enhance TM implementation, adoption and dissemination.

CHAPTER 3

TOWARDS A FRAMEWORK FOR IMPLEMENTING REMOTE PATIENT MONITORING FROM AN INTEGRATED CARE PERSPECTIVE: A SCOPING REVIEW

3.1. Chapter Summary

Chapter 2 showed that remote care solutions, namely TM and RPM, has been increasingly adopted over the last decade, with the COVID-19 pandemic fostering its rapid development. As RPM implementation is recognised as complex and highly demanding in terms of resources and processes, multiple challenges were identified in Chapter 2 regarding RPM provision in an integrated logic.

To examine the structural elements that are relevant for implementing RPM integrated care, this Chapter presents a comprehensive scoping review conducted in PubMed, Scopus, and Web of Science, leveraging a search strategy that combines terms relative to (1) conceptual models and real-life initiatives; (2) RPM; and (3) care integration.

Twenty-eight articles were included, covering nine conceptual models and 19 real-life initiatives. Eighteen structural elements of RPM integrated care implementation were identified among conceptual models, defining a structure for assessing real-life initiatives. 78.9% of those initiatives referred to at least ten structural elements, with *patient education and self-monitoring promotion*, *multidisciplinary core workforce*, *ICTs and TM devices*, and *health indicators measurement* being present in all studies, and therefore being core elements to the design of RPM initiatives. A three-tier model for implementing an RPM-based integrated care initiative is proposed, constituting the main contribution of this Chapter.

Chapter's conclusions point that RPM goes far beyond technology, with underlying processes and involved actors playing a central role in care provision. The structural elements outlined in the proposed framework can guide RPM implementation and promote maturity in adoption. Key elements like *health indicators measurement*, *outcome measurements*, *clinical dashboards*, *health data centre*, *shared decision-making culture*, and *collaborative design process* highlight the need for more robust management tools enabling multidisciplinary teams to process and utilise clinical and operational data effectively, driving improved and collaborative decision-making within RPM programs.

3.2. Introduction

In a 2014 essay on the main trends in healthcare provision for 2020 and beyond (Deloitte, 2014), the Deloitte Centre for Health Solutions envisaged a healthcare system that integrates home care and technology. Hence, "the home is where much of the medical care takes place. (…) The ubiquity of digital communication means that many doctor-patient contacts are now virtual and deliver care to the patient in their home. Specialist hospital treatment is reserved for trauma and emergency surgery; (…) while chronic and long-term conditions are managed in the community". While this essay was meant to be bold and provocative, this prediction captures the paradigm that healthcare has had to adapt to as a result of the COVID-19 pandemic (Kumpunen *et al.*, 2021; Xu *et al.*, 2021; Smith *et al.*, 2022).

Out of necessity, remote care initiatives, mainly conceived as small pilots (Azevedo, Rodrigues and Londral, 2021; Schlieter *et al.*, 2022), overcame existing technological barriers and asserted themselves as viable solutions to deliver care that would otherwise remain unprovided (Gülmezoglu *et al.*, 2020; Newhouse, Farmer and Whelan, 2020; Tersalvi *et al.*, 2020; Kronenfeld and Penedo, 2021). RPM can be defined as "a mode of health care delivery that gathers and integrates patient data outside of traditional health care settings, allowing providers to track, assess, and engage patients regardless of location" (Casale *et al.*, 2021). RPM can thus constitute an alternative (but also a complement) to conventional care, with potential social and economic value for both patients and providers. The latter can follow multiple patients simultaneously, monitor their vital signs and reported symptoms, provide educational materials that promote health literacy and self-care, and adapt care delivery to meet patients' needs better. In return, patients can receive care in a more comfortable and familiar environment, avoiding exposure to increased and unnecessary risks (e.g., hospital-acquired infections) and psychological distress (Annis *et al.*, 2020; Castelnuovo *et al.*, 2020; Krenitsky *et al.*, 2020; Watson, Wah and Thamman, 2020).

While RPM was far from widespread before the COVID-19 pandemic (Vegesna *et al.*, 2017; George and Cross, 2020), afterward, its implementation rapidly responded to emerging adversities (Jain *et al.*, 2022), but faced design limitations (Doraiswamy *et al.*, 2020; Hincapié *et al.*, 2020; Amorim *et al.*, 2021). To our knowledge, and as shown for the Portuguese context in Chapter 2, there is still a considerable gap worldwide in implementing RPM within a continuum of care, which requires coordination and communication between actors and full consideration of involved technology, procedures, and outcome measurement (Lluch and Abadie, 2013; Melchiorre *et al.*, 2018; Struckmann *et al.*, 2018).

To fill this gap, this Chapter presents a scoping review (Tricco *et al.*, 2018) that aims to examine what structural elements need to be considered to promote an integrated care implementation of RPM initiatives. Existing literature on conceptual models and real-life initiatives will be assessed, allowing a comprehensive appraisal of the state-of-the-art. To ensure the assessment of the integrated care perspective and enable the identification of the main structural elements encompassed, the **S**ustainable int**E**grated chronic care mode**L**s for multi-morbidity: delivery, **FI**nancing, and performanc**E** (SELFIE) framework for integrated care for multi-morbidity (Leijten *et al.*, 2018) is adapted and applied to the context of remote care provision.

3.3. Methods

3.3.1. Search Strategy and Study Selection

A search for scientific literature was conducted on June 8th, 2021, in the following bibliographic databases: PubMed, Scopus, and Web of Science. Articles were searched according to a comprehensive search protocol based on keyword combination and considering terminology variations and alternative spellings. This protocol was applied to the title and abstract fields of articles published since 2010, ensuring a thorough analysis of the state-of-the-art over the last decade and over the pandemic period (period of high proliferation of telehealth (Müller *et al.*, 2021)). The search algorithm combined terms referring to (*a*) conceptual models, programs, and initiatives; (*b*) RPM and TM; and (*c*) care integration and continuity of care. The search protocol for article identification can be consulted in Table 3.1.

Table 3.1. Rules for scoping review search: [("A" or "B") and ("C" or "D" or "E") and ("F" or "G" or "H" or "I")].

A: concept* OR theor* OR framework* OR model* OR plan*	G: "care continuity" OR "care continuation" OR "continuity of care" OR "continuity of patient care"
B: program* OR action* OR project* OR approach* OR initiative* OR implement*	H: "patient-centred" OR "patient-centered" OR "patient-centred care" OR "patient-centered care"
C: "remote patient monitoring" OR "remote monitoring" OR "remote care" OR "home monitoring"	I: "managed care" OR "patient care management" OR "management model" OR "comprehensive care" OR "comprehensive health care" OR "care coordination" OR "collaborative care" OR "shared care" OR "accountable care" OR "multidisciplinary care" OR "interdisciplinary care" OR "inter-disciplinary care" OR "transmural care" OR "holistic care"
D: telemonitor* OR telesurveillance OR telemetric	
E: tele-monitor* OR tele-surveillance OR tele-metric	
F: "care integration" OR "integrated care" OR "integrated care delivery" OR "care delivery" OR "health care delivery" OR "integrated health care delivery" OR "integration of care" OR "delivery of health care integrated" OR "integrated medicine" OR "clinical integration"	

The existence of duplicates was first verified using the Mendeley's "Check for Duplicates" tool, with duplicate references being merged. The same verification process was then performed manually. Hereafter, article screening was conducted in two steps – the first on the title and abstract fields, to identify articles relevant for retrieval, and the second on full-text eligibility for review inclusion.

During the first step, all references whose title and abstract suggested configuring (even if tenuously) an RPM implementation framework or program and following a care integration logic were sought for retrieval. The second step was predominantly conducted by me and validated by a co-author whenever the decision to include an article was not immediately clear.

Exclusion criteria were defined according to Armstrong et al. (Armstrong *et al.*, 2011) methodology for developing scoping reviews. Articles were excluded if (*a*) full-text was not written in English; (*b*) literary object was an editorial, letter to the editor, commentary or conference abstract; (*c*) report did not describe an RPM intervention (Casale *et al.*, 2021); or (*d*) report failed to present a framework or program of integrated implementation of RPM (i.e., report must describe both human and non-human elements intervening in a coordinated RPM care delivery, with the patient playing an active role managing its health status). For instance, reports describing solely videoconferencing (VC), telephone-based monitoring, EMR integration, or telerehabilitation were not considered. Additionally, reports describing self-management or information-gathering solutions, with no patient-provider communication nor coordination between providers, were also excluded.

To meet the main objective of this scoping review and the logical distinction between assessed bodies of literature, the selected articles were divided into two groups – *conceptual models* and *real-life initiatives* (e.g., case studies, clinical trials). Conceptual models were analysed first and initiatives second, in the same order in which the results are presented.

PRISMA extension for Scoping Reviews (PRISMA-ScR) (Tricco *et al.*, 2018) guidelines were followed in the development of the scoping review integrating this Chapter.

3.3.2. Assessing the Integrated Care Nature of the Studies – the SELFIE Framework

The SELFIE framework (Leijten *et al.*, 2018) was built upon existing models for integrated and person-centred care (such as the Chronic Care Model, the Guided Care Model, and the Development Model for Integrated Care), and enriched through a highly comprehensive scoping review and consultation of experts from 8 EU countries and representatives of relevant stakeholder groups (i.e., patients, partners, professionals, payers, and policy makers). SELFIE was set to target multi-morbidity and capture complexity in the delivery of care; it provides a structure of interconnected concepts that can be applied to guide the development, implementation, description, and evaluation of integrated care programs (Leijten *et al.*, 2018).

Under SELFIE, the holistic understanding of the person with multi-morbidity and respective environment is placed at the centre of the framework, interacting with surrounding elements pertaining to integrated care. These elements are further grouped according to six components – *service delivery*, *leadership & governance*, *workforce*, *financing*, *technologies & medical products*, and *information & research* – and, within each component, the distinction is made between the micro (comprised elements), meso (coordination) and macro (legislation and policies) levels. Transversal to all components and levels is a *Monitoring* component to stimulate continuous improvement in the remaining ones. Each component and subsequent levels are described in detail in Leijten et al. (Leijten *et al.*, 2018).

In the context of the present Chapter, the SELFIE framework was used as a starting point to systematically identify and describe the elements of care integration present in included studies. As we intended to identify the structural elements for integrated care implementation of RPM initiatives, the macro level of the SELFIE components was not considered, since legislative and policy issues were defined as outside the scope of analysis.

The results from conceptual model studies' analysis are presented along SELFIE care integration components, allowing to group identified elements of RPM care integration. However, we did not differentiate identified elements at the micro or meso levels of the framework, as we believe this adds a layer of unnecessary complexity to our work.

3.4. Results

3.4.1. Literature Search Results

A literature search conducted on the specified databases identified 823 records meeting the described keyword combinations. After duplicate removal, 411 articles remained for title and abstract screening, leading to the exclusion of 311 references. Not being possible to retrieve full text for 4 records, 96 articles were assessed for review inclusion eligibility. Exclusion criteria application led to rejecting 70 articles – 4 not written in English language, 4 conference abstracts, 1 letter to the editor, and 61 out of scope. 2 further articles were deemed relevant (identified through updated search) and added, thus, 28 studies were included in the scoping review – 9 conceptual models and 19 real-life initiatives of RPM-based integrated care implementation. The identification and screening process conducting to this final sample is depicted in Figure 3.1.

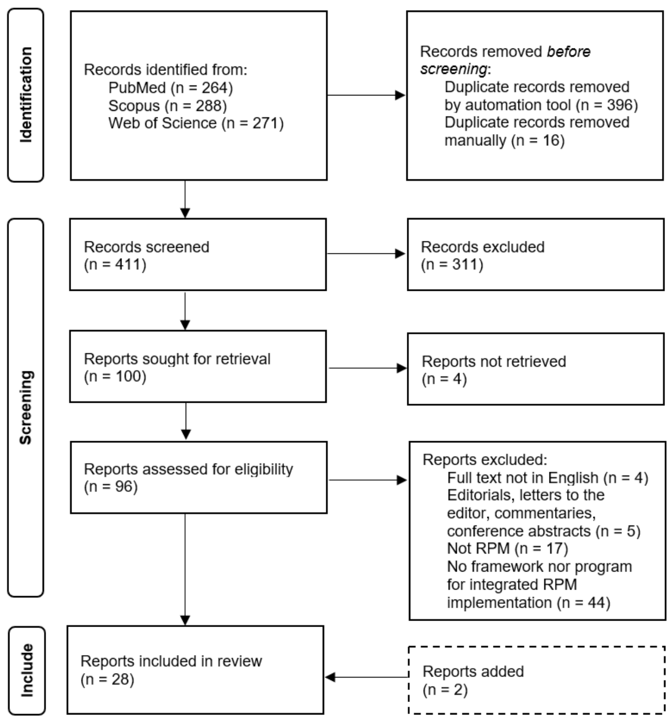


Figure 3.1. PRISMA-ScR flow diagram of the study selection and exclusion criteria used.

3.4.2. Study Characteristics

The 28 selected studies spanned across 10 different nations (i.e., country where the study was conducted or, if not stated, first author institution's country) – USA (13 studies) (Sheeran *et al.*, 2011; Singh *et al.*, 2011; Pelletier *et al.*, 2011; Brooks *et al.*, 2013; Black *et al.*, 2014; Chen and Levkoff, 2015; Dimengo and Stegall, 2015; Cheville *et al.*, 2018; Schenkel *et al.*, 2020; Krenitsky *et al.*, 2020; Casale *et al.*, 2021; Foster *et al.*, 2021; Aronoff-Spencer *et al.*, 2022), Italy (3) (Ricci and Morichelli, 2013; Donner *et al.*, 2018; Realdon *et al.*, 2018), Netherlands (3) (Grustam *et al.*, 2017; Herkert *et al.*, 2020; Dontje *et al.*, 2021), Canada (2) (Gordon *et al.*, 2020; Agarwal *et al.*, 2021), France (2) (Bourret and Bousquet, 2013; Ferrua *et al.*, 2020), Austria (Modre-Osprian *et al.*, 2014), Finland (Vuorinen *et al.*, 2014), Germany (Schmidt *et al.*, 2018), Norway (Smaradottir *et al.*, 2017), and Scotland (Fairbrother *et al.*, 2014).

Concerning the diseases, conditions or the specific groups of patients addressed, these selection of studies focuses predominantly (71.4%) on chronic conditions (20) i.e., on generalized chronic patients' management (Bourret and Bousquet, 2013; Grustam *et al.*, 2017; Gordon *et al.*, 2020), HF (Black *et al.*, 2014; Fairbrother *et al.*, 2014; Modre-Osprian *et al.*, 2014; Vuorinen *et al.*, 2014; Dimengo and Stegall, 2015; Schmidt *et al.*, 2018; Herkert *et al.*, 2020), COPD (Smaradottir *et al.*, 2017; Donner *et al.*, 2018; Herkert *et al.*, 2020), cancer (Cheville *et al.*, 2018; Ferrua *et al.*, 2020; Aronoff-Spencer *et al.*, 2022), diabetes (Pelletier *et al.*, 2011), amyotrophic lateral sclerosis (ALS) (Dontje *et al.*, 2021), dementia (Realdon *et al.*, 2018), infants with single ventricle physiology (SVP) (Foster *et al.*, 2021), and patients possessing cardiac implantable electronic devices (CIED) (Ricci and Morichelli, 2013). Other non-chronic conditions or specific groups of patients addressed are COVID-19 patients (Krenitsky *et al.*, 2020; Agarwal *et al.*, 2021; Casale *et al.*, 2021), prenatal care (Krenitsky *et al.*, 2020), older adults (Chen and Levkoff, 2015), patients with mental illnesses (post-traumatic stress disorder [PTSD] (Brooks *et al.*, 2013) and depression (Sheeran *et al.*, 2011)), lung transplant (Schenkel *et al.*, 2020) and post-acute care (Singh *et al.*, 2011) patients.

3.4.3. Conceptual Models for Integrated Care Implementation of RPM

Articles included in conceptual models' analysis can be grouped into three categories, according to the main purpose of the study: (*a*) conceptual extension of an implemented initiative (Modre-Osprian *et al.*, 2014; Ferrua *et al.*, 2020; Gordon *et al.*, 2020); (*b*) expert recommendations (Bourret and Bousquet, 2013; Chen and Levkoff, 2015; Dimengo and Stegall, 2015; Donner *et al.*, 2018; Aronoff-Spencer *et al.*, 2022); and (*c*) RPM-specific business model proposal (Grustam *et al.*, 2017).

Conceptual extensions derive from projects already implemented, pinpointing challenges and/or inefficiencies incurred in the past. Ferrua et al. (Ferrua *et al.*, 2020) outlined an RPM system to improve oral medication cancer therapy. Gordon et al. (Gordon *et al.*, 2020) conducted interviews with patients and health professionals to inform the development of TM for multi-morbidity chronic disease management (a follow-up article was published recently (Gordon *et al.*, 2022), which we consulted for further details). Modre-Osprian et al. (Modre-Osprian *et al.*, 2014) developed a concept combining closed-loop monitoring with a collaborative network for HF management.

Studies reporting recommendations from RPM experts rely on scientific evidence and/or lived experiences to formulate best implementation practices. Although these articles do not present a model *per se*, the detail and scope were considered sufficient to infer a framework for implementation. Aronoff-Spencer et al. (Aronoff-Spencer *et al.*, 2022) describe a participatory approach to engage stakeholders in designing a framework for remote care of rural patients experiencing distress during cancer treatment. Chen and Levkoff (Chen and Levkoff, 2015) outline recommendations on human-computer interaction within TM care for older adults. Dimengo and Stegall (Dimengo and Stegall, 2015) propose recommendations on team-based care TM in patients with HF, leveraging self-efficacy and behaviour change strategies. Donner et al. (Donner *et al.*, 2018) present a summary of a workshop on telemedicine use to facilitate the integrated care of COPD. Bourret and Bousquet (Bourret and Bousquet, 2013) propose an integrated health system combining ICTs, shared-decision making and primary care services to treat noncommunicable diseases.

Grustam et al. (Grustam *et al.*, 2017) compared *business-to-business* (B2B) and *business-to-consumer* (B2C) models for TM from the perspectives of both activity system theory and transaction cost theory.

Conceptual model articles were examined considering SELFIE's components of care integration, according to which the results of this analysis are presented below.

Holistic understanding of the individual in his/her environment (Individual & environment). Assessing patients' perspectives throughout program design (Ferrua *et al.*, 2020; Gordon *et al.*, 2020, 2022; Aronoff-Spencer *et al.*, 2022) allows providers to adapt the intervention to the end-users' technological and self-management capabilities, as well as understand possible reasons for dissatisfaction with conventional care.

Technology Acceptance Model (TAM) and digital divide theory offer insights into the factors that influence the willingness-to-accept technology for health management (Chen and Levkoff, 2015). Individuals, particularly older adults, are often influenced by affordability, ease to assemble/operate, or user-friendliness in perceiving benefit (Dimengo and Stegall, 2015). Physical impairments can also reduce one's confidence to operating technology (Chen and Levkoff, 2015; Donner *et al.*, 2018). Geography, community context and language are also major determinants of technological acceptance (Gordon *et al.*, 2020, 2022; Aronoff-Spencer *et al.*, 2022).

Service delivery. Patient education and self-monitoring promotion are transversal themes among studies. During enrolment and throughout intervention phases, individuals (and caregivers) are instructed on correctly using TM equipment, educated about their condition, and presented with self-management opportunities (Modre-Osprian *et al.*, 2014), contributing to increase therapeutic adherence (Ferrua *et al.*, 2020). Online classrooms, social networking, simulation/gaming (Donner *et al.*, 2018), self-care knowledge quizzes, and support group sessions (Dimengo and Stegall, 2015) are relevant activities for promoting self-management and behaviour change.

Tailoring service delivery to the patients' complex needs (e.g., considering the challenges of multi-morbidity (Grustam *et al.*, 2017; Ferrua *et al.*, 2020)) and dynamic evolution of their health status also plays an important role in improving care quality and engagement (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014; Gordon *et al.*, 2020). As therapy progresses, improvements in patient's health status and self-management capacity may not justify maintaining the intervention as is. Thus, Modre-Osprian et al. (Modre-Osprian *et al.*, 2014) introduces the concept of "dynamic trajectory of illness", according to which the individual can engage in four configurations of RPM – *collaborative telemonitoring* (leveraging multidisciplinary intensive care unit (ICU) coordination), *"classical telemonitoring"*, *home-care monitoring* and *self-management*.

Grustam et al. (Grustam *et al.*, 2017) presented two models for TM care delivery – the B2B model, describing a *hospital-to-home* (H2H) care delivery, since communication takes place between the patient's home and a hospital-located telehealth team using ICTs, during outpatient rounds (i.e., vital signs are assessed remotely against personal goals/thresholds); and the B2C model, describing a *high-touch-high-tech* (2HT) approach, based on a TM centre that coordinates stakeholder interaction, where *telenurses* act both as "healthcare navigators" and "personal health coaches", aided by personalized, smart algorithms for patient monitoring. H2H care delivery is set for discharged patients after an urgent episode, while 2HT delivery is particularly relevant for chronic disease management.

Leadership & governance. A shared decision-making culture, involving all stakeholders (including patient and caregivers), is considered one major feature of integrated care delivery (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014; Donner *et al.*, 2018). Coordination of micro-level decision-making processes (i.e., patient-provider interaction) is usually ensured by a coordination pivot (e.g., case managers, nurse navigators). In most studies, this role is performed by nurses (Modre-Osprian *et al.*, 2014; Grustam *et al.*, 2017; Ferrua *et al.*, 2020; Gordon *et al.*, 2020, 2022), who conduct activities from answering patients' proactive contacts (Ferrua *et al.*, 2020) to leading the entire care model, undertaking all medical coordination decisions (Modre-Osprian *et al.*, 2014).

Higher coordination is achieved through a program coordinator, responsible for orchestrating all stakeholders and partners, so they can efficiently work together (Modre-Osprian *et al.*, 2014). Grustam et al. (Grustam *et al.*, 2017) describes two program coordination types – between places of activity (*stages*) and between participants in the activity (*actors*). Within *stages*' coordination, care coordinators are needed in both interacting sites (e.g., nurse at the hospital, caregiver at home). In *actors*' coordination, TM nurses are the solo care delivery coordinators, managing person and institutional interdependencies between providers.

Workforce. Caregivers, nurses (specialists or not) and physicians (specialists or general practitioners) are the main actors responsible for monitoring and acting upon clinical deterioration, constituting the core RPM workforce across studies. Other professionals may also play an important role in the intervention, such as other specialty physicians (e.g., in the context of HF, endocrinologists, pulmonologists, or psychologists (Modre-Osprian *et al.*, 2014)), dieticians, social workers (Gordon *et al.*, 2020, 2022) and pharmacists (Bourret and Bousquet, 2013; Grustam *et al.*, 2017).

Financing. Modre-Osprian et al. (Modre-Osprian *et al.*, 2014) suggests that RPM configurations such as *collaborative telemedicine* and *"classical telemonitoring"* could be covered by public funds, while *home-care monitoring* and *self-management* would be delivered by private providers, stating, however, that such public-private arrangements might complicate care continuity.

Not only in care delivery and governance, B2B and B2C models also differ in financing and payment flows. B2B models imply commercial transactions between two businesses (e.g., a TM equipment manufacturer and a hospital). In contrast, transactions are processed directly with the end-user in B2C models (e.g., TM centre and patient). New reimbursement strategies may be needed to cover possible out-of-pocket expenses, such as (*a*) reimbursement by government/insurer to patients, (*b*) payment by government/insurer to TM centre for a patient cohort, or (*c*) payment by informal caregivers to TM centres (Chen and Levkoff, 2015; Grustam *et al.*, 2017).

Technologies & medical products. In most studies, patient portals, mobile-based apps, and TM devices are core technological components. Using a smartphone, tablet or web-based platform, one can acquire vital signs through TM devices (Grustam *et al.*, 2017), send messages, collect electronic patient reported outcomes (e-PROs) (Aronoff-Spencer *et al.*, 2022), schedule appointments, provide educational materials, storage exam results, and/or check/deliver reminders (Ferrua *et al.*, 2020). Aronoff-Spencer et al. (Aronoff-Spencer *et al.*, 2022) and Chen and Levkoff (Chen and Levkoff, 2015) draw recommendations on interface design: (*a*) compatibility with existing hardware; (*b*) simplified design, based on existing or low-cost-low-training devices; (*c*) critical judgement in deciding what information to include; (*d*) automated and unobtrusive data collection and transmission (e.g., Bluetooth (BT)-enabled); (*e*) use of audio-visual communication.

At a higher level of technological coordination, Modre-Osprian et al. (Modre-Osprian *et al.*, 2014) proposes a health data centre, an interoperable information system capable of processing and analysing data, detecting upcoming adverse events and producing action triggers, through artificial intelligence-driven DSS.

Information & research. DataViz can be supported by clinical dashboards that provide comprehensive follow-up of patients' health status in a user-friendly manner (Modre-Osprian *et al.*, 2014; Grustam *et al.*, 2017; Aronoff-Spencer *et al.*, 2022). Dashboards should include both manually- and automatically-gathered data, and be accessible to all relevant stakeholders involved (Donner *et al.*, 2018).

Aspects to be monitored are condition-dependent, thus shall be defined according to target population's needs. Blood pressure (BP), heart rate, electrocardiogram (ECG), weight, glycaemia, dyspnoea, blood oxygenation, sleep patterns, anxiety, or physical activity are examples mentioned across studies. Relevant information which cannot be measured through TM devices can be assessed by e-PRO questionnaires (Dimengo and Stegall, 2015; Donner *et al.*, 2018).

Monitoring. Outcome measurements (Dimengo and Stegall, 2015; Aronoff-Spencer *et al.*, 2022) such as number of admissions/readmissions, ED visits, inpatient length of stay (LoS), all-cause mortality, changes in patterns of use, health-related QoL variation, overall patient satisfaction, user experience and system usability (SUS), cost saving for patients and providers, and return on investment (ROI) are only some relevant performance indicators to consider in RPM.

Table 3.2 presents a summary of the good practices and/or recommendations inferred from studies' analysis, grouped by 18 distinct elements of integrated care implementation of RPM, in turn grouped according to the components of integrated care proposed by the SELFIE framework (Leijten *et al.*, 2018).

Table 3.2. Elements of RPM integrated care implementation identified from conceptual model studies' analysis.

SELFIE framework's components	Elements of integrated care implementation of RPM	Code	Good practices and/or recommendations from studies
Individual & environment	Collaborative design process	(a)	Conduct interviews with patients and caregivers to develop end-user-tailored interventions (Ferrua *et al.*, 2020; Gordon *et al.*, 2020; Aronoff-Spencer *et al.*, 2022)
			Apply co-design techniques to engage all relevant stakeholders in the cocreation process (Aronoff-Spencer *et al.*, 2022)
	Patient-centred implementation	(b)	TAM and digital divide theory (Chen and Levkoff, 2015)
			Consider the impact of physical impairments on technology usage (Chen and Levkoff, 2015; Donner *et al.*, 2018)
			Consider in-home limitations and difficulties to assemble/operate TM equipment (Dimengo and Stegall, 2015)
			Geographical and community context role in technological acceptance and digital literacy (Gordon *et al.*, 2020; Aronoff-Spencer *et al.*, 2022)
Service delivery	Patient education and self-monitoring promotion	(c)	Continuously instruct patients (and caregivers) on how to correctly use the TM equipment (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014; Chen and Levkoff, 2015; Dimengo and Stegall, 2015; Grustam *et al.*, 2017; Donner *et al.*, 2018; Ferrua *et al.*, 2020; Gordon *et al.*, 2020; Aronoff-Spencer *et al.*, 2022)

			Promote education on the patient's health condition and on self-monitoring opportunities (Modre-Osprian *et al.*, 2014; Ferrua *et al.*, 2020)
			Promote online classrooms, social networking, online simulation/gaming, quizzes to assess self-care knowledge, support group sessions (Dimengo and Stegall, 2015; Donner *et al.*, 2018)
	Multi-morbidity care	(d)	Consider adjacent health manifestations when designing care delivery pathways (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014)
			Micro-level coordination role in improving patient navigation within this complex care setting (Grustam *et al.*, 2017; Ferrua *et al.*, 2020)
	Dynamic trajectory of illness	(e)	Individuals can engage in different RPM levels according to their needs (Modre-Osprian *et al.*, 2014)
	H2H vs *2HT*	(f)	Communication takes place between the home-located patient and a hospital-based team *vs* a TM centre coordinating all stakeholders involved (Grustam *et al.*, 2017)
Leadership & governance	Coordination pivot	(g)	Main actor responsible for coordinating care delivery between the multidisciplinary team and the patient (Modre-Osprian *et al.*, 2014; Ferrua *et al.*, 2020; Gordon *et al.*, 2020)
	Shared decision-making culture	(h)	Patient, informal caregivers and multidisciplinary care team members all take part on the care process (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014; Donner *et al.*, 2018)
	Stages vs *actors'* coordination	(i)	Program coordination is achieved between places of activity *vs* between participants in the activity (Grustam *et al.*, 2017)
Workforce	Multidisciplinary core workforce	(j)	Informal caregivers, nurses, GPs, and central condition specialists are the main responsible actors (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014; Chen and Levkoff, 2015; Dimengo and Stegall, 2015; Grustam *et al.*, 2017; Donner *et al.*, 2018; Ferrua *et al.*, 2020; Gordon *et al.*, 2020)
	Supporting workforce	(k)	Other specialty physicians (e.g., endocrinologists, psychologists, psychiatrists), dieticians, social workers, pharmacists (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014; Grustam *et al.*, 2017; Gordon *et al.*, 2020)
Financing	Coverage and/or reimbursement model	(l)	Public-private arrangements along the trajectory of illness (Modre-Osprian *et al.*, 2014)
			Consider new reimbursement models (e.g., *pay-for-performance*, direct fees to TM centres) (Chen and Levkoff, 2015; Grustam *et al.*, 2017)
	B2B vs *B2C*	(m)	Financing/payment flow between two businesses *vs* directly with the end-user (Grustam *et al.*, 2017)
Technologies & medical products	ICTs and telemonitoring devices	(n)	Integration of synchronous communication services (e.g., VC), two-way interface mobile-based apps / patient portals and TM devices (Bourret and Bousquet, 2013; Ferrua *et al.*, 2020; Aronoff-Spencer *et al.*, 2022)
			Consider recommendations for comprehensive, unobtrusive (e.g., BT-enabled devices), intuitive application and device design (Chen and Levkoff, 2015; Aronoff-Spencer *et al.*, 2022)
	Health data centre	(o)	Interoperable information system that allows information sharing with all the relevant actors (Bourret and Bousquet, 2013; Modre-Osprian *et al.*, 2014)
Information & research	Health indicators measurement	(p)	For example, BP, heart rate, ECG, weight, glycaemia, dyspnoea, blood oxygenation, sleep patterns, anxiety, physical activity, e-PROs, symptom scores (Dimengo and Stegall, 2015; Donner *et al.*, 2018)
	Clinical dashboards	(q)	Allows a health status comprehensive monitoring in a user-friendly manner (Modre-Osprian *et al.*, 2014; Aronoff-Spencer *et al.*, 2022)
			Allows monitoring several patients at the same time (Grustam *et al.*, 2017)
			Access shall be granted to all stakeholders involved, to allow shared decision-making (Donner *et al.*, 2018)
Monitoring	Outcome measurements	(r)	For example, admissions/readmissions, ED visits, inpatient LoS, all-cause mortality, QoL, patient satisfaction, SUS scores, cost savings, cost/benefit analysis, ROI (Dimengo and Stegall, 2015; Aronoff-Spencer *et al.*, 2022)

3.4.4. Real-Life Initiatives of Integrated Care Implementation of RPM

Considering the elements of RPM integrated care implementation identified in Table 3.2, we assessed the extent to which the 19 real-life initiative studies followed the good practices and/or recommendations defining each element. Table 3.3 presents the conducted assessment, where studies are classified as fully, partially, or not complying with Table 3.2's good practices.

Table 3.3. Analysis of 19 real-life initiative studies regarding the extent to which each study entails the elements identified for RPM integrated care implementation.

First Author, Year, Country	Target Population (and Study Design)	Individual & Environment		Service Delivery				Leadership & Governance			Workforce		Financing		Technologies & Medical Products		Information & Research		Monitoring	Applied Technologies
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	
Agarwal et al, 2021, Canada[47]	COVID-19 (Descriptive study)	○	◐	◐	○	●	H2H	●	◐	S	◐	●	○	B2B	●	○	●	●	●	Telephone and/or VC + Messaging service + Patient portal (to collect e-PROs) + TM devices (ie, pulse oximeter, thermometer) + EMR + e-learning + Dashboard
Black et al, 2014, USA[29]	HF (RCT)	○	●	●	○	○	H2H	◐	○	S	●	◐	◐	B2B	◐	◐	●	○	●	Telephone + BT-enabled TM devices (ie, scale, BP monitor) + EMR
Brooks et al, 2013, USA[35]	PTSD (Program assessment)	●	●	●	○	◐	2HT	●	●	A	●	●	○	-	◐	○	◐	○	◐	VC + Patient portal (to collect e-PROs) + EMR + e-learning
Casale et al, 2021, USA[11]	COVID-19 (Program assessment)	○	◐	●	○	◐	H2H	●	◐	S	●	●	◐	B2B	◐	◐	●	○	○	Telephone + TM devices (ie, pulse oximeter, BP monitor, thermometer) + EMR
Cheville et al, 2018, USA[37]	Cancer and hematologic conditions (RCT)	○	◐	◐	◐	○	2HT	●	◐	A	●	●	○	-	●	◐	●	◐	●	Telephone and/or VC + Patient portal (to collect e-PROs) + Telerehabilitation + Pedometer + EMR + e-learning
Dontje et al, 2021, Netherlands[44]	ALS (Participatory action study)	●	●	●	○	○	H2H	◐	○	S	●	○	○	B2B	◐	◐	◐	◐	●	Messaging service + Patient portal (ie, mobile app, to collect e-PROs) + Weighting scale + EMR
Fairbrother et al, 2013, Scotland[54]	HF (Qualitative study)	○	○	◐	○	○	H2H	○	○	S	◐	○	○	B2B	◐	○	●	○	○	Telephone + Patient portal (to collect e-PROs) + BT-enabled TM devices (ie, pulse oximeter, BP monitor, scale) + e-learning
Foster et al, 2021, USA[34]	Infants with SVP (Program assessment)	○	◐	●	◐	◐	H2H	●	◐	S	●	◐	◐	B2B	●	○	●	●	●	VC + Patient portal (ie, mobile app, to collect e-PROs and for video/photo sharing) + TM devices (ie, scale and pulse oximeter) + EMR + e-learning + Dashboard
Herkert et al, 2020, Netherlands[45]	HF + COPD (Quasi-experimental study)	●	●	●	●	●	H2H	●	◐	S	●	○	○	B2B	●	○	●	●	●	Telephone and VC + Messaging service + Patient portal (to collect e-PROs) + BT-enabled TM devices (ie, BP monitor, pulse oximeter, scale, and thermometer) + EMR + Dashboard
Krenitsky et al, 2020, USA[14]	COVID-19 + prenatal care (Program assessment)	○	○	◐	●	○	H2H	○	○	S	◐	○	○	B2B	●	◐	●	○	◐	VC + Patient portal (to collect e-PROs) + BT-enabled TM devices (ie, BP monitor, pulse oximeter, and thermometer) + EMR
Pelletier et al, 2011, USA[33]	Diabetes (Program assessment)	○	◐	◐	○	○	H2H	◐	○	S	●	◐	●	B2B	◐	○	◐	●	◐	Messaging service + Patient portal (for self-care enhancement) + TM devices (ie, glucometer and BP monitor) + Dashboard
Realdon et al, 2018, Italy[41]	Dementia (Program assessment)	○	●	◐	◐	◐	H2H	○	○	S	●	○	◐	B2B	●	●	●	●	○	Messaging service + Patient portal (to collect e-PROs) + BT-enabled TM devices (ie, BP monitor, pulse oximeter, thermometer, scale, ECG, glucometer) + Smartwatch + Telerehabilitation + CRM + EMR–e-learning + Dashboard
Ricci and Morichelli, 2013, Italy[42]	Patients with CIED (Program assessment)	○	◐	●	○	○	2HT	●	◐	A	●	○	○	B2C	◐	○	●	○	●	Telephone and e-mail + Patient portal (for data entry) + (Wireless) CIED
Schenkel et al, 2020, USA[38]	Lung transplant patients (Program assessment)	○	●	●	◐	◐	2HT	●	◐	A	●	○	◐	B2C	●	○	●	◐	●	VC + Patient portal (to collect e-PROs) + BT-enabled TM devices (ie, BP monitor, pulse oximeter, scale, glucometer, spirometer) + EMR + e-learning
Schmidt et al, 2018, Germany[52]	Chronic cardio-vascular diseases (RCT)	○	◐	●	○	◐	2HT	●	◐	A	●	○	○	B2C	●	◐	◐	●	●	Telephone + Patient portal (to collect e-PROs) + TM devices + EMR + e-learning + Dashboard
Sheeran et al, 2011, USA[32]	Depression (Feasibility study)	○	◐	●	○	○	H2H	●	◐	S	●	○	○	-	◐	○	◐	○	●	Telephone + Patient portal (to collect e-PROs) + BT-enabled TM devices (ie, BP monitor, pulse oximeter, scale, ECG, glucometer) + e-learning
Singh et al, 2011, USA[31]	Post-acute care (Longitudinal case study)	◐	●	●	◐	◐	2HT	●	●	A	●	○	●	B2C	◐	●	●	●	●	Telephone + TM devices (ie, BP monitor, pulse oximeter, thermometer, scale, ECG, spirometer) + EMR + Dashboard
Smaradottir et al, 2017, Norway[53]	COPD (Program assessment)	○	●	●	○	○	2HT	◐	○	A	◐	○	●	B2C	◐	◐	◐	●	◐	Patient portal (to collect e-PROs) + Pulse oximeter + Dashboard
Vuorinen et al, 2014, Finland[51]	HF (RCT)	○	◐	●	○	◐	H2H	◐	◐	S	●	○	○	B2B	●	◐	●	○	●	Telephone + Patient portal (ie, mobile app, to collect e-PROs) + TM devices (ie, BP monitor, scale) + EMR

Notes: ● Fully complying with Table 3.2; ◐ Partially complying with Table 3.2; ○ Not complying with Table 3.2; H2H: hospital-to-home; 2HT: high-touch-high-tech; A: actors' coordination; S: stages' coordination; B2B: business-to-business; B2C: business-to-consumer; (a) collaborative design process, (b) patient-centred implementation, (c) patient education and self-monitoring promotion, (d) multi-morbidity care, (e) dynamic trajectory of illness, (f) H2H vs 2HT, (g) coordination pivot, (h) shared decision-making culture, (i) stages vs actors' coordination, (j) multidisciplinary core workforce, (k) supporting workforce, (l) coverage and/or reimbursement model, (m) B2B vs B2C, (n) ICTs and telemonitoring devices, (o) health data centre, (p) health indicators measurement, (q) clinical dashboards, (r) outcome measurements.

To illustrate, a study is "fully compliant" regarding the *shared decision-making culture* element if patients, caregivers, and all care team members take part on decision processes; "partially compliant" if patients and/or caregivers are not part of the decision-making process but exists a shared decision-making culture within the multidisciplinary care team; "not compliant" if good practice is not followed. For elements defined by multiple recommendations, failing to address any of them constitutes partial compliance, and failing to address all recommendations is a case of non-compliance.

Most studies referred to, at least, 10 elements of integrated care implementation of RPM (n=15), in full or partial compliance with Table 3.2. 12 studies reported a H2H service delivery model, associated to a *stages*' coordination context. 11 studies complied with a B2B business model, 5 with a B2C and in 3 it was not sufficiently clear.

Four elements were present in all studies: *patient education and self-monitoring promotion* (13 for full, 6 for partial compliance), *multidisciplinary core workforce* (15 full, 4 partial), *ICTs and telemonitoring devices* (9 full, 10 partial), and *health indicators measurement* (13 full, 6 partial). Combining these four elements suggests the elementary design of an RPM intervention, based on a clinical team responsible for monitoring patients' health status and educating them on correctly operating TM devices to carry out biomedical data collection. *Patient-centred implementation* (n=17), *coordination pivot* (n=16), and *outcome measurements* (n=16) are also present in most studies. Adding these three elements to the previous four allows us to outline a design that meets Leijten et al. (Leijten *et al.*, 2018) definition of integrated care (i.e., structured efforts to provide coordinated, proactive, person-centred, multidisciplinary and collaborative care, with transversal performance monitoring). Elements such as *collaborative design process* (n=4), *multi-morbidity care* (n=7), *supporting workforce* (n=7), and *coverage and/or reimbursement model* (n=8) were present in less than half of the studies, and, when present, mostly were only partially complying with Table 3.2. Although constituting value-added contributions to the design of interventions, the presence of these elements was not fundamental to consider these initiatives as integrated care implementations of RPM.

Figure 3.2 summarises the results of the scoping review, organising the structural elements identified in Table 3.2 according to a three-tier model for implementing an RPM-based integrated care initiative, informed by the results of the assessment of real-life initiatives (presented in Table 3.3) – (1) *elementary design of an RPM intervention*, (2) *key integrated care delivery elements*, and (3) *added-value elements*.

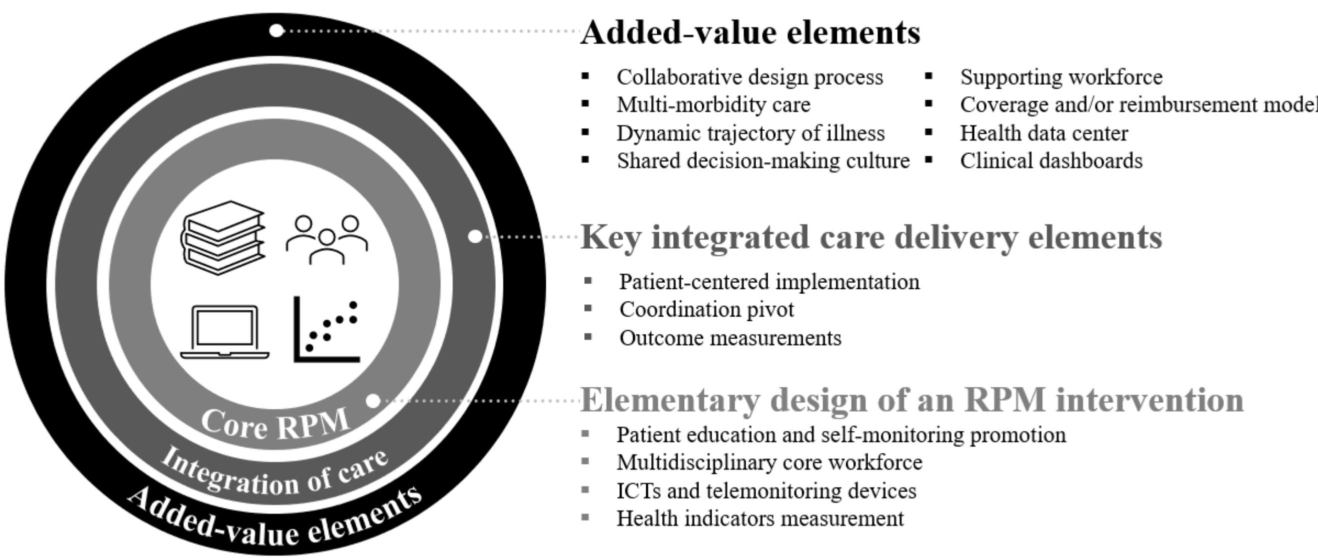


Figure 3.2. Three-tier model for implementing an RPM-based integrated care initiative, according to the structural elements identified in conceptual models' literature and based on the results of real-life initiatives' analysis.

3.5. Discussion

3.5.1. General Considerations

Throughout this Chapter, scientific literature published on conceptual models and real-life initiatives of RPM integrated care implementation was examined, allowing a thorough identification and assessment of key concepts addressed in this field over the past decade. Included studies comprise a broad diversity of diseases, conditions or target populations (16 different, mostly cardiovascular and/or chronic conditions), as well as a wide geographic dispersion (studies cover 10 different European and North American nations), representing a relevant sample regarding the clinical, cultural, and economic contexts of intervention.

Applying the SELFIE framework (Leijten *et al.*, 2018) as a schema for appraisal of included studies ensured the assessment of the main structural components of integrated care delivery. While this framework was developed specifically for the context of multi-morbidity and most RPM initiatives focus on a target condition, we consider that RPM requires an integrated care delivery that should encompass altogether the global health context of the patient i.e., associated comorbidities, nutrition and mental care, and social environment, making this framework more suitable for this context (in comparison to other general integrated care models).

Within SELFIE's integrated care components, 18 elements of RPM integrated care delivery emerged among analysed conceptual model studies. As a result of a greater thematic focus on aspects related to patient-centred design and coordination between involved actors, the elements associated with *Individual & Environment*, *Service delivery* and *Leadership & Governance* components are found in equal numbers in relation to the remaining ones. In contrast, elements associated with *Financing* and *Monitoring* are not very representative when analysing the literature on conceptual models. Regarding the first, issues related to financing and reimbursement models in RPM were rarely addressed topics in reviewed studies, so it could be beneficial to explore other sources e.g., economic-financial and/or "grey" literature. Guidelines for coverage and reimbursement of healthcare services based on remote care delivery are still not well defined, although there has been progress during the pandemic, namely in coverage for telemedicine services by the Medicare and Medicaid systems in the USA (Binder *et al.*, 2020; Davis *et al.*, 2020; Tahan, 2020; Kronenfeld and Penedo, 2021) and Australia (O'Mara, Monani and Carey, 2021). As for the *Monitoring* component, there was a greater preponderance of this theme in real-life initiatives' analysis, with the outcomes to be measured being context-dependent and aligned with interventions' objectives. Such findings highlight the limitations of "one-size-fits-all" approaches when selecting indicators for multidimensional management tools for RPM. Consequently, the approaches and tools proposed in the next Chapter embed this knowledge, emphasising the need for rigorously structuring value aspects according to the specific assessment context prior to tool building.

3.5.2. Key Messages on RPM Integrated Care Delivery

This Chapter generates insights for RPM implementation that go far beyond technology. One can interpret that RPM implementation must be a co-creation process between all involved actors, focused on the patient's needs and encouraging comprehensive and coordinated care delivery. It must address the patient as a complex biological and social system, involving the persons themselves, their caregivers, community, and environment, and not just health professionals and hospital services. Within this view, technology becomes a facilitator of collecting and sharing information (through ICTs and data centres), enabling coordination (through ICTs and dashboards), and permitting evidence-based actions and continuous improvement (through dashboards and outcome measurement).

The assessment of real-life initiatives showed that most included studies already present a significant degree of care integration, with 78.9% referring to at least 10 of the 18 identified structural elements. Despite being an interesting result, it is not unexpected, as failing to present an integrated care RPM program was an exclusion criterion from the screening process.

Although elements such as *patient-centred implementation* and *ICTs and TM devices* are present in most studies, they often partially comply with the good practices and/or recommendations from Table 3.2. Only 8 studies were able to develop truly patient-centred interventions i.e., that consider the patient's needs, preferences, and environment in their fullness. Culture and economic context adaptation of the intervention, and clear definition of informal caregivers' roles are still issues that need further development. Lack of caregivers' roles definition also impacts on *shared decision-making culture*, as studies fail to include patient and caregiver in the decision-making process. Likewise, although *ICTs and TM devices* is one of four unanimous elements across studies, 10 only partially comply with Table 3.2 definition. Programs may not incorporate TM devices (i.e., monitoring of e-PROs and symptoms, but not vital signs), fail to provide communication channels between patient/caregiver and provider (e.g., patient portals, VC) or may not integrate collected TM data into the EMR. Nevertheless, patient portals (84.2% of real-life initiative studies), EMR (73.7%), telephone, BP monitors, pulse oximeters (57.9% each) and weighting scales (52.6%) are technologies mentioned in most studies, reinforcing the role of technology in allowing (*a*) synchronous and asynchronous communication, (*b*) monitoring the patient's health status, and (*c*) data recording and sharing with all involved actors. Other elements, such as *dynamic trajectory of illness* and *health data centre*, also exhibit high levels of partial compliance, thus new projects should consider including them.

Besides *coverage and/or reimbursement model* (already discussed above), *collaborative design process*, *multi-morbidity care*, and *supporting workforce* are present in less than half of the studies. Stakeholder involvement in the design process appears to correlate with developing patient-centred solutions, as the three studies that fully comply with *collaborative design process* are also fully compliant with *patient-centred implementation*. Furthermore, lack of *multi-morbidity care* and *supporting workforce* elements across studies suggest a devaluation of their importance in improving care, as it may add a complexity layer that does not necessarily translate into added value.

Last, but not least, even though an assessment of implemented initiatives was carried out, it was not intended to develop correlations between intervention complexity and its effectiveness in care provision. The latter largely depends on the target condition of intervention, the patient groups included, and the objectives outlined for it. However, for comparable implementation scenarios, it is our expectation that an intervention comprising a greater number of structural elements will lead to better clinical, social, and economic outcomes. Further studies should be conducted to respond to this hypothesis.

3.5.3. Implications for Practice and Future Research

The structural elements identified and the good practices and/or recommendations that define them should contribute to the development and organisation of care integrated models in RPM. By highlighting the contribution of these elements to a more patient-focused, more efficiently coordinated, and more attentive implementation, this review deepens our understanding of the added value of remote care initiatives in delivering more needs-driven healthcare, optimising resource allocation, and improving the overall experience and QoL of the patient.

The development of a dissemination strategy for RPM should be an active policymaking process, involving different health sectors (e.g., primary, secondary, tertiary), whether public, private, or social, and may also include religious institutions, employers, housing, local communities, and education. Furthermore, for technology providers and implementation partners, the results of this scoping review can inform about the perspectives of patients (and caregivers) and health professionals regarding which features should be considered in developing more end-user-centric ICT technologies. Chapter 4 draws on these conclusions to propose a collaborative, needs-oriented approach to management tool building.

Moreover, both Chapter 2 and this Chapter showed that literature combining RPM and care integration is still scarce and novel studies to inform its implementation are in need. An increased focus by researchers on legislation and policy for remote care provision can inform the implementation of newly designed RPM programs and help to better predict their applicability, feasibility, and success in specific geopolitical contexts.

Additionally, the RPM care integration elements identified throughout this Chapter can be leveraged as a starting point for developing a systematic review of RPM initiatives or comparative study between RPM interventions, aiming at developing comprehensive assessments of the relationship between completeness in intervention design and its effectiveness, measured by clinical criteria and non-clinical outcomes.

3.5.4. Limitations

While efforts have been made to assure methodological thoroughness, this scoping review is not without limitations. Despite conducting a comprehensive search strategy, which considered terminological variations and alternative spellings of search keywords, the terms “telehealth” or “telemedicine” were not included, which may have led to the non-identification of relevant studies. The decision not to include these terms was the result of the trade-off between how many relevant *versus* non-relevant studies would have been identified, concluding that it was preferable not to include, given the time and resource limitations in the development of this work.

From our perspective, and as already discussed, using the SELFIE framework positively contributed to the appraisal of the integrated care nature of RPM studies. However, and as identified by the authors of the framework (Struckmann *et al.*, 2018), topics related to the use of eHealth, although believed to have great potential for improving integrated care for multi-morbid patients, are scarce in multi-morbidity literature. Thus, the use of the SELFIE framework for the RPM context may present limitations, as most literature that informs the framework’s development does not consider a digital-first care delivery setting.

As already mentioned, the lack of elements concerning *Financing* could be resolved by including economic-financial or "grey" literature in the search protocol. Additionally, although included studies present an enriching diversity regarding the diseases, conditions or target populations addressed, this also poses a challenge in the aggregation and appraisal of results, since the elements identified as structural in RPM care integration can acquire greater importance in certain clinical contexts.

3.6. Conclusion

As Chapter 2 identified the lack of care integration to be a significant barrier to widespread remote care adoption, the overall aim of this Chapter was to provide a comprehensive analysis of what structural elements should be considered in the implementation of RPM solutions that are aligned with a logic of care integration. Based on literature referring to conceptual models and real-life initiatives of RPM, 18 structural elements were identified, described according to good practices and recommendations that guide their implementation, and organized into a three-tier model, based on the practical contribution of each element within the scope of implementation.

Care integration elements such as *health indicators measurement*, *outcome measurements*, *clinical dashboards*, *health data centre*, *shared decision-making culture*, and *collaborative design process* confirm the need for RPM decision-makers to have improved day-to-day management tools that empower multidisciplinary RPM teams to make informed tactical and strategic decisions, supporting sustained, long-term adoption of RPM programs.

The next Chapter builds on the foundations established in Chapters 2 and 3 to propose an innovative integrative approach for developing decision-support tools tailored to RPM management. These tools aim to address challenges such as stakeholder scepticism toward RPM, often rooted in difficulties with objectively and transparently demonstrating its value. Additionally, the proposed approaches and tools recognise the complexity of RPM as a care delivery model. This complexity includes the learning curve required by both patients and providers, a multidimensional, multi-stakeholder and multidisciplinary assessment environment, as well as the nuances in RPM configurations that influence the choice of value aspects to continuously monitor and consider within HTA processes, and the analytical features incorporated into daily management tools.

CHAPTER 4

ALIGNING ACTIONABLE MONITORING WITH HEALTH TECHNOLOGY ASSESSMENT IN REMOTE PATIENT MONITORING: AN INTEGRATIVE APPROACH TOWARDS A VALUE-BASED MANAGEMENT DASHBOARD

4.1. Chapter Summary

Implementing and operating RPM programs effectively requires continuous monitoring and evaluation to identify areas for improvement. However, current methods and tools for performance and value assessment are limited, constraining efficient program management and contributing to current challenges related to scepticism and unwillingness to invest, as shown in Chapters 2 and 3.

To address the need for practical tools that support day-to-day assessment, this Chapter introduces an innovative integrative approach called **S**tructuring, **B**uilding and **I**mplementing a **M**ultidimensional **D**ashboard with **S**takeholders, **B**usiness **I**ntelligence and **M**ulticriteria **D**ecision-aiding. **SBI-MD** combines decision-aiding and DataViz tools with MCDA and stakeholder participation techniques to create MMDs to assist decision-makers in continuously monitoring and evaluating RPM programs.

Departing from a collaborative framework, the proposed approach engages stakeholders in socio-technical processes for (*a*) identifying KPIs and evaluation criteria that are aligned with producing RPM value and achieving managerial targets; (*b*) building a flexible multicriteria model and a classification system to help decision-makers monitoring the added value of RPM and understanding which areas need improvements; and (*c*) integrating information from (*a*) and (*b*) into a user-friendly MMD.

The three pivotal phases of **SBI-MD** are described: structuring RPM value dimensions and indicators, building the MMD, and implementing the MMD. Recommendations are provided for methods and tools to support modelling tasks and collaborative processes. We also reflect on the anticipated outcomes of applying **SBI-MD**, which will be tested in the subsequent application-focused Chapters of this thesis, particularly Chapter 7.

SBI-MD is expected to advance MCDA for HTA by offering a clear, step-by-step guide that integrates practical tools and methods from BI and stakeholder engagement, supporting the development of MMD systems that automate evidence reporting, improve outcomes interpretation through intuitive visuals, and allow for real-time and interactive value measurement. These advancements help address long-standing challenges in HTA, particularly for complex health interventions like RPM.

4.2. Introduction

Telehealth applications hold great potential to increase value in health by preventing unnecessary interventions, promoting shared decision-making, and strengthening patient-provider relationships (Grustam *et al.*, 2018). Within the concept of telehealth is RPM (Velayati *et al.*, 2022). RPM constitutes “a mode of health care delivery that gathers and integrates patient data outside of traditional health care settings, allowing providers to track, assess, and engage patients regardless of location” (Casale *et al.*, 2021). Studies on chronic disease management evidenced the benefits of RPM (Kitsiou, Paré and Jaana, 2013; Lundell *et al.*, 2015), encompassing decreased hospital admissions and stays, enhanced self-care and lower mortality (Heinzelmann *et al.*, 2005; Ware *et al.*, 2020). However, barriers to adoption persist, including high costs without proper reimbursement (Chronaki and Vardas, 2013), limited digital literacy and insufficient telehealth training (Scott Kruse *et al.*, 2018), and patient and provider reluctance towards RPM (Palacholla *et al.*, 2019). Furthermore, as evidenced in Chapter 2’s discussion, challenges arise when integrating RPM into existing care pathways, as there is a lack of standardised guidelines, frameworks and methods for implementation, monitoring and evaluation.

While emerging research addresses RPM as a complex, integrated care delivery model, as demonstrated by the conceptual models and real-life initiatives reviewed in Chapter 3, assessment literature primarily reports standalone, proof-of-concept practice. Studies often examine health outcomes alone or the trade-off between costs and clinical benefits, applying traditional HTA techniques like CEA (Peretz, Arnaert and Ponzoni, 2018; Neumann, 2021). Alternatively, RPM assessment and management needs to consider its multidimensional context, involving clinical, operational, social, and economic challenges, benefits, and risks, and engaging various stakeholders (e.g., patients, caregivers, health professionals and managers, technology suppliers, payers, policymakers) (Kidholm *et al.*, 2012).

This requires a paradigm shift and the development of innovative and comprehensive HTA approaches (Nangalia, Prytherch and Smith, 2010). Stakeholders' perspectives on key monitoring and evaluation aspects (and their operationalisation) are often overlooked, leading to poorly designed decision-support methods and tools for RPM program management (Angelis and Kanavos, 2016). This hampers effective prioritisation and execution of short-term corrective actions and long-term strategic decisions (e.g., program scaling) (Azevedo, Rodrigues and Londral, 2021). Moreover, with increasing pressure on health resource management, growing complexity of health conditions (e.g., age-, lifestyle-induced and transmissible diseases), and highly dynamic ICT innovation, tools are required to aid decision-making in this data-complex environment and provide real-time information to managers in the field (Rabiei *et al.*, 2024). A 2021 survey of 22 European HTA organisations found that challenges in evaluating complex health technologies stem primarily from data insufficiencies, not the technologies' complexity (Hogervorst *et al.*, 2022). To manage this data overload and information complexity, a focus on developing BI and DataViz systems is rising (Ain *et al.*, 2019).

Hence, MMDs offer an effective solution, constituting on-demand technology-enabled PMS for managing and controlling ongoing operations, enabling real-time monitoring, rapid target adjustments, and analysis of how targets interact and influence each other (Ippolito *et al.*, 2022).

Driven by the pressing need for comprehensive, yet practical HTA approaches and tools that help teams manage the complex and dynamic context of RPM interventions, this Chapter introduces an innovative integrative approach for developing an MMD for continuously monitoring and evaluating RPM programs. The proposed approach aims to leverage HTA with agile and actionable BI methods and tools within a user-friendly, needs-oriented DSS that helps stakeholders in accompanying project implementation while promoting strategic decision-making.

Following this introduction, Section 4.3 reviews literature relevant for the development of the proposed integrative approach, covering HTA and value measurement, BI and PMS, stakeholder participation, and their interrelations in MMD development for healthcare. Section 4.4 outlines the methodology for designing an MMD to monitor and evaluate RPM initiatives. Finally, Section 4.5 discusses the approach's expected outcomes from real-world application, foreseen application challenges and recommendations to address them, and maps research to be developed in the future.

4.3. Review of Studies

This section reviews relevant studies supporting the development of methods, approaches, and tools proposed in this Chapter. It emphasises the theoretical and empirical foundations for aligning HTA with value-based measurement, leveraging BI to facilitate performance assessment, and fostering active stakeholder engagement. Furthermore, it explores how these components can be integrated to develop comprehensive dashboard tools for healthcare management.

4.3.1. HTA and Value Measurement

Due to an unprecedented fast-paced development of health technologies (Bondy *et al.*, 2021), stakeholders are pressured to make more efficient and evidence-informed decisions on whether to develop a technology, acquire it, or ensure its appropriate use, pricing, and reimbursement (Baghbanian *et al.*, 2020). We refer to the multidisciplinary process that uses explicit methods to determine the value of health technologies at different points in their lifecycle and inform decision-making to promote an equitable, efficient, and high-quality health system as HTA (O'Rourke, Oortwijn and Schuller, 2020).

Vis et al. (Vis *et al.*, 2020) systematically reviewed eHealth assessment frameworks. While no RPM-specific framework was identified, eleven HTA frameworks relate to telemedicine. Table 4.1 summarises the main features and outcomes addressed in each framework.

Most identified frameworks encompass technical, clinical, economic, organisational, ethical, and legal domains, along with healthcare system characteristics and stakeholder needs. However, there is considerable variation in the guidelines for outcome measurement and available instruments, and the evidence demonstrating real-world framework applicability is scant. The influence relationships between evaluation domains and their impact on intervention goals (Vukovic *et al.*, 2018) are also overlooked. Moreover, although these frameworks enhance telemedicine assessment compared to traditional HTA techniques, none address continuous program monitoring, which supports corrective action and long-term strategy decision-making for sustaining performance over time (Ferretti *et al.*, 2017).

Table 4.1. Main characteristics of telemedicine HTA frameworks identified in (Vis *et al.*, 2020).

Framework	**General approach to the assessment**
Staged approach to telemedicine evaluation (DECHANT *et al.*, 1996)	The framework identifies four stages: (i) technical efficacy (accuracy and reliability), (ii) system objectives (feasibility in access, quality, or cost), (iii) system analysis (global impact on access, quality, and cost), and (iv) external validity (impact in a different system).
Three-dimensional evaluation model (Bashshur, Shannon and Sapci, 2005)	Assessment of applications (public health, education, clinical), perspectives (client, provider, society), and technological features (synchronous, asynchronous, transmission modes, bandwidth, diagnostic/treatment devices).
Multi-method telemedicine application evaluation (Brear, 2006)	Assessment of utilisation (nature and frequency), clinical impact, organisational context, technical performance, costs and cost-effectiveness, and their interrelated influences.
Health Services Research Framework (Grigsby, Brega and Devore, 2005)	Assessment focusing on (a) structure (transmission speed, equipment, skills, costs, accessibility), (b) process (diagnostic accuracy, evidence-based treatment), and (c) outcomes (clinical short-term, adherence and satisfaction, long-term quality of life and health status).
Telehealth Evaluation Framework (Hebert, 2001)	Assessment of individual structure (e.g., access, acceptability, training), organisational structure (e.g., scheduling, culture, costs), care process (e.g., interaction effectiveness), individual outcomes (e.g., quality of life, re-admissions), and organisational outcomes (e.g., resource use).
Commonwealth Scientific and Industrial Research Organisation framework(Nepal *et al.*, 2014)	Domain assessment and classification, services (e.g., consultation, diagnosis), technology (e.g., postal mail, telepresence), communication methods (e.g., telephone), environmental settings (e.g., people, locations), and socioeconomics.
Assessment of telemedicine applications (Ohinmaa, Hailey and Roine, 2001)	Assessment of technical aspects (e.g., image/voice quality), effectiveness (e.g., diagnostic quality), user assessment (e.g., usability), costs (including patient-related costs), study design (e.g., control groups), economic evaluation (e.g., cost-effectiveness), and sensitivity analysis.
Telemedicine evaluation plan (Stensgaard and Sørensen, 2001)	Assessment of users' expectations and reactions, logistics, organisation and technology, medical gain, waiting time, travel, economic factors, competence transfer, and recruiting/retaining staff.
Telemedicine Quality Control system (Giansanti, Morelli and Macellari, 2008)	Phase I: preliminary evaluation; Phase II: technical file detailing (i) product description, system design, security standards, clinical evaluation, and documentation, and (ii) a quality assessment checklist (e.g., patient safety, data privacy, certification, efficacy, design, manufacturing, and testing, and economic and social evaluation).
Model for Assessment of Telemedicine Applications (MAST) (Kidholm *et al.*, 2012)	Phase 1: preceding considerations e.g., legislation, reimbursement, maturity, and scale; Phase 2: multidisciplinary assessment (e.g., health problems and application characteristics, safety, clinical effectiveness, patient perspectives, economic, organisational, and socio-cultural, ethical, and legal aspects; Phase 3: potential for expansion to other disorders and/or systems.
Comprehensive telemedicine evaluation model (Alfonzo *et al.*, 2007)	Three areas of attention: (1) analysis level (individual, community, or society), (2) focus of analysis (i.e., driving forces of healthcare related to quality, accessibility, cost, and acceptability), (3) different uses (administrative, educational, ICU, midlevel care, and home care).

Vis et al. (Vis *et al.*, 2020) consider the MAST framework (Kidholm *et al.*, 2012) to be the most comprehensive for eHealth HTA. Nonetheless, it is implied that not all MAST domains may apply to every eHealth service, so its use should be tailored to the specific service goals. As a starting point for HTA, the authors suggest combining MAST with other frameworks providing extensive outcomes and assessment methods. Furthermore, Vis et al. (Vis *et al.*, 2020) recommend (*a*) standardising the reporting of eHealth service characteristics (clinical aim, target group, working mechanism, and implementation specifics), and (*b*) following a tailored stepped approach to assess outcomes based on service functionality.

Considering the identified limitations of current telemedicine HTA frameworks, MCDA may constitute a well-structured, stakeholder-driven approach to building transparent and explainable multidomain evaluation models for remote care services (Haig *et al.*, 2023).

MCDA operates within a paradigm of rationality (Simon, 1957), providing a philosophy grounded in logical axioms and supported by a methodology and systematic procedures derived from those axioms (Keeney, 1982). Keeney and Raiffa (Keeney and Raiffa, 1993) define MCDA as “an extension of decision theory that covers any decision with multiple objectives. A methodology for appraising alternatives on individual, often conflicting criteria, and combining them into one overall appraisal…” A broader interpretation of MCDA is embraced in (Thokala *et al.*, 2016), including methods that support deliberative discussions using explicitly defined criteria but without quantitative modelling – a "partial" form of MCDA. While its roots lie in operations research, MCDA is enriched by intellectual contributions from other fields (e.g., social sciences, statistics), functioning as a wide and versatile toolbox of concepts, models, and tools (Howard, 2004; Köksalan, Wallenius and Zionts, 2011).

MCDA methods are commonly used in decisions on transport, education, investment, energy or defence; in healthcare, as awareness of these techniques has grown, there has been a significant increase in applications (Thokala *et al.*, 2016). By modelling value in health as a multidimensional concept, MCDA is increasingly recognised as a practical approach for estimating the relative value of new or existing medical technologies or services (Mühlbacher and Kaczynski, 2016; Radice, 2020). According to Angelis and Kanavos (Angelis and Kanavos, 2016), MCDA enables (*a*) explicit inclusion of numerous value domains and criteria, (*b*) quantitative weight assignment across criteria, enhancing transparency on the relative importance of evaluation aspects, and (*c*) direct involvement of all stakeholders as model co-creators, bolstering assessment legitimacy, accountability, and democracy.

Recent literature reviews have explored the use of MCDA in HTA and other health settings. Khan et al. (Khan, Pintelon and Martin, 2022) identified 158 studies on MCDA in healthcare. In a review of MCDA in overall technology selection and assessment, Kozłowska (Kozłowska, 2022) found 90 documents (30% of Web of Science results) related to HTA or health, making it the “biggest thematic cluster” in the review. Zhang et al. (Zhang *et al.*, 2022) reported 19 health value assessment frameworks using MCDA, noting its growing popularity due to its ability to combine multiple value attributes into a single index. Focusing specifically on MCDA in HTA, Oliveira et al. (Oliveira, Mataloto and Kanavos, 2019) reviewed 129 studies, 56% published since 2015, showing a rising trend. According to the authors, MCDA applications include selecting health technologies, resource allocation, and assigning reimbursement or pricing categories. Framework applications address evaluating new technologies, comparing existing and new ones, social values, benefit-risk balances, consensus decision-making, policymaking, and prioritising value for money under budget constraints.

Several approaches have been used to address multiple dimensions in health and HTA, such as the analytical hierarchy process, TOPSIS and MACBETH (Marsh *et al.*, 2016; Oliveira, Mataloto and Kanavos, 2019; Khan, Pintelon and Martin, 2022). Nevertheless, not all of these approaches have been recalled as theoretically sound and rooted in multiattribute value theory (MAVT). Among those theoretically sound – framed within multicriteria value measurement (Belton and Stewart, 2010) –, MACBETH (Sanchez-Lopez, Bana e Costa and De Baets, 2012; Bana e Costa, De Corte and Vansnick,

2016) stands out for its cognitive ease in empirical settings (Fasolo and Bana e Costa, 2014; Guarini, Battisti and Chiovitti, 2017).

Rooted in MAVT (Von Winterfeldt and Edwards, 1986; Keeney and Raiffa, 1993), MACBETH uses an interactive questioning procedure based on qualitative preference judgements between paired elements. Through a process of constructive thinking, stakeholders appraise the overall impacts of alternatives in multiple criteria by choosing one of seven categories of difference in attractiveness, ranging from “no difference” to “extreme,” enabling qualitative swing weighting as an alternative to quantitative judgments. Such a procedure enhances user-friendliness and facilitates compromise among involved actors, while maintaining methodological soundness – in doing so, MACBETH avoids common issues such as “direct rating,” arbitrary-shaped functions, or failure to explicitly model decision-makers’ preferences (Montignac, Noirot and Chaudourne, 2009; Angelis and Kanavos, 2016; Rodrigues *et al.*, 2017; Gomes *et al.*, 2023).

However, obstacles persist in advancing MCDA for HTA. Oliveira et al. (Oliveira, Mataloto and Kanavos, 2019) identify twelve challenges including evidence and data management, balancing methodological intricacy with resources, addressing criteria selection and measurement, and introducing flexibility features for model generalisation. Research on BI and performance measurement can address these challenges in MCDA by integrating evidence synthesis through automatic reporting, by facilitating discussions and interactive model building, by handling large datasets, by enhancing result interpretation and validation through user-friendly graphs and charts, by identifying root causes of poor performance (temporal analysis, in-depth analytics features), as well as by enabling continuous, real-time value assessment models (Bana e Costa, Carnero and Oliveira, 2012; Abastante, Lami and Lombardi, 2017; Oliveira, Mataloto and Kanavos, 2019).

4.3.2. BI, Performance Measurement and Value-Based Decision-Support

BI technology is believed to have emerged from operations research (like MCDA) and been practice-driven by industry needs (Phillips-Wren *et al.*, 2015), having no agreed-upon definition – it is frequently categorised regarding its ability to process various data sources into decision-making insights (Phillips-Wren, Daly and Burstein, 2021). Similarly, there is no consensus on the relationship between BI and DSS: some argue BI evolved from DSS (Safwan, Meredith and Burstein, 2016); others claim independence (Ain *et al.*, 2019). Since BI tools primarily serve performance measurement (Rajnoha *et al.*, 2016), BI is often linked with PMS in literature (Vallurupalli and Bose, 2018). PMS play a central role in organisational learning and knowledge dissemination (Neely *et al.*, 2000), with strategic PMS applications identifying opportunities or threats in competitive dynamics, and non-strategic (monitoring) PMS providing feedback on performance deviations from targets (Demartini and Trucco, 2017).

Understanding the interplay among key concepts like value, performance, indicators, KPIs, criteria, and measures is essential when examining the literature on BI, PMS, value measurement, and MCDA. These terms often overlap and are used interchangeably, reflecting diverging perspectives. The concept of “value,” for instance, varies widely depending on the context. Healthcare providers tend to define value based on the cost-effectiveness of interventions, while patients often value health interventions for their ability to enhance accessibility, equity, and the quality of care (Zhang *et al.*, 2022).

The terms “indicator” and “KPI” are primarily associated with performance monitoring and often derive from well-defined objectives. BI and PMS literature highlights the role of KPI monitoring in fostering a culture of change management and accountability (Concannon, Herbst and Manley, 2019; Ippolito *et al.*, 2022). Rabiei et al. (Rabiei *et al.*, 2024) also emphasise that for KPI monitoring to be effective, it must resonate with stakeholders' objectives, understanding, and knowledge. This perspective aligns with MCDA literature, which posits that indicators are instrumental in tracking the achievement of defined objectives (Marttunen *et al.*, 2019) and suggests a hierarchical relationship between fundamental objectives and their corresponding performance indicators (Bana e Costa, Oliveira, Rodrigues, *et al.*, 2023). Angelis and Kanavos (Angelis and Kanavos, 2017) define a “criterion” as an “individual measurable indicator” of a key value dimension according to which alternatives may be compared, while an “attribute” represents a “quantitative or qualitative measure of performance associated with a particular criterion” (Belton and Stewart, 2010).

In Zhang et al. (Zhang *et al.*, 2022), however, constituent value attributes are said to be known interchangeably as value elements, criteria, or domains. This interconnectedness is further highlighted in (Bana e Costa and Beinat, 2005), where the term “descriptor” is used to describe what (Keeney and Raiffa, 1993) term an “attribute.” Other synonymous terms in the literature include performance measure, measure of effectiveness, criterion, and evaluation measure (Bana e Costa and Beinat, 2005).

Bana e Costa and Beinat (Bana e Costa and Beinat, 2005) present their concepts clearly. *Areas of concern* group *key-concerns*, reflecting fundamental values for comparing alternative options. *Key-concerns* may cluster interrelated *elementary concerns*, which are non-isolable or judgmentally dependent (Dyer and Sarin, 1979). A *descriptor of impacts* is an ordered set of plausible impact levels tied with a *key-concern*. To align BI/PMS terminology with that of value measurement and MCDA, Chapters 4-7 will adopt the following terms:

- **Value dimensions** for *areas of concern*,
- **Indicators** for *concerns*,
- **KPIs** (or *monitoring indicators*) for *elementary concerns*,
- **Criteria** (or *evaluation indicators*) for *key-concerns*,
- **Measures** for *descriptors/attributes*

To operationalise KPI monitoring and value measurement, MMDs are visual and interactive BI tools that provide actionable evidence to support management decisions, helping end-users identify, explore, and communicate opportunities and problem areas (Peters *et al.*, 2016). According to Pauwels et al. (Pauwels *et al.*, 2009), a dashboard ensures *consistency*, *communication*, *planning* and *monitoring* – often intertwined purposes. Dashboards reinforce consistency in measures within and across departments; facilitate transparent communication; enable analysis of operational scenarios and enhance action planning; day-to-day monitoring triggers timely corrective actions to improve performance. The monitoring aspect is often considered the fundamental purpose of a dashboard (Iftikhar *et al.*, 2019).

There are three main types of dashboards – *operational*, *tactical*, and *strategic* (Rasmussen, Bansal and Chen, 2009; Kerzner, 2017). While all three types align with the purposes outlined by Pauwels et al. (Pauwels *et al.*, 2009), they differ in their practical applications, frequency of updates, and the degree to which they focus on monitoring, analysis, or management activities. The purpose(s) and dashboard type subsequently impact measures, features, and presentation elements (Kirk, 2012).

In healthcare, BI technologies process large volumes of clinical and operational data, aggregate sparse information and provide real-time evidence for informing treatment and management decisions (Elg, Palmberg Broryd and Kollberg, 2013). Dashboards find various healthcare applications, like operating room optimisation (Park *et al.*, 2010), emergency flux management (Martinez *et al.*, 2018), monitoring radiology doses (Morgan *et al.*, 2008), improving patient safety, satisfaction, and communication (Isazad Mashinchi, Ojo and Sullivan, 2020), supporting chronic care delivery (Dagliati, Sacchi, *et al.*, 2018), and decision-making in community health (Kunjan, Doebbeling and Toscos, 2019).

Stepped approaches were identified for developing an MMD in healthcare contexts. Vitacca and Vitacca (Vitacca and Vitacca, 2019) describe the activities of a dashboard development working group: (*a*) identifying measurement items, (*b*) formulating action strategy, (*c*) evaluating involved personnel, (*d*) mission reformulation, (*e*) defining dashboard architecture, (*f*) evaluating selection criteria, (*g*) selecting performance areas, (*h*) establishing reference levels, (*i*) identifying strategic actions, (*j*) proposing cause/effect maps, and (*k*) validation. Lau et al. (Lau *et al.*, 2019) outline a nine-step framework for clinical dashboard building: (*a*) determine dashboard goals, (*b*) identify patients, (*c*) develop metrics, (*d*) develop Structured Query Language (SQL) queries, (*e*) extract, transform, load (ETL) process, (*f*) report development, (*g*) automation, (*h*) implementation and (*i*) sustainability. Orlando and Sunindyo (Orlando and Sunindyo, 2017) modify an existing approach to accommodate heterogeneous stakeholders, outlining five steps: (*a*) identifying needs, (*b*) planning, (*c*) designing a prototype, (*d*) testing and evaluation and (*e*) implementation. Mashinchi et al. (Isazad Mashinchi, Ojo and Sullivan, 2020), while not detailing an MMD development process, highlight essential dashboard elements for supporting value-based decision-making: (*a*) comprehensive care cycle information, (*b*) encompassing various data types, (*c*) enabling access and communication among parties, (*d*) allowing value measurement, (*e*) enabling health outcome-cost transparency, and (*f*) providing interoperability standards.

While MMD applications and development approaches exist in various healthcare contexts, limited literature covers managing remote care programs (Dixit *et al.*, 2020; Perry *et al.*, 2022). Current BI and decision-support tools overly prioritise clinical aspects, often neglecting operational and social impacts (as discussed in Chapters 2 and 3). Despite the proliferation of healthcare dashboard providers, little is known about effective DataViz choice (Sedrakyan, Mannens and Verbert, 2019). Unintuitive and unappealing interfaces, scant EMR interoperability, and limited analytics are also factors that hamper adoption (Dagliati, Tibollo, *et al.*, 2018).

Research on information systems design stresses the need to understand the specific information needs of all stakeholders and involve them in tool development. Kunjan et al. (Kunjan, Doebbeling and Toscos, 2019) emphasise aligning dashboards with user and organisational goals, noting that while involvement may raise initial conflict, it ultimately fosters user buy-in and brings about constructive conflict resolution. Neumann (Neumann, 2021) calls for more research into value perception and user experience to improve dashboard relevance and usability, proposing user engagement to test which value domains and visual display types resonate best.

These challenges highlight the complexity of MMD building, as stakeholders bring varying levels of knowledge about the task in hand, diverse modelling preferences, and differing interests. Additionally, cognitive factors influence how information is presented, depending on the composition of the stakeholder group. However, these challenges also emphasise the importance of engaging stakeholders throughout design, development, implementation, and testing. By involving health professionals, administrators, ICT specialists, and patients, the dashboard can reflect a broad range of perspectives, ultimately enhancing MMD adoption. Early collaboration enables stakeholders to shape data selection, dashboard features, and DataViz formats, fostering a sense of ownership among users.

4.3.3. Stakeholder Engagement in Dashboard Building

Participatory approaches foster social cohesion by facilitating perspective-share within complex decision-making scenarios (Keeney, 1996). Participants may include laypersons, stakeholders, experts or policymakers, with differing interests, needs, influence, and priorities (Bindels *et al.*, 2016). Moreover, the choice of participatory methods depends on participant count, context, and time or budget constraints (Voinov *et al.*, 2018). On this issue, Woudstra et al. (Woudstra *et al.*, 2022) conducted a scoping review on participatory approaches in medical device development. Workshops were found to constitute the most used method in collaboration papers (i.e., stakeholder participation in decision-making); interviews in involvement (i.e., alignment between decisions and stakeholders' concerns) and consultation (i.e., obtaining feedback) papers. The authors conclude that stakeholder collaboration, involvement and consultation share methodological characteristics, suggesting that researchers should tailor approaches to the needed degree of participation, stakeholders, methods, and context rather than adhere to a fixed approach.

Several authors advocate the importance of stakeholder engagement in dashboard building. Perry et al. (Perry *et al.*, 2022) identify co-design between investigators and key stakeholders (e.g., patients, clinic staff) as the first strength of their study, promoting person-centred care and increasing the likelihood of successful implementation, regretting that time and money constraints often lead other initiatives to forfeit stakeholder engagement. Salgado et al. (Salgado *et al.*, 2022) state that "the inclusion and collaboration of potential users are essential in the phase of requirements' elicitation", warning that neglecting requirements' elicitation can result in poorly implemented dashboards. Similarly, Fazaeli et al. (Fazaeli *et al.*, 2021) argue that user participation in all stages of a COVID-19 dashboard development ensured success, contrasting with initiatives that lack user interest due to minimal involvement. However, some authors perceive stakeholder collaboration as challenging or even counterproductive. Lau et al. (Lau *et al.*, 2019) discuss the difficulties in aligning stakeholder input on metrics, data usage and validation; though authors still praised the multidisciplinary collaboration during development. François et al. (François *et al.*, 2021) question the benefits of participatory design when finding that truck dashboards resulting from (*a*) user-centred design (designed by expert designers) and (*b*) individual design sessions with drivers were perceived as more usable and accepted than the dashboard resulting from (*c*) the participatory workshop with several drivers, suggesting that expert-driven design, with user input, may yield better results.

Limited research explores the use of participatory methods in MMD building. Most studies focus on determining stakeholders' requirements and preferences for dashboard design (Dowding, Merrill and Russell, 2018; Salgado *et al.*, 2022), indicator selection (Sardain, Tang and Potvin, 2016; Salgado *et al.*, 2020), DataViz choices (Ignatenko, Ribeiro and Oliveira, 2022), feature and customisation options' selection (Mentzakis, Tkacz and Rivas, 2020), and usability assessment (Orlando and Sunindyo, 2017). Some research suggests techniques for engaging stakeholders in multiple building tasks (Lau *et al.*, 2019; Fazaeli *et al.*, 2021; Ludlow *et al.*, 2021; Patel *et al.*, 2022; Perry *et al.*, 2022). However, a significant gap exists in promoting stakeholder engagement and using participatory methods consistently throughout the MMD building.

Stakeholder engagement is generally seen as valuable in dashboard-building tasks, as it helps foster consensus and align tool design with both user and organisational needs. However, participation effectiveness can be hindered by misaligned understandings and time constraints. Research highlights the need for consistently and comprehensively applying participatory methods throughout the MMD building process. This is a critical concern in the context of RPM program management, which is inherently complex due to its multidimensional, multi-stakeholder nature and the absence of a tailored value assessment framework. Additionally, RPM data is often scattered across various sources and formats, requiring robust tools to synthesise and present information in a way that is easily accessible, understandable, user-friendly, and interactive.

The next section outlines our innovative proposal for integrating value measurement, BI, and stakeholder engagement methods and tools within a comprehensive methodology to build a day-to-day MMD that supports RPM stakeholders in tactical and strategic decision-making for sustained performance and long-term program success.

4.4. Methodology

4.4.1. Underlying Principles

An MMD for RPM program evaluation and management should serve two key functions:

- **Continuous performance monitoring**, providing real-time and actionable insights to program managers, hospital administrators, and health professionals on KPIs aligned with producing RPM value and achieving managerial targets, promoting objective, transparent and inclusive knowledge-sharing.
- **Support for RPM continuous HTA**, processing managerial evidence across value dimensions through a stakeholder-agreed value measurement model, identifying underperforming areas and informing strategy adjustments to enhance service access, improve patient experience and deliver cost-effective care.

Given this dual function, we outline five underlying principles guiding MMD development to ensure it meets its expected purposes:

Stakeholder collaboration. Stakeholder input should shape methods and tools, promoting user-centricity, consensus, and commitment, and collaborative MMD building dispels the "black box" effect, as involved actors understand and are instructed about employed methods. Collaborative value modelling (Vieira, Oliveira and Bana e Costa, 2020) can be uptake to guide stakeholder engagement through all MMD building socio-technical steps, aligning indicators, features, and models with user values and perspectives. Hence, participation degree, addressed topics, stakeholders, methods and DSS should be tailored to the technical task, understanding that different decision contexts require different resources (Woudstra *et al.*, 2022).

Indicator monitoring. Indicators are essential and should derive from combining available evidence and stakeholder appraisal, validation and refinement (Cadilhac *et al.*, 2020; Salgado *et al.*, 2020). Definitions and measures should be clear and agreed upon by all stakeholders, reinforcing measurement consistency and effective team communication (Pauwels *et al.*, 2009). Data collection, validation, and reporting can be supported by automated processes and user feedback for reliable and timely use (Lau *et al.*, 2019). Users should be the ones to monitor and act on RPM KPIs, intervening on care protocols, technological setups, organisational factors, and particular program challenges.

Value modelling. Multicriteria value models can address the complexity of RPM program assessment by considering an extended number of criteria, whose relative importance is explicitly modelled through stakeholder-informed value functions/scales and quantitative criteria weights, resulting in an overall value score and a multicriteria profile (Bana e Costa, Carnero and Oliveira, 2012). MACBETH (Sanchez-Lopez, Bana e Costa and De Baets, 2012; Bana e Costa, De Corte and Vansnick, 2016) is deemed suitable for value modelling as (*a*) it proposes a cognitively friendly questioning procedure to 'drive' the interactive quantification of values through pairwise verbal judgements, (*b*) its technical parameters are clear and easily interpretable, improving stakeholder acceptance, (*c*) its interactive protocol is supported by a robust software (M-MACBETH) allowing reliable use and advanced features for sensitivity and robustness analysis, and (*d*) it has been successfully applied to several problems with similar domain, scope or constraints to RPM program management and assessment (Bana e Costa and Oliveira, 2012; Bana e Costa, Carnero and Oliveira, 2012; Carnero and Gómez, 2016; Mateus, Bana e Costa and Matos, 2017; Bana e Costa *et al.*, 2019; Angelis *et al.*, 2020; Gansen and Klinger, 2020; Bana e Costa, Oliveira, Vieira, *et al.*, 2023; Fernandes *et al.*, 2024).

Accomplishment levelling. Interpreting outcomes and overall scores may be difficult without reference levels (Goretzki *et al.*, 2018). Performance targets, achievement classes and assignment rules can provide clarity. On the one hand, each KPI can be linked to performance targets informed by literature and expert consultation. Targets provide context for desirable performance levels, allowing for intuitive analysis of the displayed information (Elg, Palmberg Broryd and Kollberg, 2013). On the other hand, value model outputs can be categorised into stakeholder-defined achievement classes. Achievement classes – supported by clear assignment rules – can help align calculated value scores with organisational goals, facilitating the identification of areas requiring additional managerial focus (Bana e Costa, Carnero and Oliveira, 2012).

Dashboard visualisation. Dashboard pages (i.e., reports) can integrate KPI visuals and the value model into a single DSS, fulfilling the MMD dual function and ensuring data and measurement consistency between tactical and strategic purposes (Pauwels *et al.*, 2009). Intuitive DataViz allow users to assess program performance regardless of familiarity with the condition, RPM configuration, or assessment methods (Rajnoha *et al.*, 2016). Clear visual aids (e.g., reference lines, gauge charts, colour coding) may help detect strategic uncertainties and prioritise actions. Users should be able to adjust dimension weights through bounded sliders to customise performance profiles according to their specific concerns and assessment objectives (Kasparian and Rolland, 2012).

Figure 4.1 summarises the underlying principles for constructing an RPM MMD, methodological requirements for MMD development guided by user needs the DSS is designed to meet.

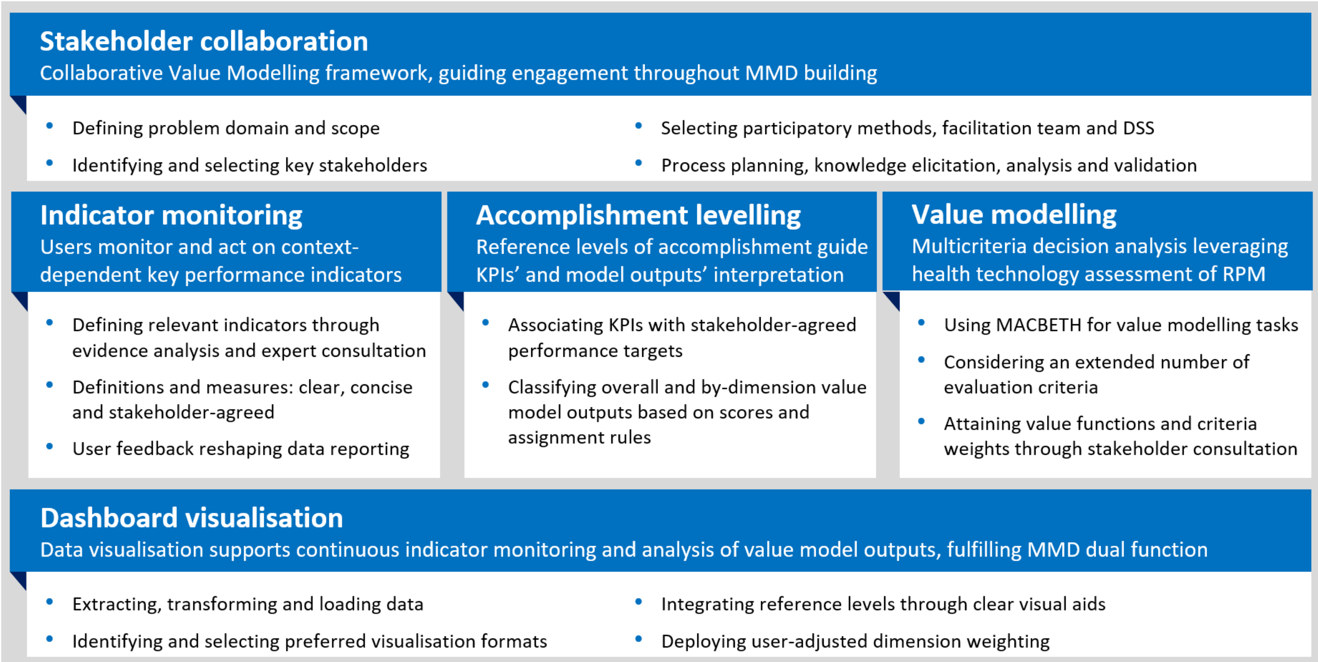


Figure 4.1. Underlying principles for building an MMD for continuous RPM program assessment.

4.4.2. SBI-MD: A Stepped Approach Towards MMD Implementation

Adopting the view that the use of a stepped approach is critical in HTA (Vis *et al.*, 2020) – as it provides a comprehensive, standardised and replicable roadmap for stakeholders and technical developers to progress from concept to execution –, Figure 4.2 presents our proposed step-by-step methodology for the design, development and implementation of MMDs for continuously monitoring and evaluating RPM programs. **SBI-MD** – standing for **S**tructuring, **B**uilding and **I**mplementing a **M**ultidimensional **D**ashboard with **S**takeholders, **B**usiness **I**ntelligence and **M**ulticriteria **D**ecision-aiding – consists of an integrative approach, divided into three pivotal phases: (1) structure RPM value dimensions and indicators, (2) build the MMD, and (3) implement the MMD. Each phase contains four objective-oriented steps, with sub-steps linking methods to the objectives to attain. The following sub-sections detail the twelve steps of SBI-MD, proposing value measurement, BI, and stakeholder engagement methods and tools for conducting involved sub-steps and specific tasks.

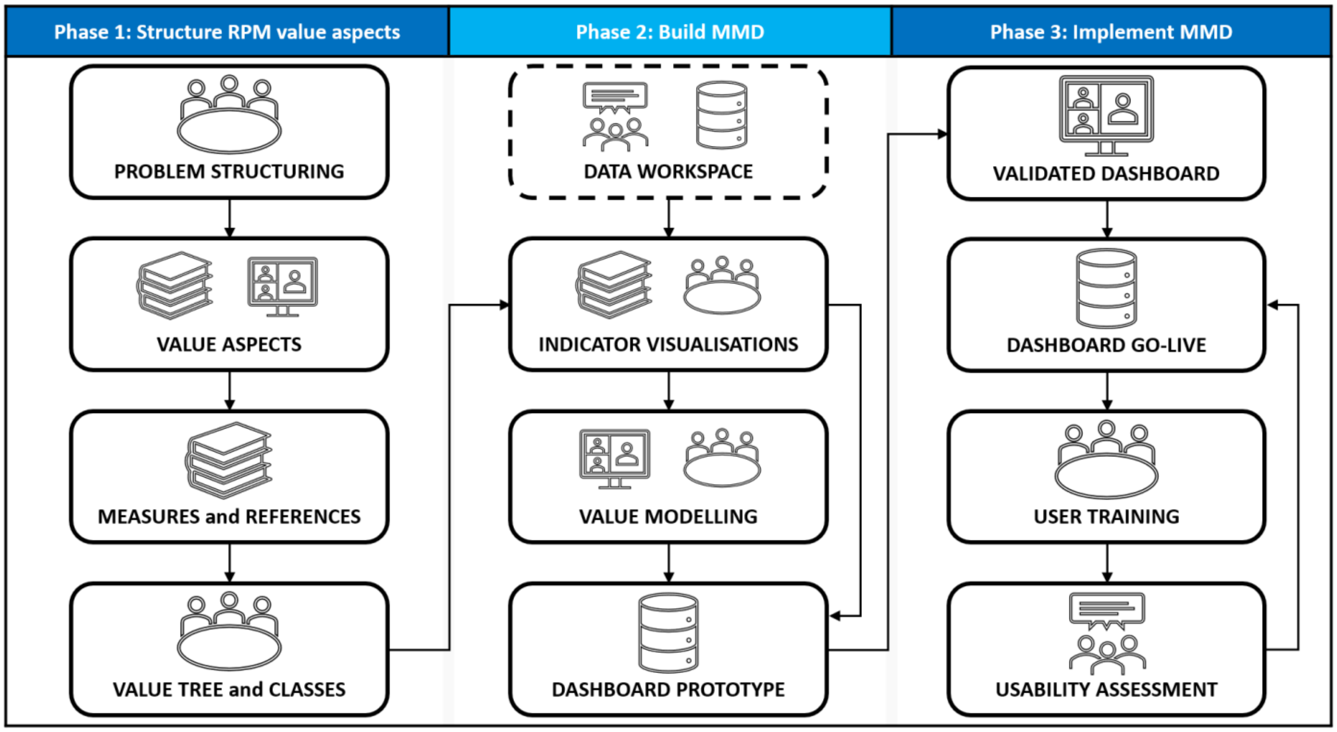


Figure 4.2. SBI-MD: an innovative 3-phase, 12-step approach towards MMD implementation.

4.4.2.1. Phase 1: Structure RPM Value Dimensions and Indicators

Figure 4.3 outlines the sub-steps in Phase 1, specifying the process type (collaborative or non-collaborative), methods, and tasks. Detailed descriptions of sub-steps are provided in subsections named after the steps in Figure 4.2. Phase 1 starts with process design and sets up the MMD building environment. By the end of Phase 1, KPIs (with names, descriptions, measures, and reference levels) and criteria (which are understandable, agreed-upon, isolable, and operational (Keeney, 1996; Belton and Stewart, 2010)) are established, enabling the transition to MMD building in Phase 2.

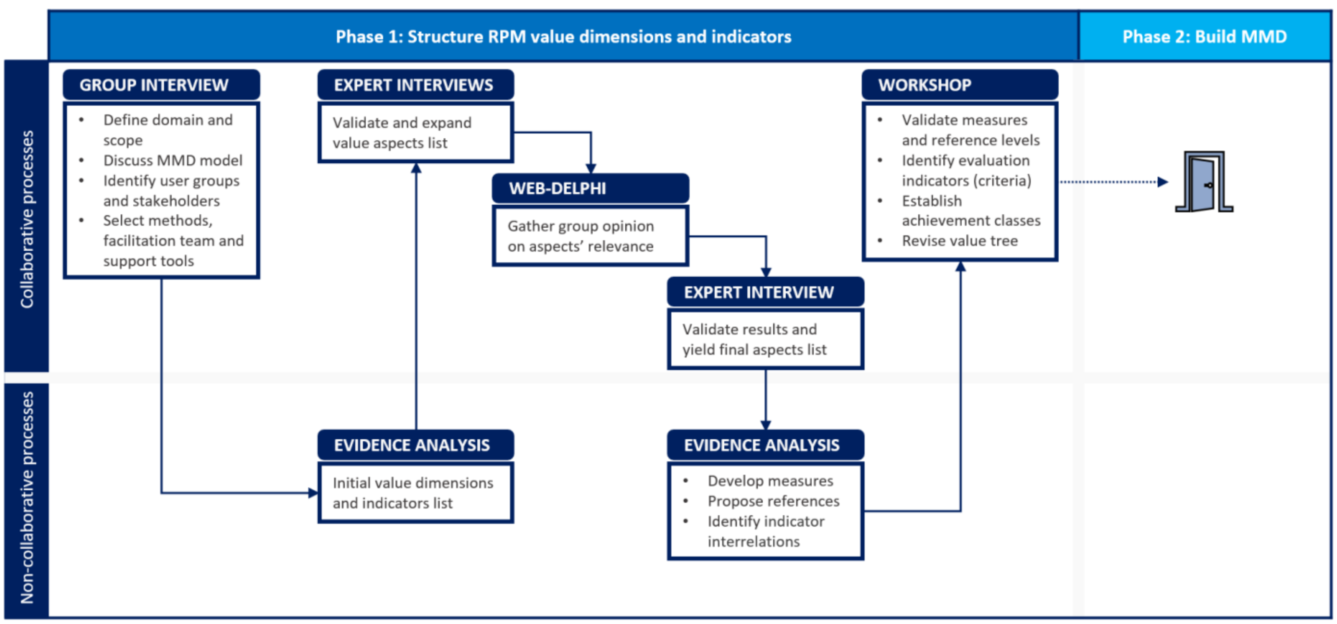


Figure 4.3. Phase 1 of SBI-MD: Structure RPM value dimensions and indicators.

Step 1.1: Problem Structuring and Model Design

Adopting a collaborative value modelling perspective (Vieira, Oliveira and Bana e Costa, 2020), Phase 1 begins with problem structuring and model design for setting the MMD building environment, comprising four tasks conducted in a group interview with project keyholders (PKs). Firstly, the assessment problem is defined by specifying its domain and scope. MAST (Kidholm *et al.*, 2012) ensures alignment with a telemedicine assessment context like RPM by addressing four questions:

- *What is the purpose of the telemedicine application?*
- *Which are the relevant alternatives?*
- *Is the assessment international, national, regional or local?*
- *What is the maturity of the application?*

Secondly, PKs align with the MMD value model. Managing an RPM program is a continuous HTA challenge, requiring input from multiple stakeholders and consideration of various value dimensions, indicators, and performance targets. This problematic context is consistent with the one described by Bana et al. (Bana e Costa, Carnero and Oliveira, 2012) for auditing a predictive maintenance program in a Spanish hospital. Consequently, the value measurement model for our problem is expected to resemble the two-level hierarchical additive value model structure proposed by Bana et al.

Since the MMD is designed both to provide a PK-agreed RPM program assessment and to encourage debate on differing PK views about program value, it incorporates two model variants – the *HTA* mode, using predefined, PK-agreed (HTA) weights, and the *Interactive* mode, incorporating user-adjusted, interval weighting features.

The value model should comprise a finite set of L value dimensions $d = \{1, \ldots, L\}$, each including several understandable, agreed-upon, isolable, and operational criteria $c_{di} = \{c_{d1}, \ldots, c_{dN}\}$. Each criterion may consist of a single KPI (i.e., $c_{di} = k_{dj}$) or a combination of KPIs (e.g., $c_{di} = \{k_{d1}, \ldots, k_{d4}\}$). $P(c_{di})$ represents the measure for criteria c_{di} (e.g., $P(c_{di}) = G(\{P(k_{d1}), \ldots, P(k_{d4})\})$ for a composite criterion c_{di}). $V_{c_{di}}^{p} = V_{c_{di}}(P_{c_{di}})$ represent the partial program value score on criterion c_{di}, resulting from converting performance $P_{c_{di}}$ into value through value function $V_{c_{di}}$. Values reflect the attractiveness of performances, measured considering reference levels of performance (as defined in (Rodrigues *et al.*, 2017)): *Target* (representing an undoubtedly attractive performance) and *Minimally acceptable* (neither attractive nor unattractive) are recommended. Partial program value scores assume $V_{c_{di}}^{p} = 0$ if $P(c_{di}) = P_{Min.acc.}(c_{di})$ and $V_{c_{di}}^{p} = 100$ if $(c_{di}) = P_{Target}(c_{di})$).

Considering these mathematical elements, for the *HTA* mode, V_d^p – the partial program value score on value dimension d – and the program's overall value V^p are, respectively, given by:

$$V_d^p = \sum_{i=1}^{N} V_{c_{di}}^{p} \cdot \frac{w_{c_{di}}}{w_d} \tag{4.1}$$

$$V^p = \sum_{d=1}^{L} V_d^p \cdot w_d = \sum_{d=1}^{L} \sum_{i=1}^{N} V_{c_{di}}^{p} \cdot w_{c_{di}} \tag{4.2}$$

where $w_{c_{di}}$ represents the PK-agreed weight for criterion c_{di}, with $\sum_d \sum_i w_{c_{di}} = 1$ and $w_{c_{di}} > 0$, and $w_d = \sum_i w_{c_{di}}$ being the value dimension weight.

For the *Interactive* mode, MMD users will be allowed to adjust predefined value dimension weights w_d within adequate intervals $\left[w_d^{min}, w_d^{max}\right]$ to reflect their individual views, with a program's alternative overall value V^{alt} given by:

$$V^{alt} = \sum_{d=1}^{L} V_d^p \cdot w_d^{adj} \tag{4.3}$$

where w_d^{adj} is the user-adjusted weight for value dimension d, with $\sum_d w_d^{adj} = 1$. In Step 2.3, we outline the constraints and recommended procedure for defining adequate weight adjustment intervals.

Partial by-dimension scores V_d^p and the program's overall values V^p and V^{alt} (i.e., for both model variants) are assigned achievement classes using a classification system that combines compensatory scores with PK-defined assignment rules, complementing the value measurement model. A finite set of achievement classes $C = \{C_1, \dots, C_X\}$ forms the basis of the classification system. These classes are ordered to reflect a scale of accomplishment per value dimension and overall i.e., $C_1 \prec \cdots \prec C_X$ where $\prec$ means "precedes". However, class descriptions and boundaries vary by dimension and respective to the overall value i.e., $\underline{b(C_x)} \neq \underline{b_1(C_x)} \neq \cdots \neq \underline{b_L(C_x)}$ where $\underline{b(C_x)}$ represents the C_x class lower boundary for the program's overall value and $\underline{b_L(C_x)}$ is the C_x class lower boundary for the partial program value score on value dimension L (omitted notation clarification follows the same rational). Important also to notice that $\underline{b_d(C_x)} = \overline{b_d(C_{x-1})}$, as classes succeed to one another.

Overall and by-dimension achievement class boundaries ($\underline{b(C_x)}$ and $\underline{b_d(C_x)}$, respectively) are attained through a facilitator-guided group procedure described in Step 2.1. Class boundaries for the program's overall score V^p (similar for by-dimension partial program values V_d^p) are set as

$$C = \begin{cases} C_1, if\ V^p \leq \underline{b(C_2)} = V^p(C_2) \\ \dots \\ C_x, if\ V^p \leq \underline{b(C_{x+1})} = V^p(C_{x+1}) \\ \dots \\ C_X, if\ V^p \geq \underline{b(C_X)} = V^p(C_X) \end{cases} \tag{4.4}$$

A similar approach can be applied at the criterion level for improved interpretation and visualisation using criterion-specific class boundaries $\underline{b_{c_{di}}(C_x)} = V_{c_{di}}^p(C_x)$.

Thirdly, <u>PKs identify potential user groups and relevant individuals to involve in MMD development</u>. Should the need arise for additional experts in specific collaborative processes (e.g., web-Delphi), they may be included later. Lastly, <u>a facilitation team is appointed for the project, and the methods and DSS to employ are chosen</u> (e.g., dashboard-building software, online participation platforms). Within collaborative procedures, this team guides participation, encouraging open expression of opinions, and stimulating creative thinking. Facilitators are neutral participants, intervening solely to assist participants in problem-solving and decision-making – PKs own the problem and its solution (Thokala *et al.*, 2016).

Step 1.2: Identifying and Selecting Value Aspects

After problem structuring and model design, four sequential sub-steps (described in detail in Chapter 5) guide the selection of relevant value aspects for continuous monitoring and evaluation of a condition-specific RPM program. An evidence-informed list of value dimensions and indicators (for monitoring and evaluation) is first compiled, drawing from relevant literature on HTA (e.g., MAST (Kidholm *et al.*, 2012)), care model configuration (e.g., the framework proposed in Chapter 3, Figure 3.2) and the target condition/group. Next, interviews with a restricted group (e.g., only PKs) validate and expand the initial list. The predefined questions asked are as follows:

1. *Should this value dimension (indicator) be considered when monitoring and evaluating the RPM program?*
2. *Do you find this description of the value dimension (indicator) clear and accurate?*
3. *Considering the study's purpose, would you suggest any changes or additional dimensions (indicators)?*

After the interviews, a web-Delphi process gathers opinions on the relevance of each value dimension and indicator, involving an enlarged group of stakeholders and experts (whether directly engaged in the RPM program). Participants express their agreement with the pertinence of the value aspects using a Likert scale (e.g., five levels, from *strongly disagree to strongly agree*) and provide comments for improved clarity. Participants may be asked to suggest additional aspects in the starting web-Delphi round. In subsequent rounds, participants review their responses in light of aggregated results from the previous round, including the distribution of answers and comments from others. The process concludes when specific conditions are met, such as completing a predefined number of rounds, achieving broader agreement, or observing minimal changes in aggregated results between rounds.

Following the web-Delphi process, the final sub-step involves a conclusive interview with a knowledgeable and respected PK. This PK, who possesses both clinical and technical expertise, critically evaluates the outcomes of the web-Delphi process. Their analysis provides deeper insights into RPM value aspects, yielding recommendations for selection and adjustments to finalise the list.

Step 1.3: Defining Measures and References

Having a finite set of value dimensions and indicators – though not yet operational nor isolable –, the next step involves structuring the value model by defining performance measures, proposing reference levels, and assessing the interrelations between indicators. Facilitators draw an initial proposal autonomously, which is subsequently validated and refined by PKs in Step 1.4. At this stage, one starts to recognise which indicators may constitute criteria and how KPIs can be clustered under these criteria, laying the foundation for the hierarchical structure of the value measurement model.

Performance measures are developed for each indicator based on their names and definitions. Through literature and based on facilitators' experience, commonly used measures or proxies are identified. These measures must be simple to calculate using basic mathematical and logic operations and conditional statements (Lau *et al.*, 2019). Identifying reference levels of performance (i.e., *Target* and *Min. acc.*) also involves reviewing literature and/or considering facilitators' experience, as well as consulting the program's historical data.

Lastly, potential indicator interrelations are identified through interrelation matrices and preference independence tests (Rodrigues *et al.*, 2017; Vitacca and Vitacca, 2019). Each indicator is appraised against others within its dimension to uncover key preference dependencies, non-isolable (those that overlap or contain one another), and redundant indicators. Reference levels ensure commensurateness between indicators, so dependence testing should be anchored on the *Target* and *Min. acc.* references of each indicator (Lopes *et al.*, 2014). When there is suspicion about preference dependence, the following MACBETH testing protocol is suggested:

> Consider two indicators (#1 and #2) with *Target* (T) and *Min. acc.* (M) references. To test for interdependencies, a set of global performances would be (T1, T2), (T1, M2), (M1, T2), (M1, M2). For verifying if #1 is dependent on #2, the following questions are asked: (*i*) *What is the attractiveness of the swing/improvement from (M1, M2) to (T1, M2)?* and (*ii*) *What is the attractiveness of the swing/improvement from (M1, T2) to (T1, T2)?* Since the swings contemplated in (*i*) and (*ii*) only differ on the level of #2, if #1 is preference independent of #2, these improvements should be equally valued using the MACBETH scale. Since preference dependence is not symmetric, it is necessary to verify how differing swings on the level of #1 are valued.

If interrelations are confirmed, KPIs are combined into single criteria by constructed or composite measures – KPIs can be combined using various methods (Rodrigues *et al.*, 2017; Greco *et al.*, 2019), such as proxy composite measures, counts of KPIs meeting their *Target* reference, descriptors combining reference levels, decision rules, mathematical models, or weighted averages.

Step 1.4: Validating the Value Tree and Defining Achievement Classes

PKs are invited to participate in a workshop (preferably in-person) to validate and refine the outcomes of Step 1.3. The primary goal is to develop a value tree and define achievement classes for program classification. The facilitation team starts by presenting proposed measures and reference levels, seeking feedback from PKs for validation and any necessary adjustments. If Step 1.3 lacked sufficient evidence from literature, past experiences, or historical data, PKs work collaboratively to establish appropriate measures and references for the missing indicators.

Once measures and references are validated, the group analyses the indicator interrelations identified by facilitators. Based on this analysis, PKs discuss which indicators should serve as criteria and which KPIs can be merged into singular, distinct criteria. By the conclusion of the workshop, participants aim to define a set of understandable, agreed-upon, isolable, and operational criteria c_{di} and monitoring KPIs k_{dj} for comprehensive RPM program assessment.

The third workshop task requires PKs to collaborate in establishing a finite set of achievement classes which will form the basis of the MMD's classification system. The number of classes and their names are consistent across dimensions/overall, e.g., four classes EXCELLENT, GOOD, ACCEPTABLE, and ALERT as in (Bana e Costa, Carnero and Oliveira, 2012), while class descriptions and boundaries vary. Achievement classes' boundaries are defined in Phase 2, Step 2.2.

Lastly, criteria are organised into a value tree and analysed. PKs verify whether the value modelling requirements hold, specifically if criteria are understandable, agreed-upon, isolable and operational (Keeney, 1996; Belton and Stewart, 2010). Then, they discuss whether additional KPIs or criteria should be included and if any defined measures, reference levels, or achievement classes are inappropriate for assessing the RPM program. If PKs have no additions or adjustments and consider the value tree exhaustive (i.e., with no sense of incompleteness), Phase 1 concludes. Otherwise, adjustments are made until exhaustiveness is achieved.

4.4.2.2. Phase 2: Build the Multidimensional Management Dashboard

Figure 4.4 illustrates the socio-technical sub-steps proposed for Phase 2. Departing from validated KPIs and a value tree, PKs, assisted by the facilitation team, constructively collaborate towards the creation of MMD monitoring reports and the multicriteria value model. This involves technical (and autonomous) work by facilitators and collaborative sessions with PKs for gathering requirements, sharing perspectives, and validating decisions. Phase 2 concludes with a functional MMD prototype embedding the value model in the dashboard for program monitoring and HTA. Data aggregation and processing begin early in Phase 2 and proceed alongside other tasks.

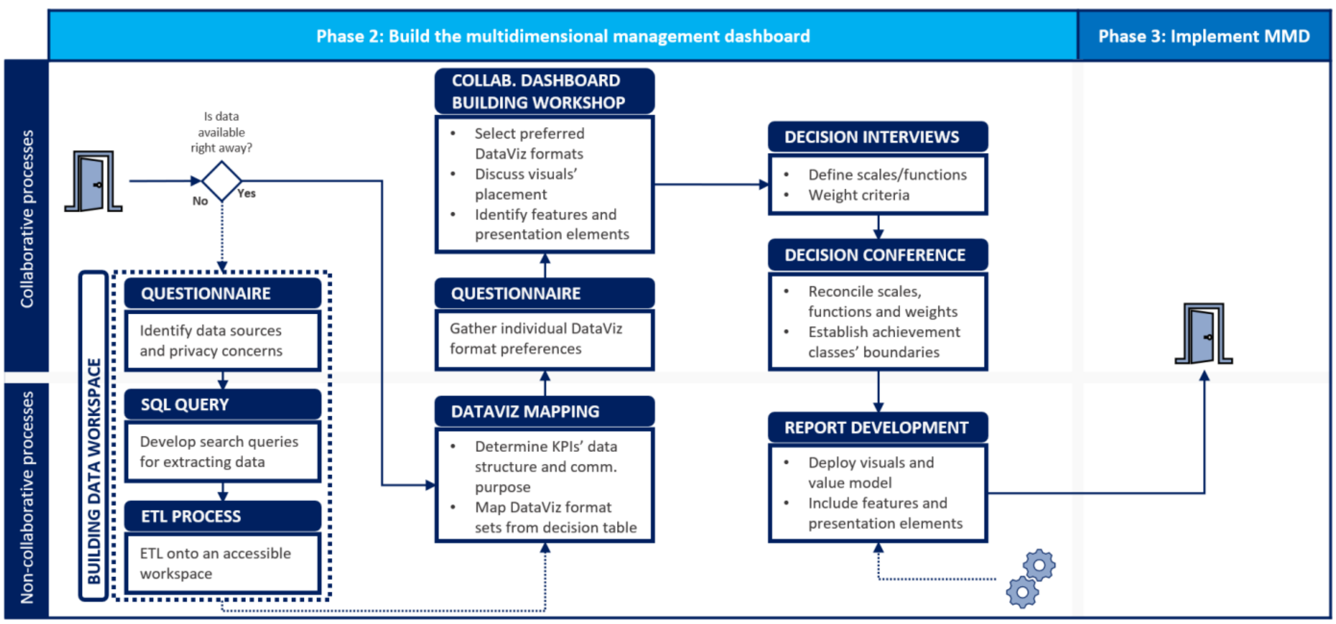


Figure 4.4. Phase 2 of SBI-MD: Build the multidimensional management dashboard.

Step 2.0: Building a Data Workspace

Before starting MMD development, RPM program data accessibility must be confirmed. If data is available, development starts immediately. Otherwise, facilitators collaborate with the institution's IT services to create a consolidated data workspace. Temporarily, facilitators use synthetic data to continue MMD development, ensuring the models seamlessly integrate with real data once accessible.

A comprehensive questionnaire to PK-appointed data owners can be used to identify all relevant data sources – RPM data is often spread across non-communicating systems and databases, including EMR, TM platforms, e-PROs, billing systems, and medication management software (Vitacca and Vitacca, 2019). Moreover, the questionnaire should cover privacy issues (e.g., data anonymization, access permissions), data integration and security concerns, quality and confidence levels, and potential future data sources.

After mapping data sources, SQL queries are created based on Phase 1 KPI descriptions and measures. Privacy regulations should guide whether direct database access is allowed or if file uploads are used instead (Orlando and Sunindyo, 2017). Once ETL is completed onto a cloud workspace, dashboard-building software can access raw data for producing real-time and on-demand actionable visualisations (Lau *et al.*, 2019). Alternatively, a local, autonomous workspace can be integrated into the dashboard-building software.

Step 2.1: Deploying Indicator Visualisations

MMD development begins with a CDB approach, combining facilitators' autonomous work with user input to design prototype reports based on Phase 1 KPIs. This process involves three sub-steps: mapping DataViz formats for each KPI, gathering KPI DataViz preferences via a questionnaire, and holding a CDB workshop to finalise choices. Chapter 6 provides a detailed explanation of the CDB approach, focusing primarily on the first and third sub-steps, as the second configures a refinement to the final version of SBI-MD, in response to limitations identified in Chapter 6's implementation study. Chapter 7 already implements SBI-MD's Step 2.1 in full.

Departing from Phase 1 KPIs, facilitators determine each KPI's communication properties (i.e., data structure and purpose) based on their names, descriptions, and measures. The data structure is represented by a string where length indicates variable count and letters denote attribute types (e.g., "CQ" for one categorical and one quantitative variable). Six communication purposes are allowed: *Assessing hierarchies and part-to-whole relationships*, *Comparing categories*, *Displaying dimensionless measures, Mapping geospatial data*, *Plotting connections and relationships* and *Showing changes over time*. A literature-informed decision table (see Table 6.2 in Chapter 6) then identifies the most common DataViz formats according to KPI's properties.

Next, using dashboard-building software, the facilitators create DataViz alternatives for each KPI to visually support PKs in choosing their preferred format through an online questionnaire. The questionnaire platform should enable structured survey design, easy sharing of screenshots, commenting, and automatic result aggregation for analysis. Each participant will review DataViz sets one at a time, vote on a preferred alternative, provide feedback on their choice, and suggest alternative formats if needed.

The CDB workshop follows, employing a modified NGT approach. Unlike the approach described in Chapter 6 (beginning with silent analysis and voting on DataViz alternatives), the final proposal for Step 2.1 uses the former questionnaire as the initial NGT voting round. Participants review aggregated questionnaire results and justifications for the first KPI and then discuss its optimal DataViz format. This process repeats for each KPI. Lastly, participants co-create prototype reports for value dimensions, placing chosen formats onto single dashboard pages and selecting key features for the final version. These prototypes, while not fully functional, assist value modelling.

Step 2.2: Value Modelling

SBI-MD employs MACBETH to develop a hierarchical additive value model for ongoing program assessment. The first value modelling task implies defining value functions $V_{c_{di}}$. For each criterion, value functions are constructed through PKs' judgments of differences of attractiveness between performance levels. M-MACBETH, the DSS implementing MACBETH, applies linear programming to derive a numerical scale from these judgments. For a criterion c_{di}, with an ordered set of Z performance levels $P(c_{di}) = \{P_1(c_{di}), \dots, P_Z(c_{di})\}$, PKs are asked: "What is the difference of attractiveness between a $P_1(c_{di})$ and $P_2(c_{di})$ on criterion c_{di}, assuming all other criteria are at $P_{Min.acc.}(c_{di})$?" PKs compare several levels, ranging from $Z-1$ comparisons (only between consecutive levels) to $Z(Z-1)/2$. Making more than $Z-1$ judgments is recommended to ensure consistency can be assessed (Bana e Costa *et al.*, 2008).

Weights $w_{c_{di}}$ are then assigned to each criterion c_{di}, "harmonising" value functions $V_{c_{di}}$ and reflecting the relative importance of each criterion c_{di} – derived considering its performance measure $P(c_{di})$ and reference levels $P_{Min.acc.}(c_{di})$ and $P_{Target.}(c_{di})$. PKs are first asked to rank the attractiveness of swings from *Min. acc.* to *Target* for each criterion, then provide qualitative judgments for each swing against an "all *Min. acc.*" hypothetical alternative (Bana e Costa, Oliveira, Vieira, *et al.*, 2023). As for value functions, additional judgments are recommended.

<u>Within the decision interviews' social process, PK's judgments for building value functions and weights are elicited individually</u>. Because PKs may perceive performance improvements differently, each interview may yield unique MACBETH matrices, $V_{c_{di}}$ and $w_{c_{di}}$ (Mateus, Bana e Costa and Matos, 2017). MACBETH addresses these differences by facilitating argumentation, voting, and the resolution of conflicts to build consensus (Fasolo and Bana e Costa, 2014). Although effective, it can be time-intensive, often requiring multiple iterations to reach a compromise. A more pragmatic approach involves reconciling judgements, functions and weights.

On value function reconciliation, List (List, 2012) explores semantic judgment aggregation by introducing a logical rule to form collective judgments from individual ones, before the value function is built. Another approach involves directly averaging the points of the value functions, as discussed in (Fernandes *et al.*, 2024) – which proves effective in reconciling one-dimensional value scales (further elaborated in Chapter 7). Keeney and Raiffa (Keeney and Raiffa, 1993) define the aggregated value function as a weighted average of individual functions. Building on this concept, Fernandes et al. (Fernandes *et al.*, 2024) present a web-based DSS enabling reconciling multiple value functions (each represented by sets of points) into a single one by fitting exponential delta functions through square error minimisation (as described by Corner (Corner, 1994)). Functions are defined by parameters $x_i^0 = \min(V_{c_d}^p)$ and $x_i^* = \max(V_{c_d}^p)$ (i.e., the first and last $x_i = V_{c_d}^p$ in the first set of points, respectively) and the trade-off attitude constant δ, which is chosen to minimise the square error between provided $V_{c_d}^p$ and the fitted function.

For clarification, the constant trade-off attitude (or "delta") property implies that a decision maker's trade-offs between different attributes remain consistent, regardless of the attribute levels, ensuring decision-making consistency, intuitiveness, and interpretability (Kirkwood and Sarin, 1980; Keeney and Raiffa, 1993; Corner, 1994). Maintaining this property is important as it ensures that fitted functions not only reflect PKs perspectives but also preserve consistency in judgment (making PK trade-offs predictable) and keep value model scores stable and reliable, regardless of changes in the RPM patient population or of how slight or dramatic are variations in program performance (Vieira, Oliveira and Bana e Costa, 2020). While polynomial, logarithmic, power, sigmoid, or other exponential functions can be used for curve fitting, they may not maintain the desirable delta property (Fernandes *et al.*, 2024).

Regarding weights reconciliation, it can occur at either the input level (i.e., based on criteria rankings and qualitative judgments) or the output level (i.e., reconciling the obtained weights for each PK into a unified set of criteria weights) (Dias and Clímaco, 2005). Since criteria rankings can differ among PKs, reconciling weights at the output level becomes less meaningful, as each PK's value judgments are based on their own individual ranking. Therefore, we recommend reconciling weights at the input level, with final judgments depends on group consensus. A results visualisation inspired by MACBETH-voting applications (Mateus, Bana e Costa and Matos, 2017; Bana e Costa, Oliveira, Rodrigues, *et al.*, 2023) is recommended, displaying individual decision interviews' judgments in a matrix aligning the reconciled criteria ranking with MACBETH scale levels. Each cell indicates the number of interviewees selecting a specific MACBETH judgment for how attractive an improvement from an "all *Min. acc.*" alternative to one rated as *Target* on a single criterion would be. While statistical analysis of individual weights does not directly affect weight reconciliation, it helps define the boundaries for group weighting.

<u>Once value functions and weights are reconciled, a DC (stands for decision conference) takes place</u>. During the DC, participants revise the reconciled value scales/functions and weights, adjusting them to reflect group agreement following discussion. The DC model represents the collective viewpoint of the group, allowing participants to understand its outputs as a supportive analysis that arises from a collective effort rather than a deterministic solution (Phillips, 2007).

The final DC task consists of a facilitator-guided procedure to attain the classification system's achievement class boundaries $\underline{b(C_x)}$. Considering the *HTA* mode of the value model (i.e., using predefined, PK-agreed weights), PKs are first asked to imagine an hypothetical RPM program that would have the lowest program's overall value V^p that would correspond to a C_x classification i.e., which would be the minimum simultaneous program performances $P^p_{c_{di}}$ on every criteria c_{di} conducing to V^p? Thus, $\underline{b(C_x)} = V^p(C_x)$. The procedure is repeated for each class, except for C_1, which is the lowest class, therefore $\overline{b(C_1)} = \underline{b(C_2)}$. Moreover, this procedure allows defining the remaining by-dimension boundaries as $\underline{b_d(C_x)} = V^p_d(C_x)$, considering only the influence of criteria c_d belonging to dimension d.

Model reliability is not solely guaranteed by employing sound methods; it is also essential to test how well the model's outputs align with the value systems of PKs (Vieira, Oliveira and Bana e Costa, 2020). This can be achieved through recursive, interactive, and extensive sensitivity and robustness analyses, which allow for adjustments towards model requisiteness (Phillips, 1984). Traditionally, this knowledge verification phase takes place in the DC to ensure a thorough and comprehensive review of the model's reliability (Phillips, 2007). However, in SBI-MD, we recommend conducting sensitivity and robustness analyses at the start of Phase 3 during a dedicated validation workshop. This approach facilitates a focused and comprehensive validation of the entire MMD tool in a single session, reducing the cognitive load associated with the DC. PKs hereby concentrate on assessing data reliability, value model requisiteness, classification system appropriateness, and the tool's ease of use.

Step 2.3: Building the MMD Prototype

In the final step of Phase 2, the facilitation team builds on the outcomes of Steps 2.1 and 2.2 to deploy the final KPI visuals and embed the MACBETH value model in the MMD. Value dimension reports are revised based on CDB workshop feedback and the value modelling process. KPI DataViz and value model must be fed by the same measures to ensure alignment between tactical (program monitoring) and strategic (evaluation) purposes (Pauwels *et al.*, 2009). If a criterion derives from a KPI (i.e., $c_{di} = k_{dj}$), this KPI's DataViz should show the computed value used for the value model's performance for that criterion (i.e., $P_{c_{di}} = P_{k_{dj}}$), helping users track how KPI performance affects the program's overall value. Moreover, embedding the MACBETH model directly in the MMD ensures continuity in value assessment, allowing users to explore problem areas highlighted by the value model and dive deeper using the KPI visuals (Abastante, Lami and Lombardi, 2017). For value model embedding, value scales, functions, and weights are inputted into the dashboard as defined by PKs. Value scales use conditional "if" clauses to assign values to performance levels, while value functions rely on the defined delta functions. Class assignment rules are also established to ensure that strong performance in a few areas does not overshadow weaker ones in attributing an achievement class (Bana e Costa and Oliveira, 2012; Figueira *et al.*, 2023).

Finally, the dashboard is enhanced for improved usability and usefulness with analysis and presentation features. For example, user-adjusted weights allow different performance profiles to be reflected according to the user's specific concerns and assessment objectives (e.g., health system, patient, staff) (Kasparian and Rolland, 2012), enabling the model's *Interactive* mode. Once different types of "good" program performances are not only admitted but also desirable, weights should be flexible within reasonable bounds (Bana e Costa and Oliveira, 2012; Bana e Costa, Carnero and Oliveira, 2012) – interval weighting within each value dimension. To ensure significance and alignment with PK perspectives, following Step 1.1 notation, weights and their bounds respect the following constraints:

- w_d^{min} and w_d^{max} are informed by the different weights attained during K decision interviews, where:
  - $w_d^{min} \geq \sum_i^N \min\left(\left\{w_{c_{di}^1}, \ldots, w_{c_{di}^K}\right\}\right)$
  - $w_d^{max} \leq \sum_j \max\left(\left\{w_{c_{di}^1}, \ldots, w_{c_{di}^K}\right\}\right)$
- $w_d \in \left[w_d^{min}, w_d^{max}\right], d \in \{1, \ldots, L\}$
- The sum of adjusted dimension weights must always equal 1 ($\sum_d w_d^{adj} = 1$)

As such constraints may impose variation limits across value dimension weights, a procedure to establish interval bounds w_d^{min} and w_d^{max} shall aim to maximise each variation interval $\left[w_d^{min}, w_d^{max}\right]$ while minimising adjustments to the PK-derived intervals – ideally, one wants $w_d^{min} = \sum_i^N \min\left(\left\{w_{c_{di}^1}, \ldots, w_{c_{di}^K}\right\}\right)$ and $w_d^{max} = \sum_j \max\left(\left\{w_{c_{di}^1}, \ldots, w_{c_{di}^K}\right\}\right)$ for each dimension d.

Class assignment rules, user-adjusted weights and other MMD analysis features can be employed through design elements like colour coding, variable-defining sliders, simplified navigation (e.g., hyperlinks, selection filters), and concise summaries, improving user experience.

4.4.2.3. Phase 3: Implement the Multidimensional Management Dashboard

Figure 4.5 details the socio-technical steps in Phase 3. The facilitation team presents an MMD prototype to stakeholders in an online workshop, highlighting its key features and use cases. PKs suggest tasks to test the tool's robustness and data validity. If necessary, the facilitators refine the tool; otherwise, they set automation rules, sustainability protocols, and monitoring routines. A follow-up workshop trains users, and a usability questionnaire starts a feedback loop to maintain communication between users and developers, ensuring continuous improvement and adoption.

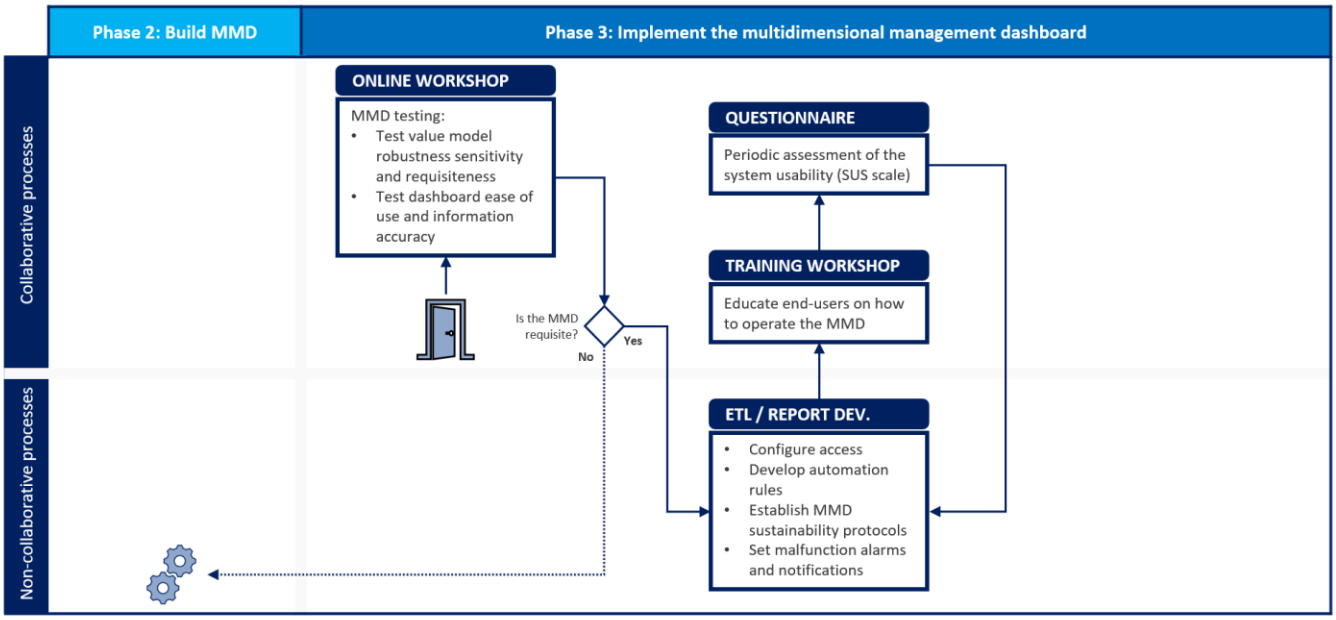


Figure 4.5. Phase 3 of SBI-MD: Implement the multidimensional management dashboard.

Step 3.1: Validating the Proposed MMD Prototype

Stakeholders, including PKs and potential future users, are invited to an online workshop to test the dashboard's robustness, sensitivity, and data validity. The facilitation team first demonstrates the MMD's main features. Use cases can be provided alongside each dashboard report and respective DataViz formats to enhance demonstration engagement. These use cases should include fact expressions – clear, everyday language statements describing information to be verified (de Mul *et al.*, 2012) (e.g., "In March 2018, patients on beta-blockers lost an average of 2.1 days of activity") – and cover typical, daily tasks, such as specific dates, patient groups, and combined visualisations.

Understanding how uncertainty affects assessment results and verifying if decision outcomes remain valid under different scenarios is also crucial (Phillips, 1984; Briggs, Sculpher and Buxton, 1994). Probabilistic sensitivity analysis addresses parameter uncertainty (e.g., alternatives' performance variation). Structural uncertainty (e.g., changes in criteria choices) can be explored through scenario analyses (i.e., using different criteria sets to analyse if value model outcomes alter). Moreover, incorporating weights and scores from various stakeholder groups helps account for preference heterogeneity (Thokala *et al.*, 2016). M-MACBETH provides visual tools for sensitivity and robustness analysis, allowing "what-if" questions to understand the impact of uncertainties on performance measurement and weighting (Bana e Costa, Oliveira, Rodrigues, *et al.*, 2023).

Participants are then encouraged to suggest additional pilot tests to ensure reporting works across all dashboard pages and provide feedback. Since new reporting needs frequently arise in BI environments, these tests are never fully complete (de Mul *et al.*, 2012). Ongoing feedback in Phase 3 is vital, as this validation workshop starts a feedback loop between users and developers. This loop enables continuous improvements, sustains the tool, and supports updates to visuals, case definitions, and data validation.

Step 3.2: MMD *Go-live*, Automation and Sustainability

Once the MMD meets stakeholders' requirements, online access will be configured. The dashboard will be accessible via a web browser, without device restrictions or special software. User access levels control data visibility, ensuring security. Verification mechanisms, such as password logins, will protect confidentiality.

Automation is another key aspect in dashboard reporting, streamlining manual tasks like *ad hoc* data queries and curation. Automated updates enhance efficiency and consistency. Lau et al. (Lau *et al.*, 2019) note that dashboard-building software can run SQL queries through stored procedures – subroutines that reliably and repeatedly execute SQL commands –, which can be scheduled (e.g., nightly updates), ensuring near real-time data.

Finally, to ensure MMD sustainability, ongoing monitoring is essential to maintain accuracy and reliability, and troubleshooting issues like system inoperability, data access, permissions, or updates (Lau *et al.*, 2019). Workflow triage systems can minimise downtime by enabling quick responses to these issues. Additionally, a user feedback loop, through periodic usability questionnaires, should inform developers of needed improvements, with survey frequency balanced to gather concerns without overwhelming users.

Step 3.3: User Training

MMD users must learn to analyse and interpret data in the MMD, as the format differs from typical medical data presentations and reports (de Mul *et al.*, 2012). Education for users and stakeholders can be delivered in various ways. Lau et al. (Lau *et al.*, 2019) suggest several approaches:

- *Teleconferencing.* Webinars (live or recorded) provide wide-reaching, interactive training on MMD, without location or scheduling conflicts.
- *Visual aids and live demonstrations*. Key MMD features can be explained through visual materials, detailed documents and manuals, and live demonstrations.
- *Onsite demonstration and training.* Involves hands-on education and training as part of a Basic Skills Training program.
- *Train-the-trainer model*. Upon completing their education program, trained users can teach others.

We recommend starting with onsite demonstration and training (i.e., a training workshop), while the feedback loop adopts asynchronous formats. For scaling, train-the-trainer and recorded webinars offer efficient education.

Step 3.4: Assessing MMD usability

To assess MMD usability and learnability, we recommend gathering regular, structured user feedback using SUS. It is widely used across various technologies, including hardware, consumer software, websites, and mobile phones, becoming an industry standard, with over 600 citations (Orlando and Sunindyo, 2017). It is frequently used in assessing dashboard usability (Orlando and Sunindyo, 2017; Dagliati, Sacchi, *et al.*, 2018; François *et al.*, 2021; Perry *et al.*, 2022).

SUS has proven validity against more comprehensive usability scales (Kidholm *et al.*, 2017) and is available in translated, culturally adapted, and validated versions (Martins *et al.*, 2015), covering factors like system usage frequency, complexity, ease of use, technical support, component integration, consistency, learning speed, user confidence, and educational requirements (Martins *et al.*, 2015). It is a simple tool with 10 items rated on a five-level Likert scale, computing a global score of up to 100 points (François *et al.*, 2021).

As mentioned, questionnaire frequency should be carefully balanced to avoid overwhelming users while still capturing relevant feedback. For instance, Perry et al. (Perry *et al.*, 2022) used SUS to evaluate patients' and clinicians' perspectives on usability, acceptability, and adoption at 3- and 6-month intervals.

4.5. Discussion

Chapters 5 through 7 will present applied studies that test the integrative approach proposed in this chapter. These studies focus on the application domain of RPM interventions for managing patients with HF, with each study building on the findings of the previous one. Chapters 5 and 6 will explore specific steps of SBI-MD (Step 1.2 and Step 2.1, respectively) as standalone approaches to achieve distinct goals in MMD development: identifying value dimensions and indicators for assessing HF RPM programs, and selecting DataViz formats for presenting these indicators. Chapter 7 demonstrates the application of Phases 1 and 2 of SBI-MD, testing it as an integrative methodology.

Notwithstanding, the discussion section of the present Chapter aims to provide a broader reflection on anticipated outcomes of SBI-MD application, foreseen challenges, and directions for future research, independent of a specific problem domain and scope. While some of these considerations are supported by the findings in Chapters 5 through 7, those will be further examined in their respective chapters to address context-specific challenges related to the application case.

4.5.1. Expected Outcomes From SBI-MD Application

The procedural implications of applying SBI-MD are examined first. This is followed by a focus on examples from MMD report pages that highlight the key features resulting from SBI-MD's application. Illustrative figures from the study in Chapter 7 are provided here to support this discussion.

The social engagement component of SBI-MD involves thirteen participatory processes: an initial group interview (Step 1.1), individual expert interviews, a web-Delphi process and a subject-matter expert interview for indicator identification, refinement, and selection (Step 1.2), a validation workshop (Step 1.4), a questionnaire for data source identification (Step 2.0), a questionnaire and a CDB workshop for

DataViz format selection (Step 2.1), decision interviews and a DC for value modelling (Step 2.2), an online workshop for MMD prototype testing (Step 3.1), a training workshop (Step 3.3), and a SUS questionnaire (Step 3.4). Each PK is engaged for approximately 16 hours and 20 minutes, estimating group processes averaging 2 hours, individual interviews 1 hour, and questionnaires 20 minutes. Phase 1 requires 6h20, Phase 2 requires 5h40, and Phase 3 requires 4h20 of engagement, emphasising the critical role of problem and model structuring – “the most important activity, which often encompasses the entire justification and validity of the facilitation exercise” (Bana e Costa and Beinat, 2005) –, but also of user feedback and training, which continues *ad aeternum* to ensure tool improvement and sustained and proper MMD use. Notice, however, that if indicators are predefined, 2h20 can be saved by omitting Step 1.2. Step 2.0 questionnaire may also be exclusive to IT services, not engaging PKs.

Compared to other MCDA or BI projects, SBI-MD is anticipated to be a practical and efficient approach for completing a wide range of value modelling and DataViz tasks. Bana et al. (Bana e Costa, Oliveira, Vieira, *et al.*, 2023) report a two-day decision conferencing process with a group of 13 senior experts. Maguire et al. (Maguire *et al.*, 2022) report a total duration of four hours for an NGT process. Lau et al. (Lau *et al.*, 2019) note that the time required for dashboard development varies significantly, ranging from three to six months. Despite these examples, directly comparing the efficiency of such projects with SBI-MD is challenging due to differences in participant engagement, group size, scheduling, and the expertise of facilitators.

The SBI-MD application should conduce to an MMD including, at a minimum, one dashboard page per value dimension for detailed program monitoring and an overview page embedding the multicriteria value model for program evaluation. An additional program evaluation page with per criteria detail and a contextual page (e.g., program case-mix and patient population demographics) are recommended. Monitoring and evaluation pages should be powered by a unified data source, ensuring consistency in performance reporting and program assessment.

For value dimension-specific monitoring pages, the key features are exemplified in Figure 4.6. Each page displays all DataViz formats agreed upon by PKs for the KPIs within that dimension. To maintain a clean, single-screen layout for at-a-glance analysis, KPIs should be aggregated into concise DataViz formats to minimise visual clutter. Format variety also enhances the dashboard's cohesiveness and readability. Elements such as titles, subtitles, footnotes, and legends provide users with the context needed to understand and interpret the displayed KPIs. Reference lines indicate *Target* and *Min. acc.* performance levels, helping users assess current performance against agreed-upon RPM program objectives. When software limitations or readability concerns prevent the use of reference lines, colour coding can be employed to indicate *Target* performance. Interactive filtering allows users to focus on specific details, such as selecting a particular year of activity to analyse all KPIs for that time period simultaneously.

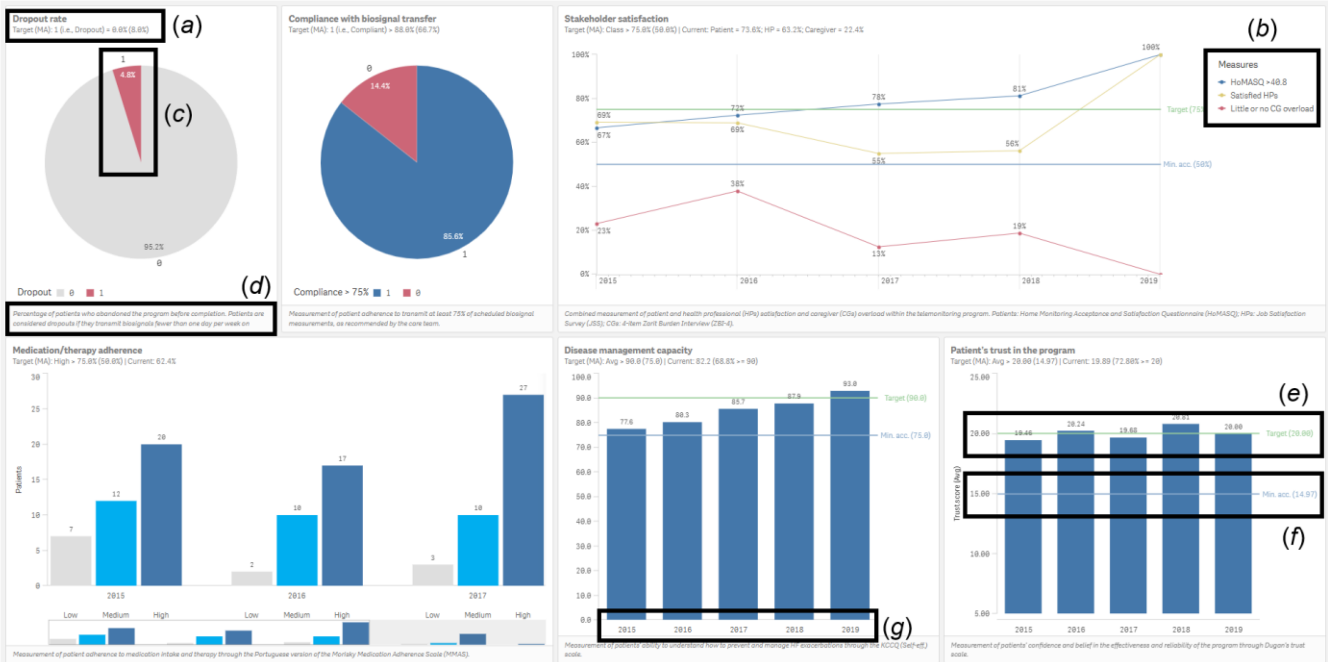


Figure 4.6. By-dimension monitoring page example. Legend: (*a*) Title and subtitle show the KPI name and compare current performance to reference levels; (*b*) Aggregated DataViz legend, with each KPI represented by a distinct coloured line; (*c*) Colour coding highlights the percentage corresponding to the relevant KPI (*d*) Footnote provides the KPI description and measurement scale (if applicable); (*e*) *Target* reference line; (*f*) *Min. acc.* reference line; (*g*) Year axis for interactive time filtering.

The overview page for program evaluation, as detailed in Figure 4.7, displays a gauge chart for each value dimension that influences the value model, as well as a gauge for the overall value score and classification. Additionally, there is a comprehensive table that summarises value scores, partial values, and performances for each year. In the table, the performance of each KPI contributing to each criterion is indicated. A green ball shows when a KPI meets the *Target* reference, while red text indicates when performance falls below the *Min. acc.* level. Partial value scores are calculated automatically using value scales and functions embedded in the dashboard. The colours in the table correspond to achievement classes for each criterion. Each achievement class is assigned a specific colour, agreed upon by PKs, and this colour scheme is maintained across all visualisations on the page.

Figure 4.7. Program evaluation page example. Legend: (*a*) Gauge showing the overall value score, based on user-adjusted weights; (*b*) HTA weight for a specific dimension; (*c*) Achievement class from compensatory score and assignment rules; (*d*) Slider for user-adjusted by-dimension weighting; (*e*) Footnote explaining assignment rules for the dimension; (*f*) Reset button to revert user-adjusted weights to HTA defaults; (*g*) Yearly overall value score using HTA weights; (*h*) KPI performance: green (above *Target*), red (below *Min. acc.*); (*i*) Partial value scores for each criterion.

Sliders are provided to allow users to activate the *Interactive* model mode by adjusting dimension weights according to their personal preferences, within predefined boundaries. These boundaries ensure that the weights remain relevant for fulfilling the RPM program objectives. If users wish to reset the dimension weights to the default *HTA* model mode, they can do so by clicking the "Reset" button. Adjusting the dimension weights will update the value scores and classification, but the assignment rules remain fixed, as they are necessary conditions for achieving a specific achievement class and maintaining alignment with RPM program objectives.

4.5.2. Foreseen Challenges

The SBI-MD approach presents many key strengths that contribute to its practicality, effectiveness, and relevance. However, one must be aware of potential challenges in real-world applications and try to minimise their impacts if unable to avoid them.

MACBETH enables the creation of a quantitative value model for evaluating RPM programs using PKs' qualitative judgments about differences in attractiveness (or value added to the hospital). These judgments are based on reference levels of RPM performance across multiple criteria (Sanchez-Lopez, Bana e Costa and De Baets, 2012; Bana e Costa, De Corte and Vansnick, 2016). While MACBETH is robust and explainable – enhancing PKs' confidence in the model – challenges may arise in ensuring the long-term appropriateness of criteria and reference levels, especially in volatile, immature program assessment environments. If the evaluation model is developed at an early stage of the RPM program, its objectives may still be evolving. This could lead to criteria that later prove insignificant or omit essential factors. In such cases, revisiting phases of the SBI-MD approach will be necessary, including reconstructing measures, updating reference levels, and reanalysing interrelations between indicators to ensure criteria remain preference-independent. Additionally, weight elicitation must be repeated, as any change to criteria affects the weighting profile.

Another particularly sensitive issue is revising reference values. Changing a criterion's reference values requires reassessing its value scale/function and repeating the weight elicitation process, as these depend on the chosen references. To address this, SBI-MD suggests using a *Target* level representing an aspirational yet achievable performance and a *Min. acc.* level reflecting a neutral baseline. These references should align with the program’s ends objectives, remain stable over time, and be realistic within the program’s timeline (Keeney, 1996). Nonetheless, program managers should also set periodic targets (lower than *Target*) to facilitate monitoring and short-term adjustments, without affecting program evaluation.

To mitigate these risks, the facilitation team must emphasise Phase 1 of SBI-MD, ensuring the assessment model is as durable as possible. While the DataViz aspects of the MMD are less affected by these modelling uncertainties, careful attention to structuring remains crucial. The MMD should act as a requisite model, balancing completeness and simplicity to address key issues without overcomplicating (Phillips, 1984). Overloading the model with excessive value dimensions, KPIs and criteria can make tasks in Steps 2.1 and 2.2 of SBI-MD time-consuming and impractical. Moreover, dashboards, designed for quick, at-a-glance analysis, must consider the cognitive limitations of their end users. The "magical number seven, plus or minus two," is often used as an information system design reference for determining the number of informational elements to present on a single page (Miller, 1956; Eckerson, 2010; Concannon, Herbst and Manley, 2019). Each dashboard page should present a manageable number of KPIs to facilitate clear and actionable insights.

Another potential challenge is determining the optimal timing for incorporating real data from the RPM program into MMD DataViz and models. Integrating real data at the start of SBI-MD’s Phase 2 provides a better context for PKs, helping ensure that the models and visuals align closely with the program’s reality. However, using real data early can complicate DataViz design, as PKs may become distracted by displayed program performances, leading to unrelated discussions among PKs and slowing down social processes. Conversely, delaying data integration until the end of Phase 2 helps maintain the PKs' focus, as using synthetic data promotes a conjectured analysis. This approach allows clearer thinking about the visualisations and models without being influenced by real-world complexities. However, the downside is ensuring the correct calculation of performance measures and value functions when the real data is eventually integrated.

Both approaches have advantages and drawbacks. If real data is available at the start of Phase 2, early integration is generally recommended due to its importance for context in MMD development. However, in many cases, building the full data workspace for the RPM program takes time. Waiting for this data can significantly delay the rest of the system’s development.

Lastly, defining appropriate variation ranges for the user-adjusted dimension weights presents a significant challenge due to the interdependence of weight ranges across different value dimensions and the associated constraints. To preserve the meaningfulness of these intervals, we propose using the maximum and minimum weights for each value dimension as defined during the decision interviews as interval boundaries. However, this approach may lead to overlapping ranges or impractical scenarios, as the sum of all weights must always equal 1. Additionally, no value dimension should weigh zero or one, as this would distort the group's perspective. Each user can (and should) express their personal view of the relative importance of each value dimension but must also respect the group's consensus that all dimensions are relevant and should contribute to the program's value. These constraints create a complex mathematical optimisation problem that demands advanced techniques and resources not addressed in SBI-MD, representing a limitation that future research must tackle.

4.5.3. Directions for Future Work

While the SBI-MD approach brings innovative and robust methods and tools for developing MMD tools for RPM program management, several avenues for future research remain, which could further enhance our proposed approach.

The ability for users to adjust value dimensions weights using interactive sliders in the MMD is a powerful tool for fostering discussions and exploring different perspectives on the success or failure of an RPM program. However, the constraints on weight variation may prevent users from fully expressing contrasting viewpoints about the importance of specific criteria within a value dimension. For example, one stakeholder might prioritise patient health status and QoL, while another might focus more on reducing mortality. Therefore, the possibility of adjusting weights at the individual criterion level would be valuable to explore. However, there is a need to assess how this would impact the user's cognitive load and whether allowing such interactions at the criterion level is practical within the MMD.

Machine learning algorithms also present promising opportunities for advancing SBI-MD and the tools developed within it. These algorithms can efficiently analyse complex, dynamic, high-dimensional data sets in an automated and rapid manner. By learning from real-time data, they can identify patterns, predict outcomes, and optimise decisions, enhancing the accuracy and adaptability of MMDs. Additionally, these algorithms could enable more user-friendly features for conducting performance analysis in RPM programs, such as allowing users to ask questions about specific criteria or KPIs in natural language or recommending corrective actions for underperforming program dimensions. Future research could also explore hybrid models that combine machine learning with MACBETH e.g., predictive models, using machine learning to supplement stakeholders' qualitative judgments with data-driven insights from past decisions or program performance history, for generating initial KPI or criteria sets, exploring their interrelations, or help reconcile value functions.

Another potential direction for future work is to investigate forecasting methodologies to develop an MMD module that complements the monitoring and evaluation modules. A forecasting module could enable projections of the RPM program's expected evolution and assist in negotiating timelines for achieving specific goals, such as identifying the year when the program should attain an EXCELLENT achievement class. Since an MMD, developed using SBI-MD, will aggregate all relevant program information across years of activity and the necessary components for such a model are already structured, pursuing forecasting capabilities appears to be a logical next step.

CHAPTER 5

UNLOCKING CONTINUOUS IMPROVEMENT IN HEART FAILURE REMOTE MONITORING: A PARTICIPATORY APPROACH TO UNVEIL VALUE DIMENSIONS AND PERFORMANCE INDICATORS

5.1. Chapter Summary

HF constitutes a public health concern affecting QoL, survival, and costs. Chapters 2 and 3 showed that HF management has become a focal area of RPM implementation, given the potential benefits associated with actively involving patients and improving follow-up. While current HF RPM assessments emphasise CEA, there is a need to consider wider RPM impacts and integrate stakeholders' perspectives into assessments for better comprehensiveness.

Based on the methods and tools described in SBI-MD's Step 1.2 (Chapter 4), a four-stage participatory approach to select value dimensions and indicators for continuous HF RPM assessment was developed: Stage 1 involved building a literature-informed initial list; Stage 2 utilised expert interviews for validation and list expansion; Stage 3 involved a web-Delphi process with Portuguese stakeholders and experts for agreement assessment; and Stage 4 included a conclusive expert interview.

A literature review identified fourteen studies on telehealth, RPM and HF, informing an initial list of four value dimensions (*Access*, *Clinical aspects*, *Acceptability*, and *Costs*) and 22 indicators. Seven semi-structured interviews validated and further adjusted the list to 38 indicators. Subsequently, the web-Delphi process engaged 29 stakeholders, giving their opinions regarding assessment aspects' relevance and proposing additional elements – one dimension and twelve indicators. Five value dimensions and 38 indicators (76.0%) reached group agreement for selection, while twelve did not reach an agreement. Upon expert appreciation, five dimensions, 43 indicators and six case-mix parameters were considered relevant.

This social approach captured diverse stakeholder perspectives and promoted agreement to create a comprehensive list of pertinent HF RPM monitoring and evaluation indicators, a major contribution of the thesis. Chapter findings confirm the appropriateness and feasibility of SBI-MD Step 1.2 methods, central to Phase 1 of the integrative approach. Moreover, the list informs visualisation and management tool development (addressed in Chapters 6 and 7), aiding day-to-day RPM evaluation and identification of improvement opportunities.

5.2. Introduction

In the past five decades, the population aged 60+ has tripled worldwide, and projections are to triple again by 2050 (Department of Economic and Social Affairs of the United Nations (Population Division), 2020). Although people live longer, they now face more disabilities and a rising prevalence of chronic diseases (Pare, Jaana and Sicotte, 2007). According to the World Health Organization (World Health Organization, 2022), chronic diseases account for 74% of annual deaths, and, along with mental illnesses, expectations are their global economic impact will surpass 40 trillion euros by 2030 (Bloom *et al.*, 2011; Vos *et al.*, 2020). HF is a public health concern among chronic diseases due to its high prevalence, costs, and impact on QoL and survival (Black *et al.*, 2014).

HF is caused by a structural and/or functional cardiac abnormality, resulting in reduced cardiac output and/or elevated intracardiac pressures, often induced by age- and lifestyle-related changes in the cardiovascular system, and frequently coexists with other ailments like hypertension or diabetes (Cowie *et al.*, 2014). In developed countries, approximately 2%-3% of the population is affected by HF, with its prevalence rising to 8% among individuals aged ≥75 years (Apantaku *et al.*, 2022). In Portugal, HF ranked as the second largest cause of hospital activity in 2014, with nearly 19,000 admissions and an average stay of around ten days (Timóteo *et al.*, 2020).

As proper HF management requires continuous surveillance, RPM offers a potential solution by promoting closer patient follow-up even at a distance, encouraging therapy adherence and active patient involvement, ultimately reducing costs, hospital admissions and LoS (Chaudhry *et al.*, 2007). In Chapter 3, the proposed three-tier model for implementing an RPM-based integrated care initiative (Figure 3.2) highlights how RPM leverages an interactive combination of technological and human components, including self-monitoring of vitals and symptoms, patient education, multi-morbidity and adaptive care delivery and technology-enabled shared decision-making.

The COVID-19 pandemic accelerated RPM adoption for HF management, overcoming past barriers (Casale *et al.*, 2021). In Chapter 2, Table 2.1 shows that 13 Portuguese public hospitals offered state-funded HF TM in 2021. Yet, enrolment remained limited, with only 258 treated patients nationwide. This contrasts the estimated 120,000 class II HF patients in Portugal, group for which the European Society of Cardiology recommends TM, as emphasised in Chapter 2's discussion. Chapter 2 also highlighted that challenges like patient and provider scepticism, insufficient telehealth training and expensive setup and maintenance hinder widespread adoption. Moreover, assessment studies still fall short of comprehensively demonstrating RPM value, as shown in Chapter 4's Section 4.2.

RPM assessments often focus solely on health outcomes or intervention's cost-benefit trade-off, applying traditional HTA approaches (Zanaboni *et al.*, 2013; Vestergaard *et al.*, 2020). Nevertheless, as argued in Chapter 4, to effectively assist providers and payers in making informed decisions on RPM adoption, two aspects should be considered (Mohebali and Kittleson, 2021): (*a*) monitoring the adoption behaviours of HF patients and providers; and (*b*) thoroughly evaluating HF RPM impacts. It is essential to recognise that defining and measuring value in health is wildly variable and extends far beyond costs and clinical benefit, as one should account for the socio-economical context of intervention, technology characteristics, local policies, and legal frameworks, which highly influence the indicators considered relevant for RPM continuous monitoring and evaluation (Zhang *et al.*, 2022). Furthermore, existing HTA techniques often lack stakeholder engagement, paramount for comprehensive healthcare assessment and for the uptake of economic evaluation studies (Angelis and Kanavos, 2016).

In complex decision-making contexts, participatory methods aid agreement among stakeholders and facilitate perspective-sharing when conflicts arise (Voinov *et al.*, 2018). Workshops, Delphi processes, interviews and surveys have been used to identify, select or validate monitoring and evaluation indicators and select suitable visualisation formats (Basto-Pereira *et al.*, 2015; Freitas *et al.*, 2018, 2023; Sampurno *et al.*, 2018; Cadilhac *et al.*, 2020; Ignatenko, Ribeiro and Oliveira, 2022). When multiple abovementioned objectives need to be achieved, combining approaches may be necessary (Vieira, Oliveira and Bana e Costa, 2020). For instance, an initial indicator set identified through expert interviews can be validated and refined by a Delphi process involving a broader panel of stakeholders, enhancing the final set's reliability (Salgado *et al.*, 2020; Bana e Costa, Oliveira, Vieira, *et al.*, 2023).

In line with this view, this Chapter proposes a participatory approach that combines evidence analysis and stakeholder engagement to identify key value dimensions and indicators to continuously monitor and inform the evaluation of RPM programs for HF management. The contribution of this Chapter is two-fold. First, by fostering agreement among Portuguese stakeholders on a comprehensive list of HF RPM assessment aspects (beyond cost and clinical aspects) – to our knowledge, the first list at both national and international levels –, informing visualisation and management tool development (addressed In Chapters 6 and 7). Second, by adopting a collaborative and value-based structured approach to identify value dimensions and indicators, validating SBI-MD's Step 1.2 (Chapter 4), as the methods and tools proposed here are based on those described in SBI-MD's Phase 1.

5.3. Methods

Four sequential stages are comprised (Figure 5.1) – evidence analysis to identify relevant information (stage 1), a series of interviews with selected experts (stage 2), a web-Delphi process with a broad stakeholder panel (stage 3), and a final interview with a subject-matter expert (stage 4). This approach is designed to promote knowledge construction among an enlarged and diverse set of stakeholders on which value dimensions and indicators to consider in monitoring and evaluating HF RPM, and embeds the principles of collaborative value modelling (Vieira, Oliveira and Bana e Costa, 2020).

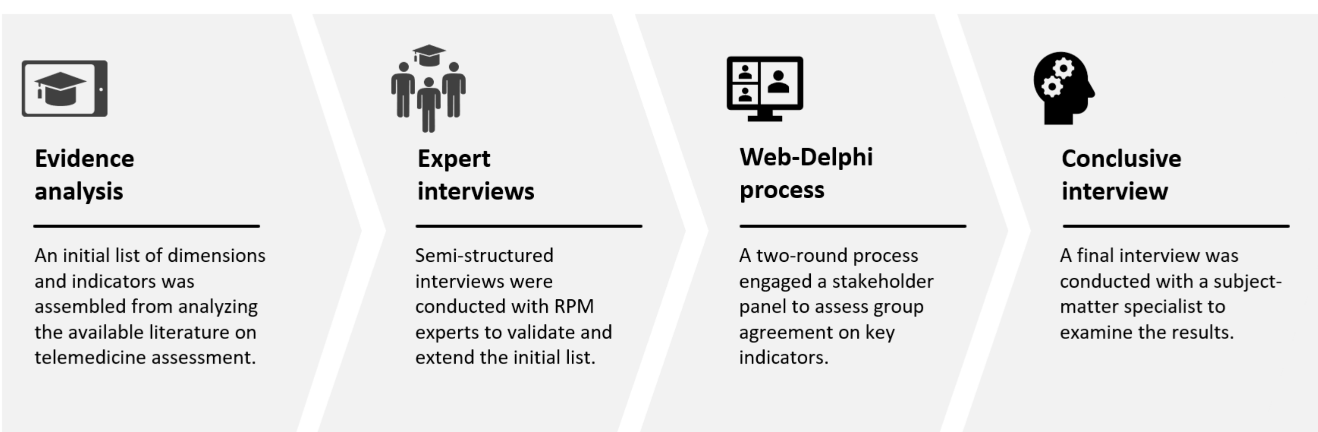


Figure 5.1. Overview of the deployed participatory approach for developing a list of value dimensions and indicators for continuously monitoring and informing the evaluation of RPM programs in HF settings.

5.3.1. Stage 1: Evidence Analysis

Information pertaining HF RPM program assessment was identified through a literature review (Silvério, 2022) examining economic evaluations in HF settings, HTA reports, value assessment frameworks and other related documents. Search queries employed context-specific keywords like "remote patient monitoring," "remote monitoring," "remote care management," "remote care," "home monitoring," "assessment," "technology assessment," "monitoring," "indicators," "KPI," and “heart failure.” Two reviewers jointly analysed and synthesised the collected information into a list of value dimensions and indicators. Included dimensions and indicators were carefully defined for clear and unambiguous interpretation. A third reviewer further validated the initial list.

5.3.2. Stage 2: Expert Interviews

To enhance the initial list, a series of individual online semi-structured interviews was conducted with a restricted panel of Portuguese experts, identified based on previous collaboration engagements with our research team. Invited experts were deemed knowledgeable in telemedicine or cardiology, either through practical experience or ongoing research. To ensure perspective diversity, we aimed to include at least one specialist in each of the following areas: medicine, nursing, healthcare administration, academia and MedTech industry.

The interviews followed a semi-structured format, allowing for flexibility in asking spontaneous follow-up questions. This approach enabled us to seek clarification of the expert's viewpoints and foster in-depth knowledge sharing (Voinov *et al.*, 2018). The predefined questions asked were as follows:

1. *In your view, should this value dimension (indicator) be considered when monitoring and evaluating an RPM program targeting HF?*
2. *Do you find this description of the value dimension (indicator) clear and accurate?*
3. *Considering the study's purpose, would you suggest any changes or additional dimensions (indicators)?*

While the first two questions concerned each individual value dimension (indicator), the third concerned the overall set.

5.3.3. Stage 3: Web-Delphi Process

The third stage aimed at (*a*) assessing stakeholders’ agreement on each HF RPM value dimension and indicator and (*b*) providing completeness on the list resulting from expert interviews. A two-round web-Delphi process was conducted and administered through the Welphi platform (http://www.welphi.com/) (Decision Eyes, 2020). Two rounds were considered ideal for preventing overwhelming and minimising the likelihood of a high dropout rate.

Participants selection followed a purposive sampling strategy targeting healthcare professionals (i.e., doctors, nurses, technicians) and administrators, academics, industry or other professionals who were (*a*) found to be involved in RPM programs in Portugal (according to Tables 2.1 and 2.2 [Chapter 2]), (*b*) recommended by the Stage 2 participants, or (*c*) identified through a “snowball” effect (Willemse *et al.*, 2014). Since there is no consensus on the optimal panel size for a Delphi process (Freitas *et al.*, 2018; Salgado *et al.*, 2020), we aimed at including as many qualified participants from all stakeholder groups as possible.

Web-Delphi panel members were invited to participate through email. Upon registration on the Welphi platform, participants were directed to an introductory page providing context and study objectives. Participants were required to complete an informed consent form and provide demographic information. As panel members frequently hold multiple roles (e.g., being a physician and a researcher), they were asked to indicate which stakeholder group was being considered while responding.

Next, participants were invited to give their opinion on the relevance of each RPM value dimension and corresponding indicators. The process was conducted using a five-level Likert scale, with the following options: *strongly disagree* (SD), *disagree* (D), *neither disagree nor agree* (NDA), *agree* (A), and *strongly agree* (SA). An additional option, *do not know/do not want to answer* (DK/DA), was included. Participants could also provide comments and suggestions for each dimension/indicator individually. Finally, a closing question invited participants to add other value dimensions or indicators to the existing list in case they sensed incompletion.

In the second round, participants were given similar screens (except for the final question from the first round) but with access to their previous answers, first-round answers' distribution, and other participants' comments. Participants were encouraged to review their answers considering the acquired knowledge and express their opinions on the aspects emerging from the first round's final question.

The type of group agreement regarding analysed value dimensions and indicators was determined by applying Eq. (5.1), which defines a set of decision rules adapted from (Freitas *et al.*, 2018):

$$Agreement = \begin{cases} Rej.\,if\ SD + D > 50\% \\ App.\,if \begin{cases} SD + D < 33.3\% \ \cap \ SA > 50\%\ (AM) \\ A + SA > 75\%\ (QM) \end{cases} \\ NA\ if\ else \end{cases} \tag{5.1}$$

where *App.* signifies "approval," *AM* is "absolute majority," *NA* is "no agreement," *QM* is "qualified majority," and *Rej.* is "rejection."

5.3.4. Stage 4: Conclusive Interview

A final interview was conducted with a nursing and business administration specialist, working at industry assisting clients in enacting value-based healthcare initiatives, including RPM. Moreover, the expert is certified by the Portuguese General Health Department for facility assessment. Given their clinical and technical proficiency, a thorough examination of the web-Delphi process outcomes was deemed relevant. The interview aimed yielding further insights into RPM value dimensions and indicators, drawing conclusions, and proposing final list adjustments.

5.4. Results

5.4.1. Stage 1: Initial HF RPM Dimensions and Indicators List

A literature search was initiated June 6, 2022, covering bibliographic databases including Google Scholar, PubMed, and EMBASE. Fourteen studies (including the one reported in Chapter 3) were retrieved pertaining to telehealth HTA, assessment of RPM programs and interventions for managing HF (Scott *et al.*, 2003; Heinzelmann *et al.*, 2005; Lampe *et al.*, 2009; Kidholm *et al.*, 2012; Bongiovanni-Delarozière and Le Goff-Pronost, 2017; Sekhon, Cartwright and Francis, 2017; National Quality Forum, 2017; Ware *et al.*, 2020; Nunes-Ferreira *et al.*, 2020; Dawson *et al.*, 2021; Faragli *et al.*, 2021; McDonagh *et al.*, 2021; Mitterer *et al.*, 2021). The initial list was significantly influenced by four frameworks (Scott *et al.*, 2003; Kidholm *et al.*, 2012; Bongiovanni-Delarozière and Le Goff-Pronost, 2017; National Quality Forum, 2017), informing the essential value dimensions with potential relevance for monitoring and evaluating HF RPM programs. Afterwards, the most appropriate indicators for each dimension were selected based on the findings from the remaining studies.

Four value dimensions were defined: *Access*, *Clinical aspects*, *Acceptability*, and *Costs*. Subsequently, 22 indicators were categorised into these four value dimensions: 7 for *Access*, 8 for *Clinical aspects*, 2 for *Acceptability*, and 5 for *Costs*. Table 5.1 contains the initial list, descriptions for each dimension and indicator, and the consulted sources informing identification.

Table 5.1. Initial list of four value dimensions and 22 indicators, retrieved from the evidence analysis.

Value dimensions and indicators	**Description**
Acceptability	**Acceptability refers to the perception that patients admitted to the remote monitoring program have regarding the adequacy of the program to their condition and context. On the other side, it refers to the perception that health professionals have regarding the adequacy of the program to provide care to patients.**
Level of self-care	Ability of a patient to preserve or improve one’s own health. Measure of self-efficacy with medications, diet, symptoms control, etc.
User satisfaction	Measurement of the patient or healthcare professional’s global impression of the program. Measures the degree to which the medical service corresponds to their expectations.
Access	**Access refers to the timely receipt of appropriate care. In other words, it is related to the ease or difficulty in obtaining care, or the availability of the right care at the right time without undue burden.**
Length of stay	The time that each patient spent in the unit before discharge or death.
Number of emergency visits	Number of emergency visits resulting in admission to critical care unit.
Number of HF-related hospitalisations	Times a patient received treatment in a hospital due to heart failure (HF).
Number of hospital readmissions	Times a patient return to the hospital after discharge to remote monitoring during a given period.
Number of km to nearest healthcare facility	Distance to the nearest hospital or clinic (primary, secondary, or tertiary care).
Number of teleconsultations	Number of telehealth sessions with a health professional in a given time (e.g., week/month).
Waiting time for a teleconsultation	Waiting time between the appointment and the tele- consultation with the health professional of expertise.
Clinical aspects	**Clinical aspects refer to the effects of the condition and/or services provided that affect the patient. They are based on or characterized by being observable and diagnosable symptoms (e.g. symptom relief, improved mobility, survival).**
All-cause mortality	Number of death occurrences during a given period (e.g., full program length).
Comorbidities	Knowledge of patients’ comorbidities is very important given their effects upon mortality, clinical outcomes, hospitalisations, functional status, and discharge status.
HF-related mortality	Number of death occurrences due to heart failure causes during a given period (e.g., full program length).
Left ventricular Ejection Fraction (LVEF)	Percentage of blood that is pumped out of a full left ventricle with each heartbeat.
Mental health	Assessment of the mental status of an individual (e.g., Anxiety, depression).
NYHA classification	The New York Heart Association (NYHA) classification of heart failure stratifies patients with HF according to their symptoms and to the physician’s objective assessment of the patient.

NT-ProBNP level (pg/ml)	Measurement of the levels of N-terminal pro-B-type natriuretic peptide (NT-proBNP).
Quality of life	Degree to which an individual is healthy, comfortable, and able to participate in or enjoy life events.
Costs	**The actual cost associated with providing health services through a remote monitoring program.**
Administrative	Cost of the paperwork; Supplies; Space.
Equipment	Maintenance fees; Installation charges; Depreciation rate; Software.
Staffing	Salaries and wages; Fees for service; Hospital personnel costs; Training.
Telecommunication	Investment costs of equipment and line charges; Telecommunication services; Cell phone usage.
Travel	Patient/clinician travel costs; Transport

5.4.2. Stage 2: Validation and Extension of the Initial List

Seven semi-structured interviews were conducted (28 July-9 August 2022) with experts and stakeholders from different and complementary backgrounds: medicine (2), nursing (2), MedTech industry (2) and digital health research (1). Interviews were conducted online using Microsoft Teams™, a video conferencing platform. Each interview lasted approximately 45 to 60 minutes.

The initial list expanded from 22 to 38 indicators after the interviews' completion. Modifications included splitting three indicators into six separate ones (for *Number of teleconsultations*, *Length of stay* and *User satisfaction*) and introducing 18 entirely new indicators. Notably, all initial *Costs* indicators were replaced. Table 5.2 presents an overview of the modifications made to the list from Table 5.1.

Table 5.2. Modifications to the HF RPM indicators list, resulting from the expert interviews' process.

Dimension	Stage 1 indicator	Modification	Stage 2 indicator
Access	Length of stay	Division	Length of stay in intensive care Length of stay in ward
	Number of teleconsultations	Division	Number of scheduled teleconsultations Number of unscheduled teleconsultations
		Addition	Number of days of activity lost Number of program dropouts Number of scheduled face-to-face consultations Number of unscheduled face-to-face consultations Patients followed by the RPM program (%) Time to medical action Waiting time for a face-to-face consultation
Clinical aspects	Mental health	Name change	Mental health self- perception
	Quality of life	Name change	Quality of life self-perception
		Addition	Classification of HF according to LVEF
Acceptability	User satisfaction	Division	Health professional satisfaction Patient satisfaction
		Addition	Caregiver overload Error rate (%) Patient adherence to the program
Costs	Administrative Equipment Staffing Telecommunication Travel	Replacement	Costs of hospitalisation in intensive care Emergency service admission costs Face-to-face consultations costs Hospital admission costs Program cost per patient Surgical intervention costs Teleconsultation costs

5.4.3. Stage 3: Group Assessment of RPM Dimensions and Indicators

A total of 43 experts or stakeholders were identified and invited to participate in the web-Delphi process. The first round (30 August-10 September 2022) was completed by 29 participants (67.4% acceptance rate), with 24 (17.2% dropout rate) completing the second round (11-23 September 2022). Working sector and stakeholder group distributions and the respective dropout rates are presented (Table 5.3).

Table 5.3. Characteristics of the web-Delphi panel (invited and accepting participants) and dropout behaviour.

Characteristic		Invited	Participants		Dropout (%)
			Round 1	Round 2	
Working sector	Private	18	14	13	7.1%
	Public	25	15	11	26.0%
Stakeholder group	Academics	7	6	5	16.0%
	Doctors	14	8	5	37.5%
	Hospital administration	8	4	4	0.0%
	Industry	9	6	5	16.0%
	Information systems	1	1	1	0.0%
	Nurses	2	2	2	0.0%
	Therapeutics and diagnostics technicians	2	2	2	0.0%
TOTAL		**43**	**29**	**24**	**17.2%**

After participants completed the second and final round of the web-Delphi process, results were analysed. Table 5.4 presents the distribution of responses from the panel for each dimension and respective indicators. Moreover, it indicates the type of agreement (or absence thereof) as determined according to Eq. (5.1).

Table 5.4. Results from the web-Delphi process, presenting group response percentages and type of agreement.

Dimension	Indicator	Group response (%)						Agreement
		SD	D	NDA	A	SA	DK/DA	
Access		0%	0%	0%	13%	88%	0%	**AM**
	Number of km to nearest health care facility	0%	17%	4%	46%	33%	0%	**QM**
	Patients followed by the RPM program (%)	0%	4%	4%	46%	46%	0%	**QM**
	Number of program dropouts	0%	13%	4%	46%	38%	0%	**QM**
	Number of days of activity lost	0%	8%	8%	25%	54%	4%	**AM**
	Time to medical action	0%	4%	4%	21%	71%	0%	**AM**
	Number of scheduled teleconsultations	0%	4%	17%	33%	42%	4%	NA
	Number of unscheduled teleconsultations	0%	4%	8%	33%	54%	0%	**AM**
	Number of scheduled face-to-face consultations	0%	0%	21%	42%	33%	4%	NA
	Number of unscheduled face-to-face consultations	0%	0%	17%	33%	50%	0%	**QM**
	Waiting time for a teleconsultation	4%	4%	8%	38%	42%	4%	**QM**
	Waiting time for a face-to-face consultation	4%	4%	4%	50%	38%	0%	**QM**
	Number of emergency visits	0%	0%	4%	8%	83%	4%	**AM**
	Number of HF-related hospitalisations	0%	0%	0%	8%	88%	4%	**AM**
	Number of hospital readmissions	4%	0%	13%	25%	50%	8%	NA
	Length of stay in intensive care	4%	8%	13%	46%	25%	4%	NA
	Length of stay in ward	0%	4%	17%	42%	33%	4%	NA
Clinical aspects		0%	0%	0%	13%	88%	0%	**AM**
	Quality of life self-perception	0%	0%	0%	17%	83%	0%	**AM**
	Mental health self-perception	0%	0%	0%	33%	67%	0%	**AM**

	All-cause mortality	4%	8%	13%	33%	42%	0%	NA
	HF-related mortality	0%	0%	4%	25%	71%	0%	**AM**
	Comorbidities	0%	4%	4%	25%	67%	0%	**AM**
	NT-ProBNP level (pg/ml)	0%	0%	4%	33%	25%	38%	NA
	Left ventricular ejection fraction (LVEF)	0%	0%	4%	29%	33%	33%	NA
	NYHA classification	0%	0%	0%	21%	42%	38%	NA
	Classification of HF according to LVEF	0%	0%	13%	21%	42%	25%	NA
	Oedema self-perception ([a])	0%	0%	8%	21%	54%	17%	**AM**
	Level of physical activity ([a])	0%	0%	0%	42%	54%	4%	**AM**
	Biosignals ([a])	0%	0%	0%	8%	88%	4%	**AM**
	Number of alerts generated and severity of alerts ([a])	0%	0%	13%	42%	46%	0%	**QM**
	Avoidable hospital admissions due to heart failure compared to the homologous period (%) ([a])	0%	4%	4%	21%	71%	0%	**AM**
	Number of implantable device events ([a])	0%	0%	4%	17%	75%	4%	**AM**
Acceptability		0%	0%	0%	13%	88%	0%	**AM**
	Patient adherence to the program	0%	0%	0%	4%	96%	0%	**AM**
	Level of self-care	0%	0%	8%	42%	50%	0%	**QM**
	Caregiver overload	0%	0%	8%	42%	50%	0%	**QM**
	Error rate (%)	0%	0%	8%	33%	50%	8%	**QM**
	Patient satisfaction	0%	0%	0%	4%	92%	4%	**AM**
	Health professional satisfaction	0%	0%	0%	17%	79%	4%	**AM**
	Medication/therapy adherence ([a])	0%	0%	0%	13%	88%	0%	**AM**
	Users with weight registered on half of the year's days (%) ([a])	0%	4%	25%	38%	25%	8%	NA
	Patient's trust in the program ([a])	0%	0%	4%	17%	79%	0%	**AM**
	Disease management capacity after the program ([a])	0%	0%	13%	21%	67%	0%	**AM**
Costs		0%	0%	0%	33%	67%	0%	**AM**
	Costs of hospitalisation in intensive care	0%	4%	4%	38%	54%	0%	**AM**
	Hospital admission costs	0%	4%	4%	33%	58%	0%	**AM**
	Teleconsultation costs	0%	4%	4%	33%	58%	0%	**AM**
	Face-to-face consultations costs	0%	8%	4%	46%	42%	0%	**QM**
	Surgical intervention costs	0%	8%	8%	29%	54%	0%	**AM**
	Emergency service admission costs	0%	4%	4%	42%	50%	0%	**QM**
	Program cost per patient	0%	0%	4%	21%	75%	0%	**AM**
	Patient travel costs to scheduled appointments ([a])	0%	4%	21%	46%	29%	0%	NA
	Costs for the patient ([a])	0%	4%	4%	46%	46%	0%	**QM**
Technology ([a])		0%	4%	13%	29%	50%	4%	**QM**

Notes: ([a]) Dimensions or indicators added during the first round; SD = Strongly disagree; D = Disagree; NDA = Neither disagree nor agree; A = Agree; SA = Strongly agree; DK/DA = Do not know/do not want to answer; AM = approval by absolute majority; NA = no agreement; QM = approval by qualified majority. Colour scheme: Group response % (GR%): □ GR% < 25%; ■ GR% ≥ 25%; ■ GR% ≥ 50%; ■ GR% ≥ 75%.

From the list generated during the semi-structured interviews and presented to the panel since the first round, all dimensions (4, AM agreement) and 28 indicators (71.1%) reached a group agreement for approval. Specifically, 68.8% of indicators from *Access* (11, 5 AM) and 44.4% from *Clinical aspects* (4, all AM) reached agreement for approval. All indicators from *Acceptability* (6, 3 AM) and *Costs* (7, 5 AM) reached agreement for approval. No agreement was reached on the remaining 10 indicators.

Regarding the value dimensions and indicators contributed by the participants at the end of the first round, the same rules from Eq. (5.1) were applied. The panel had suggested a total of 12 indicators and one dimension (*Technology*), from which 10 indicators (83.3%, 8 AM) and the dimension (QM) reached a group agreement for approval. Overall, in the final round of the web-Delphi process, the panel have examined a total list of five value dimensions and 50 indicators, reaching agreement for the approval of all dimensions and 38 indicators, while agreement was not reached on 12 indicators.

5.4.4. Stage 4: Final Subject-Matter Appreciation

Findings were shared with a subject-matter specialist for further insights on the list and conclusive refinements. Noteworthy remarks from the interview can be found in the Appendix of the thesis document.

After incorporating the expert's input and making minor adjustments to indicator descriptions and names (e.g., changing *Costs of hospitalisation in intensive care* to *ICU hospitalisation costs*), the final list of relevant dimensions and indicators to be considered for ongoing assessment of HF RPM programs was established (Table 5.5). This list encompasses a case-mix comprising 6 parameters, 5 value dimensions, and 43 indicators. The breakdown includes: 14 for *Access*, 10 for *Clinical aspects*, 9 for *Acceptability*, 8 for *Costs*, and 2 for *Technology*.

Table 5.5. Final list of HF RPM value dimensions and indicators.

Dimension	Description
Access	**Ability to readily obtain healthcare services, including services availability, appropriateness of care and geographical proximity to healthcare facilities, ensuring equitable and timely access to care.**
Eligible patients followed by the RPM program (%)	Percentage of eligible HF patients from the healthcare institution who are enrolled in the remote monitoring program.
Length of stay in the ward	Average length of stay, in days, in the hospital ward due to HF-related causes before discharge or death, within program duration.
Length of stay in intensive care	Average length of stay, in days, in the intensive care unit due to HF-related causes before transfer or death, within program duration.
Number of days of activity lost	Total days of absence or reduced activity due to health-related needs (e.g., emergency room admission, hospitalisation, premature death).
Number of HF-related emergency visits	Total count of admissions to the emergency department due to HF-related causes within the program duration.
Number of HF-related hospitalisations	Total count of inpatient admissions (to ward or ICU) due to HF-related causes within the program duration.
Number of HF-related readmissions	Total count of subsequent admissions (ED or ward/ICU) after first discharge due to HF-related causes within the program duration.
Number of scheduled face-to-face consultations	Total count of in-person appointments as defined by the patient's care plan.
Number of unscheduled face-to-face consultations	Total count of unplanned in-person appointments within the program duration.
Number of scheduled teleconsultations	Total count of teleconsultation sessions as defined by the patient's care plan.
Number of unscheduled teleconsultations	Total count of unplanned teleconsultation sessions within the program duration.
Waiting time for a face-to-face consultation	Time, in days, from appointment request to initiation of an in-person consultation.
Waiting time for a teleconsultation	Time, in days, from appointment request to initiation of a teleconsultation session.
Time to medical action	Duration of time, in minutes, from an alert of patient deterioration or decompensation to taking appropriate action for intervention and monitoring.
Clinical aspects	**Medical and healthcare-related effects of the intervention, characterized by measurable and observable outcomes (e.g., symptoms, survival, well-being perception, need for intervention).**
Avoidable hospital admissions due to HF compared to the homologous period (%)	Percentage of preventable hospital admissions related to HF within the program duration, compared to, e.g., same month-last year, previous year.
Biosignals	Average monthly days with, at least, one vital sign measurement outside the range considered normal according to patient HF classification.
Left ventricular ejection fraction (LVEF)	Percentage of enrolled patients with worsened levels of blood pumped out of the (full) left ventricle with each heartbeat within the program duration.

HF-related/All-cause mortality ratio	Ratio between the number of deaths directly linked to HF and all occurring deaths within the program duration.
Number of alerts generated and severity of alerts	Count and severity of alerts related to patient deterioration or decompensation for timely intervention and monitoring.
Level of physical activity	Measurement of patients' physical activity levels.
NT-ProBNP level (pg/ml)	Average monthly days with N-terminal pro-B-type natriuretic peptide (NT-proBNP) levels outside the range considered normal according to patient HF classification.
Mental health self-perception	Measurement of patients' subjective perception of their mental health status (e.g., anxiety, depression).
Oedema self-perception	Measurement of patients' subjective perception and self-assessment of oedema (swelling).
Quality of life self-perception	Measurement of patients' subjective perception of their overall health status and well-being and ability to participate in or enjoy moments of everyday life.
Acceptability	**Willingness and satisfaction of patients, caregivers, or healthcare providers with a remote monitoring program, reflecting its convenience, usability, and precepted adequacy for patient care.**
Patient adherence to the program	Overall measurement of patients' compliance and adherence to the care plan and healthcare professionals' recommendations (e.g., technology, medication, diet, lifestyle change).
Patient satisfaction	Overall measurement of satisfaction among patients with the remote monitoring program.
Health professional satisfaction	Overall measurement of satisfaction among health professionals with the remote monitoring program.
Caregiver overload	Measurement of stress or burden (i.e., physical, mental, social or financial) felt by the informal caregiver of an enrolled patient.
Disease management capacity after the program	Measurement of patients' ability to manage their disease after program completion.
Level of self-care	Measurement of patients' ability to independently manage their health status and use technologies to perform self-assessment.
Patient's trust in the program	Measurement of patients' confidence and belief in the effectiveness and reliability of the program.
Medication/therapy adherence	Average monthly days a patient has not complied with prescribed medication or therapy.
Number of program dropouts	Count of patients who abandoned the program before its planned completion.
Costs	**Overall expenses incurred while providing health services through a remote monitoring program.**
Program cost per patient	Total cost associated with a patient's clinical pathway within the program duration.
Costs for the patient	Total expenses directly incurred by the patient within the program duration.
Emergency service admission costs	Total cost associated with admitting patients to the emergency department within the program duration.
Hospital admission costs	Total cost associated with patient hospitalisation within the program duration.
ICU hospitalisation costs	Total cost associated with patient hospitalisation in the intensive care unit (ICU) within the program duration.
Surgical intervention costs	Total cost associated with surgical interventions within the program duration.
Face-to-face consultations costs	Total cost associated with (scheduled and unscheduled) face-to-face consultations within the program duration.
Teleconsultation costs	Total cost associated with (scheduled and unscheduled) teleconsultations within the program duration.
Technology	**Outcomes associated with properly using information and communication technologies for healthcare delivery, measured in terms of efficiency, effectiveness and user satisfaction.**
Number of implantable device events	Count of occurrences involving implantable medical devices, such as malfunctions or interventions.
Error rate (%)	Percentage of errors or mistakes (e.g., incorrect measurement or data entry, data transmission failing) leading to false or missing alarms in a specified timeframe.
Case mix	**Set of variables used to describe and quantify the complexity and types of patients enrolled in the remote monitoring program, helping to assess and compare the patient population's diversity and acuity across different HF programs or providers.**
Age group	Categorization of individuals based on their age range for demographic analysis and care planning.
Classification of HF according to LVEF	Categorization of HF based on LVEF. There are three classes: HF with reduced ejection fraction, HF with slightly reduced ejection fraction, or HF with preserved ejection fraction.
Comorbidities	Knowledge of additional ailments occurring alongside the program's primary condition. In HF, common comorbidities include hypertension, diabetes and chronic obstructive pulmonary disease.
Distance to the nearest healthcare facility	Distance, in kilometres, from the patient's residence to the nearest healthcare facility (primary, secondary, or tertiary care).
Literacy level	Individuals' ability to read, write, comprehend basic information and use digital tools.
NYHA classification	The New York Heart Association (NYHA) categorization of HF severity based on functional limitations, symptoms and the physician's objective assessment.

5.5. Discussion

This Chapter contributes to the literature in two primary aspects: (*a*) it provides a stakeholder-agreed list of dimensions and indicators for monitoring and evaluating HF RPM programs. This outcome marks an initial step towards addressing the lack of standardised criteria for effectively demonstrating the value of RPM programs; (*b*) the proposed participatory approach has a versatile and transferable nature while maintaining robustness through a rigorous design, enabling its application to different contexts and fields. Notably, to our knowledge, this is the first study combining evidence analysis and stakeholder engagement in selecting value aspects for assessing an HF RPM program.

Regarding the methodological approach, conducting iterative review stages for the list of HF RPM value dimensions and indicators (e.g., semi-structured interviews after evidence analysis, followed by web-Delphi) proved valuable and confirmed the appropriateness and feasibility of SBI-MD Step 1.2 methods. Comprised stages allowed adding previously overlooked aspects and permitted formal modifications to the list (e.g., refining descriptions to enhance clarity and straightforwardness). Through this ongoing validation and enhancement process, a coherent, exhaustive, and non-redundant list of assessment aspects was achieved. Moreover, as all stages of stakeholder engagement were executed remotely, we enjoyed the flexibility of involving experts regardless of their geographic location. Additionally, scheduling was streamlined, resulting in the successful completion of all seven interviews in less than two weeks and in gathering additional feedback from 29 acknowledged Portuguese stakeholders within a timeframe of 25 days.

Regarding the results, there are several notable observations. Firstly, during the interviews, the indicators falling under *Costs* generated the most extensive discussions, ultimately leading to a complete replacement – interviewees considered that the initial cost indicators (i.e., *Administrative*, *Equipment*, *Staffing*, *Telecommunication* and *Travel*) should be classified as cost components rather than standalone cost indicators. It is worth noting, however, that all the newly proposed indicators incorporate these cost components within their metrics. For instance, *Teleconsultation costs* will inevitably factor in telecommunication and staffing costs.

Secondly, the approach proved effective in encouraging discussion and reflection among participants, facilitating group agreement. Following two web-Delphi rounds, results demonstrated a notable convergence of opinions on all *Costs* indicators. Concerning *Acceptability*, strong group agreement was evident from the outset, with each indicator revelling 86% to 96% A+SA responses in the first round. This trend persisted during the second round, with all indicators surpassing 83% A+SA responses. Regarding *Access* and *Clinical aspects*, comparatively lower agreement levels were noted. Interestingly, within *Clinical aspects*, indicators achieving AM or QM displayed increasing agreement throughout the process. In contrast, indicators with NA experienced a decline in group agreement between rounds (excluding *All-cause mortality*). Lastly, regarding *Access*, it is noteworthy highlighting the indicators *Waiting time for a teleconsultation* and *Number of days of activity lost* as these showed significant shifts in group agreement between rounds (transitioning from NA to AM and QM, respectively).

Lastly, *NT-PROBNP level (pg/ml)*, *Left ventricular ejection fraction (LVEF)*, *NYHA classification* and *Classification of HF according to LVEF*, indicators pertaining to *Clinical aspects*, presented high DK/DA response rates. This same trend was observed during Stage 2, where some interviewees refrained from expressing opinions due to "lack of knowledge about the condition." These findings emphasise the significance of involving specialists who possess expertise in the health condition. Considering this, an alternative strategy for assessing *Clinical aspects* indicators could involve restricting participation to health professionals. This adjustment might alleviate the questionnaire's length-related burden for other participants, without compromising the reliability of the results. This strategy is evident in the studies discussed in Chapters 6 and 7, which primarily involve cardiology physicians and nurses, key stakeholders in HF RPM program management.

5.5.1. Limitations

While efforts were taken for methodological rigor, there are still some limitations. Firstly, the research was conducted solely in Portugal, with national stakeholders, possibly constraining result generalisation. Nevertheless, the initial list drew from international literature, offering insights beyond Portugal. Furthermore, employing a web-Delphi process post interviews validated results and suggested additional aspects, minimising bias towards available telemedicine, HF or Portuguese healthcare literature. This limitation was further addressed in the thesis by involving stakeholders from two different national healthcare institutions – HESE (Chapter 6) and HSM (Chapter 7) – to explore the potential for generalisation within the national context.

Secondly, an imbalance was observed across stakeholder groups in the web-Delphi panel, with medical doctors representing a significant proportion (27.6% of the panel). While this uneven distribution is typical in Delphi processes, as panels are often purposive or convenience-guided, efforts were made (e.g., sending invitations and reminders) to encourage participation and prevent dropout, particularly in underrepresented groups like nursing and technical fields.

Lastly, the Delphi process itself has inherent limitations. Interactions among participants can introduce cognitive biases, such as the influence of majority positions. Moreover, the large number of assessed indicators could be overwhelming. Addressing these concerns, the participant panel was diverse and acknowledged, indicators were grouped by value dimension for ease of assessment, and participants had the flexibility to focus on specific dimensions at their convenience.

5.6. Conclusions

This Chapter presents a comprehensive and stakeholder-validated list of value dimensions and indicators for monitoring and evaluating HF RPM programs. This information can be valuable for new and existing telemedicine services aiming to assess their practices or compare the quality of care and operational efficiency with other healthcare services. The value aspects included in Table 5.5 will inform the development of DataViz, models, and tools described in Chapters 6 and 7.

We hope this Chapter contributes to standardising and strengthening frameworks and tools for RPM HTA processes and supporting continuous improvement of remote care initiatives. Given that the development and testing of a visualisation and management tool that can effectively operationalise the selected list of HF RPM indicators was identified as a top priority following the study reported in this Chapter, the subsequent Chapters focus on addressing this need.

CHAPTER 6

CO-DESIGNING HEALTHCARE MANAGEMENT DASHBOARDS: A NOVEL APPROACH TOWARDS STAKEHOLDER-ALIGNED DATA VISUALISATION

6.1. Chapter Summary

Clinical, operational, and financial data are crucial for informed decisions in healthcare, but deriving insights from vast, sparse datasets is cognitively challenging and prone to interpretation errors. Dashboards offer user-friendly analytics to combat data overload, but adoption suffers due to user unfamiliarity and a lack of tailored solutions, as end users are often excluded from the design process.

This Chapter introduces a novel collaborative approach to engage dashboard users in designing prototype reports based on predefined KPIs, addressing the top priority identified in Chapter 5 of developing a tool to operationalise the selected HF RPM indicators. Employed methods and tools are based on those outlined in SBI-MD's Step 2.1 (Chapter 4). Through a literature-informed analysis of the communication properties of KPIs, by-KPI sets of suitable DataViz formats are identified. Then, the CDB workshop follows, leveraging a modified NGT to select preferred formats for each KPI to integrate the dashboard. Participants then review prototype reports, which are rapidly built on-site, offering suggestions for visual coherence improvement.

To maintain domain coherence with Chapter 5, a use case in HF RPM in a Portuguese public hospital (HESE) describes the approach application under real-world conditions. Six HF RPM experts and potential users were engaged in a hybrid-format workshop to collectively analyse the six case-mix parameters and 17 of the 43 KPIs identified in Chapter 5, focusing on RPM program *Access* and *Clinical aspects*. This collaborative process facilitated consensus on the co-creation and validation of two dashboard pages, tailored to meet group needs and expectations.

Chapter findings underscore the added value of involving stakeholders in dashboard design. By fostering direct collaboration, the process bridges the gap between end-user preferences and developer perspectives while encouraging consensus through a structured yet user-friendly methodology. A post-workshop survey revealed high participant satisfaction and strong approach endorsement. This process validated SBI-MD's Step 2.1 and demonstrated the value of using the social approach independently for rapid dashboard development.

6.2. Introduction

The widespread adoption of digital technologies led to massive data generation across industries, causing "data overload" that hinders managers' ability to extract information and make decisions (Matheus, Janssen and Maheshwari, 2020), stalling process improvements and innovation (Roberts, Campbell and Vijayasarathy, 2016). As data complexity and volume increase, there is a growing demand for advanced tools to ensure efficient processing and actionable insights (Few, 2006). In response, organisations increasingly rely on BI tools to transform sparse and diverse data into user-friendly visualisations (Phillips-Wren, Daly and Burstein, 2021). As digitalisation advances, DataViz has become essential for conveying complex information (Chung *et al.*, 2020) by leveraging human cognitive abilities and visual perception to enable intuitive pattern recognition, sense-making, correlation inference, and causality identification (Kirk, 2012).

Among BI tools, dashboards provide real-time, actionable information through interactive interfaces using DataViz formats like graphs and charts (Vukšić, Bach and Popovič, 2013), aiding continuous monitoring of KPIs for optimised decision-making (Pauwels *et al.*, 2009). Despite the potential added value, dashboard adoption remains inconsistent (Grover *et al.*, 2018) due to e.g., difficulty in understanding and validating presented information, varying digital literacy among users, and unfamiliarity with the interface (Rabiei and Almasi, 2022). Moreover, designing and developing dashboards is a complex task posing various challenges, namely, creating user-tailored solutions (Kruglov, Strugar and Succi, 2021), managing information volume (Eckerson, 2010) and balancing complexity and usability (Few, 2006), as excessive features may negatively impact the user's decision-making ability (Hou, 2012). Additionally, the choice of visualisation formats and presentation elements is crucial for effectively conveying desired information (Yigitbasioglu and Velcu, 2012).

Within this context, the present Chapter is motivated by two interconnected issues. First, as addressed in Chapter 4, while data are abundant, there is a corresponding scarcity of structured and actionable information. Dashboards have been proposed as a solution, but their adoption is hampered by a second issue: the frequent lack of user involvement during design and development. This often results in systems that become obsolete or remain unused. Thus, this Chapter seeks to address these challenges by proposing innovative methods and tools to foster collaboration in designing cohesive and stakeholder-aligned DataViz. Building on the contributions of Chapter 5 while maintaining domain coherence, an application case related to HF RPM serves as a testbed for the proposed methods. This work was conducted in partnership with HESE, a public hospital in the Alentejo region of Portugal.

6.3. Literature Review

6.3.1. Dashboards in Healthcare Management

In healthcare, where timely detection of issues and prompt interventions can be a matter of life or death, dashboards play a critical role by providing real-time access to patient biosignals, aiding data interpretation and supporting clinical decision-making (Buttigieg, Pace and Rathert, 2017). Beyond clinical monitoring, dashboards address middle management weaknesses in strategy implementation and operations management by integrating fragmented data, consolidating monitoring systems and balancing financial and clinical/operational analyses (Ippolito *et al.*, 2022). Moreover, such inter-organisational systems facilitate value co-creation and group decision-making by overcoming syntax, semantic, and pragmatic knowledge boundaries among diverse stakeholders in interdependent tasks (Shi, Cui and Kurnia, 2023).

Dashboards find various applications in healthcare management, including, among many others, operating room optimisation (Park *et al.*, 2010), ED flux management (Martinez *et al.*, 2018), radiology dose monitoring (Morgan *et al.*, 2008), and chronic care delivery support (Dolan, Veazie and Russ, 2013). Across these applications, dashboards contribute to improved communication and collaboration among health professionals and between patients and care teams, fostering a more transparent and efficient healthcare system (Dowding *et al.*, 2015; Concannon, Herbst and Manley, 2019).

Our use case addresses dashboard implementation for HF RPM program management. Recapping Chapter 5, HF is a chronic disorder caused by a structural and/or functional cardiac abnormality, leading to chronic symptoms of fatigue and shortness of breath, punctuated by sporadic episodes of decompensation. As proper HF management requires close patient surveillance, RPM can offer a potential solution by facilitating patient-physician relationships, and encouraging therapy adherence and patient involvement – ultimately reducing costs, admissions, and hospital stays (Koehler, Koehler, Deckwart, Prescher, Wegscheider, Winkler, *et al.*, 2018). Effective RPM implementation demands real-time insights into program performance, emphasising the need for data aggregation, processing and visualisation support systems like dashboards.

6.3.2. Stakeholder Collaboration in Dashboard Building

Creating a valuable dashboard that caters to user needs demands incorporating input from stakeholders and end users during design and development (Orlando and Sunindyo, 2017), as active collaboration improves the likelihood of sustained acceptance and adoption (François *et al.*, 2021). Such a human-centric digital innovation environment involves individuals from diverse backgrounds, ranging from application specialists and software engineers to policymakers or ordinary citizens. This rich diversity brings varied perspectives to the development process, contributing to more effective and adaptable systems (Hevner and Gregor, 2022).

Participatory approaches promote social cohesion and consensus building by enabling stakeholders to share their perspectives in complex decision-making situations (Keeney, 1996). Yet, one must understand that participatory method selection hinges on participant numbers, decision context, and time or budget constraints (Voinov *et al.*, 2018).

Numerous studies use participatory methods like interviews, surveys (e.g., Delphi), design sessions, and workshops to understand user preferences and achieve consensus among stakeholders in dashboard-building tasks. These tasks include setting design requirements (Dixit *et al.*, 2020; Opie *et al.*, 2021; Salgado *et al.*, 2022; Wang *et al.*, 2023), selecting KPIs and performance measures (as in Chapter 5 or in (Martinez *et al.*, 2018; Vitacca and Vitacca, 2019; Salgado *et al.*, 2020)), developing DataViz (Arcia *et al.*, 2016; Ignatenko, Ribeiro and Oliveira, 2022), dashboard testing (Halwani *et al.*, 2016; Li *et al.*, 2023) and evaluating usability (Dolan, Veazie and Russ, 2013; Mentzakis, Tkacz and Rivas, 2020; Alhmoud *et al.*, 2022). Some studies propose techniques for engaging stakeholders throughout multiple building tasks (Lau *et al.*, 2019; Fazaeli *et al.*, 2021; Ludlow *et al.*, 2021; Patel *et al.*, 2022; Perry *et al.*, 2022). However, there is a notable gap concerning user involvement in collaboratively selecting KPI visualization formats and co-creating coherent dashboard report pages. Bridging this gap is crucial for ensuring comprehensive user participation in dashboard development. There are, however, other participatory methods that can be used to gather collective knowledge and gain consensus on a topic of interest, such as the NGT (Maguire *et al.*, 2022).

6.3.3. The Nominal Group Technique

NGT is a structured brainstorming method, facilitating equal participation and generating a prioritised list of ideas or solutions (Gallagher *et al.*, 1993; Harb *et al.*, 2021). Originating for conducting potentially problematic group sessions, NGT became a popular technique for structuring stakeholder collaboration (Allen, Dyas and Jones, 2004; Maguire *et al.*, 2022). According to Duggan et al. (Duggan and Thachenkary, 2004), partitioning activities into creative thinking and idea generation, evaluation, and decision-making prevents negative group dynamics, fostering the free flow of information and leading to solutions reflecting group judgment and potential synergy. NGT traditionally follows the five phases described in (Lago *et al.*, 2007):

- *Idea generation*: Participants silently generate ideas to solve a task statement.
- *Round robin*: Participants take turns sharing one idea each until everyone has shared all their ideas. If someone runs out of ideas, their turn is skipped for that round, but they can contribute again in the next.
- *Clarification*: Ideas are discussed sequentially, starting from the first idea generated and ending with the last. Participants can propose combining or rewording ideas, which are implemented only if all agree.
- *Voting*: Participants choose a set number of ideas from a predefined list, rank them individually, and then share their rankings with the facilitator in a round robin sequence.
- *Final discussion*: Participants receive voting results and can comment on them.

While many studies follow the five-phase NGT, some employ modified versions. Harb et al. (Harb *et al.*, 2021) conducted a scoping review on NGT in health research, noting significant variability, e.g., items elicited before the NGT meeting, idea sharing at will, roundtable brainstorming, and voting/rating instead of ranking. Nelson et al. (Nelson *et al.*, 2022) include multiple modifications, having conducted a three-phase focus group study using NGT, starting with a pre-assembled list of attributes from the literature. Firstly, participants anonymously ranked attributes on a Google Sheets survey, followed by a group review of rankings and idea sharing. Finally, based on discussions, participants could adjust their personal ranking, without pressure to achieve consensus. Gallagher et al. (Gallagher *et al.*, 1993) also used a group review of rankings and subsequent individual re-ranking. This iterative voting procedure is also a common modification (Harb *et al.*, 2021). Regarding the meeting environment, Lago et al. (Lago *et al.*, 2007) adapted NGT for online use, finding traditional NGT performed better in process-related variables, mainly due to technological limitations. However, both modalities achieved similar outcomes, with online participants feeling less inhibited and online sessions being easier to schedule.

In this Chapter, we aim to contribute to the NGT literature by further exploring modifications to the traditional technique (e.g., *a priori* idea generation and online voting), using existing and user-friendly DSS to facilitate voting procedures and information sharing during in-person and online/hybrid sessions.

6.4. Methods

6.4.1. A Novel Approach to Collaborative Dashboard-Building

Based on the methods and tools outlined in SBI-MD's Step 2.1 (Chapter 4), a four-stage CDB approach is proposed to involve dashboard stakeholders and end users in designing prototype reports based on predefined KPIs (see Figure 6.1). In Stage 1, KPI's data structure and communication purpose are determined, based on their names and descriptions. In Stage 2, a set of suitable DataViz formats is mapped for each KPI using a literature-informed decision table. Stage 3 involves a CDB workshop, a modified NGT session where stakeholders and users (*a*) reflect, discuss, and vote on their preferred DataViz formats for each KPI and (*b*) co-design prototype dashboard reports based on the selected formats. Stage 4 includes a post-workshop survey to assess approach acceptance and gather feedback for potential improvements. It is important to note that, unlike SBI-MD's Step 2.1, the approach outlined in this Chapter does not incorporate a pre-CDB workshop questionnaire between Stages 2 and 3 to collect individual KPI DataViz preferences. This modification was later introduced in SBI-MD to better resolve scheduling conflicts among workshop participants, as it enables shorter CDB workshops.

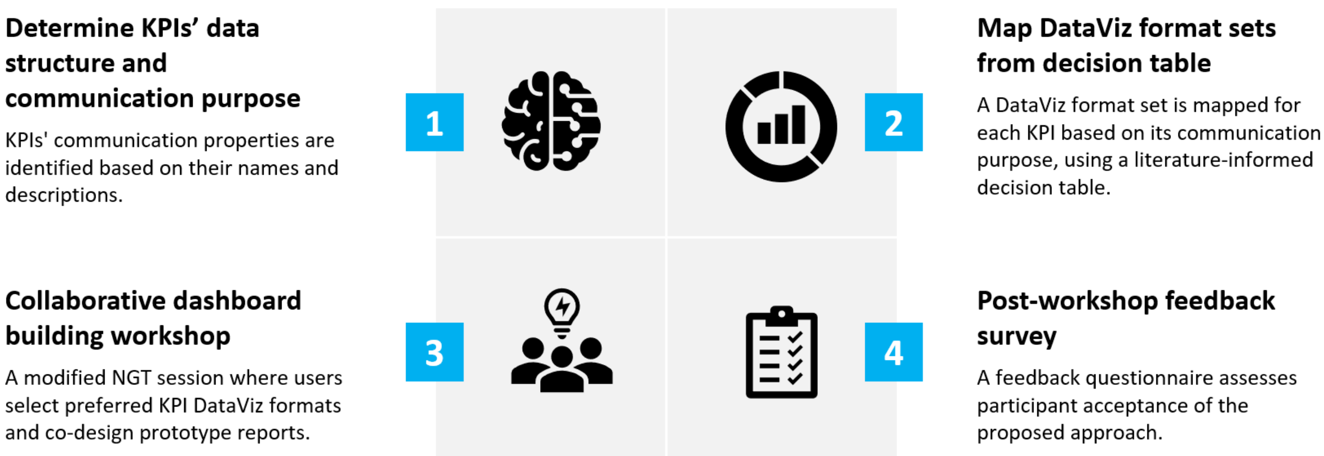


Figure 6.1. Four-stage CDB approach.

6.4.1.1. Stage 1: Determine KPIs' Data Structure and Communication Purpose

Stage 1 involves identifying KPI variables, categorising them based on attribute types – quantitative or categorical (qualitative) – and reflecting upon KPIs' communication purpose. Quantitative variables represent numerical values, while categorical variables include nominal or ordinal values (e.g., disease classification or age groups). Following Ignatenko et al. (Ignatenko, Ribeiro and Oliveira, 2022), a KPI data type can be represented by a string, where the length indicates variable number and "C" or "Q" denotes categorical or quantitative types, respectively. Illustrating, "CQ" implies a KPI DataViz format using one categorical and one quantitative variable (e.g., *Number of alerts generated* [Q] *and severity of alerts* [C]). Having identified KPIs' data structure, one considers their intended communication purpose using Kirk's taxonomy (Kirk, 2012). Table 6.1 outlines the different communication purposes identified by Kirk.

Table 6.1. Primary communication purpose of each DataViz method classification (Kirk, 2012).

Method classification	Communication purpose
Assessing hierarchies and part-to-whole relationships	To provide a breakdown of categorical values in their relationship to a population of values or as constituent elements of hierarchical structures. The example here would be the pie chart.
Comparing categories	To facilitate comparisons between the relative and absolute sizes of categorical values. The classic example would be the bar chart.
Mapping geospatial data	To plot and present datasets with geo-spatial properties via the many different mapping frameworks. A popular approach would be the choropleth map.
Plotting connections and relationships	To assess the associations, distributions, and patterns that exist between multivariate datasets. This collection of solutions reflects some of the most complex visual solutions and usually focuses on facilitating exploratory analysis. A common example would be the scatter plot.
Showing changes over time	To exploit temporal data and show the changing trends and patterns of values over a continuous timeframe. A typical example is the line chart.

6.4.1.2. Stage 2: Map DataViz Formats Sets from Decision Table

In Stage 2, an extended Ignatenko et al.'s (Ignatenko, Ribeiro and Oliveira, 2022) decision table (see Table 6.2), enriched with formats identified in (Kirk, 2012) and reflecting dashboard software advancements (i.e., novel formats and the ability to display dimensionless variables (Qlik, 2024)), is employed. The proposed decision table allows deducting a suitable DataViz set for each KPI by considering their communication purpose and variable count and type. As a range of appropriate visualisation formats is obtained, further reflection considering individual user preferences and dashboard content is required to select the preferred format for each KPI.

Table 6.2. Decision table for DataViz format identification (Q – 1 categorical variable, QC - 1 quantitative, 1 categorical variable, QQ - 2 quantitative variables, QCC - 1 quantitative, 2 categorical variables, QQC - 2 quantitative, 1 categorical variable, QQQ - 3 quantitative variables).

Data structure Communication purpose	Q	QC	QCC	QQ	QQC	QQQ
Assessing hierarchies and part-to-whole relationships	-	Pie Chart, (100%) Stacked Bar Chart	Circle Packing Diagram, [a] (100%) Stacked Bar Chart	-	Waterfall Chart [b]	-
Comparing categories	-	Area Size Chart, [a] Bar Chart, Word Cloud [a]	Dot Plot, [a] Grouped Bar Chart, Two-sided Bar Chart	Histogram [a]	Floating Bar Chart, [a] Gantt Chart, [a] Waterfall Chart [b]	-
Displaying dimensionless measures	(Linear) Gauge, [b] KPI [b]	-	-	-	-	-
Mapping geospatial data	-	-	Dorling Cartogram [a]	Dot Plot Map [a]	Network Connection Map [a]	Bubble map, Cartogram, [a] Choropleth map, Dasymetric map, Point map
Plotting connections and relationships	-	-	-	Scatter Plot	-	Bubble Plot
Showing changes over time	-	Bar Chart	Grouped Bar Chart, (100%) Stacked Bar Chart	Area Chart, Line Chart, Sparklines [a]	(Stacked [a]) Area Chart, Line Chart, Streamgraph [a]	-

Notes: ([a]) Additional formats identified in (Kirk, 2012); ([b]) Additional formats identified in (Qlik, 2024).

6.4.1.3. Stage 3: Collaborative Dashboard-Building Workshop

Once KPI alternative DataViz formats are identified, a CDB workshop is held either in-person, online, or in a hybrid format. In-person is preferred, but hybrid or online may be employed due to scheduling conflicts or logistical issues. During the workshop, dashboard end users and key stakeholders work together to determine optimal DataViz formats for KPIs and create prototype dashboard pages.

The CDB workshop employs a modified NGT; unlike traditional NGT, *idea generation* occurs before the workshop in our approach, as alternatives (i.e., DataViz formats within sets) are determined during Stage 2 according to a literature-informed decision table. Moreover, *clarification* and *voting* processes are also modified. After a welcome to participants and a brief description of the workshop purpose and process, the facilitation team explains the rationale behind the DataViz alternatives under analysis for the first KPI. During the workshop, dashboard-building software will display multiple visualisation formats for a KPI at a time. Participants analyse the DataViz alternatives and vote for their preferred format. Voting results are silently analysed and participants may provide anonymous comments to stimulate productive opinion sharing during group discussion. While Stage 2 DataViz sets are considered, participants can suggest additional visualisation formats after Voting Round 1. After group discussion, a subsequent vote is conducted to finalise format selection. The process is repeated for every KPI.

Participants vote anonymously on an online platform, avoiding unintended group influence. Although individual votes remain anonymous, a summary is provided, enabling collective review and discussion, potentially influencing subsequent voting based on shared knowledge construction. To support an extensive and informed group discussion, a spacious environment with a minimum of two monitors is essential – one for analysing DataViz options and the other for displaying voting results. In a hybrid format, a third monitor may be needed for onsite-online participant interaction. Additionally, preparation includes selecting a dashboard-building software (for preparing visualisation alternatives and for onsite report development) and an online voting platform.

After selecting a preferred DataViz format for all KPIs, report pages are developed for each aggregated KPI level, i.e., an evaluation dimension or thematic area. Report development entails integrating chosen formats onto a single dashboard page and identifying important features to include in the final dashboard. Within this process, workshop participants analyse report prototypes (prepared by the facilitation team during a brief timeout), considering report coherence, ease of information extraction, and alignment with user perspectives. If necessary, the second most voted format for several KPIs is tested for improved visual cohesion. Stakeholders also contribute input on presentation elements (e.g., colours, logos, lettering style) and desired analysis features (e.g., reference levels, drill-down, filters).

6.4.1.4. Stage 4: Post-Workshop Feedback Survey

To assess the acceptance and effectiveness of the developed approach, a post-workshop survey shall follow. This survey serves as a tool to collect participants' feedback and insights on the methodology. Literature on questionnaire design guides survey development (Lago *et al.*, 2007; Rattray and Jones, 2007; Kishore *et al.*, 2021).

6.4.2. Application Case

In this section, we demonstrate the practical application of the proposed approach in selecting user-preferred DataViz formats for a subset of the predetermined list of HF RPM KPIs identified in Chapter 5. The approach culminates in the co-creation of prototype dashboard pages for monitoring two performance dimensions of a Portuguese HF RPM program at HESE. The following subsections detail insights into the application of Stages 1 to 4 within the context of the HF RPM case.

6.4.2.1. Stage 1: Determine KPIs' Data Structure and Communication Purpose

For the application case, we built upon the list of expert-agreed program dimensions and KPIs for continuous HF RPM assessment outlined in the previous Chapter. As described in Chapter 5, KPIs were selected through a comprehensive participatory approach encompassing evidence analysis, expert interviews and a web-Delphi process with Portuguese stakeholders and experts. Notably, the experts involved here also participated in the Chapter 5 Delphi process, ensuring continuity of context.

KPI names and descriptions (as depicted in Table 5.5 in Chapter 5) were first analysed to determine the data structure (i.e., number and type of variables) better representing the KPI measure. Several KPI descriptions included "within the program duration" without specifying whether the KPI should indicate an absolute value (linked to program evaluation) or a breakdown by period (linked to program monitoring). In such cases, we assumed a monthly representation of values, as managers typically prioritise monitoring in daily analysis and absolute values can be derived from partial ones.

Regarding communication purposes, selected KPIs primarily serve ongoing tactical and strategic performance assessment, making Kirk's taxonomy *Showing changes over time* predominant. Nonetheless, as several KPIs are tied to assessment questionnaires or population classes, the classification *Assessing hierarchies and part-to-whole relationships* is also common, particularly for case-mix parameters. Table 6.3 outlines the data structure and communication purpose associated with each KPI and case-mix parameter.

Table 6.3. KPIs' data structure and communication purpose.

KPI (within dimension)	Variables	Data structure	Communication purpose
Access			
Eligible patients followed by the RPM program (%)	Current value (versus Reference)	Q	Displaying dimensionless measures
Length of stay in the ward	Average number per Month	QC	Showing changes over time
Length of stay in intensive care	Average number per Month	QC	Showing changes over time
Number of days of activity lost	Average number per Month/Year	QC	Showing changes over time
Number of HF-related emergency visits	Total number per Month	QC	Showing changes over time
Number of HF-related hospitalisations	Total number per Month	QC	Showing changes over time
Number of HF-related readmissions	Total number per Month	QC	Showing changes over time
Number of scheduled face-to-face consultations	Average number per Month	QC	Showing changes over time
Number of unscheduled face-to-face consultations	Average number per Month	QC	Showing changes over time

Number of scheduled teleconsultations	Average number per Month	QC	Showing changes over time
Number of unscheduled teleconsultations	Average number per Month	QC	Showing changes over time
Waiting time for a face-to-face consultation	Average time per Month	QC	Showing changes over time
Waiting time for a teleconsultation	Average time per Month	QC	Showing changes over time
Time to medical action	Average time per Severity	QC	Comparing categories
Clinical aspects			
Avoidable hospital admissions due to HF compared to the homologous period (%)	Current value (versus Reference)	Q	Displaying dimensionless measures
Biosignals	Average number over threshold per Date	QQ	Showing changes over time
Left ventricular ejection fraction (LVEF)	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
HF-related/All-cause mortality ratio	Current value (versus Reference)	Q	Displaying dimensionless measures
Number of alerts generated and severity of alerts	Total number per Severity	QC	Assessing hierarchies and part-to-whole relationships
Level of physical activity	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
NT-ProBNP level (pg/ml)	Total days over threshold per Month	QC	Showing changes over time
Mental health self-perception	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Oedema self-perception	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Quality of life self-perception	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Acceptability			
Patient adherence to the program	Compliance ratio per Month	QC	Showing changes over time
Patient satisfaction	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Health professional satisfaction	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Caregiver overload	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Disease management capacity after the program	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Level of self-care	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Patient’s trust in the program	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Medication/therapy adherence	Average number per Month	QC	Showing changes over time
Number of program dropouts	Total number per Month	QC	Showing changes over time
Costs			
Program cost per patient	Average cost per Month per Cost component	QCC	Showing changes over time
Costs for the patient	Total cost per Month	QC	Showing changes over time
Emergency service admission costs	Total cost per Month	QC	Showing changes over time
Hospital admission costs	Total cost per Month	QC	Showing changes over time

ICU hospitalisation costs	Total cost per Month	QC	Showing changes over time
Surgical intervention costs	Total cost per Month	QC	Showing changes over time
Face-to-face consultations costs	Total cost per Month	QC	Showing changes over time
Teleconsultation costs	Total cost per Month	QC	Showing changes over time
Technology			
Number of implantable device events	Total number per Device type per Event type	QCC	Comparing categories
Error rate (%)	Current value (versus Reference)	Q	Displaying dimensionless measures
Case-mix parameters			
Age group	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Classification of HF according to LVEF	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Comorbidities	Total number per Condition	QC	Comparing categories
Distance to the nearest healthcare facility	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Literacy level	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
NYHA classification	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships

Notes: C = categorical; Q = quantitative.

6.4.2.2. Stage 2: Map DataViz Format Sets from Decision Table

Considering KPIs' data structure and communication purpose (as defined in Table 6.3), the DataViz sets are derived directly from Table 6.2. As an example, for *Eligible patients followed by the RPM program (%)*, represented by a Q data structure and a communication purpose of *Displaying dimensionless measures*, the corresponding DataViz set comprises a Gauge and a KPI format. However, due to unclear communication properties in KPI descriptions, a Bar Chart format (corresponding to a QC structure for *Showing changes over time*) is also included in the set.

To streamline dashboard reporting and address interrelated KPIs (e.g., *Length of stay in the ward* and *Length of stay in intensive care*, both measuring the LoS but differing in service), combined DataViz was developed. Table 6.4 presents an updated KPI list, showing which KPIs are comprised in the composite KPI, the updated data structure and the associated DataViz set for the composite KPI.

Table 6.4. Updated KPI list (considering composite KPIs) and corresponding visualisation formats sets.

Composite KPI	Short name	KPI	Data structure	DataViz formats set
Access				
Eligible patients followed by the RPM program (%)	% Patients	=	Q	(Linear) Gauge KPI Bar Chart (if per Month)
Length of stay	LoS	Length of stay in the ward Length of stay in intensive care	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI)

Number of days of activity lost	DAL	=	QC	Bar Chart (Linear) Gauge (if Q) Area Chart (if QQ) Line Chart (if QQ)
Number of HF-related admissions	Admissions	Number of HF-related emergency visits Number of HF-related hospitalisations Number of HF-related readmissions	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI)
Number of consultations	Cons.	Number of scheduled face-to-face consultations Number of unscheduled face-to-face consultations Number of scheduled teleconsultations Number of unscheduled teleconsultations	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI) Waterfall Chart (if QQC and *Comp. categories*)
Waiting time	=	Waiting time for a face-to-face consultation Waiting time for a teleconsultation	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI)
Time to medical action	Time to MD	=	QC	Area Size Chart Bar Chart Word Cloud Grouped Bar Chart (if QCC)
Clinical aspects				
Avoidable hospital admissions due to HF compared to the homologous period (%)	Avoidable	=	Q	(Linear) Gauge KPI Area Chart (if QQ) Bar Chart (if QC)
Biosignals	=	=	QQ	Area Chart Line Chart Sparklines Bar Chart (if QC)
Left ventricular ejection fraction (LVEF)	LVEF	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if per Month)
HF-related/All-cause mortality ratio	% HF death	=	Q	(Linear) Gauge KPI Area Chart (if QQ) Bar Chart (if QC)
Number of alerts generated and severity of alerts	Alerts	=	QC	Pie Chart (100%) Stacked Bar Chart Grouped Bar Chart (if per Month)
Level of physical activity	Physical	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
NT-ProBNP level (pg/ml)	NT-ProBNP	=	QC	Bar Chart (Linear) Gauge (if Q) Area Chart (if QQ) Line Chart (if QQ)
Mental health self-perception	Mental health	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)

Oedema self-perception	Oedema	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Quality of life self-perception	QoL	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Acceptability				
Overall compliance	Compliance	Patient adherence to the program Medication/therapy adherence Number of program dropouts	QQC	(Stacked) Area Chart Line Chart Streamgraph
Stakeholder satisfaction	Satisfaction	Patient satisfaction Caregiver overload Health professional satisfaction	QCC	Dot Plot Grouped Bar Chart Two-sided Bar Chart (100%) Stacked Bar Chart (if *Showing changes over time*)
Disease management capacity after the program	Awareness	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Level of self-care	Self-care	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Patient's trust in the program	Trust	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Costs				
Program cost per patient	€ Avg	=	QCC	Grouped Bar Chart (100%) Stacked Bar Chart
Costs for the patient	€ OoP	=	QC	Bar Chart Area Chart (if QQ) Line Chart (if QQ) Sparklines (if QQ)
Total program cost	€ Total	Emergency service admission costs Hospital admission costs ICU hospitalisation costs Surgical intervention costs Face-to-face consultations costs Teleconsultation costs	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Waterfall Chart (if QQC and *Comp. categories*) KPI (for each KPI)
Technology				
Number of implantable device events	ID events	=	QCC	Dot Plot Grouped Bar Chart Two-sided Bar Chart
Error rate (%)	% Error	=	Q	(Linear) Gauge KPI Bar Chart (if per Month)
Case-mix parameters				
Age group	Age	=	QC	Pie Chart (100%) Stacked Bar Chart

Classification of HF according to LVEF	LVEF class	=	QC	Pie Chart (100%) Stacked Bar Chart
Comorbidities	=	=	QC	Area Size Chart Bar Chart Word Cloud
Distance to the nearest healthcare facility	Distance	=	QC	Pie Chart (100%) Stacked Bar Chart
Literacy level	Literacy	=	QC	Pie Chart (100%) Stacked Bar Chart
NYHA classification	NYHA	=	QC	Pie Chart (100%) Stacked Bar Chart

Notes: C = categorical; Q = quantitative.

As real-world HF RPM program data was unavailable to support DataViz development, synthetic datasets were constructed by the research team using Python™ *pandas* data analysis library. Five synthetic tables were generated – *Admissions*, *Appointments*, *Deceased*, *Stays*, and *Patient_Data*. Data on program acceptability and costs were excluded from synthesis as they fell beyond the scope of the CDB workshop. The synthetic tables were then uploaded to Qlik Sense®, a dashboard-building software, where dataset relationships were established.

Qlik Sense® dashboard report pages were generated for individualised visualisation and appraisal of the DataViz sets for each KPI from Table 5.5 related to *Access* and *Clinical aspects*. Each page includes up to four alternative DataViz formats for a single (or composite) KPI. Figure 6.2 depicts a report page featuring the DataViz set for *% Patients*, as presented to participants. Additionally, a prototype report page was designed for the entire case-mix, proposing a single format for each parameter.

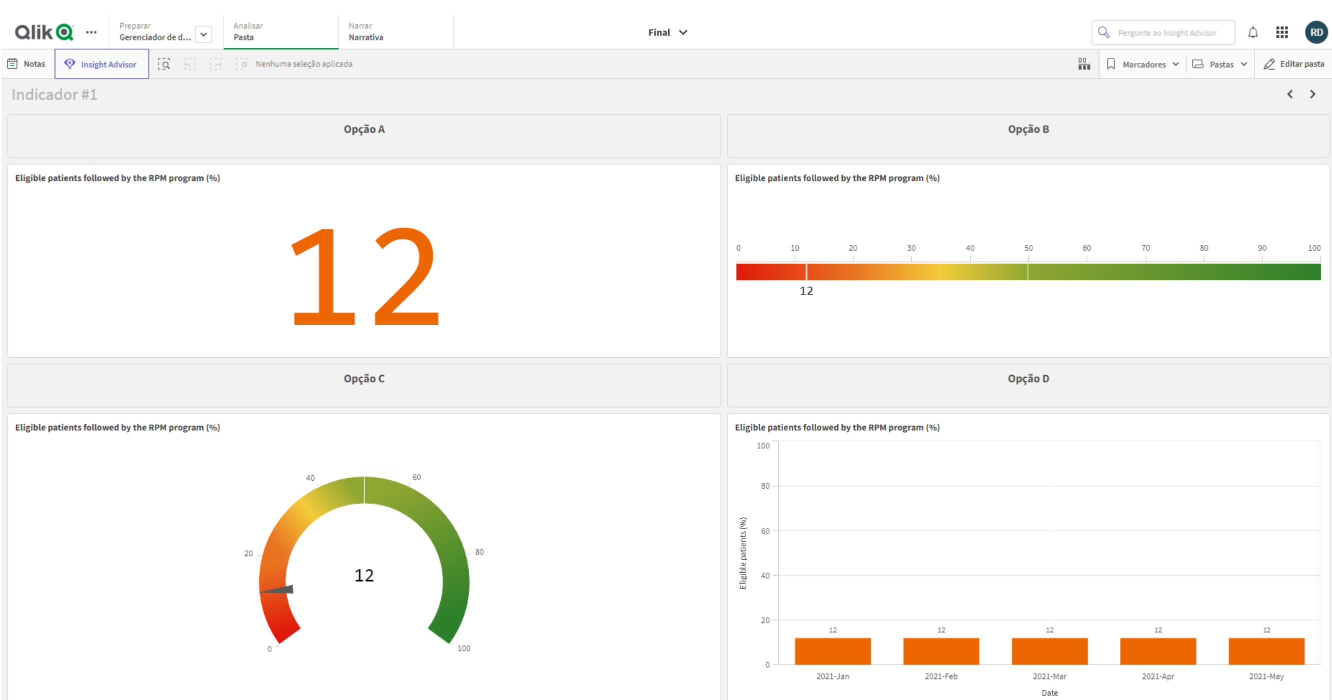


Figure 6.2. Qlik Sense® page example for *Eligible patients followed by the RPM program (%)*.

6.4.2.3. Stage 3: Collaborative Dashboard-Building Workshop

The CDB workshop took place at HESE, in Évora, Portugal, on September 13, 2023, lasting 2 hours and 38 minutes. Six HF RPM experts and program stakeholders, including a physician/RPM program coordinator, two HF nurses, a TM technology company owner and their application specialist, and a healthcare consultant, were invited to participate via email (which detailed workshop context, objectives, proposed agenda, date, and venue).

The workshop was originally planned as an in-person session, held at the program coordinator's office. However, due to unforeseen constraints, two participants were unable to attend, leading to protocol adjustments for a hybrid format. As depicted in Figure 6.3, onsite participants sat at a round table facing two screens – one displaying voting results through Menti™, the selected online voting system, and the other showing DataViz options on Qlik Sense®. To ensure online engagement and equitable information access, a laptop ran a Microsoft Teams™ meeting, allowing screen sharing and enabling interaction between online and onsite participants. A camera was used for video recording for later analysis and an internet router ensured stable connectivity during the workshop.

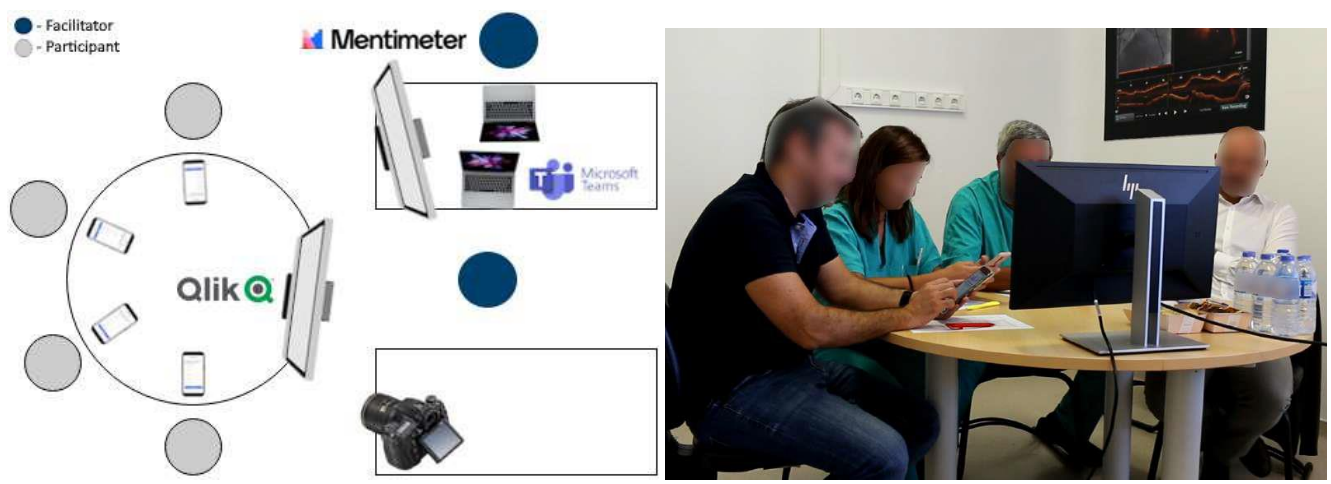


Figure 6.3. Workshop room setup. (Left) Layout schematic, showing seating arrangement, screen positioning and employed support systems; (Right) Photograph of participants engaged in workshop activities.

Before the workshop started, voice consent to video recording was requested from participants and facilitators – a moderator and a decision analyst. Starting the workshop, participants were (re-)briefed about workshop objectives and approach. Next, the Qlik Sense® screen showcased the DataViz set related to the first KPI under analysis, participants were requested to appraise all options silently and then vote in their preferred format using Menti™.

Menti™ enables free access through any internet-connected device by visiting http://menti.com and entering a unique session code, eliminating the need for a mobile application download. Facilitators created a Menti™ survey for employing the modified NGT approach, allowing participants to vote and comment anonymously. Four voting options (A, B, C, D) aligned with DataViz alternatives are displayed on Qlik Sense® for each KPI. An additional option (E) allowed participants to express disagreement with available alternatives. Figure 6.4 depicts the Menti™ mobile interface for participants and how voting results were showcased.

To mitigate potential group biases, Voting Round 1 occurred without prior interactions, with results revealed on Menti™ only after all participants submitted their answers. Following the results display, participants silently provided anonymous written comments on Menti™ before active discussion. Such procedure encourages more productive opinion sharing, allowing all participants to engage, even if they prefer not to speak aloud. Comments were then displayed on Menti™ and the moderator prompted participants to add insights, (dis)advantages, constraints discouraging an option, or alternative interpretations to the KPI communication properties. This stage also provides an opportunity for participants disagreeing with predetermined DataViz options to suggest an alternative format for the KPI. The new format was associated with option E in a subsequent voting round. Following group discussion, the moderator called for a second voting round. The most voted option was selected as the preferred DataViz format for the first KPI.

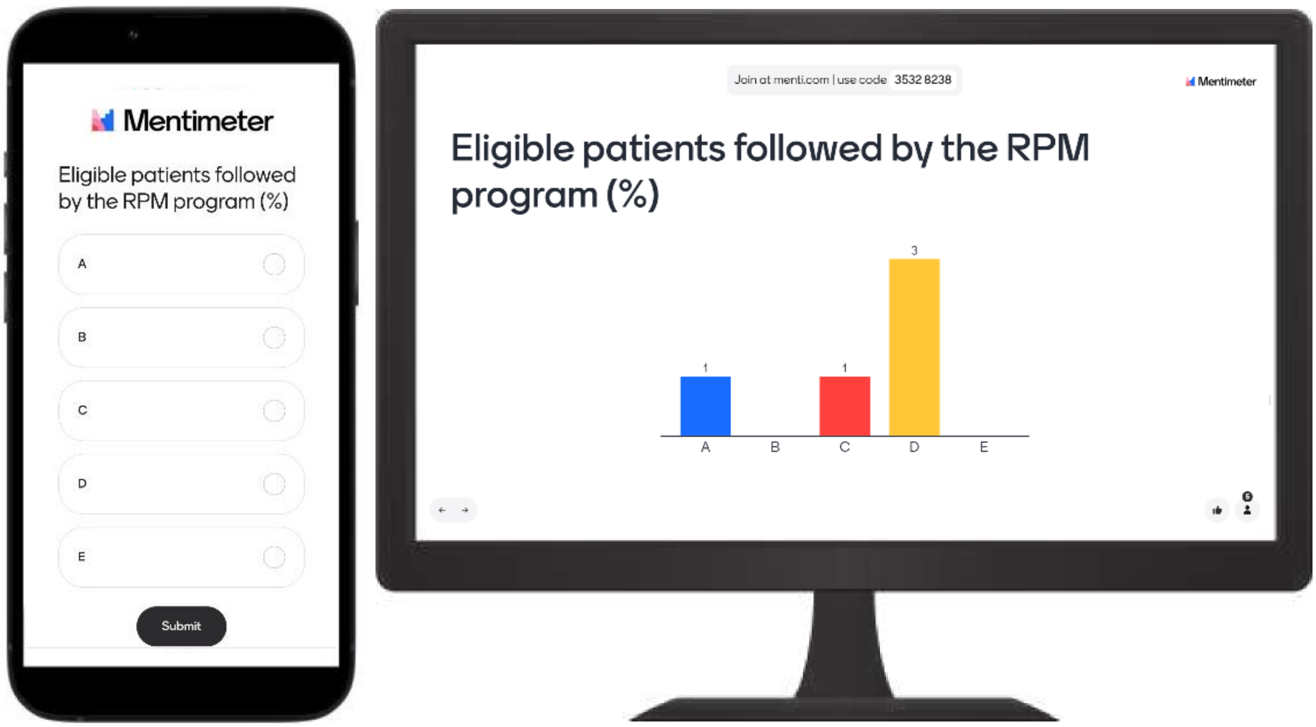


Figure 6.4. Menti™ mobile interface (left) and voting results (right), as presented to participants.

This protocol repeated for each of the 17 KPIs under analysis until a preferred format was determined for all. A timeout permitted the decision analyst and moderator to compile chosen formats into two dashboard report pages for the *Access* and *Clinical aspects* program dimensions. After recess, participants reviewed and discussed the prototype dashboard pages, suggesting improvements for visual cohesion and features to include in a final report version. A similar appraisal process was applied to the case-mix report.

6.4.2.4. Stage 4: Post-Workshop Feedback Survey

Following the CDB workshop, participants received an email acknowledging their active participation along with a post-session feedback survey. Google Forms was selected as the delivery platform due to its formatting features, accessibility, and user-friendly interface. The survey comprised seven statements related to the workshop, inviting participants to express their agreement on a five-point Likert scale, ranging from Strongly Disagree (SD) to Strongly Agree (SA). Additionally, a final comment section was included for more detailed, open-ended feedback. The statements comprised in the survey are as follows (translated to English from Portuguese):

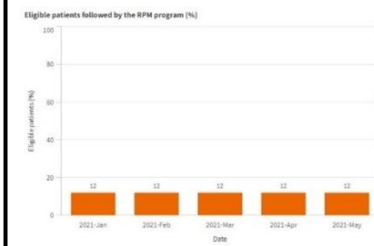
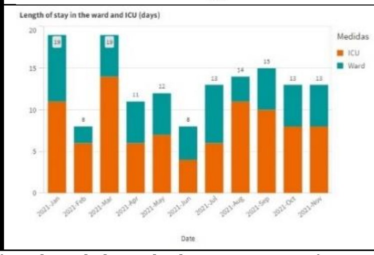
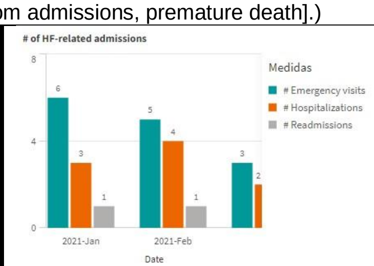
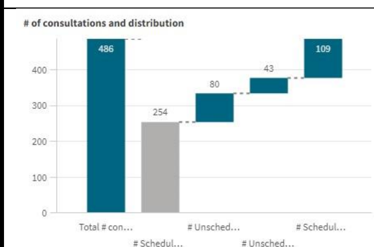
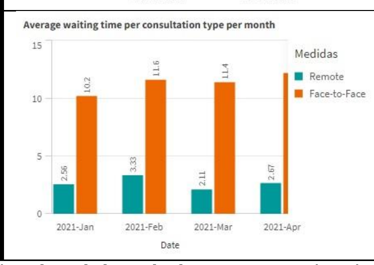
1) *I found the approach to be user-friendly in practice.*
2) *The workshop was effective in promoting consensus.*
3) *This approach helps bridge the gap between end-user preferences and dashboard developer decisions.*
4) *This approach is adaptable to various healthcare contexts.*
5) *This approach should be a standard practice when developing dashboards.*
6) *This approach helps ensure that developed dashboards are more effective in facilitating decision-making.*
7) *Overall, I am satisfied with this approach.*

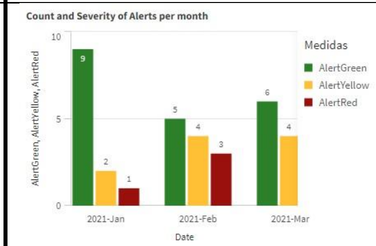
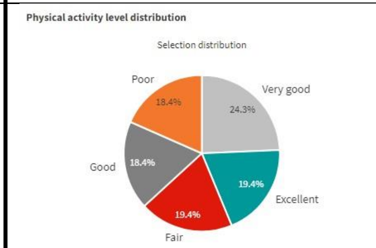
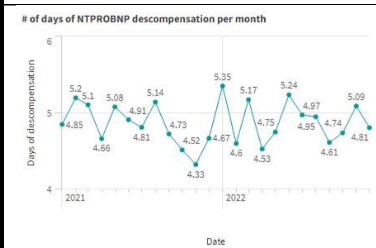
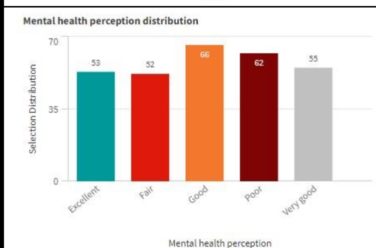
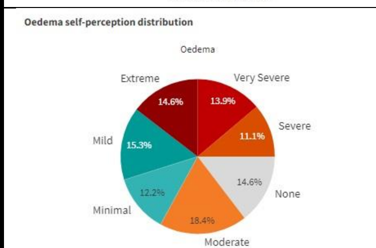
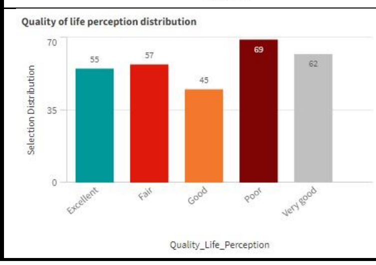
Please, share any feedback, ideas, or recommendations for enhancing the approach or its implementation.

6.5. Results

In the described use case, the CDB workshop promoted active involvement and constructive dialogue among dashboard users and stakeholders, fostering opportunities to reflect, vote, and discuss in determining the most suitable DataViz formats for effective communication of HF RPM program information and improving daily performance monitoring and evaluation. Table 6.5 summarises the workshop outcomes, illustrating the voting shifts between Voting Rounds 1 and 2 and presenting the selected DataViz format for each KPI alongside its visual representation (as displayed in the workshop).

Table 6.5. Complete list of voting results for every KPI reviewed in the workshop session.

KPI	**Round 1**					**Round 2**					**Most voted format**	**DataViz format**
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**		
Access												
% Patients	1	0	1	**3**	0						Bar Chart	
LoS	0	0	2	3	0	0	1	0	**5**	0	Stacked Bar Chart	
DAL											Not assessed (**Updated description:** Average days of absence or reduced activity due to HF-related needs [e.g., hospitalisation, emergency room admissions, premature death].)	
Admissions	0	0	3	3	0	0	0	**5**	1	0	Grouped Bar Chart	
Cons.	1	1	2	0	2	0	1	1	0	**4**	Waterfall Chart + Time	
Waiting time	0	0	**4**	2	0						Grouped Bar Chart	
Time to MD											Not assessed (**Updated description:** Average time interval, expressed in hours and by alert severity, from a clinical alert signaling potential patient deterioration to medical doctor appropriate intervention.)	
Clinical asp.												
Avoidable											Not assessed (**Updated description:** Yearly count of preventable emergency department admissions [i.e., admitted patients with unresolved clinical alerts within the past 24 hours].)	
Biosignals	1	0	0	0	5	0	0	0	0	**6**	Modify KPI (**Updated description:** Average monthly count of clinical alerts [i.e., when a patient exhibits two or more vital sign measurements outside their defined normal range]).	
LVEF											Not assessed (Participants suggested excluding this KPI, as LVEF is more relevant as a case-mix parameter i.e., *LVEF class*)	

% HF death	1	1	3	1	0	**3**	0	**3**	0	0	Area Chart	
Alerts	0	0	**6**	0	0						Grouped Bar Chart	
Physical	**4**	0	1	1	0						Pie Chart	
NT-ProBNP	**5**	1	0	0	0						Line Chart	
Mental health	4	1	0	1	0	2	**3**	0	1	0	Bar Chart	
Oedema	**5**	0	1	0	0						Pie Chart	
QoL	1	**5**	0	0	0						Bar Chart	

Due to a large delay in attendance by one online participant, Voting Round 1 for both *% Patients* and *LoS* received only five votes, while subsequent rounds received six. A minimum two-thirds agreement was reached for 10 out of 13 assessed KPIs. *% Patients* and *Mental health* garnered a relative majority (three votes in the preferred alternative) and *% HF death* had no clear majority after two rounds, with options A and C both receiving three votes. Nonetheless, an Area Chart format was chosen for the latter as it received three votes in both Voting Rounds 1 and 2, and participants could revisit this selection during prototype report page appraisal.

DAL, *Time to MD*, *Avoidable*, and *LVEF* were excluded from the assessment as the facilitators deemed their KPI descriptions too ambiguous, opting for addressing this issue during the CDB workshop by soliciting participant input to clarify KPI interpretation (see Table 6.5 for the updated KPI descriptions). Furthermore, although assessed, modifications were also proposed for *Biosignals*, as participants found the proposed DataViz alternatives unsuitable for effective program assessment, resulting from misinterpretation stemming from the KPI description.

Participants and facilitators decided to forego Voting Round 2 for seven KPIs. This decision was based on the majority agreement reached in Voting Round 1, coupled with the absence of compelling arguments favouring a change during the discussion. In the remaining six cases, four exhibited a strengthened majority for the initially favoured alternative after Voting Round 2, while in two instances there was a change in the preferred option (resulting in a tie for *% HF death*).

Following a timeout, participants reviewed prototype dashboard report pages produced by the facilitators. Figure 6.5 shows the finalised prototype pages for *Access* (top) and case-mix (bottom). Participants decided to maintain previously selected DataViz formats for the *Access* report page, with only minor adjustments to colours for consistency across KPI representations. However, Qlik Sense® does not support the requested Waterfall Chart + Time format for *Cons.* – alternatively, the decision analyst suggested adding a Month filter to enable similar analysis capabilities with a simple Waterfall Chart. Regarding the case-mix page, participants favoured a combination of Pie and Donut (a special case of the former) Charts to enhance visual diversity and report cohesion. Pie Charts will display demographic data (i.e., *Age*, *Distance*, and *Literacy*), while Donut will depict HF-related information (i.e., *LVEF class* and *NYHA*). For *Comorbidities*, participants preferred a Bar Chart over an Area Size Chart, which was the facilitators' proposal. Moreover, to ensure clear theme separation, demographic data will be placed in the top row, and HF-related data in the bottom of the report. A prototype was not generated for *Clinical aspects* due to time constraints.

Figure 6.5. Prototype dashboard report pages for *Access* (top) and case-mix (bottom).

Regarding the post-workshop feedback survey, five out of six participants completed the questionnaire. Survey data is summarised in Figure 6.6. Respondents expressed satisfaction with the proposed approach, endorsing its application within dashboard development. Workshop participants found the methodology to be user-friendly and believe it can enhance dashboard effectiveness, with one participant noting that "bringing together the different users allows the development of more accurate and user-friendly solutions."

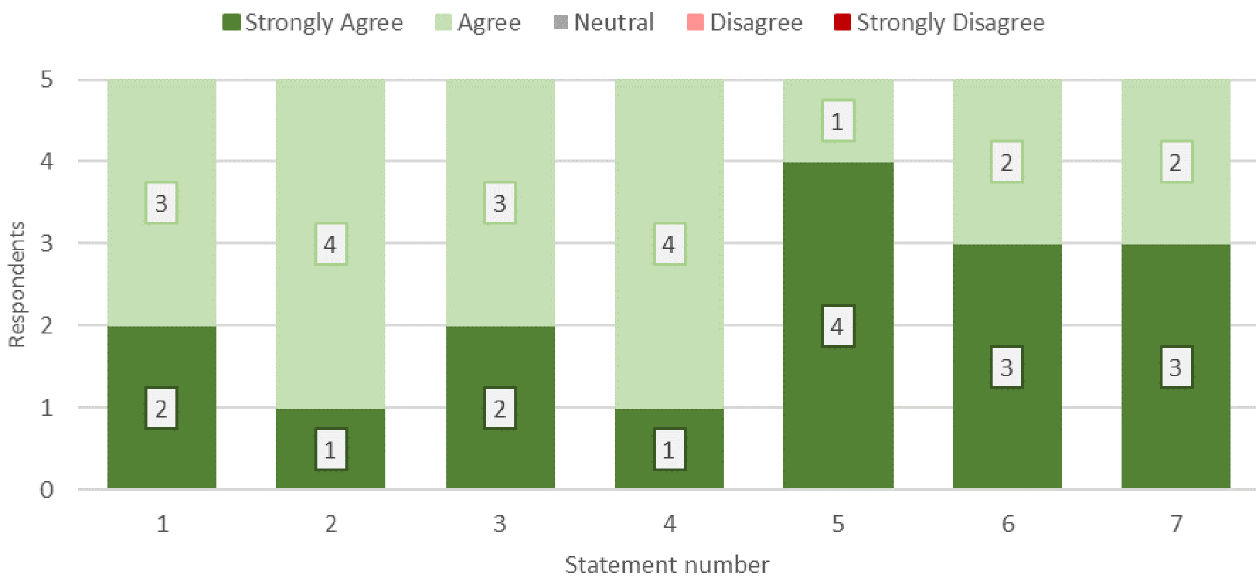


Figure 6.6. Post-workshop feedback survey results.

6.6. Discussion

6.6.1. General Considerations

This Chapter introduces a novel participatory approach for collaboratively developing dashboards (based on the methods and tools described in SBI-MD's Step 2.1), demonstrated in creating prototype pages for a management dashboard for an RPM program targeting HF patients. Through a CDB workshop, dashboard users and stakeholders identified suitable DataViz formats for predefined KPIs, culminating in high-fidelity, user-validated report pages.

Unlike traditional technocentric design, this approach actively engages users in a constructive, co-creation process with technical developers. This human-centric, cooperative process enhances software acceptance and adoption, fostering resilient innovation in healthcare management dashboards (Carayannis, Canestrino and Magliocca, 2024). By making users co-developers, systems better meet stakeholders' diverse needs and users gain a deeper understanding of the technology, effectively opening the "black box."

The research team anticipated that introducing a novel approach involving individual analysis of multiple alternatives, iterative voting, and group discussions, repeated for each KPI, might lead to a prolonged and tedious session. Consequently, we focused solely on *Access* and *Clinical aspects* KPIs from Table 5.5 (Chapter 5), along with case-mix parameters. Despite a duration of around two and a half hours, participants remained engaged, enjoying interactive dashboard building and praising the user-friendly voting platform. As the workshop progressed, participants became familiar with the approach, DataViz formats, and dashboard objectives, resulting in quicker evaluation of KPIs' DataViz sets. We hypothesise that, given such rapid learning, an extra half hour might suffice to complete all KPIs. Moreover, the workshop includes a timeout for participants to rest and engage in conversations while facilitators produce dashboard report prototypes onsite. For instance, a technocentric design approach typically involves weeks or months of iterative development and validation between dashboard users and developers to progress from KPI identification to producing prototypes (François *et al.*, 2021). In contrast, the proposed approach enables stakeholders and users to collaborate in dashboard building during a single workshop, resulting in initial prototype reports that incorporate participant-selected DataViz formats. Additionally, participants can adjust previous DataViz choices in real-time during prototype appraisal, ensuring a cohesive dashboard design.

However, Chapter 7's application study (which follows the finalised version of SBI-MD) introduces a pre-CDB workshop questionnaire to streamline the decision-making process. By aggregating participant input beforehand, the questionnaire reduces extended in-person discussions. Specifically, it gathers individual preferences for KPI DataViz formats, replacing the initial round of silent voting and anonymous commenting. The rationale behind this modification is to address scheduling challenges among workshop participants, allowing for shorter and decisive CDB workshops.

6.6.2. Key Insights on Real-World Group Dynamics

The CDB workshop, originally planned for exclusive onsite participation, had to adapt to a hybrid modality as two participants were unable to attend in person. This adjustment posed technical challenges, particularly with Microsoft Teams™ screen-sharing and engaging online participants. Ensuring consistent access to information (e.g., Qlik Sense® or Menti™ screens) for both onsite and online participants proved difficult for the decision analyst. Moreover, facilitating interactions during fast-paced discussions was problematic, affecting balanced participation. These challenges underscore how workshop format influences session dynamics and, potentially, effectiveness. Predefining workshop modality and adequate preparation are crucial, as last-minute changes can introduce unforeseen constraints. In Chapter 7's application study, no hybrid sessions were conducted; all social processes were carried out exclusively in person, remotely, or asynchronously.

Akin to other modified NGT applications (Gallagher *et al.*, 1993; Nelson *et al.*, 2022), iterative voting was established for the CDB workshop protocol, including a first vote, a discussion of results, and a final voting round. In practice, however, if post-vote discussion reaffirmed group agreement on the most voted option, a second round was deemed unnecessary, saving time, and reducing participants' cognitive load. This adjustment was particularly notable in analysing *Clinical aspects* KPIs, where similar communication properties led to analogous decisions, such as for *Mental health* and *QoL*, with a common selection of a Bar Chart format, after a single round for the latter, as similar arguments favoured the preferred format arising from the Voting Round 1. If further voting was required, exempting a second vote had limited impact, as format choices could be revisited during prototype report page reviews, allowing for decision validation.

In contrast, even if one option garners a strong majority in the initial vote, a second vote exemption should not be granted when no clear group agreement arises from discussion. Compelling arguments and unexpected perspectives can sway the group and significantly impact subsequent voting outcomes. Notably, in the discussion on KPI *Mental health*, the group shifted from option A (66.7% agreement in Round 1) to option B (only one previous vote) after well-presented arguments from the participant supporting option B. Therefore, we advocate for maintaining the standard protocol of two sequential voting rounds as default. Facilitators shall assess each situation individually and consult participants before deciding to forego a second vote.

The proposed approach addressed potential group biases by implementing anonymous voting and comment-sharing through Menti™. Workshop participants positively received anonymous voting through Menti™ but tended towards open dialogue after initial voting. Recognising participants' preference for verbal perspective sharing, immediate argument exchange after Voting Round 1 was allowed, proving practical and encouraging group engagement. Despite positive effects, open discussion posed challenges, particularly regarding the influence of a participant with a leadership position and peer-recognized expertise in the HF field, revealing a dominant personality among group members. To mitigate this undesirable influence, the moderator made additional efforts to ensure that everyone had a chance to express their views before the dominant personality intervened, promoting equal participation among participants.

6.6.3. Limitations

Although participant feedback in the post-workshop survey indicates the success of our approach, the proposed approach is not without limitations. First, the use of synthetic data may not fully capture real-world characteristics. Synthetic data was developed due to data unavailability, posing challenges in generating credible datasets for all KPIs. Despite extensive exploration of healthcare databases to mimic real-world data, there remains a lack of guidance on effectively generating synthetic data and accurately representing each KPI. Assumptions were made to align KPI communication properties with user requirements. To reduce uncertainty, we suggest an additional stage between identifying KPIs and selecting DataViz formats, wherein explicit measures for each KPI should be collaboratively defined with potential dashboard users. This approach is realised in SBI-MD's Phase 1 through Steps 1.3 (*Defining Measures and References*) and 1.4 (*Validating the Value Tree and Defining Achievement Classes*) and proved valuable during the implementation study in Chapter 7, as will be presented.

Second, participants' digital literacy is key in dictating the effectiveness of workshop techniques. In our application case, combining Microsoft Teams™, Menti™, and Qlik Sense® was successful, as participants understood the tasks and exhibited contentment. For less digitally literate groups, however, alternative approaches may be required. In in-person sessions, removing anonymity and using a show of hands for voting could be a simple solution if minimising the complexity of the approach is a priority. In Chapter 7, the CDB workshop adopted this straightforward approach, as group members were comfortable communicating openly and prioritised quick decision-making.

Finally, the moderator's lack of experience may have affected the workshop's dynamics. A more experienced moderator might have better-guided participation, balanced dominant personalities, and managed time and discussions more effectively. To compensate for this issue, the decision analyst, a more experienced facilitator, supported the moderator in both operating DSS and co-moderating group interventions.

6.7. Conclusions

The research was able to produce a novel workshop process to actively involve end-users in the selection of the most appropriate DataViz format for a predefined KPI list, ensuring that the final dashboard truly resonates with their needs and expectations. Moreover, this Chapter is anchored in a comprehensive and rigorous literature review, forming the basis of the proposed approach, combining participatory approaches with BI techniques to enhance dashboard development.

Post-workshop survey results showed high satisfaction among participants and endorsement for the approach, validating the appropriateness of the methods and tools described in SBI-MD's Step 2.1 and the approach's added value as a standalone methodology for rapid dashboard development. To our knowledge, this is one of the first attempts to actively involve users in live dashboard development, aiming to enhance acceptance and sustained adoption. However, it had its limitations, many of which were addressed in the final version of SBI-MD and validated through the application study discussed in Chapter 7 – only through practical use and testing can opportunities for improvement be identified.

Moreover, our findings confirm the impact of user participation and feedback in technology design, emphasising the approach's significance in dashboard development literature. This collaboration effort between health professionals, scholars, industry and technology developers to build a new management tool leveraging clinical, operational, societal, and financial data aligns with the principles of Society 5.0 – a data-driven society where technocentric and human-centric perspectives converge to ensure prosperity by balancing economic growth, technological development, and social welfare (Carayannis, Canestrino and Magliocca, 2024).

CHAPTER 7

A MULTIDIMENSIONAL MANAGEMENT DASHBOARD FOR HEALTH TECHNOLOGY ASSESSMENT OF HEART FAILURE TELEMONITORING

7.1. Chapter Summary

RPM has proved valuable in the early detection of HF decompensation, enabling dynamic therapy adjustments and effectively managing multimorbidity. The HF RPM program at HSM in Lisbon, Portugal, showcases these benefits through a protocol-based TM intervention. However, program scale-up faces operational challenges, requiring robust evidence of value for money to secure additional funding. As traditional HTA overlooks complex care models' broader impacts and everyday evaluation needs, innovative tools are vital for comprehensive and fair HF RPM assessment.

This Chapter details the application of **SBI-MD** for constructing an MMD for the tactical and strategic management of the HSM RPM program. In collaboration with HSM's cardiology department, the project aimed to (*a*) enhance the quality of care delivery by conducting continuous HTA to identify areas for improvement, and (*b*) transparently demonstrate the program's impacts to HSM leadership and the broader Portuguese healthcare community. Moreover, this Chapter validates the approach proposed in Chapter 4 by applying it in a real-world setting.

From December 2023 to August 2024, HSM project stakeholders partaken in six participatory processes to co-develop a functional MMD prototype. The MMD offers (*a*) a comprehensive performance overview across key program dimensions – *Access*, *Clinical aspects*, *Acceptability*, and *Costs* –, and (*b*) assigns achievement classifications both globally and by dimension to assess program success. These classifications are determined based on partial value scores and assignment rules in a set of stakeholder-agreed criteria. Their relative importance is represented by stakeholder-elicited weights, which reflect their collective perspectives and goals for the HF remote care program.

The Chapter highlights the effectiveness of SBI-MD in producing a robust, user-friendly and automated DSS that empowers RPM program managers to quickly identify underperforming areas and take corrective actions to drive continuous improvement and sustained performance. Engaging stakeholders in co-creation ensured alignment and ownership, fostering long-term MMD adoption.

7.2. Introduction

Driven by the COVID-19 pandemic, telehealth adoption experienced enormous proliferation, enabling health professionals to monitor patients' physiological parameters and symptoms at a distance (Thomas *et al.*, 2024). As shown in Chapter 2, Portugal followed this global trend, with remote care solutions like TM and RPM gaining traction, especially for chronic (and NHS-reimbursed) conditions like HF or COPD. Chronic conditions are responsible for over two-thirds of the 41 million annual global deaths and their prevalence is expected to keep rising due to ageing and lifestyle-related risk factors (Khanal *et al.*, 2024). Among these, HF is estimated to affect 1-3% adults worldwide (M. S. Khan *et al.*, 2024), accounting for 17% of all-cause mortality and 44% of hospitalisations annually (Nunes-Ferreira *et al.*, 2020).

As highlighted in Chapter 3, innovative, integrated care models – that comprise multidisciplinary teams and technology to continuously monitor patients' health status – are essential for managing complex conditions like HF. RPM has proven particularly promising for HF management, facilitating early detection of decompensations, allowing continuous and dynamic therapy adjustments, and addressing multimorbidity (Alami *et al.*, 2023). Even before the pandemic, the Telemedical Interventional Management in Patients with HF (TIM-HF2) trial (Koehler, Koehler, Deckwart, Prescher, Wegscheider, Kirwan, *et al.*, 2018) demonstrated that structured RPM interventions could reduce the days lost due to unplanned cardiovascular hospitalisations and all-cause mortality. Current European Society of Cardiology's HF clinical practice guidelines (Seferovic *et al.*, 2019; McDonagh *et al.*, 2021) endorse similar strategies.

As reported in Tables 2.1 and 2.2 (Chapter 2), the cardiology department at HSM in Lisbon, Portugal, runs an RPM program for HF patients since 2017, in collaboration with a MedTech company that supplies technology and data analysis (*A telemonitorização como auxiliar ao tratamento da IC*, 2020). The RPM intervention employs protocol-based, non-invasive TM for HF patients with reduced ejection fraction (HFrEF). Patients are enrolled after hospital discharge for acute HFrEF and provided with home-monitoring devices to regularly measure physiological parameters. A clinical monitoring centre, operated by the MedTech partner, oversees patient data and offers round-the-clock phone support. Personalised alerts are triggered when two or more parameters are abnormal, prompting direct contact with the patient. Depending on severity, appropriate actions are taken, such as adjusting therapy, scheduling in-person consultations, or making emergency referrals. Full intervention details can be found in (Nunes-Ferreira *et al.*, 2020), a prospective study conducted by the program team to assess the intervention's feasibility and effectiveness. The study reports reductions in all-cause hospitalisation/mortality and HF-related hospitalisation (compared to usual care), and in days lost due to unplanned admissions/death (compared with an optimised protocol-based follow-up program (PFP) and usual care).

The HSM RPM program has demonstrated feasibility and effectiveness, offering an intervention aligned with several care integration elements outlined in the framework presented in Figure 3.2 (Chapter 3). However, the program faces resource challenges in scaling and managing a larger population. According to (Administração Central do Sistema de Saúde, 2024), 32 patients were treated in 2020 and 2021, increased to 35 in 2022, but dropping to 25 in 2023. As healthcare institutions face resource constraints, stronger evidence of value for money is need to ensure funding (Bidonde *et al.*, 2024).

Regulatory agencies and healthcare institutions use HTA to decide whether to fund specific models and technologies (O'Rourke, Oortwijn and Schuller, 2020). While CEA is at the core of HTA, it often overlooks broader valuable aspects (e.g., QoL, resource optimisation, caregiver burden, self-care capacity) (Zhang *et al.*, 2022), disadvantaging complex care models like RPM (as evidenced in Chapter 5). The societal impacts of HF RPM remain largely unexplored, with most studies focusing only on clinical benefits and direct costs (Mokri, van Baal and Rutten-van Mölken, 2024). Additionally, the rapid evolution of ICT and the data-intensive nature of chronic disease management expose the inadequacies of traditional HTA methods and tools. A survey of 22 European HTA organisations identified data processing gaps as the primary challenge in assessing complex technologies (Hogervorst *et al.*, 2022). These limitations hinder RPM managers from accessing reliable, up-to-date, and complete evidence needed for informed decision-making, stressing the need for advanced HTA DSSs (Rabiei *et al.*, 2024).

To meet the need for practical yet comprehensive tools that support day-to-day monitoring and RPM HTA, Chapter 4 introduced SBI-MD, an innovative integrative approach combining MCDA, DataViz tools and stakeholder participation to collaboratively create value-based management dashboards. From a value measurement perspective, MCDA offers a viable alternative to CEA in RPM HTA, integrating additional aspects into assessment and improving transparency of their relative influence on decisions (Angelis, Kanavos and Phillips, 2020; Khanal *et al.*, 2024). Despite its excellent potential, MCDA still faces challenges in processing data and evidence and providing model flexibility (Oliveira, Mataloto and Kanavos, 2019). Moreover, many studies rely on *ex-ante*, short-term assessments rather than ongoing HTA (Hogervorst *et al.*, 2022). To address these challenges, SBI-MD enhances MCDA by integrating BI and PMS methods, including automated evidence synthesis, interactive model-building, *big data* management, user-friendly visualisation, advanced analytics, and real-time value measurement (Bana e Costa, Carnero and Oliveira, 2012; Bollaerts *et al.*, 2018; Valks *et al.*, 2021).

Furthermore, when conducting HTA for complex health interventions like RPM, key aspects of complexity are often overlooked e.g., shifting perspectives, indeterminate phenomena, uncertainty, unpredictable outcomes, historicity, and time and path dependencies (Lysdahl *et al.*, 2017; Sarri *et al.*, 2021). To address this, SBI-MD integrates participatory approaches like workshops, Delphi, NGT, and DC. These methods complement data-driven evidence with insights from stakeholders' experiences, fostering social cohesion, facilitating knowledge-sharing, and ensuring that developed tools are user-focused and meet stakeholders' needs (Bindels *et al.*, 2016; Woudstra *et al.*, 2022).

Within this context, this Chapter describes the application of the SBI-MD approach for constructing an MMD for the tactical and strategic management of the HF RPM program at HSM, addressing two main objectives. The first is to progress with HSM's care integration efforts by fostering continuous outcome evaluation and identifying areas for improvement, improving access, care quality and acceptability. The second is to objectively, transparently, and comprehensively demonstrate the program's impacts to top decision-makers and society at large. Specifically, this collaborative effort with the cardiology department at HSM aims to create a DSS that functions as a daily management tool, but also as a facilitating platform for C-level discussions on securing additional resources, which would strengthen the care team and infrastructure, enabling the RPM program to scale up and serve more HF patients. Within the scope of this thesis, the study validates the approach proposed in Chapter 4 within a real-world healthcare setting.

7.3. SBI-MD Application to the HSM Case

As outlined in Chapter 4, SBI-MD is an integrated stepped approach intended to guide the design, construction, and implementation of MMDs in the complex, multidimensional, and multi-stakeholder context of RPM HTA. The approach is divided into three pivotal phases: (1) **Structure RPM value dimensions and indicators**; (2) **Build the MMD**; and (3) **Implement the MMD**. Each phase consists of four objective-oriented steps, further broken into sub-steps that align technical tasks with social processes to ensure successful execution.

In the design and construction of an MMD to manage the HF RPM program in the cardiology department at HSM, the project focused on Phases 1 and 2 of SBI-MD. This project scope resulted in a prototype MMD to be considered for review by a broad group of stakeholders, including the cardiology department director and the clinical director of HSM. If approved, implementation (Phase 3) automates real-world data integration, contingent upon ethics approval. Indeed, Step 2.0 (**Building a Data Workspace**) was not completed; instead, the project progressed using a partial, anonymised dataset shared by PKs (based on (Nunes-Ferreira *et al.*, 2020) data, for 2017-2019) and supplemented with synthetically generated data. Figure 7.1, adapted from Figure 4.2 in Chapter 4, clarifies the project scope.

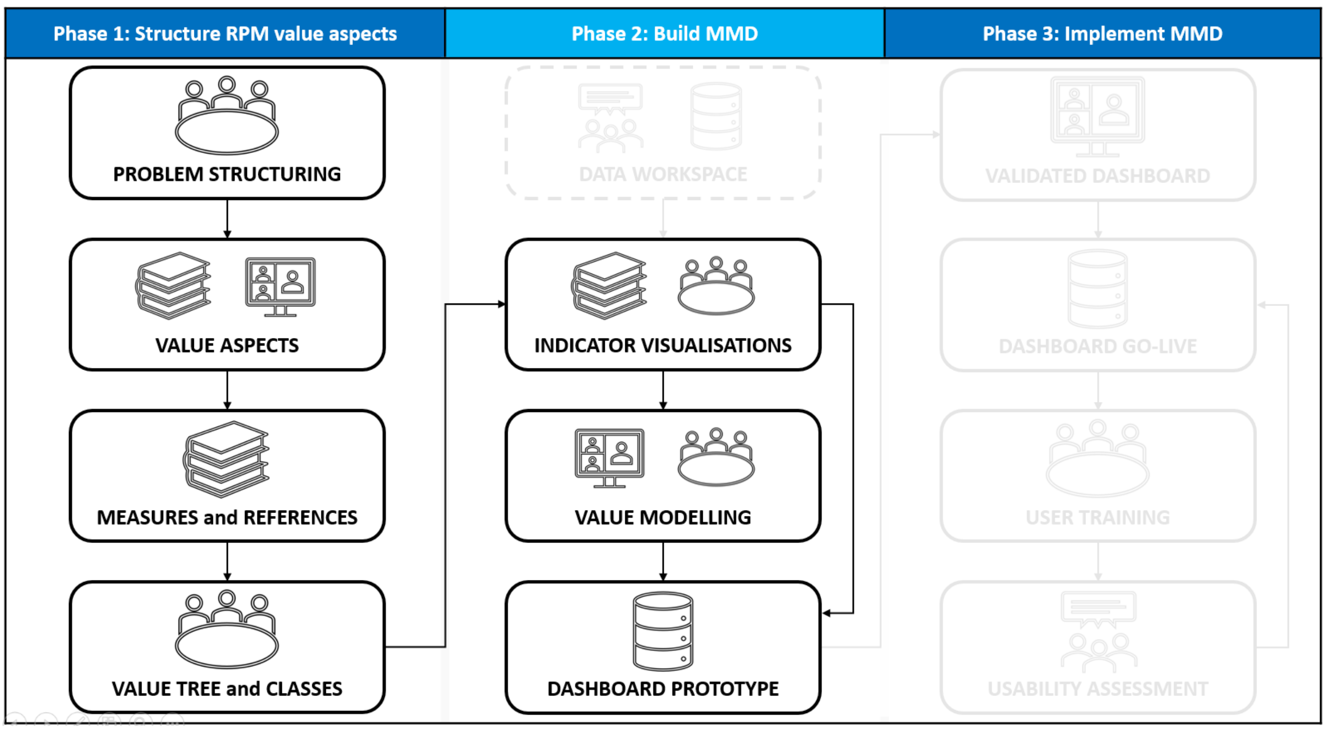


Figure 7.1. Overview of the SBI-MD scope for HSM project. Phases 1 and 2 are conducted to support the design and construction of an MMD prototype for HF RPM program management.

This Chapter continues to focus on the application domain of HF RPM, therefore building upon the work outlined in Chapters 5 and 6. Continuity facilitated the reuse of results from those Chapters in the HSM case, enabling a more expedite approach. Specifically, the list of value dimensions and indicators from Table 5.5 (Chapter 5) and the DataViz formats selected in Chapter 6 for case-mix parameters (Figure 6.5, bottom) and indicators related to *Access* and *Clinical Aspects* (Table 6.5). These elements were presented to HSM PKs for validation, leading to context-specific modifications to the methods described in Chapter 4 for Steps 1.2 and 2.1. Notably, the transferability of the Table 5.5 list posed no significant challenges, as one PK participated as an expert in the participatory process described in Chapter 5. The following sub-sections explain how each step of the SBI-MD approach was applied to the HSM case. Context-specific adjustments made to address encountered application challenges are described and the results obtained at each step are presented.

7.3.1. Step 1.1: Problem Structuring and Model Design

On December 28, 2023, a group session was held at HSM with four cardiologists from the HF RPM program. The facilitator introduced SBI-MD, explained the model structure, and presented the potential MMD tool. After obtaining informed consent from participants, a 1.5-hour group interview followed, comprising three tasks: defining the problem's domain and scope, identifying relevant actors, and selecting methods, a facilitation team, and support tools.

Guided by the MAST framework (Kidholm *et al.*, 2012), the problem's domain and scope was defined. Two alternatives to HF RPM were identified: PFP (Agostinho *et al.*, 2019) and usual care (as described in (Nunes-Ferreira *et al.*, 2020)). The program, mature and operational for over six years, features a stable clinical team and scientific outreach (Agostinho *et al.*, 2019; Nunes-Ferreira *et al.*, 2020; Rigueira *et al.*, 2021; Rodrigues *et al.*, 2023) but is constrained by staffing shortages and non-exclusive dedication, limiting enrolment to 50-100 patients. The group determined that the MMD tool could support local management (HSM level) and benchmarking at the regional level (Lisbon and Tagus Valley).

In the second task, participants added a fifth cardiologist to the PKs group and identified three relevant decision-makers for strategic, financial, and data privacy matters to be informed throughout the project and involved in Phase 3. Two monitoring centre professionals were appointed as relevant for data gathering and processing topics. The facilitation team, comprising a lead facilitator (RM) and a senior supervisor (MDO), was then established. Qlik Sense® was selected for dashboard building (leveraging the lead facilitator’s expertise and widespread recognition), M-MACBETH for value modelling, Menti™ for voting and at-distance surveying, and Microsoft Teams™ for online sessions.

7.3.2. Step 1.2: Identifying and Selecting Value Aspects

The participatory approach associated with this Step was employed in Chapter 5 to identify and select value aspects for monitoring and evaluating HF RPM programs. For HSM, we built upon this work, starting with the value dimensions and indicators outlined in Table 5.5. To ensure the list’s relevance, we validated its transferability with HSM PKs. However, due to the specific requirements of the HSM TM surveillance protocol, the list was adjusted to align with the context of care provision.

After a brief review (Step 1.1, post-process design) and an in-depth analysis (Step 1.4), one value dimension (*Technology*) and seven indicators were excluded, two case-mix parameters were added, and 25 text and conceptual adjustments were implemented. These changes included 10 minor text revisions, 10 scale clarifications, and 5 conceptual updates. The conceptual updates were guided by (*a*) the patient surveillance protocol, which involved no scheduled consultations and relied on telephone contacts, (*b*) the recognition that NT-ProBNP variation is more informative than its average value for program management, (*c*) the consideration of oedema as one of several HF symptoms, and (*d*) the simplification of the patient adherence measure to focus solely on compliance with biosignal transfer.

7.3.3. Step 1.3: Defining Measures and References

Step 1.3 outcomes are detailed in Supplementary File 7.1, an Excel file containing three spreadsheets: ***MEASURES***, ***MEASURES (After March 1st WS)*** and ***INTERRELATIONS***.

MEASURES includes a table with 50 rows – corresponding to indicators and case-mix variables from Table 5.5 in Chapter 5 (plus a PK-proposed *Medication/therapy* variable) – and seven columns. Table 7.1 presents a subset of this data, focusing on the *Access* value dimension. To avoid redundancy, the *Indicator description* column is omitted here, as the same information is already detailed in Table 5.5. *Proxy* lists the closest concept in the literature, with a *Reference* when available. The columns *Min. acc.* and *Target* specify, respectively, the lowest satisfactory performance level and a realistic and attainable "good performance." Key references supporting the definitions of *Measure*, *Min. acc.* and *Target* include (Nunes-Ferreira *et al.*, 2020) [together with the PK-shared dataset (2017-2019)], (Agostinho *et al.*, 2019), and, for *Costs*, (Calò *et al.*, 2013; da Silva Etges *et al.*, 2019; Lopez-Villegas *et al.*, 2020).

Table 7.1. Subset of ***MEASURES*** data, focused on the *Access* value dimension.

Indicator name	Proxy	Reference	Measure	Min. acc.	Target
Access					
Eligible patients followed by the RPM program (%)	-	-	COUNT(patient_id)/hospital_HF_patients		
Length of stay in the ward	LoS	(Agostinho *et al.*, 2019)	ward_discharge_date-ward_admission_date	10 (6-14.5)	
Length of stay in intensive care	-	-	icu_discharge_date-icu_admission_date		
Number of days of activity lost	Avg	(Nunes-Ferreira *et al.*, 2020)	AVERAGE(los_ward+los_icu+ed_visits+DAYS(program_end_date - death_date))	48,8	5,6
Number of HF-related emergency visits	# Unplan. Adm.	(Nunes-Ferreira *et al.*, 2020)	COUNT(patient_id[admissions])		163
Number of HF-related hospitalisations	% HF Hosp.	(Nunes-Ferreira *et al.*, 2020)	COUNT(DISTINCT(patient_id[hosp]))/COUNT(patient_id)	36%	12%
Number of HF-related readmissions	% HF Re-Adm.	(Agostinho *et al.*, 2019)	COUNT(DISTINCT(patient_id[admissions]))/COUNT(patient_id)	36%	16%
~~Number of scheduled face-to-face consultations~~					
Number of unscheduled face-to-face consultations	PFP group	(Agostinho *et al.*, 2019)	AVERAGE(GROUPBY(patient_id[consultation], unplanned_cons_dt))	8	0
~~Number of scheduled teleconsultations~~					
Number of unscheduled teleconsultations	-	(Nunes-Ferreira *et al.*, 2020)	AVERAGE(GROUPBY(patient_id[consultation], support_dt))		
Waiting time for a face-to-face consultation	-	(Nunes-Ferreira *et al.*, 2020)	unplanned_cons_dt - doctor_dt		
Waiting time for a teleconsultation	-	(Nunes-Ferreira *et al.*, 2020)	support_dt - yellow_alert_dt		
Time to medical action	-	(Nunes-Ferreira *et al.*, 2020)	doctor_dt - clinical_alert_dt		

Notes: Strikethrough indicators are not applicable to the RPM configuration and have therefore been removed.

INTERRELATIONS contains four matrices (one for each value dimension, except *Technology*) that map three types of interrelations between indicators: ∪ (potential to combine), ∑ (non-isolable indicators), and ←, →, ↔ (preference dependence, with arrows indicating direction). The analysis identified 14 criteria (marked in gold, further validated in Step 1.4), which align with program objectives: (*a*) ensuring timely care, minimising hospital stays, and promoting patient recovery; (*b*) improving clinical outcomes and preventing avoidable admissions; and (*c*) boosting patient satisfaction, therapy adherence, and self-care. The analysis also identified five opportunities for combining indicators. Figure 7.2 illustrates an example interrelations matrix for the Acceptability value dimension.

	Acceptability								
Acceptability	Compliance	Patient satisf.	HP satisf.	Caregiver	Awareness	Self-care	Trust	Therapy adh.	Dropouts
Patient adherence to the program (**Compliance**)								Σ	Σ
Patient satisfaction (**Patient satisf.**)			?	←					
Health professional satisfaction (**HP satisf.**)				↔					
Caregiver overload									
Disease management capacity after the program (**Awareness**)						Σ			
Level of self-care (**Self-care**)									
Patient's trust in the program (**Trust**)									
Medication/therapy adherence (**Therapy adh.**)									
Number of program dropouts (**Dropouts**)									

Figure 7.2. Example interrelations matrix for the *Acceptability* value dimension. Indicators' short names are shown in parentheses. Gold text represents indicators that potentially constitute criteria (*Compliance*, *Patient satisf.*, *Awareness* and *Trust*. *Caregiver* is preference dependent on *Patient satisf.*, and mutually preference dependent with *HP satisf.* *Awareness* contains *Self-care* and *Compliance* encompasses both *Therapy adh.* and *Dropouts*.

7.3.4. Step 1.4: Validating the Value Tree and Defining Achievement Classes

On March 1, 2024, a second group session was held at HSM (lasting 1h12) with four PKs, three of whom had attended the first session, while one was new, and another was absent due to scheduling conflicts. Participants received the agenda and the ***MEASURES*** spreadsheet beforehand. The facilitator (RM) presented a brief (10 min.) update on the facilitation team's progress and outlined the workshop's tasks: validating measures and references (20 min.), identifying evaluation criteria (15 min.), establishing achievement classes (5 min.), and reviewing results (10 min.). Due to PKs' clinical duties, the third task was postponed to Step 2.2.

Participants revised the ***MEASURES*** spreadsheet, focusing on *Access* and *Clinical aspects* indicators, which sparked extensive debate, while *Acceptability* indicators required minor changes but highlighted a need for improved data collection (most proposed scales had never been assessed). *Costs* revealed to be challenging to assess and deemed to require input from other HSM stakeholders, while *Technology* indicators were excluded as outside PKs' tactical scope. The revised spreadsheet ***MEASURES (After March 1st WS)*** was reduced to 44 rows (36 indicators and 8 case-mix variables).

PKs then assessed 14 proposed criteria (illustrated in M-MACBETH; Figure 7.3 shows the final tree). *Program cost per patient* and *Costs for the patient* were excluded to ensure a separate value-based assessment of benefits and costs, minimising potential preference dependence (Porter, 2010). *Eligible patients followed by the RPM program* was also excluded as it was deemed beyond PKs' control. A new *Stakeholder satisfaction* criterion was introduced to cover both patient and health professional satisfaction. Moreover, minor text edits were made (e.g. *Patient's activity loss*, *Self-perceived quality of life* or removing "due to HF compared to (…)" from *Avoidable hospital admissions*).

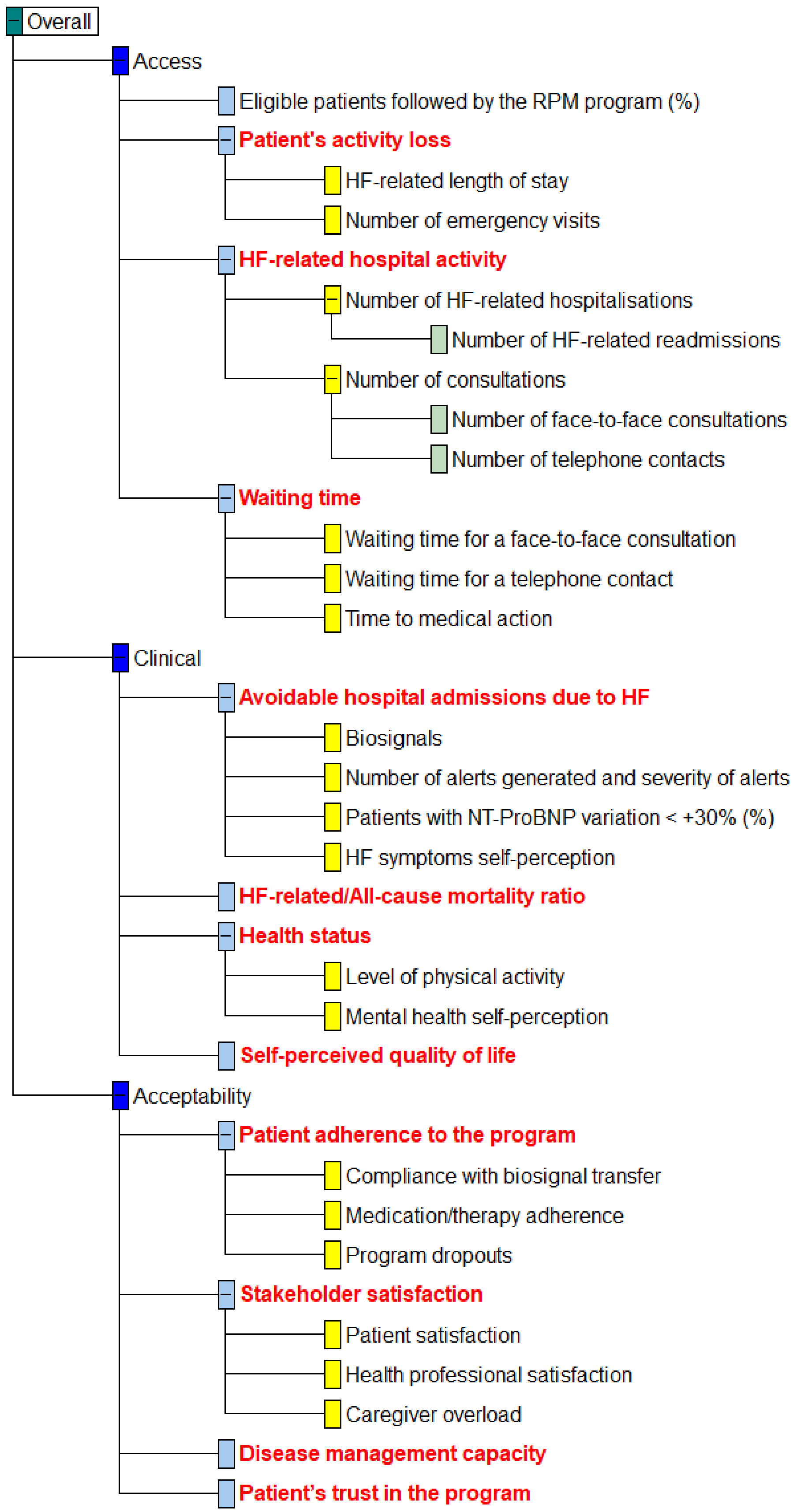


Figure 7.3. Value tree after validation by PKs. It includes 11 criteria across three value dimensions (*Access*, *Clinical aspects* and *Acceptability*).

7.3.5. Step 2.1: Deploying Indicator Visualisations

Step 2.1 of SBI-MD begins with the facilitation team conducting an autonomous analysis of KPI and case-mix parameter names, descriptions, and measures for their communication properties. Table 7.2 details their data structure and communication purpose. Most KPIs support ongoing tactical and strategic performance assessment, thus *Showing changes over time* communication is the predominant communication purpose. Nonetheless, as some KPIs are tied to scales or population classes, *Assessing hierarchies and part-to-whole relationships* is also common, especially for case-mix parameters.

Table 7.2. KPIs' data structure and communication purpose.

KPI (within dimension)	Variables	Data structure	Communication purpose
Access			
Eligible patients followed by the RPM program (%)	Current value (versus Reference)	Q	Displaying dimensionless measures
HF-related length of stay	Average number per Month	QC	Showing changes over time
Number of days of activity lost	Average number per Month/Year	QC	Showing changes over time
Number of HF-related emergency visits	Total number per Month	QC	Showing changes over time
Number of HF-related hospitalisations	Total number per Month	QC	Showing changes over time
Number of HF-related readmissions	Total number per Month	QC	Showing changes over time
Number of consultations	Average number per Month	QC	Showing changes over time
Number of telephone contacts	Average number per Month	QC	Showing changes over time
Waiting time for a consultation	Average time per Month	QC	Showing changes over time
Waiting time for a telephone contact	Average time per Month	QC	Showing changes over time
Time to medical action	Average time per Severity	QC	Comparing categories
Clinical aspects			
Avoidable hospital admissions due to HF	Current value (versus Reference)	Q	Displaying dimensionless measures
Biosignals	Average number over threshold per Date	QQ	Showing changes over time
HF-related/All-cause mortality ratio	Current value (versus Reference)	Q	Displaying dimensionless measures
Number of alerts generated and severity of alerts	Total number per Severity	QC	Assessing hierarchies and part-to-whole relationships
Level of physical activity	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Patients with ΔNT-ProBNP < +30% (%)	Current value (versus Reference)	Q	Displaying dimensionless measures
Mental health self-perception	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
HF symptoms self-perception	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Quality of life self-perception	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Acceptability			
Compliance with biosignal transfer	Compliance ratio per Month	QC	Showing changes over time
Patient satisfaction	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Health professional satisfaction	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Caregiver overload	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Disease management capacity	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Level of self-care	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Patient's trust in the program	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Medication/therapy adherence	Average number per Month	QC	Showing changes over time

Dropout rate	Dropout ratio per Month	QC	Showing changes over time
Costs			
Program cost per patient	Average cost per Month per Cost component	QCC	Showing changes over time
Costs for the patient	Total cost per Month	QC	Showing changes over time
Emergency service admission costs	Total cost per Month	QC	Showing changes over time
Hospital admission costs	Total cost per Month	QC	Showing changes over time
ICU hospitalisation costs	Total cost per Month	QC	Showing changes over time
Face-to-face consultations costs	Total cost per Month	QC	Showing changes over time
Teleconsultation costs	Total cost per Month	QC	Showing changes over time
Case-mix parameters			
Age group	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Classification of HF according to LVEF	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Comorbidities	Total number per Condition	QC	Comparing categories
Distance to the nearest healthcare facility	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Frailty class	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Literacy level	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships
Medication/therapy	Total number per Therapy	QC	Comparing categories
NYHA classification	Total number per Class	QC	Assessing hierarchies and part-to-whole relationships

Notes: C = categorical; Q = quantitative.

As the analysis of interrelations between indicators revealed opportunities to combine KPIs, DAFs reflected these findings into their DataViz proposals to PKs. DataViz sets were then derived from SBI-MD's decision table (refer to Table 6.2 in Chapter 6), considering the updated communication properties of the combined KPIs. Table 7.3 outlines the updated KPIs, specifying which individual KPIs were consolidated, the revised data structure, and corresponding DataViz sets.

Table 7.3. Updated KPI list (considering composite KPIs) and corresponding visualisation format sets.

Composite indicator	Short name	KPI	Data structure	DataViz formats set
Access				
Eligible patients followed by the RPM program (%)	% Patients	=	Q	(Linear) Gauge KPI Bar Chart (if per Month)
HF-related Length of stay	LoS	=	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI)
Number of days of activity lost	DAL	=	QC	Bar Chart (Linear) Gauge (if Q) Area Chart (if QQ) Line Chart (if QQ)
HF-related hospital activity	Activity	Number of HF-related emergency visits Number of HF-related hospitalisations Number of HF-related readmissions	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI)
Number of consultations	Cons.	Number of consultations Number of telephone contacts	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI) Waterfall Chart (if QQC and *Comp. categories*)
Waiting time	=	Waiting time for a consultation Waiting time for a telephone contact Time to medical action	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Bar Chart (for each KPI)
Time to medical action (by alert severity)	Time to MD	Time to medical action (Red alert) Time to medical action (Yellow alert) Time to medical action (Green alert)	QC	Area Size Chart Bar Chart Word Cloud

				Grouped Bar Chart (if QCC)
Clinical aspects				
Avoidable hospital admissions due to HF	Avoidable	=	Q	(Linear) Gauge KPI Area Chart (if QQ) Bar Chart (if QC)
Biosignals	=	=	QQ	Area Chart Line Chart Sparklines Bar Chart (if QC)
HF-related/All-cause mortality ratio	% HF death	=	Q	(Linear) Gauge KPI Area Chart (if QQ) Bar Chart (if QC)
Number of alerts generated and severity of alerts	Alerts	=	QC	Pie Chart (100%) Stacked Bar Chart Grouped Bar Chart (if per Month)
Level of physical activity	Physical	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Patients with ΔNT-ProBNP < +30% (%)	NT-ProBNP	=	Q	(Linear) Gauge KPI Area Chart (if QQ) Bar Chart (if QC)
Mental health self-perception	Mental health	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
HF symptoms self-perception	HF symptoms	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Quality of life self-perception	QoL	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Acceptability				
Patient adherence to the program	Compliance	Compliance with biosignal transfer Medication/therapy adherence Dropout rate	QQC	(Stacked) Area Chart Line Chart Streamgraph
Stakeholder satisfaction	Satisfaction	Patient satisfaction Caregiver overload Health professional satisfaction	QCC	Dot Plot Grouped Bar Chart Two-sided Bar Chart (100%) Stacked Bar Chart (if *Showing changes over time*)
Disease management capacity	Awareness	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Level of self-care	Self-care	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Patient's trust in the program	Trust	=	QC	Pie Chart (100%) Stacked Bar Chart Bar Chart (if *Comp. categories*)
Costs				
Program cost per patient	€ Avg	Emergency service admission costs Hospital admission costs ICU hospitalisation costs Face-to-face consultations costs Teleconsultation costs	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Waterfall Chart (if QQC and *Comp. categories*) KPI (for each KPI)
Costs for the patient	€ OoP	=	QC	Bar Chart Area Chart (if QQ) Line Chart (if QQ) Sparklines (if QQ) Waterfall Chart (if QQC and *Comp. categories*)
Total program cost	€ Total	Emergency service admission costs Hospital admission costs ICU hospitalisation costs Face-to-face consultations costs Teleconsultation costs	QCC	Grouped Bar Chart (100%) Stacked Bar Chart Waterfall Chart (if QQC and *Comp. categories*) KPI (for each KPI)
Case-mix parameters				

Age group	Age	=	QC	Pie Chart (100%) Stacked Bar Chart
Classification of HF according to LVEF	LVEF class	=	QC	Pie Chart (100%) Stacked Bar Chart
Comorbidities	=	=	QC	Area Size Chart Bar Chart Word Cloud
Distance to the nearest healthcare facility	Distance	=	QC	Pie Chart (100%) Stacked Bar Chart
Frailty index	Frailty	=	QC	Pie Chart (100%) Stacked Bar Chart
Literacy level	Literacy	=	QC	Pie Chart (100%) Stacked Bar Chart
Medication/therapy	=	=	QC	Area Size Chart Bar Chart Word Cloud
NYHA classification	NYHA	=	QC	Pie Chart (100%) Stacked Bar Chart

Notes: C = categorical; Q = quantitative.

To facilitate sets' appraisal, eleven Qlik Sense® pages were created. Since dashboard pages on *Case-mix*, *Access*, and *Clinical aspects* had already been constructed and validated (as described in Chapter 6), DAFs focused on developing alternative pages based on these, incrementing the available options. Each Qlik Sense® page for the remaining KPIs (from *Acceptability* and *Costs*) featured four DataViz formats, showing individual and combined KPI visualisation options. Figure 7.4 presents examples of alternative pages for *Case-mix* (top and middle) and the DataViz set illustrating *Patient's trust in the program* (bottom).

After preparing the Qlik Sense® pages for appraising the DataViz sets, two collaborative processes followed: an online questionnaire and a CDB workshop. The online questionnaire, launched on April 24, 2024, aimed to gather individual and anonymous PK preferences for the best DataViz alternative for each dashboard page or KPI. The survey (available in Portuguese as Supplementary File 7.2) closed on May 20, 2024, with four complete responses and one partial submission. Weekly reminders were sent to ensure all PKs participated. Hosted on Menti™ (https://www.menti.com/), the questionnaire took 15–20 minutes to complete. Participants reviewed DataViz screenshots, voted on their preferred options, and provided feedback for adjustments through anonymous comments. Voting results and comments are detailed in Supplementary File 7.2.

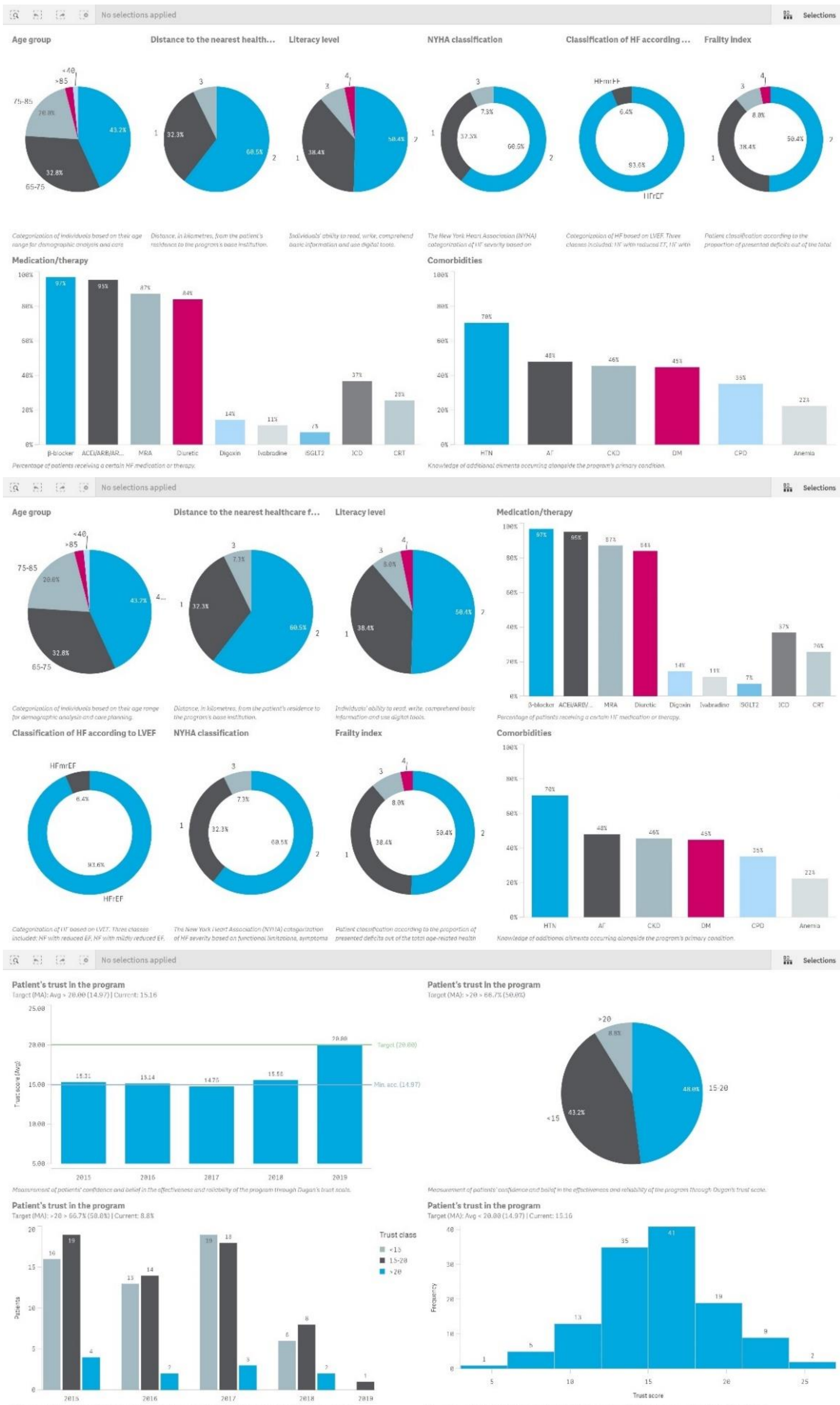


Figure 7.4. Qlik Sense® alternatives for *Case-mix* (top and middle) and *Patient's trust in the program* (bottom).

The CDB workshop on May 31, 2024, lasted 1h38 with three PKs. The agenda included a project review (10 min.), questionnaire results discussion and novel voting round (5 min. per KPI), *Costs* KPIs analysis (15 min.), building prototype dashboard pages on *Acceptability* and *Costs* (15 min.), aesthetic and analytical features selection (5 min.), and next steps (10 min.).

After discussing questionnaire results, PKs selected the final DataViz formats by consensus. Ten different formats were used to deploy 36 KPI visuals, with 38.8% being Bar or Pie Charts. New *Access* page visualisations were requested to emphasise *DAL*, *LoS*, and *Time to MD*. *Clinical aspects* KPIs were adjusted based on PK feedback, and most *Acceptability* KPIs were updated to aim for 50% (*Min. acc.* level) and 75% (*Target*) of patients in the best scale category. New visuals were created for *Dropout rate* and *Medication/therapy adherence*. *Level of self-care* was removed as redundant given *Disease management capacity* (measured by the KCCQ [Self-eff.] scale). Table 7.4 presents the final list of 8 case-mix variables and 25 KPIs for visualisation. Considering prototype building and aesthetic and analytical features, participants requested (*a*) a usual care benchmark for *Costs*, (*b*) maintaining a blue colour scheme over the hospital's palette for improved readability and neutrality, (*c*) date filters for time-dependent analysis and (*d*) a drill-down feature for *Patient's trust in the program*, enabling a switch between yearly averages and histogram.

Table 7.4. KPIs' DataViz format, description, measure(s), and reference values. References are calculated considering 125 patients through 5 years.

KPI [DataViz]	Description	Measure	Min. Acc.	Target
Case-mix parameters				
Age group [Pie Chart]	Categorization of individuals based on their age range for demographic analysis and care planning.	% Patients per Age group (5 classes)	-	-
Classification of HF according to LVEF [Donut Chart]	Categorization of HF based on LVEF. Three classes included: HF with reduced EF, HF with mildly reduced EF, and HF with preserved EF.	% Patients per Class (HFrEF, HFmrEF, HFpEF)	-	-
Comorbidities [Bar Chart]	Knowledge of additional ailments occurring alongside the program's primary condition.	% Patients with Comorbidity	-	-
Distance to the nearest healthcare facility [Pie Chart]	Distance, in kilometres, from the patient's residence to the program's base institution.	% Patients per Distance group (3 classes)	-	-
Frailty index [Donut Chart]	Patient classification according to the proportion of presented deficits out of the total age-related health variables considered.	% Patients per Class (4 classes)	-	-
Literacy level [Pie Chart]	Individuals' ability to read, write, comprehend basic information and use digital tools, according to the Digital Health Technology Literacy Assessment Questionnaire (DHTL-AQ).	% Patients per DHTL-7AQ level	-	-
Medication/therapy [Bar Chart]	Percentage of patients receiving a certain HF medication or therapy.	% Patients with Medication/therapy		
NYHA classification [Donut Chart]	The New York Heart Association (NYHA) categorization of HF severity based on functional limitations, symptoms and the physician's objective assessment.	% Patients per Class (I, II, III, IV)	-	-
Access				
Eligible patients followed by the RPM program (%) [Bar Chart]	Percentage of eligible HF patients from the healthcare institution who are enrolled in the telemonitoring program.	Ratio between TM-enrolled and hospital HF patients	-	-
HF-related length of stay [Bar Chart]	Average length of stay, in days, due to HF-related causes before discharge or death.	Avg. stay days per hospitalisation	14.5	5.6
Number of days of activity lost [Bar Chart]	Total days of absence or reduced activity due to health-related needs (e.g., emergency room admission, hospitalisation, premature death).	Avg. sum of LoS, emergency visits and premature death per year	48.8	5.6

HF-related hospital activity [Grouped Bar Chart]	Total count of healthcare events (ER, hospitalisation, inpatient admissions) due to HF-related causes.	# Emergency visits per year	49	33
		# Hospitalisations per year	45 (36%)	15 (12%)
		# (Re)admissions per year	45 (36%)	20 (16%)
Number of consultations [Waterfall Chart]	Total count of appointments (in-person or virtual) within the program duration.	# Consultations per year	1000 (8 p.p.)	500 (4 p.p.)
Waiting time [Grouped Bar Chart]	Time from request (alert or appointment) to initiation of contact (nurse phone call, medical action, or face-to-face consultation. Telephone and MD action times in hours; face-to-face in days.	Avg. time to telephone contact	6 hours	1 hour
		Avg. time to medical action	8 hours	3 hours
		Avg. time to consultation	30 days	7 days
Time to medical action [Bar Chart]	Time, in hours and by alert severity, from an alert of patient decompensation to appropriate medical intervention and monitoring.	Avg. time for green alert	TBD	4 hours
		Avg. time for yellow alert	TBD	2 hours
		Avg. time for red alert	TBD	10 min.
Clinical aspects				
Avoidable hospital admissions due to HF [Area Chart]	Percentage of preventable (i.e., clinical alert is not responded to) hospital admissions related to HF within the program duration.	% Admissions w/ unresponded clinical alerts within 24h	33%	0%
Biosignals [Bar Chart]	Average monthly count of clinical alerts i.e., when a patient exhibits two or more vital sign measurements outside their defined normal range.	# Clinical alerts per month	170	113
HF-related/All-cause mortality ratio [Area Chart]	Ratio between the number of deaths directly linked to HF and all occurring deaths within the program duration.	Ratio between HF and all-cause mortality	33%	10%
Number of alerts generated and severity of alerts [Grouped Bar Chart]	Count and severity of alerts related to patient deterioration or decompensation for timely intervention and monitoring.	# Alerts per alert severity (green, yellow, red) per year	-	-
Level of physical activity [Histogram]	Measurement of patients' physical activity levels through the Six Minute Walk Test (6MWT).	6MWT score	316 (50%)	417 (75%)
Patients with ΔNT-ProBNP < +30% (%) [Linear Gauge]	Percentage of HF patients exhibiting a decrease or less than 30% increase in N-terminal pro-B-type natriuretic peptide (NT-proBNP) levels from the baseline.	% Patients w/ NT-ProBNP decrease or increase by less than 30%	50%	75%
Mental health self-perception [Histogram]	Measurement of patients' perception of their mental health status through the Hospital Anxiety and Depression Scale (HADS).	HADS score	11 to 21 (50%)	0 to 7 (75%)
HF symptoms self-perception [Histogram]	Measurement of patients' perception of HF symptoms e.g., oedema, through the KCCQ (Symp.) scale.	KCCQ (Symp.) score	67 (50%)	89 (75%)
Quality of life self-perception [Histogram]	Measurement of patients' perception of overall well-being and ability to participate in or enjoy everyday life moments through the Kansas City Cardiomyopathy Questionnaire (KCCQ).	KCCQ score	60 (50%)	77 (75%)
Acceptability				
Compliance with biosignal transfer [Pie Chart]	Measurement of patient adherence to transmit at least 75% of scheduled biosignal measurements, as recommended by the care team.	% Patients w/ a ratio between performed and scheduled transfers > 75%	67%	88%
Stakeholder satisfaction [Combined Line Chart]	Combined measurement of patient and health professional (HPs) satisfaction and caregiver (CGs) overload within the telemonitoring program. Patients: Home Monitoring Acceptance and Satisfaction Questionnaire (HoMASQ); HPs: Job Satisfaction Survey (JSS); CGs: 4-item Zarit Burden Interview (ZBI-4).	% Patients w/ HoMASQ score > 40.8 (Range: 0-48)	50% (24.0)	75% (40.8)
		% HPs w/ JSS class = "Satisfied" (i.e., Score > 144)	50% (108)	75% (144)
		% Caregivers w/ >ZBI-4 class = "Little or no" (i.e., Score < 21)	50% (41)	75% (21)
Disease management capacity [Bar Chart]	Measurement of patients' ability to understand how to prevent and manage HF exacerbations through the KCCQ (Self-eff.) scale.	% Patients w/ KCCQ (Self-eff.) score > 90 (Range: 0-100)	50% (75.0)	75% (90.0)
Patient's trust in the program [Bar Chart]	Measurement of patients' confidence and belief in the effectiveness and reliability of the program through Dugan's trust scale.	% Patients w/ DTS score > 20 (Range: 5-25)	50% (14.97)	75% (20.0)

Medication/therapy adherence [Grouped Bar Chart]	Measurement of patient adherence to medication intake and therapy through the Portuguese version of the Morisky Medication Adherence Scale (MMAS).	% Patients w/ MMAS class = "High" (i.e., Score = 8)	50% (6)	75% (8)
Dropout rate [Pie Chart]	Percentage of patients who abandoned the program before completion. Patients are considered dropouts if they transmit biosignals fewer than one day per week on average.	% Patients w/ a ratio between performed and scheduled transfers < 14.3% (considering everyday transfers)	8%	0%
Costs				
Program cost [Waterfall Chart AND Stacked Area Chart]	Total program cost, including telemonitoring elements (i.e., setup, devices) and activities, external consultations, emergency service admissions and hospitalisations.	Sum of costs of TM elements and activities, consultations, emergency visits and hospitalisations	TBD	TBD
Program cost per patient [Waterfall Chart AND Stacked Area Chart]	Total cost (on average) associated with a patient's clinical pathway within one year of program duration. Cost components: telemonitoring (TM) elements; telemonitoring activities (Ongoing); external consultations (Cons.); emergency service admissions (ER); hospitalisations (Hosp.).	Avg. sum of costs of TM elements and activities, consultations, emergency visits and hospitalisations per year	TBD	TBD
Costs for the patient [Waterfall Chart AND Stacked Area Chart]	Total expenses (on average) directly incurred by the patient within one year of program duration. Cost components (Calò et al. [2013]): visit; transportation; lost income.	Avg. sum of visit, transportation and lost income costs per year	288€	0€

7.3.6. Step 2.2: Value Modelling

Four decision interviews were conducted between June 17 and July 23, 2024, with an average duration of 1h22 (ranging from 1h15 to 1h35). The interviews began by ascertaining value functions for the 11 criteria. For that purpose, a MACBETH matrix was populated with pairwise judgements comparing performance levels for each criterion. Table 7.5 presents the performance measures, with the *Target* (*Min. acc.*) level highlighted in light green (blue). PKs first ranked the performance levels by attractiveness, then the facilitator requested at least filling in the last column of the matrix (comparing against the lowest level) and the first upper diagonal (comparing consecutive levels). The M-MACBETH software then computed a scale/function for PK review (see Figure 7.5 for *Patient's activity loss)*. After repeating the process for all criteria, weights were determined. PKs ranked criteria by the attractiveness of a swing from *Min. acc.* to *Target*, followed by MACBETH judgments. First-line judgments were also gathered for consistency. Table 7.6 presents individual rankings, judgments, average weights and mean deviation.

Table 7.5. Criteria, performance measures and reference values.

Criterion	Performance measure	Performance levels
Access		
Patient's activity loss [DAL]	Average yearly number of days lost due to unplanned hospital admissions or all-cause death.	0 days 5.6 days 12.4 days 48.8 days
HF-related hospital activity [Activity]	Qualitative performance levels combining HF-related hospitalisation rate and the number of yearly face-to-face consultations.	hc: The HF hosp. rate is <=12% and the avg. yearly number of cons. is <4. hC: The HF hosp. rate is <=12% and the avg. yearly number of cons. is >=4. Hc: The HF hosp. rate is >12% and the avg. yearly number of cons. is <4. HC: The HF hosp. rate is >12% and the avg. yearly number of cons. is >=4.
Waiting time [Waiting]	Qualitative performance levels combining the average waiting time for medical action and a face-to-face consultation.	mc: The avg. wait for medical action is <3h and for a cons. is <=7 days. mC: The avg. wait for medical action is <3h and for a cons. is >7 days. Mc: The avg. wait for medical action is >3h and for a cons. is <=7 days. MC: The avg. wait for medical action is >3h and for a cons. is >7 days.
Clinical		
Avoidable hosp. admissions due to HF [Avoidable]	Percentage of hospital admissions related to HF with a non-responded clinical alert.	0% 16.5% 33% 100%
HF-related/All-cause mortality ratio [% HF death]	Percentage of patients who died due to HF-related causes out of all deceased patients.	0% 10% 21.5% 33% 100%
Health status [Health]	Qualitative performance levels combining the percentages of patients with good physical activity and good mental health levels.	PM: At least 75% of patients have a 6MWT >417m and a HADS <8. Pm: At least 75% of patients have a 6MWT >417m, but not a HADS <8. pM: At least 75% of patients have a HADS <8, but not a 6MWT >417m. pm: 50% to 75% of patients have a 6MWT >417m and a HADS <8. Bad: Less than 50% of patients have a 6MWT >417m and a HADS <8.
Self-perceived quality of life [QoL]	Percentage of patients with a good (>77) Kansas City Cardiomyopathy Questionnaire (KCCQ) score.	100% 75% 62.5% 50% 0%
Acceptability		
Patient adherence to the program [Adherence]	Qualitative performance levels combining the dropout rate and percentages of patients with good compliance with biosignal transfer and good therapy adherence.	dMC: The dropout rate is marginal, >75% of patients have high MMAS scores and >88% have >75% compliance. dMc: The dropout rate is marginal and >75% of patients have high MMAS scores. DMC: >75% have high MMAS scores and >88% have >75% compliance. dmC: The dropout rate is marginal, and >88% of patients have >75% compliance. Dmc: The dropout rate is <8%, 67% to 88% of patients have >75% compliance and 50% to 75% have high MMAS scores. Bad: Any included KPI is below *Min. acc.*
Stakeholder satisfaction [Stk. Satisf.]	Qualitative performance levels combining the percentage of satisfied patients and satisfied health professionals (HPs).	PHP: At least 75%: of patients have a HoMASQ score >40.8; of HPs have a JSS >=144. Php: At least 75% of patients have a HoMASQ score >40.8. pHP: At least 75% of HPs have a JSS >=144. php: 50% to 75%: of patients have a HoMASQ score >40.8; of HPs have a JSS >=144. Bad: Any included KPI is below *Min. acc.*
Disease management capacity [Awareness]	Percentage of patients with a good (>90) KCCQ (Self-eff.) score.	100% 75% 62.5% 50% 0%
Patient's trust in the program [Trust]	Percentage of patients with a good (>20) Dugan's trust scale score.	100% 75% 62.5% 50% 0%

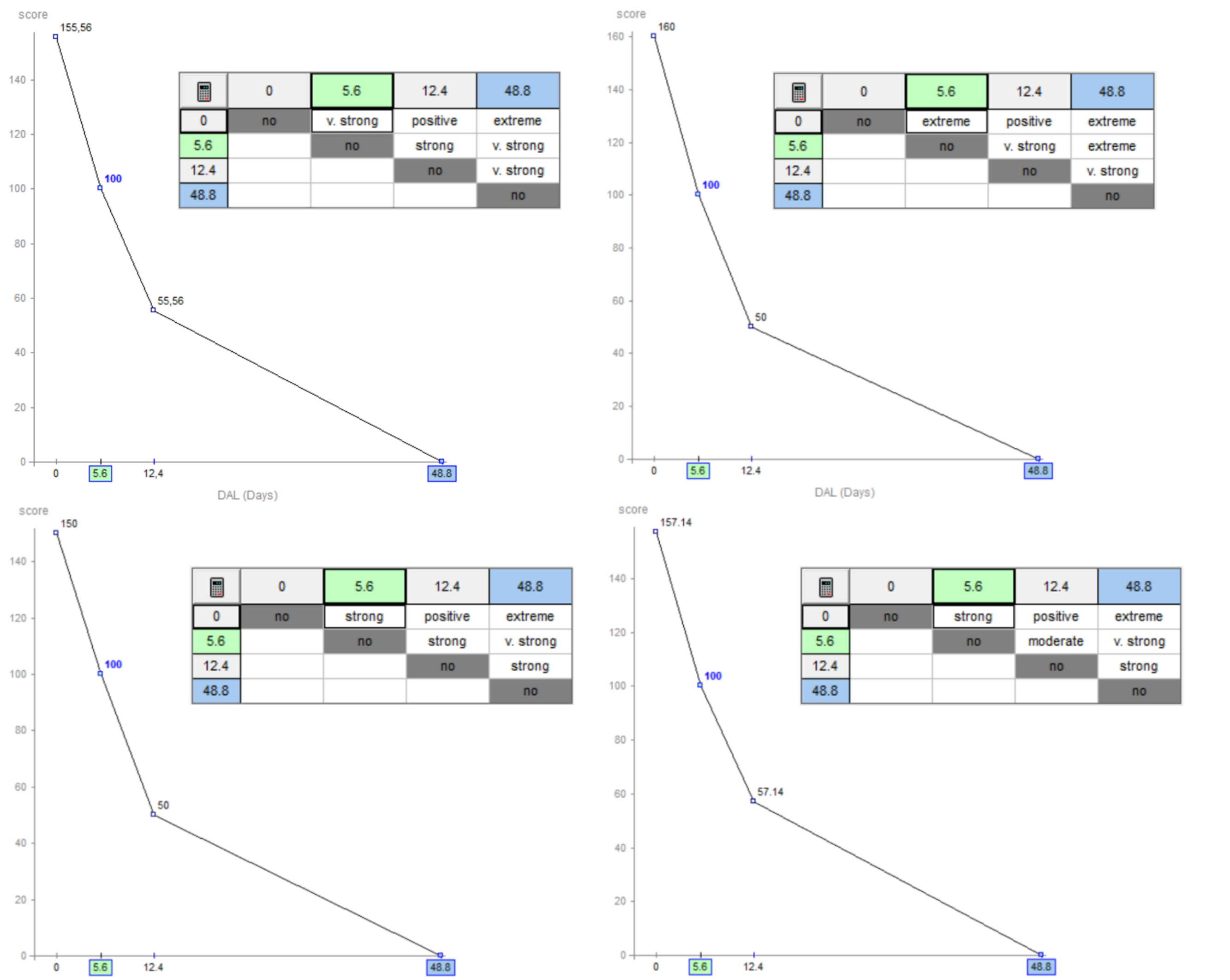


Figure 7.5. *Patient's activity loss*' MACBETH matrices and corresponding computed value functions for each interviewee.

Table 7.6. Weight elicitation results, including criteria reference levels, individual rankings, MACBETH judgements against the "all *Min. acc.*" alternative, and the average weight and mean deviation for each criterion.

Criterion	Min. Acc.	Target	Rank				Judgements							Avg.	MD
			P1	P2	P3	P4	No	VW	W	M	S	VS	E		
% HF death	<33%	<10%	1^{st}	3^{rd}	1^{st}	5^{th}					1	2	1	16,22	4,55
Activity	>12%,>=4yc	<12%,<4yc	3^{rd}	2^{nd}	4^{th}	3^{rd}					1	2	1	14,33	0,74
DAL	48.8 days	5.6 days	4^{th}	1^{st}	3^{rd}	6^{th}					1	1	2	14,22	2,22
Avoidable	<33%	0%	2^{nd}	4^{th}	2^{nd}	8^{th}				1		2	1	13,18	4,50
Health	50-75% Tar.	>75% Tar.	5^{th}	5^{th}	6^{th}	1^{st}					2	2		11,57	3,53
QoL	>50% Tar.	>75% Tar.	6^{th}	6^{th}	5^{th}	7^{th}					3	1		9,21	0,62
Adherence	Dmc	dMC	7^{th}	9^{th}	8^{th}	4^{th}					4			6,82	2,97
Self-eff.	>50% Tar.	>75% Tar.	11^{th}	7^{th}	9^{th}	2^{nd}				2	1	1		6,91	5,32
Waiting	>3h,>7d	<3h,<=7d	8^{th}	11^{th}	7^{th}	9^{th}			2	1		1		2,70	0,95
Trust	>50% Tar.	>75% Tar.	9^{th}	8^{th}	11^{th}	10^{th}		1		2	1			2,80	1,73
Stk. satisf.	50-75% Tar.	>75% Tar.	10^{th}	10^{th}	10^{th}	11^{th}		1		3				2,06	1,06

Between the decision interviews and the final DC, the facilitation team reconciled value scales/functions to determine a single group scale/function for each criterion. For one-dimensional scales, the average values from interviewees were used for each performance level. For example, in the case of *Patient adherence to the program*, all PKs ranked performance levels similarly, resulting in small mean deviations, except for the *Bad* level (45.43 mean deviation). The reconciled scale was: [(dMC, 100), (DMC, 74.54), (dMc, 49.69), (dmC, 24.77), (Dmc, 0), (Bad, -62.59)]. For *HF-related hospital activity*, *Waiting time* and *Health status*, differing rankings were addressed during the DC.

Value functions were reconciled using a web-based DSS (Fernandes *et al.*, 2024), which is limited to handling concave or convex delta functions, making it unsuitable for reconciling S-shaped functions. Additionally, the DSS does not always assign values of 0 and 100 to the *Min. acc.* and *Target* levels, as function parameters correspond to the first set of points, without appropriate significance. Therefore, the DSS was applied solely within the reference levels of the criterion, with values outside these levels determined either by (*a*) averaging the results from individual models or (*b*) using the value from the reconciled delta function. For example, the reconciled function for *Patient's activity loss* is:

$$y = 100 * \frac{1 - e^{-0.090282*(\mathrm{x}-48.8)}}{1 - e^{-0.090282*(5.6-48.8)}} \tag{7.1}$$

where the constant $c = 0.090282$, $x_i^0 = 5.6$ (*Target*) and $x_i^* = 48.8$ (*Min. acc.*). For zero DAL (above *Target*), PKs chose between values of 155.675 (average) or 167.1536 ($y(x_i = 0)$).

The DC (held online via Microsoft Teams™) on August 23, 2024, lasted 1h49 with four PKs (one had not participated in the decision interviews). The agenda included a project review (10 min.), validation of reconciled value scales/functions (55 min.), reconciled criteria ranking validation (5 min.), criteria weighting elicitation (10 min.), achievement class establishment (15 min.), and next steps (5 min.).

PKs first reviewed five value scales: *Activity*, *Waiting*, *Health*, *Adherence*, and *Stk. Satisf.* They focused primarily on the first three scales, lacking consensus on performance levels' rankings. After reaching a ranking agreement, *Activity* and *Waiting* scales were set to the average values from the individual scales already corresponding to the consensual ranking. *Health* and *Adherence* scales were adjusted using M-MACBETH's thermometer until a compromise reflected PKs' differing perspectives. The spreadsheet ***VALUE SCALES*** in Supplementary File 7.3 provides information on this reconciliation and validation process. For value function reconciliation (for *DAL*, *Avoidable*, *% HF death*, *QoL*, *Self-eff.*, and *Trust*), PKs discussed and validated delta functions' shapes, then decided the values for points beyond the reference levels. Overall, PKs decided on values minimising compensatory behaviour i.e., choosing the lowest absolute value. However, for *DAL*, *QoL*, and *Self-eff.*, PKs chose the higher absolute value at the point above *Target* to maintain function continuity, as differences between alternatives were minimal (7.4%, 1.1%, and 3.8%, respectively). The spreadsheet ***VALUE FUNCTIONS*** in Supplementary File 7.3 provides information on this reconciliation and validation process.

Criteria ranking validation took longer than planned due to conflicting views. PKs agreed on the lower-ranked criteria up to *QoL* (as ordered in Table 7.6), with the debate focusing on the top criteria. One PK advocated for a higher ranking for clinical aspects (*% HF death, Avoidable, Health*) and *DAL*, citing their patient-centred, value-based nature. However, others emphasised that *% HF death*, *Activity*, *Avoidable* and *DAL* are common HF RPM program assessment endpoints. Since *% HF death*, *DAL*, and *Avoidable* were key criteria for all PKs, these were ranked at the top, followed by *Activity* (4th, favoured 3-to-1) and *Health* (5th). Participants then provided MACBETH judgments for the weighting matrix's last column and first upper diagonal, establishing an initial weighting scale, then manually adjusted to reflect PKs' views while meeting M-MACBETH consistency and decision interviews' statistical requirements. The spreadsheet ***WEIGHTS*** in Supplementary File 7.3 provides additional information on this process. Figure 7.6 shows the final MACBETH matrix with the validated scale on the right.

	[% HF death]	[DAL]	[Avoidable]	[Activity]	[Health]	[QoL]	[Adherence]	[Self-eff.]	[Waiting]	[Trust]	[Stk. satisf.]	[all lower]	Current scale
[% HF death]	I	moderate	P	P	P	P	P	P	P	P	P	extreme	16,26
[DAL]		I	very weak	P	P	P	P	P	P	P	P	extreme	14,42
[Avoidable]			I	weak	P	P	P	P	P	P	P	extreme	13,83
[Activity]				I	very weak	P	P	P	P	P	P	v. strong	12,91
[Health]					I	moderate	P	P	P	P	P	v. strong	12,03
[QoL]						I	moderate	P	P	P	P	v. strong	10,09
[Adherence]							I	very weak	P	P	P	strong	7,23
[Self-eff.]								I	strong	P	P	strong	6,64
[Waiting]									I	weak	P	moderate	3,02
[Trust]										I	very weak	weak	1,83
[Stk. satisf.]											I	weak	1,74
[all lower]												I	0,00

Consistent judgements

Figure 7.6. MACBETH weighting matrix and corresponding computed weighting scale (after group adjustments).

Finally, PKs defined achievement classes for model scoring. PKs agreed on four names: EXCELLENT, GOOD (renamed from SATISFYING), ACCEPTABLE, and ALERT. Class definitions and boundaries followed. An EXCELLENT program exceeds the target performance, with an inherent score of 100 marking the boundary between GOOD and EXCELLENT. As model compensation may apply, one program can be rated EXCELLENT without surpassing *Target* in all criteria. Oppositely, ALERT indicates performance below minimum standards, with the inherent boundary between ALERT and ACCEPTABLE set at a score of 0, representing a *Min. acc.* performance in all criteria. Similarly to EXCELLENT, a program can be rated ALERT even if not all criteria are below *Min. acc*. The boundary for ACCEPTABLE-GOOD was based on a hypothetical "minimally good" profile, set by PKs as: [*% HF death* = 20%, *DAL* = 12.4 days, *Avoidable* = 15%, *Activity* = *hC*, *Health* = *pM*, *QoL* = *66.7%*, *Adherence* = *dMc*, *Self-eff.* = *66.7%*, *Waiting* = *mC*, *Trust* = *66.7%*, *Stk. satisf.* = *Php*] (consult Table 7.4 for level descriptions) – a score of 54.22 was determined as the boundary. Moreover, considering allowed performances and model properties, the overall score ranges from -45.80 for ALERT to 136.75 for EXCELLENT. The spreadsheet ***CLASSES*** in Supplementary File 7.3 provides additional information on this process and presents the defined assignment rules for classification.

7.3.7. Step 2.3: Building the MMD Prototype

The final MMD prototype consists of seven dashboard pages:

1. **Program case mix: Heart failure patients enrolled in RPM.** Describes the complexity and types of patients in the HF RPM program with eight DataViz formats showing demographics, severity, therapy, and comorbidities.

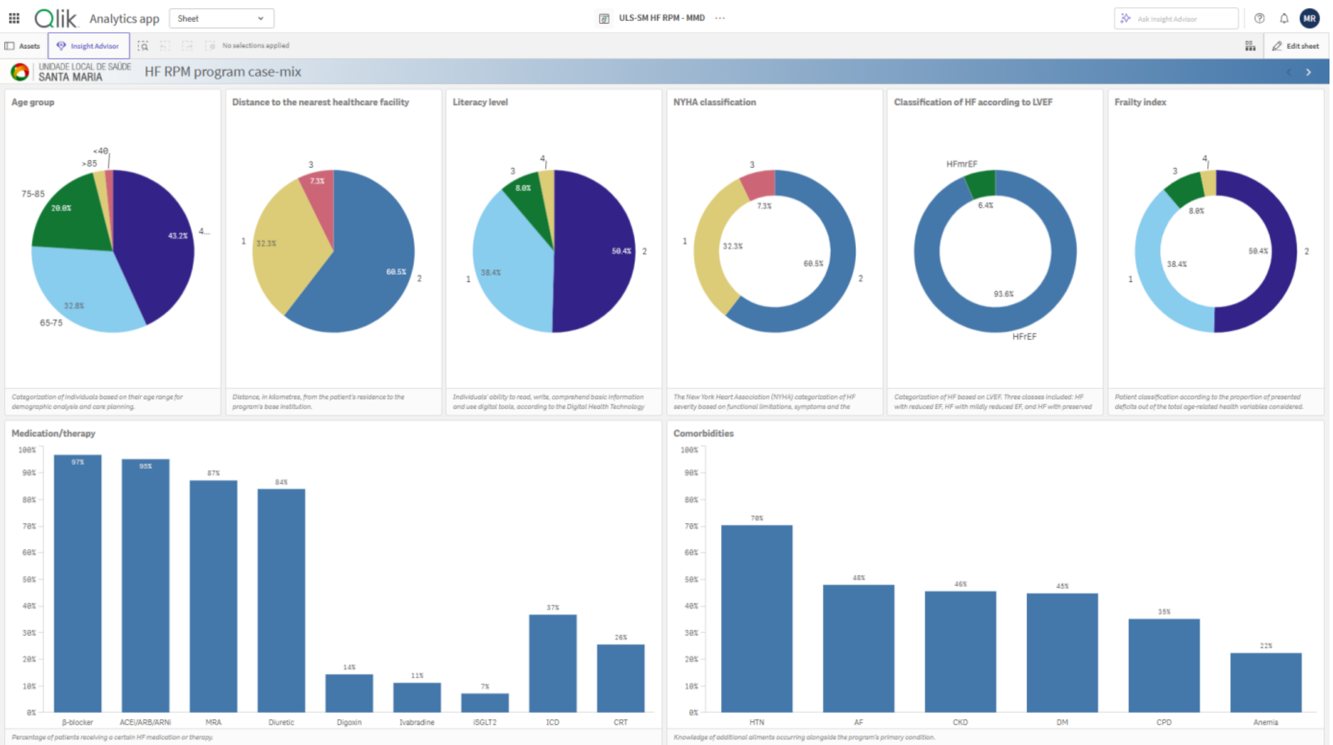


Figure 7.7. "Program case mix" report of the HSM MMD.

2. **Program evaluation: Overall and by-dimension classification.** Presents the program's performance and value profile. At the top, gauge charts display the overall and dimension-specific scores (calculated using normalised weights for each dimension), with colour coding for the four achievement classes. Instead of solid class boundaries, gradient colours illustrate that class assignment is not solely based on value model scores. Below each gauge, a colour-coded box shows the actual achievement class based on the scores and assignment rules. These rules (see spreadsheet ***CLASSES*** in Supplementary File 7.3) were created by DAFs based on PK statements and feedback throughout the study and will be validated in Phase 3. Users can adjust dimension weights within predefined limits to recalculate the overall score. However, the sliders have limits: *Access* can vary between 23.8% and 35.94%, *Clinical aspects* between 35.87% and 58.95%, while *Acceptability* – a dependent variable – can range from 5.11% to 40.33%. These limits were based on weights determined during the decision interviews. At the bottom, a performance table fully describes the program profile, displaying both criteria performance (marking performances below *Min. acc.* and above *Target*) and partial model values (as calculated by the value scales/functions before weight harmonisation).

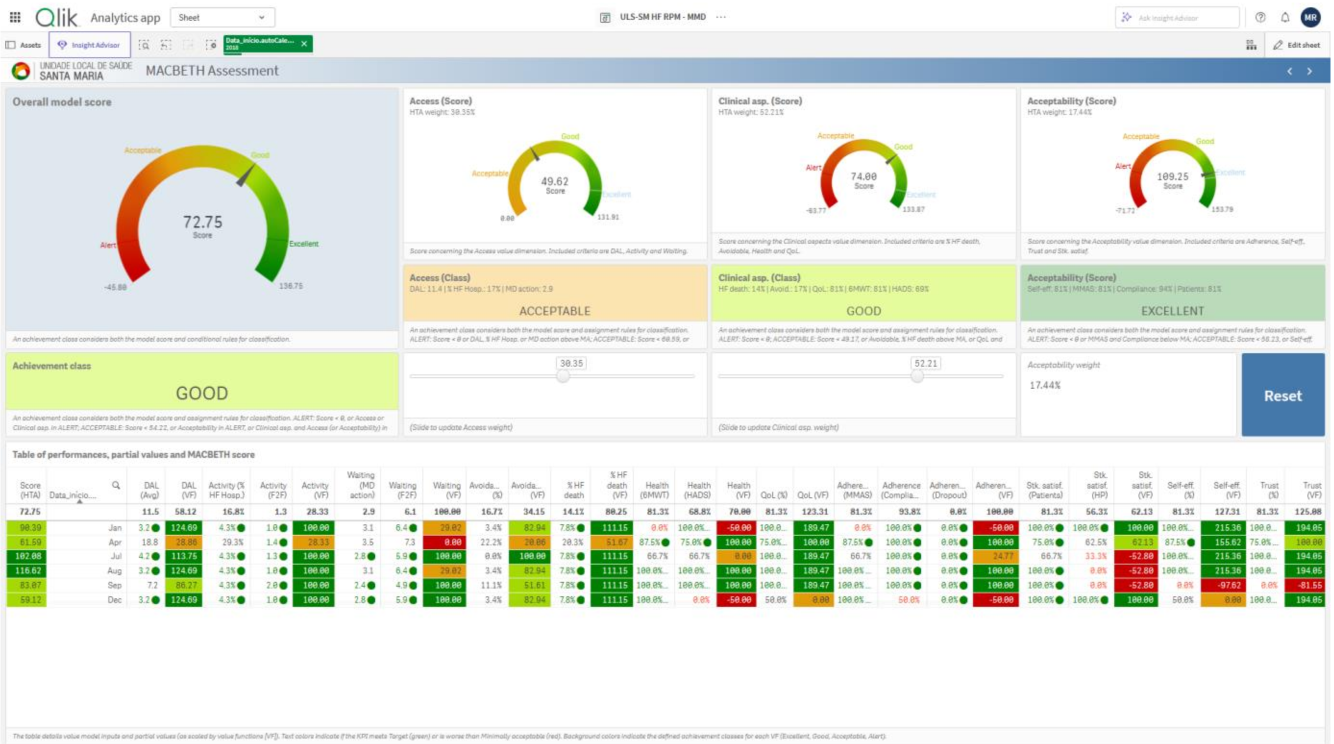


Figure 7.8. **“Program evaluation: Overall and by-dimension classification” report of the HSM MMD.**

3. **Program evaluation: KPI impact and "needs action" tracker.** A rapid analysis report highlighting areas needing corrective attention. KPIs marked red require urgent action as their performance falls below the *Min. acc.* level. Yellow indicates recommended action as KPI performance is below the required level for achieving a GOOD class. Light yellow suggests attention to poorly performing KPIs that are part of composite criteria. The size of each KPI reflects its relative weight in the value model, meaning larger KPIs have a greater impact on the overall program score when performing poorly.

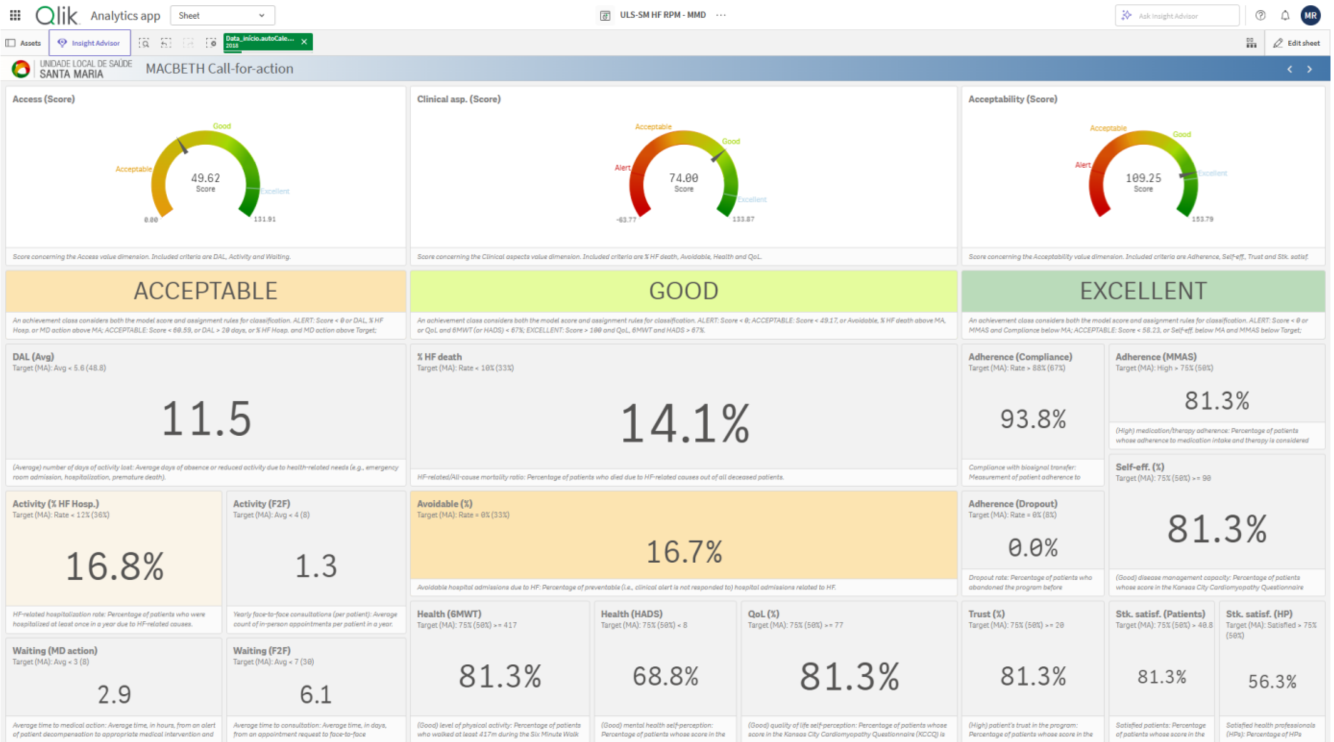


Figure 7.9. «Program evaluation: KPI impact and "needs action" tracker» report of the HSM MMD.

4. **Program monitoring: "Access to care" KPIs' analysis.** Covers the program's performance in readily providing needed health care to patients, ensuring equitable and timely access. Includes seven DataViz formats for eleven main KPIs.

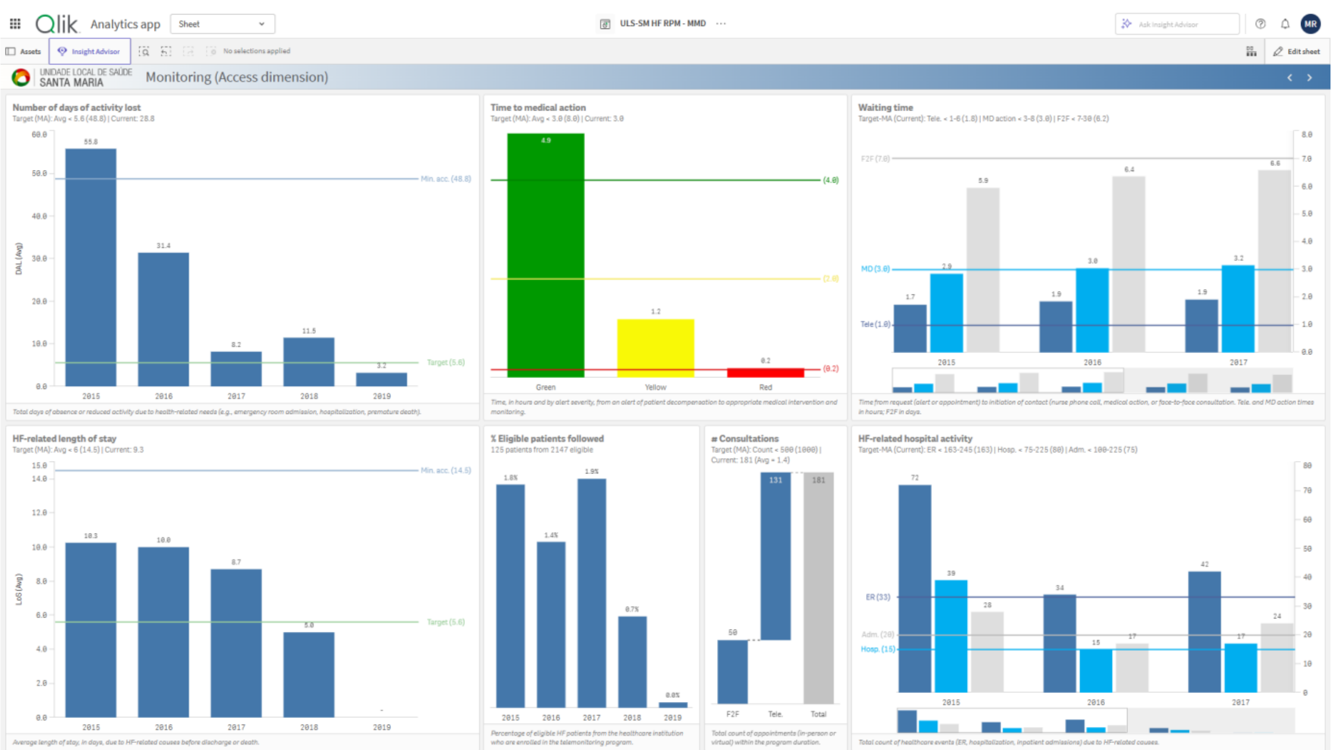


Figure 7.10. «Program monitoring: "Access to care" KPIs' analysis» report of the HSM MMD.

5. **Program monitoring: "Clinical aspects" KPIs' analysis.** Covers the program's medical and healthcare-related outcomes. Includes nine DataViz formats, without combined KPI visualisations.

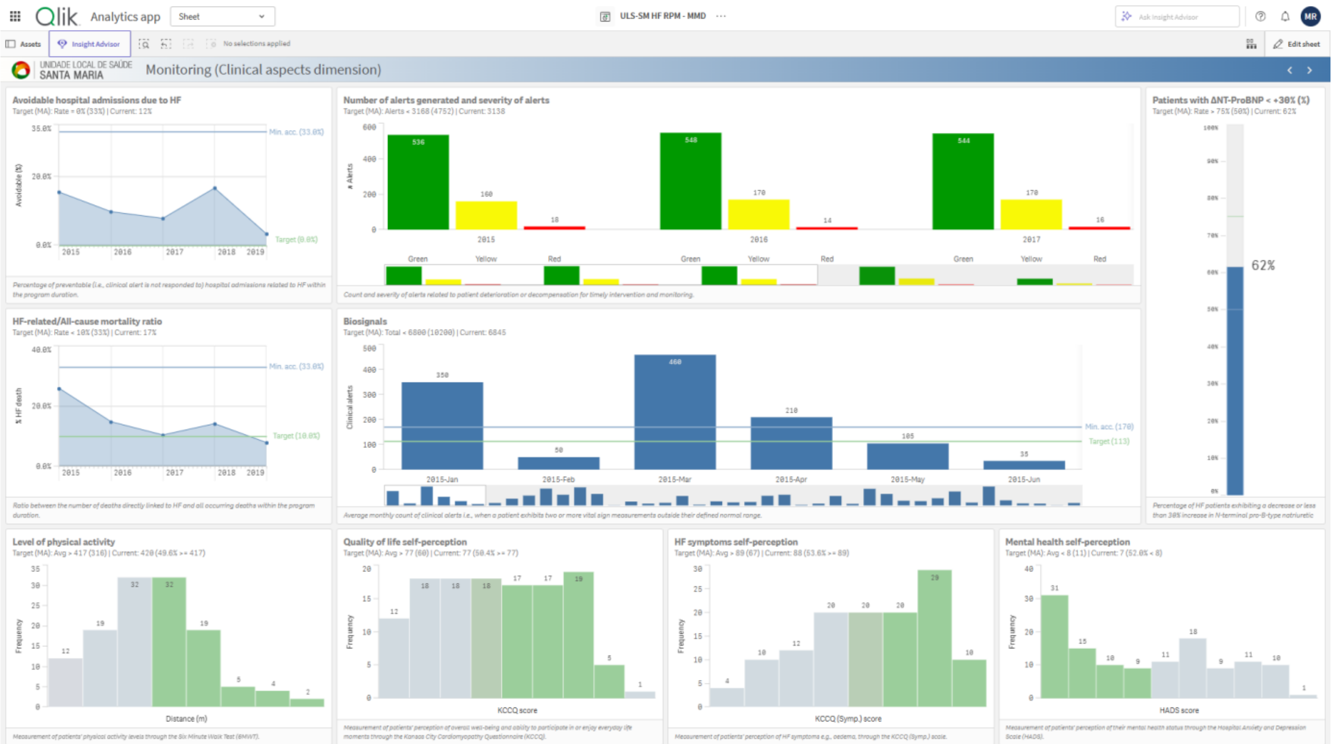


Figure 7.11. «Program monitoring: "Clinical aspects" KPIs' analysis» report of the HSM MMD.

6. **Program monitoring: "Program acceptability" KPIs' analysis.** Covers the program's performance regarding the willingness and satisfaction of patients, caregivers, and health professionals, reflecting program convenience and perceived adequacy. Includes six DataViz formats for nine main KPIs.

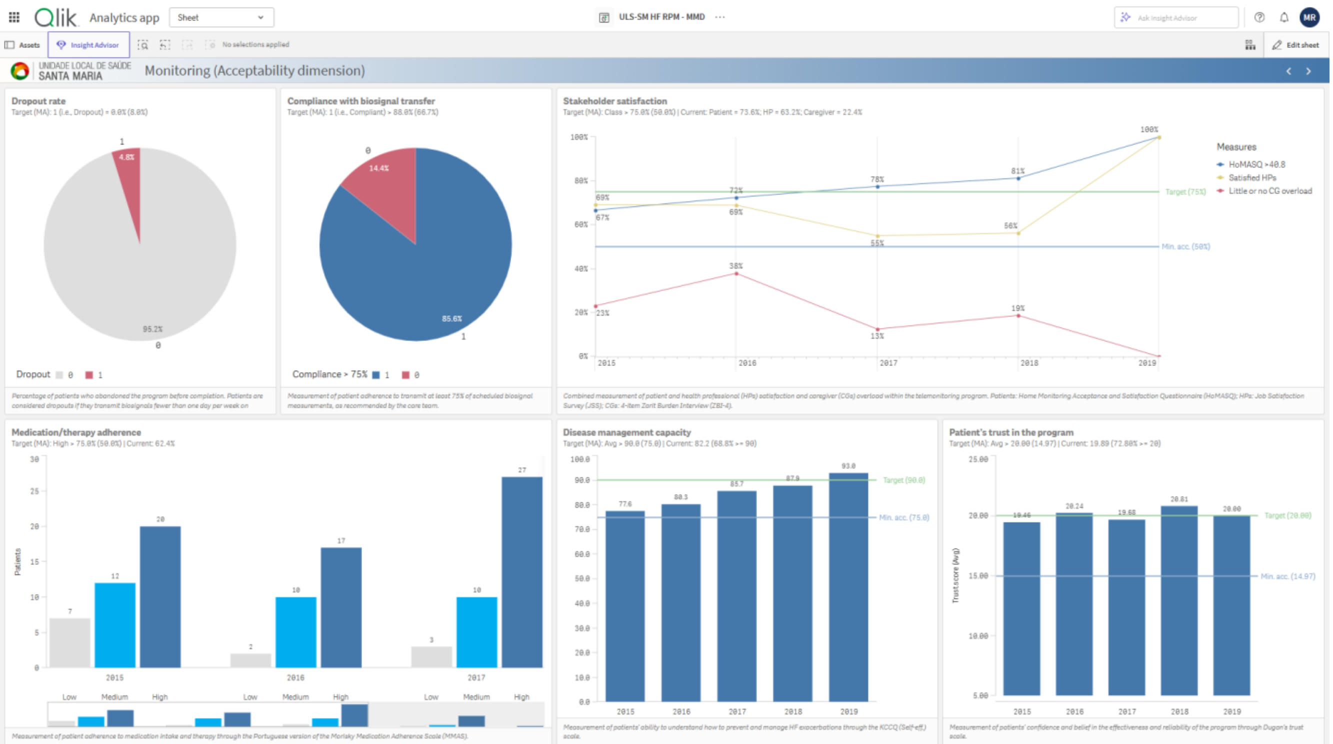


Figure 7.12. «Program monitoring: “Program acceptability" KPIs' analysis» report of the HSM MMD.

7. **Program monitoring: "Costs" KPIs' analysis.** Covers the program's performance on overall, per-patient, and out-of-pocket expenses. Includes six DataViz formats, two per main KPI, and detailing the impact of cost components i.e., TM elements, ongoing operations, consultations, emergency services and hospitalisations.

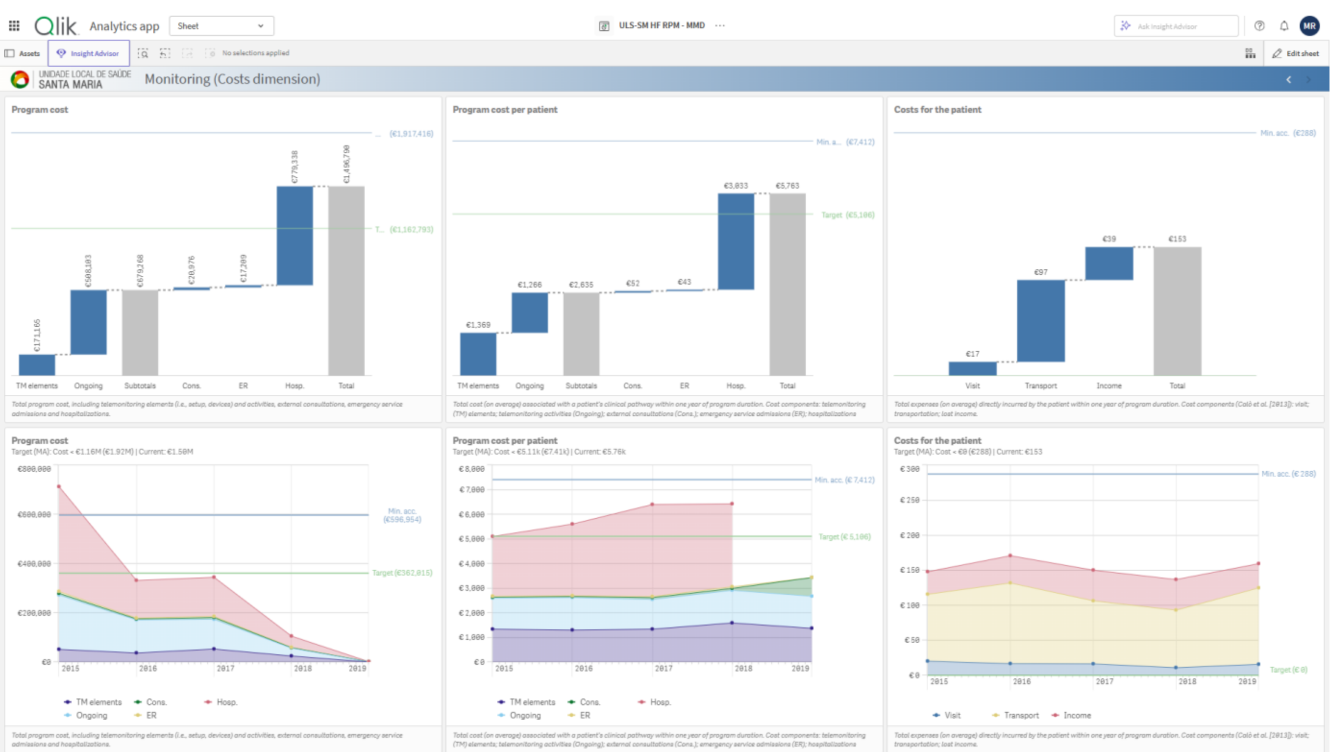


Figure 7.13. «Program monitoring: “Costs" KPIs' analysis» report of the HSM MMD.

7.4. Discussion

This section is devoted to understanding the lessons learned from applying SBI-MD to the HSM HF RPM case and taking conclusions on the appropriateness of employed methods. It also discusses the strengths and weaknesses of the developed MMD and identifies areas for future improvements to both SBI-MD and the MMD.

7.4.1. Lessons Learned

Between December 2023 and August 2024, we worked closely with five PKs to develop an MMD for continuously monitoring and evaluating their HF RPM program. The project covered the first two phases of SBI-MD, with the main deliverable being a functional MMD prototype to be validated by HSM stakeholders before implementation. During these eight months, the facilitation team conducted six participatory processes – a group interview, two workshops, a questionnaire, four individual decision interviews and an online DC. We also worked independently between these sessions to generate evidence, support decisions, and reconcile different perspectives into unified systems and models. On average, each PK spent about eight hours participating in these processes. This is comparable to other decision-making or BI projects: Bana et al. (Bana e Costa, Oliveira, Vieira, *et al.*, 2023) report that "a core group of 13 senior experts met face-to-face in a two-day decision conferencing process, with four DCs, and in a one-day final DC;" Maguire et al. (Maguire *et al.*, 2022) state "the total time of the NGT was 4h including scheduled breaks;" Lau et al. (Lau *et al.*, 2019) elucidate that "dashboard development time is highly variable, ranging between 3 and 6 months." However, direct efficiency comparisons between projects are difficult due to varying participant engagement, group dimension, scheduling, and facilitation expertise.

Several factors contributed to the project's timeline, including the facilitation team's prior expertise in HF RPM, which accelerated some processes as facilitators were able to provide insights, and PKs' conflicting schedules, work in the ICU, and the continuous availability to the clinic, which produced significant timeline delays and method adjustments. Processes conducted in previous Chapters, such as indicator selection (Chapter 5) – a three-month process, engaging 29 experts in HF RPM – and DataViz development (Chapter 6) – involving a 2.5 hours CDB workshop that produced prototypes for "Program case mix: Heart failure patients enrolled in RPM", «Program monitoring: "Access to care" KPIs' analysis» and «Program monitoring: "Clinical aspects" KPIs' analysis» –, also helped streamline the project. Conversely, medical duties and conflicting schedules, especially since all PKs were from the HSM cardiology department, often delayed the technical process due to scheduling challenges, prompting adjustments to the methods described for SBI-MD in Chapter 4 (e.g., combining group sessions or asynchronous tasks). Process design (Step 1.1) and indicators validation (Step 1.2) shared the same session. We modified the original CDB workshop approach (described in Chapter 6), including an *ex-ante* questionnaire to replace the first voting round and reduce the total step duration. However, a key challenge was gathering timely responses to the questionnaire, requiring repeated reminder emails and response deadline extensions, a common issue in similar studies (Freitas *et al.*, 2018; Aubert, Esculier and Lienert, 2020; Mentzakis, Tkacz and Rivas, 2020).

As a result, we also decided to adjust our value modelling approach, opting for individual decision interviews before group decision-making, instead of an *ex-ante* web-Delphi as suggested by the collaborative value modelling framework (Vieira, Oliveira and Bana e Costa, 2020)). This change improved PK engagement, perspective gathering, and session scheduling and played a key role in group learning, with PKs approaching the DC already familiar with the MACBETH approach and DSS, making the group session more efficient. Nevertheless, conducting the decision interviews beforehand is time-consuming for the facilitation team and can be impractical with more decision-makers. Each PK spent about 1.5 hours, but facilitators needed 6 hours overall, plus time for scheduling, data processing, and model reconciliation.

Moreover, there are other key lessons from the application of SBI-MD:

- Phase 1 is critical, but time-consuming, requiring strong commitment. Successful DataViz development and value modelling demand clearly defined objectives and value aspects (Keeney, 1996). However, given the clinical condition's complexity, numerous KPIs, and PKs' requests, DAFs must continuously review literature, prepare evidence, and develop straightforward questioning protocols to support PKs' decisions. PKs must also commit to decision-making and validation until the group agrees on the appropriateness of the selected value aspects, including definitions, measures, and reference levels.
- Nevertheless, KPI measures and reference levels were continuously reviewed throughout the project, reflecting the evolving nature of BI environments (de Mul *et al.*, 2012) and requisite modelling principles (Phillips, 2007) i.e., proving to consider all aspects relevant for decision-makers, although aiming for models to be as simple as possible.
- DAFs are fundamental in managing group processes toward agreement and ensuring effective and balanced PK participation. However, PKs are very sensitive to how DAFs formulate statements or questions, potentially introducing biases. DAFs must provide neutral information or feedback to avoid influencing decisions – yet, maintaining neutrality is challenging, as PKs often seek advice when they trust the DAFs' expertise and goodwill.
- The interrelations analysis was valuable for PKs and the facilitation team, revealing that many KPIs were preference-dependent or overlapping. Although the conducted procedure was less sophisticated than other approaches in MCDA (e.g., reasoning maps (Rodrigues *et al.*, 2017)), it led to the development of combined criteria aggregating interrelated KPIs, minimising criteria interactions and supporting the use of the additive model (Marsh *et al.*, 2016).
- Using synthetic data in MMD development has pros and cons. Advantages include eliminating confidentiality risks, focusing PK on tasks rather than data quality, customising data for testing, avoiding historical biases, and speeding up prototyping (no access or data preparation issues). However, synthetic data may lack realism, skew performance results, and cause mismatches when integrating with real data, requiring measure revisions.
- Anonymous voting, comments, and modelling (Steps 2.1 and 2.2.) helped address dominant voices (e.g., the HF RPM program coordinator was a PK), reduce disruptive group behaviour, and provide a "picture" of the group agreement levels before discussions.
- Reconciliation methods streamlined agreement by ensuring the reconciled value functions reflected the diversity of PKs' perspectives. However, there was significant debate over criteria weights' reconciliation – PKs did not agree with the proposed reconciled criteria ranking. Thus,

decision interviews' outcomes only influenced weight limits for the unified group model and, later, the design of dashboard sliders for user-adjusted weighting.

- Using widely adopted DSSs (Qlik Sense®, Menti™, Microsoft Excel, and Microsoft Teams™) proved beneficial for PKs and DAFs during participatory processes. Menti™ enhanced engagement during Step 2.1 through interactive features that enabled asynchronous surveying and real-time polling, accessible on various devices, including smartphones, enabling participation anytime and anywhere. Qlik Sense® provided diverse DataViz options (beyond Ignatenko et al. (Ignatenko, Ribeiro and Oliveira, 2022) decision table), cloud-based access and an intuitive interface allowing easy customisation (e.g., drag-and-drop creation mode), offering DAFs significant flexibility in developing the MMD and presenting it to PKs for validation. Microsoft tools promoted democratic access, avoiding a learning curve for PKs and DAFs. Furthermore, all these tools are well-documented, with numerous tutorials and support forums available to address ongoing issues. This accessibility helps young analysts become less reliant on external assistance when using these systems.

7.4.2. Strengths and Limitations of the MMD Tool

The main successes and strengths of the developed MMD at HSM can be summarised as follows:

- The MMD was co-designed by PKs, its end users, to ensure a person-centred tool. Collaboration among stakeholders increases the chances of successful implementation and impact. PKs either made or validated decisions on every MMD feature, fostering ownership, commitment, and a deeper and shared understanding of the methods used.
- The MMD embeds a value measurement model comprising the most relevant criteria aligned with PK objectives for the HF RPM program – ensuring timely access while reducing stays, promoting clinical excellence, and ensuring satisfaction and high adherence –, guaranteeing intelligibility, agreement, independence and measurability. Adding more criteria would overcomplicate the model without significant benefit, as the existing 11 criteria cover all key outcomes in clinical studies and assessment aspects for program acceptability. Moreover, the additive aggregation model is easily understandable for health professionals and managers, and well-accepted scientifically, provided criteria remain preference independent. PKs also grasped the concepts of value functions and weights, making the model highly explainable – an essential feature in MCDA models.
- One of the system's key strengths is its integration of operational monitoring reports and strategic program evaluations into a single tool. Through the MMD, users can track the population in the HF RPM program, assess program success over time, and identify trends. It helps pinpoint areas needing improvement, spot KPIs affecting overall performance, and investigate underperforming KPIs to understand causes and deviations from targets. All visuals include clear subtitles and legends with definitions, measures, scales, and reference levels, enhancing user experience and providing a unified source of evidence for program stakeholders.
- Qlik Sense®, used for MMD development, offers key advantages for legacy purposes and maintenance. It supports multiple data connectors (databases, spreadsheets, cloud services, web APIs) and provides powerful self-service BI analytics, including R and Python integration,

contextual insights, and auto-scripting. This simplifies MMD implementation and ETL automation and sustainability. Its extensive documentation and user-friendly customisation make it accessible to non-BI experts. Additionally, its responsive design ensures optimal report display across devices.

- The developed MMD features user-adjusted value dimension weights, enabling an *Interactive* mode for the value model. Users can adjust these weights by dragging a slider, reflecting their preferences on the relative importance of each dimension's criteria. A "Reset" button allows users to revert to default weights, returning to the predefined *HTA* mode. To prevent unrealistic overall scores (e.g., calculated solely on *Acceptability* criteria) and maintain program objectives amid conflicting views, weights can only vary between acceptable ranges, the maximum and minimum limits being based on weights from the decision interviews.

However, the developed tool is not without shortcomings, as follows:

- The tool includes an incomplete «Program monitoring: "Costs" KPIs' analysis» report. PKs suggested comparing RPM costs with usual care; however, this was beyond the project's scope and challenging to estimate without clear cost components. PKs were also unsure whether costs should be assessed at the patient, program, hospital, or system level. Marsh et al. (Marsh *et al.*, 2016) stress the need for comparability in cost and benefit estimation; yet PKs expressed concerns that focusing solely on program or department costs would overlook NHS reimbursement mechanisms or other opportunity costs. These challenges also justify the exclusion of cost criteria from the value model, adding to the potential preference dependence of cost criteria on other included criteria.
- Each KPI is linked to a single DataViz format, as by the literature (Pauwels *et al.*, 2009; Kirk, 2012; Ignatenko, Ribeiro and Oliveira, 2022). However, stakeholders requested viewing KPIs in varying formats (e.g., alternate *Patient's trust in the program* between yearly average and histogram).
- Since synthetic data was used to create the prototype MMD, mismatches may occur when integrating real data, requiring adjustments. Real data integration poses additional challenges like validation, missing or unavailable data, standardisation, and technical limitations. Data validation should involve cross-referencing with another dataset, but no system exists yet for comparison, and some KPIs will be developed for the first time in HSM, making validation harder. A feedback loop (Steps 3.2, 3.3 and 3.4) will be crucial for continuous improvement. Additionally, technical limitations, such as report query speed, could impact dashboard usability, which has not been tested due to the synthetic dataset's limitations.

7.4.3. Future Work

Future avenues for improving SBI-MD and the developed MMD can follow several important directions. A primary focus is completing the full implementation of the MMD at HSM (Phase 3). This step will involve hosting an online validation workshop to engage a broader range of stakeholders beyond PKs. Collaboration with the IT department will be critical for finalising the data workspace for HF RPM, integrating real data, and making the system operational. Training workshops will be provided for end users; ongoing training mechanisms such as webinars and *train-the-trainer* programs ensure long-term good practices. A SUS questionnaire will help collect user feedback, enabling continuous tool refinement.

Once real data is integrated, sensitivity analyses and validation tests will be performed to evaluate the model's behaviour under significant changes. Feedback from additional stakeholders may prompt adjustments to the MMD's structure and functionality. Technical enhancements could include adding medium- and long-term forecasting capabilities for program planning, resource allocation, and patient scale-up. Cost estimation will be another priority, employing time-driven activity-based costing (Niñerola, Hernández-Lara and Sánchez-Rebull, 2021) to provide a detailed analysis of RPM and usual care costs, addressing uncertainties and key cost components identified by HSM stakeholders.

A key focus of future academic research will be evaluating the broader applicability of SBI-MD across various contexts to determine its adaptability to different RPM domains and potentially other healthcare applications. This research may involve incorporating more diverse PKs and engaging a wider range of stakeholder types. Additionally, the potential to adapt this approach beyond the healthcare sector will be investigated, as we hypothesise that its use in less complex industries could be particularly feasible.

7.5. Conclusions

This Chapter demonstrates the feasibility and effectiveness of the SBI-MD approach in creating a robust MMD tool for monitoring and evaluating an RPM intervention for HF management in a real-world healthcare context. By integrating MCDA principles with BI tools, the MMD offers an automated, user-friendly and comprehensive DSS, empowering RPM program managers to track performance and value creation, identify underachieving areas, and take corrective actions in an ongoing manner.

This innovative tool addresses critical HTA challenges by systematically incorporating broader value dimensions – such as access to care and program acceptability – beyond traditional cost-effectiveness into the decision-making process. Moreover, throughout SBI-MD, key stakeholders were engaged in a co-creation process to structure the HTA problem, define the most relevant KPIs and evaluation criteria, select stakeholder-agreed DataViz and develop a multicriteria value model for comprehensive HTA. Such collaborative approach ensured effective communication between stakeholders, expectations alignment, and fostered a sense of ownership, thereby enhancing the likelihood of long-term tool adoption.

The resulting dashboard synthesises diverse data streams into intuitive visualisations, providing a user-friendly platform to assess KPIs and the RPM intervention's overall value. Its use in daily RPM management at HSM can enhance HF care by optimising resource allocation and supporting value-based healthcare delivery. Future research should explore the evaluation of the MMD’s impact on HSM’s TM program, apply the SBI-MD framework to other healthcare management settings, and refine the dashboard’s capabilities based on evolving user needs and technological advancements.

CHAPTER 8

OVERARCHING DISCUSSION AND FUTURE WORK

8.1. Chapter Summary

This doctoral research raised multiple issues on developing innovative approaches and tools to improve continuous monitoring and evaluation in RPM interventions. This Chapter highlights and discusses key lessons learned and implications that cut across the various Chapters. First, a critical analysis of the conducted studies is presented, evaluating their main contributions and the extent to which the research questions posed at the onset of this thesis have been addressed. Next, the key messages on RPM practice are outlined, reflecting on the evolution of the RPM landscape over the four years of this thesis and identifying the major barriers to widespread RPM adoption. Following this, the methodological implications are discussed, offering key messages for researchers. These contributions span healthcare management, policy and assessment, MCDA for HTA, BI, and stakeholder participation. Key recommendations for the industry are also provided, informed by the thesis' collaboration with Siemens Healthineers, and aimed at suppliers of RPM services and technology. Finally, this Chapter concludes by outlining future work directions and recommendations for further research.

8.2. Overarching Discussion

8.2.1. Overview of Conducted Studies and Their Contributions

The doctoral research consisted of six studies aimed at developing innovative approaches and tools to enhance continuous monitoring and evaluation in RPM interventions. The outcomes of the thesis contribute new literature and knowledge in HTA, MCDA, health policy, and information systems. These advancements comprise methodologically robust approaches and practical evaluation tools that aid decision-making and strategic planning in real-world contexts. Ultimately, the research seeks to facilitate the adoption and delivery of high-quality, cost-effective remote care services. While the studies detailed in Chapters 2 (Miranda, Oliveira, Baptista, *et al.*, 2023), 3 (Miranda, Oliveira, Nicola, *et al.*, 2023) and 5 (Miranda *et al.*, 2024) have already been published, the remaining Chapters are under preparation for publication in international and peer-reviewed journals focused on the fields of operational research, decision science, information systems, management, and health policy.

Chapters 2 and 3 provided an in-depth analysis of the RPM landscape, exploring its state-of-the-art, future directions, and the factors affecting implementation and adoption both in Portugal and abroad. Chapter 2 identified 46 Portuguese RPM programs implemented by public and private providers between 2008 and 2021 (Tables 2.1 and 2.2) – to our knowledge, the most comprehensive list of its kind in Portugal. Beyond a literature review, these Chapters proposed strategies for RPM implementation at macro and micro levels. Chapter 2 (Figure 2.4) outlined 18 strategic directions for enhancing RPM adoption in Portugal, while Chapter 3 (Figure 3.2) presented a three-tier framework for integrated RPM-based care, addressing **RQ1** (“**Which benefits, risks, costs, implementation issues and challenges should be considered for RPM successful adoption?**”).

In addressing **RQ2** (“**Which measurement and decision-aiding methods and tools can enable continuous monitoring and evaluation of RPM initiatives?**”), Chapter 4 introduced SBI-MD, an integrative, step-by-step approach combining BI, MCDA and stakeholder participation to build MMDs enabling ongoing performance measurement and RPM program HTA. The proposed approach is a major contribution to both research and practice, as SBI-MD advances MCDA for HTA by tackling challenges in evidence management, methodological complexity, and criteria selection. Its step-by-step methodology integrates practical MCDA and BI methods and tools to automate evidence reporting, enhance outcomes interpretation through intuitive visuals, and enable real-time, interactive value measurement. These innovations address longstanding HTA challenges for complex interventions like RPM and provide actionable solutions for healthcare providers and the MedTech industry.

Chapter 5 identified key value dimensions and indicators for monitoring and evaluating HF RPM programs, addressing **RQ3** (“**Which value dimensions, indicators and costs should be considered when monitoring and evaluating RPM programs?**”). Using a four-stage participatory approach based on SBI-MD Step 1.2, a comprehensive list of five dimensions, 43 indicators, and six case-mix parameters was developed (Table 5.5). This list was instrumental in subsequent Chapters, providing a foundation for designing an MMD tool (Chapter 7) and establishing agreed outcome measures to help HF RPM providers assess program value and identify improvement opportunities. While indicator applicability proved context-dependent, Table 5.5 demonstrated transferability within the HF RPM domain, with minimal adjustments for adapting the list between HESE and HSM projects.

Chapter 6 detailed a collaborative approach, grounded on SBI-MD Step 2.1, to engage dashboard users in designing prototype reports based on selected KPIs (those identified in Chapter 5). The CDB workshop demonstrated to be a flexible approach that can function both as a sub-step within SBI-MD and as an independent procedure. Participants praised the approach, particularly the employed digital tools, which facilitated both in-person and remote participation while enabling smooth transitions between anonymous and open discussions. This process resulted in two collaboratively created dashboard pages, tailored to user needs – later refined and reused in Chapter 7. Facilitators observed that while the CDB workshop improved efficiency in dashboard design, an *ex-ante* questionnaire could replicate the initial round of anonymous voting and feedback. This enhancement was incorporated into the final SBI-MD version, underscoring the importance of real-world testing for refining and validating methods.

Chapter 7 focused on the design and development of an MMD for tactical and strategic management within the HSM HF RPM program, covering the first two phases of SBI-MD. The primary outcome was an MMD prototype, to be validated by broader HSM stakeholders before implementation. Key strengths of the MMD, as outlined in the Chapter, include its co-design by PKs under DAFs' guidance, resulting in a user-centred tool that fosters ownership, commitment, and shared understanding. The MMD's value measurement model aligns with program goals by integrating tactical reports and strategic evaluations, enabling users to monitor performance, identify trends, and target areas for improvement. Its clear visuals ensure ease of use, while featured analytics and adjustable value dimension weights enable the *Interactive* model mode for enhancing flexibility in HTA.

Together, Chapters 6 and 7 addressed **RQ4** ("**Which requirements and features should an actionable BI tool incorporate for ongoing monitoring and evaluation of RPM programs, accounting for user needs and stakeholder views?**") by outlining processes for integrating KPI monitoring and value modelling into a unified DSS. This integration enables tool interactivity and user-friendliness for daily use. Additionally, these Chapters underscored the importance of participatory approaches in aligning tools with stakeholder perspectives and requirements, ensuring co-creation and fostering adoption.

8.2.2. Key Messages on RPM

Chapter 3 begins with a quote from a 2014 Deloitte report (Deloitte, 2014) that accurately predicted the rise of remote and digital care by 2020 – a trend accelerated by the COVID-19 pandemic. However, Deloitte's 2024 healthcare sector outlook (Siegel *et al.*, 2024) is less optimistic:

> *For the sector and patients to continue benefitting from [remote care] technology, however, providers should sustain investments (…).So far, this is happening slowly. (…) As demand for telemedicine and other tech solutions wane, many wonder if the technological advances of the past few years will be permanent.*

As discussed in earlier Chapters, the promise of digital healthcare persists, though economic pressures and cautious adoption have tempered early visions of a digitally dominated healthcare model. This doctoral thesis accompanied this paradigm shift, as the project proposal was written in March 2020 (at the onset of the COVID-19 pandemic in Portugal) and now concludes in a different landscape.

RPM was heralded as a solution for inclusive and cost-effective healthcare, especially for chronic patients needing ongoing care and monitoring. During 2020–2021, RPM initiatives and new technology providers surged driven by heightened demand from public and private healthcare organisations, as detailed in Chapter 2. However, this rapid expansion introduced new challenges. Many initiatives were small-scale and hastily implemented to meet urgent needs, often lacking clear guidelines for design, outcome measurement, care integration, scalability, and resource allocation.

These gaps highlighted the importance of assessing the legal, financial, and strategic aspects shaping RPM adoption and identifying success factors for effective implementation – key objectives explored in Chapters 2 and 3. Issues like low digital literacy among users, professional scepticism toward telehealth, and workforce demands expectedly emerged from studies as barriers to RPM adoption and scalability. Yet, they also uncovered unexpected insights that provide valuable directions for research and practice.

First, technological infrastructure inadequacy is now less of a barrier to RPM adoption. European and national regulations mandate certification of RPM devices and platforms, ensuring information security and safeguarding patient rights. Additionally, pandemic-driven investments have significantly enhanced broadband coverage and internet access, improving connectivity for both patients and providers.

Second, human resources are critical in coordinating and managing RPM. Chapter 3 highlights the essential role of multidisciplinary teams – comprising specialists and primary care physicians, nurses, technicians, program managers, data analysts, and informal caregivers – in daily RPM tasks. These include processing patient data, proactively contacting patients to assess their well-being, dynamically adapting care plans, and responding to emergencies.

Third. RPM's reliance on diverse professionals and advanced technology makes it resource-intensive *ab initio*. Without proper alignment to existing care practices, adequate training and dedicated time, integrating RPM services into institutions can lead to inefficiencies. Teams may resist or struggle with the new approach, reverting to standard practice or becoming burned-out, resulting in financial and clinical setbacks.

Forth, current guidelines and reimbursement policies fail to fully support RPM adoption. In Portugal, reimbursement is limited to only three conditions, with policies unchanged since 2016. This is despite existing evidence of RPM benefits for diabetes management, obstetric care or frequent ED usage. Moreover, there are no specific guidelines on program implementation, care protocols, or effective RPM configurations. Scarcity of success stories, large-scale projects, and shared best practices compounds this inertia, contradicting ministerial recommendations to expand telehealth (as discussed in Chapter 2).

Fifth, and final, tools and processes for program management and outcomes measurement are rare. While physiological signals and symptoms monitoring is central to RPM and supported by TM technology, operational, economic, and acceptability outcomes are often overlooked. The absence of technological resources, such as data centres and dashboards, hampers change management, daily program monitoring, and HTA. This shortfall limits RPM teams' ability to coordinate effectively and make collaborative, data-driven decisions to improve program outcomes.

In conclusion, the underutilisation of RPM solutions is beyond technological or financial limitations. Professional and patient scepticism, inadequate training, lack of dedication and coordination, unclear guidelines and inappropriate reimbursement updates hinder adoption. A critical challenge lies in the inability to objectively demonstrate the value of RPM, stemming from three primary gaps: (1) lack of agreement on performance measures and evaluation methods, (2) insufficient tools for ongoing value measurement to identify areas for improvement, and (3) a need for practical solutions to equip decision-makers with better evidence. SBI-MD aims to address these challenges, as a structured, detailed, and methodologically robust approach for developing actionable DSSs that assist RPM managers in implementing, scaling, and maintaining their programs.

8.2.3. Key Messages for Researchers

This doctoral research highlights the significance of methodologically robust approaches and innovative tools in advancing RPM, HTA, MCDA, health policy and management, and information systems. Thesis findings and proposed methods, approaches and tools offer valuable insights for researchers seeking to make impactful contributions to these fields.

The strategic roadmap and RPM implementation framework proposed in Chapters 2 and 3, respectively, emphasise the necessity of aligning RPM technologies with the practical needs of healthcare delivery systems. Successful implementation and sustainable adoption of RPM interventions stems from bridging technology, persons and protocols. Researchers can build on the contributions from Chapters 2 and 3 to explore further opportunities for novel RPM configurations, broader domains of application, payment and reimbursement models, or policymaking research.

The research reported in these Chapters is published and has already influenced telehealth, healthcare management and health policy literature, as evidenced by the studies citing it. Chapter 2's study (Miranda, Oliveira, Baptista, *et al.*, 2023) contributed to research on telehealth adoption (Quintal *et al.*, 2023; Ndwabe, Basu and Mohammed, 2024) and applications across various domains, including HF (Silva *et al.*, 2023), oncology (Braga *et al.*, 2024; Gottlob *et al.*, 2025), and mental health (Araújo *et al.*, 2024). The recently published Strategic Plan for Cardiovascular Health in Portugal (Cabral *et al.*, 2025), from the Portuguese Society of Cardiology, references findings from Table 2.1 (Chapter 2), a major proof of contribution to health policymaking in Portugal. Furthermore, it also impacted research into healthcare expenditure (Torrini, Grassetti and Rizzi, 2023) and telemedicine infrastructure and policy (Patel *et al.*, 2024). Similarly, Chapter 3's findings (Miranda, Oliveira, Nicola, *et al.*, 2023) shaped studies on adaption to telehealth technology (Tengblad and Vallo Hult, 2023; Liu, Prester and Kim, 2024; Yadav, 2024), innovation in virtual care, hospital-at-home (Adashi, O'Mahony and Cohen, 2023; Shi *et al.*, 2024), acute (Wilkes *et al.*, 2024) and geriatric (Băjenaru *et al.*, 2024) care models, and emerging technologies like blockchain, AI, digital twins, and IoT (Malviya *et al.*, 2023; Alexandru, Ianculescu and Paraschiv, 2024; S. Khan *et al.*, 2024). Sustainability (Fikri, 2024), advancements in diagnostics (Alamer *et al.*, 2024; Singer *et al.*, 2024), and nurse-led medication management (Vaismoradi, Lillo Crespo and Turjamaa, 2024) are other fields inspired by our research.

Chapter 5's study, also published (Miranda *et al.*, 2024), presents an exemplary case of collaboration among key Portuguese stakeholders in HF RPM. Through a web-Delphi process, participants were given a unique platform to exchange insights and collaborate on standardising HF RPM outcomes measurement. Over 30 experts participated, including cardiologists running RPM programs in regions across Portugal, such as Lisbon, Porto, Coimbra, Santarém, Alentejo, Beira Interior, and Minho. This collaboration effort also involved members of RHA Alentejo, Algarve, and Norte, MedTech and Pharma professionals, telehealth researchers, and representatives from ACSS, APAH, SPMS, and OECD. The broad participatory process fostered agreement on key program indicators, aligning practices across professionals and institutions. Researchers are encouraged to adopt similar collaborative methods to enhance RPM practices in other healthcare domains.

The SBI-MD approach, methodologically described in Chapter 4 and applied under real-world conditions in Chapters 5 to 7, represents a cornerstone contribution to HTA. SBI-MD provides a comprehensive methodology for developing actionable, evidence-based DSSs by integrating established methods and tools from MCDA (e.g., MACBETH (Bana e Costa, De Corte and Vansnick, 2016), interrelations analysis (Rodrigues *et al.*, 2017; Vitacca and Vitacca, 2019), composite measures for combining indicators (Bana e Costa and Oliveira, 2012; Greco *et al.*, 2019), value function reconciliation (Corner, 1994; Fernandes *et al.*, 2024) and MCDA classification (Bana e Costa, Carnero and Oliveira, 2012; Figueira *et al.*, 2023)), BI (e.g., indicator selection (Cadilhac *et al.*, 2020; Salgado *et al.*, 2020), DataViz format selection (Kirk, 2012; Ignatenko, Ribeiro and Oliveira, 2022), data warehousing (de Mul *et al.*, 2012), interactive weighting (Kasparian and Rolland, 2012), SUS assessment (Brooke, 1996)), and stakeholder participation (e.g., the collaborative value modelling framework (Vieira, Oliveira and Bana e Costa, 2020), MACBETH-voting (Mateus, Bana e Costa and Matos, 2017), DC (Phillips, 2007), NGT (Gallagher *et al.*, 1993; Lago *et al.*, 2007), Delphi (Belton *et al.*, 2019; Haig *et al.*, 2023)). Its phased approach offers practical insights for researchers aiming to design adaptable and user-friendly DSSs for ongoing HTA and performance measurement purposes.

The doctoral research also highlights best practices for implementing complex DSSs through SBI-MD. Building trust with stakeholders – by demonstrating empathy, adaptability, and professionalism – and clearly outlining methods and timelines at the project's outset fosters a positive start. A "champion" among stakeholders, who reinforces goals and interacts regularly with others, is essential, as this role bridges communication more effectively than DAFs. Facilitators should remain neutral and prioritise transparent communication to help stakeholders view the tools as their own rather than imposed by DAFs. Striving for a "requisite model" (Phillips, 1984) – one containing only the necessary and sufficient information to resolve the issues at hand – ensures a balance between completeness and simplicity while avoiding excessive elicitation burden. Researchers are advised to apply these principles to develop robust, comprehensive tools that align with stakeholders' needs, expectations and availability.

8.2.4. Key Messages for the Industry

This thesis was developed in close collaboration with Siemens Healthineers, accentuating the need to address challenges of transferring knowledge between academia and industry. Integrating scientific methods into agile enterprise workflows is particularly demanding, as it requires balancing methodological complexity with business objectives. Successfully addressing these challenges necessitates close cooperation between researchers and business professionals. Furthermore, the fast-paced nature of industry often outstrips the slower progress of scientific research. Naturally, this doctoral project grappled with the dynamic environment of healthcare innovation and trends. Nevertheless, the proposed methods and tools were consistently designed to align with industry needs, providing actionable insights to enhance business strategies for RPM and HTA at large. To encourage adoption, the methodologies developed aimed to be easily understandable, practical, and transferable.

The three-tier model for implementing RPM-based integrated care (Chapter 3, Figure 3.2) offers a comprehensive guide for developing commercial proposals tailored to healthcare clients seeking to adopt RPM interventions. By incorporating proposed integrated care elements, it positions these proposals as cohesive service offerings. Tools such as the MMDs from Chapter 7 enhance outcomes measurement, enabling companies to stand out as RPM technology providers. These tools support care integration, patient-centred implementation, and continuous performance measurement. By providing objective measures to assess impacts, they enable healthcare organisations to evaluate program success in terms of patient outcomes, resource utilisation, patient experience, and costs. Such insights can also inform the creation of innovative reimbursement models, such as pay-for-performance and pay-for-value approaches, reducing financial risks and upfront costs for RPM clients.

In fact, measuring the impact of health interventions and improving processes through technology is becoming a top priority for healthcare organisations. BI tools foster collaboration and evidence-based decision-making among stakeholders, addressing the industry's growing demand for accurate and fair assessment methods for RPM as a health technology. Utilising widely available BI tools like Qlik Sense® supports scalability and aligns with global trends while maintaining compatibility with legacy systems. Effective socio-technical processes are equally crucial for client interactions. Well-structured, time-bound approaches that consolidate multiple tasks into a single social process enhance stakeholder engagement and streamline RPM program development and management. Moreover, structured feedback mechanisms between users and developers, regular user training, and iterative updates help ensure tools remain user-friendly and relevant. These practices improve implementation processes, minimise low-value interactions with clients and maintain user proficiency as tools and features evolve.

Although originally designed for application in RPM domains, SBI-MD is flexible and adaptable to various healthcare settings. MMD features such as integrated accomplishment information – encompassing reference levels, achievement classes, and assignment rules – and the interactivity and flexibility of the value measurement model help bridge expertise gaps in companies implementing RPM across diverse populations and healthcare contexts. These tools empower customers to take greater control of process improvements, ensuring the applicability of RPM in a range of settings, including obstetrics, mental health care, surgical recovery, oncology, and communicable disease prevention. Additionally, DSSs like the MMD introduced in Chapter 7 not only facilitate RPM management but also optimise data aggregation and processing for clinical studies. This reduces the administrative burden on healthcare professionals, enabling more efficient and impactful research efforts.

8.3. Future Work

While the thesis successfully achieved its objectives, there remain opportunities to deepen the studies conducted and involved research. Additionally, the work gives rise to several potential avenues for future research, which are outlined below.

The study described in Chapter 7 was considered complete upon the development of the MMD prototype. However, collaboration with the HSM team remains a high priority for future work, with a primary focus on completing the full implementation of the MMD (Phase 3). This next phase will involve hosting an online validation workshop to engage a broader range of stakeholders beyond PKs. Full implementation will require data access, with ethics clearance and GDPR-compliant data sharing as prerequisites. Due to conflicts with thesis submission deadlines, integrating the prototype with real RPM data fell outside the project's scope.

Future work could involve engaging relevant health stakeholders and experts in a policy dialogue (Nabyonga-Orem *et al.*, 2016) to complement the diagnosis of the current state of RPM adoption in Portugal and abroad. Additionally, a Delphi process could be employed to broaden stakeholder involvement and facilitate consensus on policies and actions to enhance the implementation, adoption, and dissemination of remote care practices (Vieira, Oliveira and Bana e Costa, 2020).

Regarding SBI-MD, several key avenues for future research have been identified and are summarised as follows: interactive criterion-level interval weighting, automation of data processing through AI algorithms, enhanced analytics leveraging natural language processing, development of MCDA-AI hybrid models, and incorporation of a forecasting module into the MMD. Furthermore, while widely used DSS tools such as Qlik Sense®, Menti™, Microsoft Excel, and Microsoft Teams™ facilitated participatory processes in Chapters 6 and 7, their limited customisation and analysis features restricted their application. These limitations, particularly in the voting tool, inspired a 2024 master's thesis focusing on the design of a DSS tailored to voting in healthcare contexts (Mexia, 2024). Although not included in this doctoral thesis, this example underscores how practical challenges and methodological needs encountered in the project have led to new opportunities for research and collaboration.

Cost estimation will also be a key focus for future work, using time-driven activity-based costing (Niñerola, Hernández-Lara and Sánchez-Rebull, 2021) to provide a detailed analysis of RPM and usual care costs. This will address uncertainties and key cost components identified by HSM stakeholders. Continuing from a 2023 master's thesis (Afonso, 2023) inspired by this doctoral thesis' challenges of cost measurement in remote care delivery contexts, future research will aim to complement the unfinished work on the HSM case through novel cost measurement approaches. This will include a more comprehensive assessment of the *Costs* dimension and the integration of a usual care benchmark.

REFERENCES

A telemonitorização como auxiliar ao tratamento da IC (2020) *NewsFarma*. Available at: https://www.newsfarma.pt/noticias/8835-a-telemonitorização-como-auxiliar-ao-tratamento-da-ic.html (Accessed: 7 February 2022).

Abastante, F., Lami, I. and Lombardi, P. (2017) 'An Integrated Participative Spatial Decision Support System for Smart Energy Urban Scenarios: A Financial and Economic Approach', *Buildings*, 7(4), p. 103. doi: 10.3390/buildings7040103.

Acheampong, F. and Vimarlund, V. (2015) 'Business models for telemedicine services: a literature review', *Health Systems*, 4(3), pp. 189–203. doi: 10.1057/hs.2014.20.

Adashi, E. Y., O'Mahony, D. P. and Cohen, I. G. (2023) 'Remote Patient Monitoring: A Leading Anchor of the "Hospital-at-Home" Paradigm', *The American Journal of Medicine*, 137(2), pp. 81–82. doi: 10.1016/j.amjmed.2023.10.018.

Administração Central do Sistema de Saúde (2021a) *CN 3/2021 - Condições e procedimentos de pagamento das prestações de saúde realizadas aos beneficiários do Serviço Nacional de Saúde que devam ser cobradas pelas Instituições Hospitalares ao abrigo dos Contratos-Programa 2020 e 2021*.

Administração Central do Sistema de Saúde (2021b) *Termos de Referência para Contratualização de Cuidados de Saúde no SNS para 2022*. Available at: https://www.acss.min-saude.pt/wp-content/uploads/2022/02/TR-Contratualizacao_2022_VF.pdf.

Administração Central do Sistema de Saúde (2024) *Cuidados de saúde hospitalares: Contratos-Programa*. Available at: https://www.acss.min-saude.pt//category/cuidados-de-saude/hospitalares/ (Accessed: 17 January 2025).

Afonso, F. F. P. B. (2023) *Incorporating uncertainty in Healthcare Time-Driven Activity Based Costing: From a literature review to a framework for remote care interventions*. Instituto Superior Técnico, University of Lisbon. Available at: https://fenix.tecnico.ulisboa.pt/cursos/mebiom21/dissertacao/565303595503708.

Agarwal, P. *et al.* (2021) 'Adoption, feasibility and safety of a family medicine–led remote monitoring program for patients with COVID-19: a descriptive study', *CMAJ Open*, 9(2), pp. E324–E330. doi: 10.9778/cmajo.20200174.

Agência Lusa (2019a) *Doentes renais do Hospital de Vila Real podem fazer diálise em casa*, *A Voz de Trás-os-Montes*. Available at: https://www.avozdetrasosmontes.pt/doentes-renais-do-hospital-de-vila-real-podem-fazer-dialise-em-casa/ (Accessed: 7 February 2022).

Agência Lusa (2019b) *Telemonitorização em insuficiência cardíaca do Hospital da Covilhã já envolveu 37 utentes*, *Observador*. Available at: https://observador.pt/2019/10/10/telemonitorizacao-em-insuficiencia-cardiaca-do-hospital-da-covilha-ja-envolveu-37-utentes/ (Accessed: 7 February 2022).

Agência Lusa (2021a) *Hospital de Santarém com telemonitorização de doentes com insuficiência cardíaca*, *Correio da Manhã*. Available at: https://www.cmjornal.pt/sociedade/detalhe/hospital-de-santarem-com-telemonitorizacao-de-doentes-com-insuficiencia-cardiaca?ref=Pesquisa_Destaques (Accessed: 7 February 2022).

Agência Lusa (2021b) *Presidente da Sociedade Portuguesa de Cardiologia defende telemedicina e desafio será definir doentes a seguir à distância*, *Observador*. Available at: https://observador.pt/2021/05/07/presidente-da-sociedade-portuguesa-de-cardiologia-defende-telemedicina-e-desafio-sera-definir-doentes-a-seguir-a-distancia/ (Accessed: 7 February 2022).

Agostinho, J. R. *et al.* (2019) 'Protocol-based follow-up program for heart failure patients: Impact on prognosis and quality of life', *Revista Portuguesa de Cardiologia*, 38(11), pp. 755–764. doi: 10.1016/j.repc.2019.03.006.

Ain, N. *et al.* (2019) 'Two decades of research on business intelligence system adoption, utilization and success – A systematic literature review', *Decision Support Systems*, 125, p. 113113. doi: 10.1016/j.dss.2019.113113.

Alamer, M. A. M. *et al.* (2024) 'Advancements in Diagnostic Technology: Transforming Clinical Laboratory Practices', *Egyptian Journal of Chemistry*, pp. 0–0. doi: 10.21608/ejchem.2024.343652.10962.

Alami, S. *et al.* (2023) ‘Organisational Impact of a Remote Patient Monitoring System for Heart Failure Management: The Experience of 29 Cardiology Departments in France’, *International Journal of Environmental Research and Public Health*, 20(5), p. 4366. doi: 10.3390/ijerph20054366.

Alexandru, A., Ianculescu, M. and Paraschiv, E. A. (2024) ‘Harnessing the Capabilities of IoHT-Based Remote Monitoring Systems for Decision Making in Elderly Healthcare’, in, pp. 147–184. doi: 10.1007/978-3-031-62158-1_10.

Alfonzo, A. *et al.* (2007) ‘Design of a Methodology for Assessing an Electrocardiographic Telemonitoring System’, in *29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, pp. 3729–3732. doi: 10.1109/IEMBS.2007.4353142.

Algarve integra projeto de telemonitorização de doença pulmonar obstrutiva crónica (2014) *Correio da Manhã*. Available at: https://www.cmjornal.pt/cm-ao-minuto/detalhe/algarve-integra-projeto-de-telemonitorizacao-de-doenca-pulmonar-obstrutiva-cronica?ref=Pesquisa_Destaques (Accessed: 7 February 2022).

Alhmoud, B. *et al.* (2022) ‘Evaluating a novel, integrative dashboard for health professionals’ performance in managing deteriorating patients: a quality improvement project’, *BMJ Open Quality*, 11(4), p. e002033. doi: 10.1136/bmjoq-2022-002033.

Allen, J., Dyas, J. and Jones, M. (2004) ‘Building consensus in health care: a guide to using the nominal group technique’, *British Journal of Community Nursing*, 9(3), pp. 110–114. doi: 10.12968/bjcn.2004.9.3.12432.

Alves, D. S. *et al.* (2020) ‘Advances in obstetric telemonitoring: a systematic review’, *International Journal of Medical Informatics*, 134(October 2019). doi: 10.1016/j.ijmedinf.2019.104004.

Amorim, P. *et al.* (2021) ‘Telehealth Opportunities in the COVID-19 Pandemic Early Days: What Happened, Did Not Happen, Should Have Happened, and Must Happen in the Near Future?’, *Telemedicine and e-Health*, 27(10), pp. 1194–1199. doi: 10.1089/tmj.2020.0386.

Angelis, A. *et al.* (2020) ‘Early Health Technology Assessment during Nonalcoholic Steatohepatitis Drug Development: A Two-Round, Cross-Country, Multicriteria Decision Analysis’, *Medical Decision Making*, 40(6), pp. 830–845. doi: 10.1177/0272989X20940672.

Angelis, A. and Kanavos, P. (2016) ‘Value-Based Assessment of New Medical Technologies: Towards a Robust Methodological Framework for the Application of Multiple Criteria Decision Analysis in the Context of Health Technology Assessment’, *PharmacoEconomics*, 34(5), pp. 435–446. doi: 10.1007/s40273-015-0370-z.

Angelis, A. and Kanavos, P. (2017) ‘Multiple Criteria Decision Analysis (MCDA) for evaluating new medicines in Health Technology Assessment and beyond: The Advance Value Framework’, *Social Science & Medicine*, 188, pp. 137–156. doi: 10.1016/j.socscimed.2017.06.024.

Angelis, A., Kanavos, P. and Phillips, L. D. (2020) ‘ICER Value Framework 2020 Update: Recommendations on the Aggregation of Benefits and Contextual Considerations’, *Value in Health*, 23(8), pp. 1040–1048. doi: 10.1016/j.jval.2020.04.1828.

Annis, T. *et al.* (2020) ‘Rapid implementation of a COVID-19 remote patient monitoring program’, *Journal of the American Medical Informatics Association*, 27(8), pp. 1326–1330. doi: 10.1093/jamia/ocaa097.

Apantaku, G. *et al.* (2022) ‘Home Telemonitoring Technology for Patients With Heart Failure: Cost-Consequence Analysis of a Pilot Study’, *JMIR Formative Research*, 6(6), p. e32147. doi: 10.2196/32147.

Araújo, A. I. *et al.* (2024) ‘Mobile health for obsessive-compulsive disorder: users’ preference and perception of patient-centeredness’. doi: 10.21203/rs.3.rs-4433162/v1.

Arcia, A. *et al.* (2016) ‘Sometimes more is more: iterative participatory design of infographics for engagement of community members with varying levels of health literacy’, *Journal of the American Medical Informatics Association*, 23(1), pp. 174–183. doi: 10.1093/jamia/ocv079.

Armstrong, R. *et al.* (2011) ‘“Scoping the scope” of a cochrane review’, *Journal of Public Health*, 33(1), pp. 147–150. doi: 10.1093/pubmed/fdr015.

Aronoff-Spencer, E. *et al.* (2022) ‘Designing a Framework for Remote Cancer Care Through Community Co-design: Participatory Development Study’, *Journal of Medical Internet Research*, 24(4), p. e29492. doi: 10.2196/29492.

Assembleia da República (2021) *Diário da República, 1.ª série - N.º 224 — 18 de Novembro de 2021.*

Resolução da Assembleia da República n.º 293/2021.

Associação Portuguesa de Administradores Hospitalares (2019) *Barómetro da adoção: Telessaúde e de Inteligência Artificial no Sistema de Saúde*.

Associação Portuguesa de Administradores Hospitalares (2022) *Barómetro da adoção da Saúde Digital: Telessaúde e Inteligência Artificial*.

Aubert, A. H., Esculier, F. and Lienert, J. (2020) 'Recommendations for online elicitation of swing weights from citizens in environmental decision-making', *Operations Research Perspectives*, 7(June), p. 100156. doi: 10.1016/j.orp.2020.100156.

Azevedo, S., Rodrigues, T. C. and Londral, A. R. (2021) 'Domains and Methods Used to Assess Home Telemonitoring Scalability: Systematic Review', *JMIR mHealth and uHealth*, 9(8), p. e29381. doi: 10.2196/29381.

Baghbanian, A. *et al.* (2020) 'Methods for the health technology assessment of complex interventions: a protocol for a scoping review', *BMJ Open*, 10(11), p. e039263. doi: 10.1136/bmjopen-2020-039263.

Băjenaru, O. L. *et al.* (2024) 'Geriatric Healthcare Supported by Decision-Making Tools Integrated into Digital Health Solutions', *Electronics*, 13(17), p. 3440. doi: 10.3390/electronics13173440.

Bana e Costa, C. A. *et al.* (2008) 'Development of Reusable Bid Evaluation Models for the Portuguese Electric Transmission Company', *Decision Analysis*, 5(1), pp. 22–42. doi: 10.1287/deca.1080.0104.

Bana e Costa, C. A. *et al.* (2019) 'Collaborative Value Modelling in corporate contexts with MACBETH', *Procedia Computer Science*, 162(ITQM 2019), pp. 786–794. doi: 10.1016/j.procs.2019.12.051.

Bana e Costa, C. A., Oliveira, M. D., Vieira, A. C. L., *et al.* (2023) 'Collaborative development of composite indices from qualitative value judgements: The EURO-HEALTHY Population Health Index model', *European Journal of Operational Research*, 305(1), pp. 475–492. doi: 10.1016/j.ejor.2022.05.037.

Bana e Costa, C. A., Oliveira, M. D., Rodrigues, T. C., *et al.* (2023) 'Desirability–doability group judgment framework for the collaborative multicriteria evaluation of public policies', *International Transactions in Operational Research*, 30(6), pp. 3654–3686. doi: 10.1111/itor.13261.

Bana e Costa, C. A. and Beinat, E. (2005) *Model-structuring in public decision-aiding*. 05.79. London.

Bana e Costa, C. A., Carnero, M. C. and Oliveira, M. D. (2012) 'A multi-criteria model for auditing a Predictive Maintenance Programme', *European Journal of Operational Research*, 217(2), pp. 381–393. doi: 10.1016/j.ejor.2011.09.019.

Bana e Costa, C. A., De Corte, J.-M. and Vansnick, J.-C. (2016) *On the Mathematical Foundations of MACBETH*. doi: 10.1007/978-1-4939-3094-4_11.

Bana e Costa, C. A. and Oliveira, M. D. (2012) 'A multicriteria decision analysis model for faculty evaluation', *Omega*, 40(4), pp. 424–436. doi: 10.1016/j.omega.2011.08.006.

Bashshur, R., Shannon, G. and Sapci, H. (2005) 'Telemedicine Evaluation', *Telemedicine and e-Health*, 11(3), pp. 296–316. doi: 10.1089/tmj.2005.11.296.

Basto-Pereira, M. *et al.* (2015) 'Performance indicators for clinical practice management in primary care in Portugal: Consensus from a Delphi study', *European Journal of General Practice*, 21(1), pp. 52–57. doi: 10.3109/13814788.2014.907268.

Batista, A. (2022) *(In)Sucesso da Telessaúde: fatores que influenciam o processo de implementação e normalização nas organizações de saúde Ana*. ISCTE Business School.

Belton, I. *et al.* (2019) 'Improving the practical application of the Delphi method in group-based judgment: A six-step prescription for a well-founded and defensible process', *Technological Forecasting and Social Change*, 147, pp. 72–82. doi: 10.1016/j.techfore.2019.07.002.

Belton, V. and Stewart, T. (2010) 'Problem Structuring and Multiple Criteria Decision Analysis', in Ehrgott, M., Figueira, J. R., and Greco, S. (eds) *Trends in Multiple Criteria Decision Analysis*. Internatio. Boston: Springer, pp. 209–239. doi: 10.1007/978-1-4419-5904-1_8.

Bidonde, J. *et al.* (2024) 'Topic identification, selection, and prioritization for health technology assessment in selected countries: a mixed study design', *Cost Effectiveness and Resource Allocation*, 22(1), p. 12. doi:

10.1186/s12962-024-00513-8.

Bindels, J. *et al.* (2016) ‘Use of Value of Information in Healthcare Decision Making: Exploring Multiple Perspectives’, *PharmacoEconomics*, 34(3), pp. 315–322. doi: 10.1007/s40273-015-0346-z.

Binder, A. F. *et al.* (2020) ‘Treating Hematologic Malignancies During a Pandemic: Utilizing Telehealth and Digital Technology to Optimize Care’, *FRONTIERS IN ONCOLOGY*, 10, p. 1183. doi: 10.3389/fonc.2020.01183.

Bird, M. *et al.* (2021) ‘A generative co-design framework for healthcare innovation: development and application of an end-user engagement framework’, *Research Involvement and Engagement*, 7(12), pp. 1–12. doi: 10.1186/s40900-021-00252-7.

Black, J. T. *et al.* (2014) ‘A remote monitoring and telephone nurse coaching intervention to reduce readmissions among patients with heart failure: study protocol for the Better Effectiveness After Transition - Heart Failure (BEAT-HF) randomized controlled trial’, *Trials*, 15(1), p. 124. doi: 10.1186/1745-6215-15-124.

Bloom, D. E. *et al.* (2011) *The Global Economic Burden of Noncommunicable Diseases*. Geneva: World Economic Forum. Available at: https://www3.weforum.org/docs/WEF_Harvard_HE_GlobalEconomicBurdenNonCommunicableDiseases_2011.pdf.

Bollaerts, K. *et al.* (2018) ‘Benefit–Risk Monitoring of Vaccines Using an Interactive Dashboard: A Methodological Proposal from the ADVANCE Project’, *Drug Safety*, 41(8), pp. 775–786. doi: 10.1007/s40264-018-0658-y.

Bondy, C. *et al.* (2021) ‘Evaluating Technology-Mediated Collaborative Workflows for Telehealth’, *IEEE Journal of Biomedical and Health Informatics*, 25(12), pp. 4308–4316. doi: 10.1109/JBHI.2021.3119458.

Bongiovanni-Delarozière, I. and Le Goff-Pronost, M. (2017) ‘Economic evaluation methods applied to telemedicine: From a literature review to a standardized framework’, *European Research in Telemedicine / La Recherche Européenne en Télémédecine*, 6(3–4), pp. 117–135. doi: 10.1016/j.eurtel.2017.08.002.

Botrugno, C. (2018) ‘Telemedicine in daily practice: Addressing legal challenges while waiting for an EU regulatory framework’, *Health Policy and Technology*, 7(2), pp. 131–136. doi: 10.1016/j.hlpt.2018.04.003.

Botrugno, C. and Zózimo, J. R. (2020) ‘A difusão da telemedicina em Portugal: dos benefícios prometidos aos riscos de um sistema de cuidados duas velocidades’, *Sociologia, Problemas e Práticas*, (93). doi: 10.7458/SPP20209312257.

Bourret, R. and Bousquet, J. (2013) ‘An integrated approach to telemonitoring noncommunicable diseases: best practice from the European innovation partnership on active and healthy ageing.’, *World hospitals and health services : the official journal of the International Hospital Federation*, 49(3), pp. 25–28.

Braga, R. *et al.* (2024) ‘Association between sociodemographic and clinical features, health behaviors, and health literacy of patients with prostate cancer and prostate cancer prognostic stage’, *European Journal of Cancer Prevention*, 33(3), pp. 243–251. doi: 10.1097/CEJ.0000000000000854.

Brear, M. (2006) ‘Evaluating Telemedicine: Lessons and Challenges’, *Health Information Management Journal*, 35(2), pp. 23–31. doi: 10.1177/183335830603500206.

Briggs, A., Sculpher, M. and Buxton, M. (1994) ‘Uncertainty in the economic evaluation of health care technologies: The role of sensitivity analysis’, *Health Economics*, 3(2), pp. 95–104. doi: 10.1002/hec.4730030206.

Brooke, J. (1996) ‘SUS: A “Quick and Dirty” Usability Scale’, in *Usability Evaluation In Industry*. CRC Press, pp. 4–7.

Brooks, E. *et al.* (2013) ‘Reaching Rural Communities with Culturally Appropriate Care: A Model for Adapting Remote Monitoring to American Indian Veterans with Posttraumatic Stress Disorder’, *Telemedicine and e-Health*, 19(4), pp. 272–277. doi: 10.1089/tmj.2012.0117.

Buttigieg, S. C., Pace, A. and Rathert, C. (2017) ‘Hospital performance dashboards: a literature review’, *Journal of Health Organization and Management*, 31(3), pp. 385–406. doi: 10.1108/JHOM-04-2017-0088.

Cabral, S. *et al.* (2025) ‘Strategic Plan for Cardiovascular Health in Portugal – Portuguese Society of Cardiology (PESCP-SPC)’, *Revista Portuguesa de Cardiologia*, 44(1), pp. 41–56. doi: 10.1016/j.repc.2024.11.006.

Cadilhac, D. A. *et al.* (2020) ‘Establishment of an internationally agreed minimum data set for acute telestroke’, *Journal of Telemedicine and Telecare*, 27(9), pp. 582–589. doi: 10.1177/1357633X19899262.

Calò, L. *et al.* (2013) 'Economic impact of remote monitoring on ordinary follow-up of implantable cardioverter defibrillators as compared with conventional in-hospital visits. A single-center prospective and randomized study', *Journal of Interventional Cardiac Electrophysiology*, 37(1), pp. 69–78. doi: 10.1007/s10840-013-9783-9.

Carayannis, E. G., Canestrino, R. and Magliocca, P. (2024) 'From the Dark Side of Industry 4.0 to Society 5.0: Looking "Beyond the Box" to Developing Human-Centric Innovation Ecosystems', *IEEE Transactions on Engineering Management*, 71, pp. 6695–6711. doi: 10.1109/TEM.2023.3239552.

Carnero, M. C. and Gómez, A. (2016) 'A multicriteria decision making approach applied to improving maintenance policies in healthcare organizations', *BMC Medical Informatics and Decision Making*, 16(1), p. 47. doi: 10.1186/s12911-016-0282-7.

Casale, P. N. *et al.* (2021) 'The Promise of Remote Patient Monitoring', *American Journal of Medical Quality*, 36(3), pp. 139–144. doi: 10.1097/01.JMQ.0000741968.61211.2b.

Castela, E. *et al.* (2005) 'Five years of teleconsultation: experience of the Cardiology Department of Coimbra Pediatric Hospital.', *Revista Portuguesa de Cardiologia*, 24(6), pp. 835–40. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16121675.

Castelnuovo, G. *et al.* (2020) 'Fighting the COVID-19 pandemic using the technology-based second-line in Italy and Lombardy: The urgent need of home-based remote monitoring systems to avoid the collapse of the hospital-centred first line', *Journal of Global Health*, 10(2), pp. 1–2. doi: 10.7189/jogh.10.020371.

Centro de dia do Conde Ferreira tem projeto pioneiro de telemonitorização (2021) *Jornal de Notícias*. Available at: https://www.jn.pt/nacional/especial-patrocinado/videos/centro-de-dia-do-conde-ferreira-tem-projeto-pioneiro-de-telemonitorizacao--13797231.html (Accessed: 7 February 2022).

Centro Hospitalar Universitário do Algarve (2021) 'Acordo Modificativo ao CP do CHUA, E.P.E. - 2021', p. 8. Available at: https://www.acss.min-saude.pt/wp-content/uploads/2016/10/Acordo-Modificativo-2021-CHUA.pdf.

Centro Nacional de TeleSaúde (2017) *O percurso da telessaúde em Portugal*. Available at: http://www.cnts.min-saude.pt/2017/03/28/211/ (Accessed: 26 January 2022).

Centro Nacional de TeleSaúde (2019) *Plano Estratégico Nacional para a Telessaúde 2019-2022*. Lisboa.

Centro Nacional de TeleSaúde (2021a) *Evolução da telessaúde em Portugal*. Available at: http://www.cnts.min-saude.pt/2021/07/20/evolucao-da-telessaude-em-portugal/ (Accessed: 26 January 2022).

Centro Nacional de TeleSaúde (2021b) *Plano Estratégico Nacional para a Telessaúde 2019-2022: Plano Operacional 2021-2022*. Lisboa.

Chandra, K. *et al.* (2012) 'Cost-effectiveness of interventions for chronic obstructive pulmonary disease (COPD) using an Ontario policy model.', *Ontario health technology assessment series*, 12(12), pp. 1–61.

Chaudhry, S. I. *et al.* (2007) 'Telemonitoring for Patients With Chronic Heart Failure: A Systematic Review', *Journal of Cardiac Failure*, 13(1), pp. 56–62. doi: 10.1016/j.cardfail.2006.09.001.

Chen, H. and Levkoff, S. E. (2015) 'Delivering Telemonitoring Care to Digitally Disadvantaged Older Adults: Human-Computer Interaction (HCI) Design Recommendations', in G., S., J., Z., and G., S. (eds) *Human aspects of IT for the aged popultation: Design for everyday life, part II*. Department of Psychiatry, Harvard Medical School, 1280 Massachusetts Ave, Suite 505, Cambridge, MA 02138, United States: Springer Verlag (Lecture Notes in Computer Science), pp. 50–60. doi: 10.1007/978-3-319-20913-5_5.

Cheville, A. L. *et al.* (2018) 'The rationale, design, and methods of a randomized, controlled trial to evaluate the effectiveness of collaborative telecare in preserving function among patients with late stage cancer and hematologic conditions', *Contemporary Clinical Trials*, 64, pp. 254–264. doi: 10.1016/j.cct.2017.08.021.

Chronaki, C. E. and Vardas, P. (2013) 'Remote monitoring costs, benefits, and reimbursement: A European perspective', *Europace*, 15(SUPPL.1), pp. 59–64. doi: 10.1093/europace/eut110.

Chung, Y. *et al.* (2020) 'Role of visual analytics in supporting mental healthcare systems research and policy: A systematic scoping review', *International Journal of Information Management*, 50(May 2019), pp. 17–27. doi: 10.1016/j.ijinfomgt.2019.04.012.

Clarke, M. *et al.* (2017) 'Interoperable End-to-End Remote Patient Monitoring Platform based on IEEE 11073 PHD and ZigBee Health Care Profile', *IEEE Transactions on Biomedical Engineering*, 65(5), pp. 1–1. doi:

10.1109/TBME.2017.2732501.

Concannon, D., Herbst, K. and Manley, E. (2019) ‘Developing a Data Dashboard Framework for Population Health Surveillance: Widening Access to Clinical Trial Findings’, *JMIR Formative Research*, 3(2), p. e11342. doi: 10.2196/11342.

Coriat, R. *et al.* (2012) ‘Cost Effectiveness of Integrated Medicine in Patients With Cancer Receiving Anticancer Chemotherapy’, *Journal of Oncology Practice*, 8(4), pp. 205–210. doi: 10.1200/JOP.2011.000447.

Corner, J. L. (1994) ‘Operationalizing approximate multiattribute utility functions for use in practice’, *European Journal of Operational Research*, 79(1), pp. 73–84. doi: 10.1016/0377-2217(94)90396-4.

Cowie, M. R. *et al.* (2014) ‘Improving care for patients with acute heart failure: before, during and after hospitalization.’, *ESC heart failure*, 1(2), pp. 110–145. doi: 10.1002/ehf2.12021.

Crisp, N. (2015) ‘The Future of the Portuguese Health System’, *Acta Médica Portuguesa*, 28(3), p. 277. doi: 10.20344/amp.6655.

Cristino, S. (2021) *Sequelas da Covid-19 monitorizadas à distância*, *Jornal de Notícias*. Available at: https://www.jn.pt/nacional/sequelas-da-covid-19-monitorizadas-a-distancia-14138925.html (Accessed: 7 February 2022).

Cruz, I. O. *et al.* (2021) ‘Telemonitoramento da Insuficiência Cardíaca – A Experiência de um Centro’, *Arquivos Brasileiros de Cardiologia*, 118(3), pp. 599–604. doi: 10.36660/abc.20201264.

Dagliati, A., Sacchi, L., *et al.* (2018) ‘A dashboard-based system for supporting diabetes care’, *Journal of the American Medical Informatics Association*, 25(5), pp. 538–547. doi: 10.1093/jamia/ocx159.

Dagliati, A., Tibollo, V., *et al.* (2018) ‘Big Data as a Driver for Clinical Decision Support Systems: A Learning Health Systems Perspective’, *Frontiers in Digital Humanities*, 5(May), pp. 1–7. doi: 10.3389/fdigh.2018.00008.

Daly, B. *et al.* (2022) ‘Analysis of a Remote Monitoring Program for Symptoms Among Adults With Cancer Receiving Antineoplastic Therapy’, *JAMA Network Open*, 5(3), p. e221078. doi: 10.1001/jamanetworkopen.2022.1078.

Davis, S. M. *et al.* (2020) ‘Designing a multifaceted telehealth intervention for a rural population using a model for developing complex interventions in nursing’, *BMC NURSING*, 19(1), p. 9. doi: 10.1186/s12912-020-0400-9.

Dawson, N. L. *et al.* (2021) ‘Home Telemonitoring to Reduce Readmission of High-Risk Patients: a Modified Intention-to-Treat Randomized Clinical Trial’, *Journal of General Internal Medicine*, 36(11), pp. 3395–3401. doi: 10.1007/s11606-020-06589-1.

DECHANT, H. K. *et al.* (1996) ‘Health Systems Evaluation of Telemedicine: A Staged Approach’, *Telemedicine Journal*, 2(4), pp. 303–312. doi: 10.1089/tmj.1.1996.2.303.

Decision Eyes (2020) *Welphi*. Available at: https://www.welphi.com/en/Home.html (Accessed: 11 January 2024).

Deloitte (2014) ‘Healthcare and Life Sciences Predictions 2020. A bold future?’, *Deloitte Centre for Health Solutions*, p. 48.

Demartini, C. and Trucco, S. (2017) ‘Are performance measurement systems useful? Perceptions from health care’, *BMC Health Services Research*, 17(1), p. 96. doi: 10.1186/s12913-017-2022-9.

Department of Economic and Social Affairs of the United Nations (Population Division) (2020) *World Population Ageing 2019*. New York, NY, USA. Available at: https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2019-Report.pdf.

Dias, L. C. and Clímaco, J. N. (2005) ‘Dealing with imprecise information in group multicriteria decisions: a methodology and a GDSS architecture’, *European Journal of Operational Research*, 160(2), pp. 291–307. doi: 10.1016/j.ejor.2003.09.002.

Dimengo, J. and Stegall, G. (2015) ‘Team-Based Care for External Telemonitoring in Patients with Heart Failure’, *Heart Failure Clinics*, 11(3), pp. 451–465. doi: 10.1016/j.hfc.2015.03.008.

Dixit, R. A. *et al.* (2020) ‘Rapid development of visualization dashboards to enhance situation awareness of COVID-19 telehealth initiatives at a multihospital healthcare system’, *Journal of the American Medical Informatics Association*, 27(9), pp. 1456–1461. doi: 10.1093/jamia/ocaa161.

Dolan, J. G., Veazie, P. J. and Russ, A. J. (2013) 'Development and initial evaluation of a treatment decision dashboard', *BMC Medical Informatics and Decision Making*, 13(1), p. 51. doi: 10.1186/1472-6947-13-51.

Donner, C. F. *et al.* (2018) 'Incorporating telemedicine into the integrated care of the COPD patient a summary of an interdisciplinary workshop held in Stresa, Italy, 7–8 September 2017', *Respiratory Medicine*, 143, pp. 91–102. doi: 10.1016/j.rmed.2018.09.003.

Dontje, M. L. *et al.* (2021) 'Implementation and evaluation of an e-health innovation for personalized care for patients with amyotrophic lateral sclerosis (ALS): protocol for a participatory action research study', *Implementation Science Communications*, 2(1), p. 25. doi: 10.1186/s43058-021-00130-z.

Doraiswamy, S. *et al.* (2020) 'Use of Telehealth During the COVID-19 Pandemic: Scoping Review', *Journal of Medical Internet Research*, 22(12), p. e24087. doi: 10.2196/24087.

Dowding, D. *et al.* (2015) 'Dashboards for improving patient care: Review of the literature', *International Journal of Medical Informatics*, 84(2), pp. 87–100. doi: 10.1016/j.ijmedinf.2014.10.001.

Dowding, D., Merrill, J. and Russell, D. (2018) 'Using Feedback Intervention Theory to Guide Clinical Dashboard Design.', *AMIA ... Annual Symposium proceedings. AMIA Symposium*, 2018, pp. 395–403. Available at: http://www.ncbi.nlm.nih.gov/pubmed/30815079.

Duarte, I. *et al.* (2020) 'Burnout among Portuguese healthcare workers during the COVID-19 pandemic', *BMC Public Health*, 20(1), p. 1885. doi: 10.1186/s12889-020-09980-z.

Duggan, E. W. and Thachenkary, C. S. (2004) 'Integrating nominal group technique and joint application development for improved systems requirements determination', *Information & Management*, 41(4), pp. 399–411. doi: 10.1016/S0378-7206(03)00080-6.

Dyer, J. S. and Sarin, R. K. (1979) 'Measurable Multiattribute Value Functions', *Operations Research*, 27(4), pp. 810–822. doi: 10.1287/opre.27.4.810.

Eckerson, W. W. (2010) *Performance Dashboards: Measuring, Monitoring, and Managing Your Business*. 2nd Editio. Wiley.

Elg, M., Palmberg Broryd, K. and Kollberg, B. (2013) 'Performance measurement to drive improvements in healthcare practice', *International Journal of Operations & Production Management*. Edited by B. Clegg, Jillian MacBryde and Prasanta Dey, 33(11/12), pp. 1623–1651. doi: 10.1108/IJOPM-07-2010-0208.

Fairbrother, P. *et al.* (2014) 'Telemonitoring for chronic heart failure: the views of patients and healthcare professionals - a qualitative study', *Journal of Clinical Nursing*, 23(1–2), pp. 132–144. doi: 10.1111/jocn.12137.

Faragli, A. *et al.* (2021) 'The role of non-invasive devices for the telemonitoring of heart failure patients', *Heart Failure Reviews*, 26(5), pp. 1063–1080. doi: 10.1007/s10741-020-09963-7.

Fasolo, B. and Bana e Costa, C. A. (2014) 'Tailoring value elicitation to decision makers' numeracy and fluency: Expressing value judgments in numbers or words', *Omega*, 44, pp. 83–90. doi: 10.1016/j.omega.2013.09.006.

Fazaeli, S. *et al.* (2021) 'Development, Implementation, and User Evaluation of COVID-19 Dashboard in a Third-Level Hospital in Iran', *Applied Clinical Informatics*, 12(5), pp. 1091–1100. doi: 10.1055/s-0041-1740188.

Fernandes, F. S. (2021) *Prémios Saúde Sustentável: Inovação é a marca dos cuidados de saúde*, *Jornal de Negócios*. Available at: https://www.jornaldenegocios.pt/economia/saude/detalhe/inovacao-e-a-marca-dos-cuidados-de-saude (Accessed: 7 February 2022).

Fernandes, M. *et al.* (2019) 'Evaluation of telemonitoring of continuous positive airway pressure therapy in obstructive sleep apnoea syndrome: TELEPAP pilot study', *Journal of Telemedicine and Telecare*, 27(6), pp. 353–358. doi: 10.1177/1357633X19875850.

Fernandes, M. *et al.* (2024) 'Current research topics on MACBETH', in *IO2024 - XXIII Congresso da Associação Portuguesa de Investigação Operacional*. Viseu, p. 23. Available at: http://apdio.pt/documents/411767/0/Livro_de_resumos_IO2024_Viseu.pdf.

Ferretti, M. *et al.* (2017) 'Strategic monitoring of port authorities activities: Proposal of a multi-dimensional digital dashboard', *Production Planning & Control*, 28(16), pp. 1354–1364. doi: 10.1080/09537287.2017.1375146.

Ferrua, M. *et al.* (2020) 'How to Design a Remote Patient Monitoring System? A French Case Study', *BMC Health Services Research*, 20(1), p. 434. doi: 10.1186/s12913-020-05293-4.

Few, S. (2006) *Information Dashboard Design: The Effective Visual Communication of Data*. O'Reilly Media, Inc.

Figueira, J. R. *et al.* (2023) 'A multiple criteria approach for building a pandemic impact assessment composite indicator: The case of COVID-19 in Portugal', *European Journal of Operational Research*, 309(2), pp. 795–818. doi: 10.1016/j.ejor.2023.01.025.

Fikri, E. (2024) 'Decarbonisation of Kidney Care in the United Arab Emirates: A Roadmap to an Environmentally Sustainable Care [Letter]', *International Journal of Nephrology and Renovascular Disease*, Volume 17, pp. 275–276. doi: 10.2147/IJNRD.S502317.

Filipe, M. T. M. (2019) *Telessaúde: Análise Económica do Projeto de Telemonitorização da DPOC na ULSAM*. Faculdade de Economia da Universidade do Porto.

Filipe, S. (2020) *Monitorização cardíaca feita no conforto do lar*, *Jornal de Notícias*. Available at: https://www.jn.pt/local/noticias/aveiro/aveiro/monitorizacao-cardiaca-feita-no-conforto-do-lar--11826380.html (Accessed: 7 February 2022).

Fonseca, C. *et al.* (2018) 'Insuficiência cardíaca em números: estimativas para o século XXI em Portugal', *Revista Portuguesa de Cardiologia*, 37(2), pp. 97–104. doi: 10.1016/j.repc.2017.11.010.

Fonseca, C. *et al.* (2022) 'NT-proBNP for heart failure diagnosis in Primary Care: Costs or savings? A budget impact study', *Revista Portuguesa de Cardiologia*, 41(3), pp. 183–193. doi: 10.1016/j.repc.2021.03.009.

Foster, C. C. *et al.* (2021) 'Integrated Multimodality Telemedicine to Enhance In-Home Care of Infants During the Interstage Period', *Pediatric Cardiology*, 42(2), pp. 349–360. doi: 10.1007/s00246-020-02489-7.

Franc, S. *et al.* (2019) 'Efficacy of two telemonitoring systems to improve glycaemic control during basal insulin initiation in patients with type 2 diabetes: The TeleDiab-2 randomized controlled trial', *Diabetes, Obesity and Metabolism*, 21(10), pp. 2327–2332. doi: 10.1111/dom.13806.

Franco, L. A. and Montibeller, G. (2010) 'Facilitated modelling in operational research', *European Journal of Operational Research*, 205(3), pp. 489–500. doi: 10.1016/j.ejor.2009.09.030.

François, M. *et al.* (2021) 'Usability and acceptance of truck dashboards designed by drivers: Two participatory design approaches compared to a user-centered design', *International Journal of Industrial Ergonomics*, 81(November 2020), p. 103073. doi: 10.1016/j.ergon.2020.103073.

Frankland, J. *et al.* (2019) 'Follow-up care after treatment for prostate cancer: evaluation of a supported self-management and remote surveillance programme', *BMC Cancer*, 19(1), p. 368. doi: 10.1186/s12885-019-5561-0.

Freitas, Â. *et al.* (2018) 'Indicators for evaluating European population health: a Delphi selection process', *BMC Public Health*, 18(1), p. 557. doi: 10.1186/s12889-018-5463-0.

Freitas, L. *et al.* (2023) 'Which value aspects are relevant for the evaluation of medical devices? Exploring stakeholders' views through a Web-Delphi process', *BMC Health Services Research*, 23(1), p. 593. doi: 10.1186/s12913-023-09550-0.

Gagnon, M. L. (2011) 'Moving knowledge to action through dissemination and exchange', *Journal of Clinical Epidemiology*, 64(1), pp. 25–31. doi: 10.1016/j.jclinepi.2009.08.013.

Gallagher, M. *et al.* (1993) 'The Nominal Group Technique: A Research Tool for General Practice?', *Family Practice*, 10(1), pp. 76–81. doi: 10.1093/fampra/10.1.76.

Gansen, F. and Klinger, J. (2020) 'Reasoning in the valuation of health-related quality of life: A qualitative content analysis of deliberations in a pilot study', *Health Expectations*, 23(2), pp. 405–413. doi: 10.1111/hex.13011.

Garattini, L., Badinella Martini, M. and Mannucci, P. M. (2021) 'Improving primary care in Europe beyond COVID-19: from telemedicine to organizational reforms', *Internal and Emergency Medicine*, 16(2), pp. 255–258. doi: 10.1007/s11739-020-02559-x.

George, L. A. and Cross, R. K. (2020) 'Remote Monitoring and Telemedicine in IBD: Are We There Yet?', *Current Gastroenterology Reports*, 22(3), p. 12. doi: 10.1007/s11894-020-0751-0.

Giansanti, D., Morelli, S. and Macellari, V. (2008) 'Telemedicine Technology Assessment Part I: Setup and Validation of a Quality Control System', *Telemedicine and e-Health*, 13(2), pp. 118–129. doi: 10.1089/tmj.2008.9963.

Gomes, L. S. *et al.* (2023) 'Using MCDA to assist an Intermunicipal community develop a resilience strategy in face of the pandemic caused by the SARS-CoV-2', *Socio-Economic Planning Sciences*, 87(March), p. 101588. doi: 10.1016/j.seps.2023.101588.

Gonçalves, L., Castelo-Branco, M. and Nando Campanella (2018) *e-Saúde - Livro de ensino para estudantes de cursos de ciências da Saúde e para profissionais de saúde*. Covilhã: Tipografia da Universidade da Beira Interior.

Gonçalves, M. (2009) *Telemold reduz idas ao hospital a 25 mil doentes*, *Jornal de Notícias*. Available at: https://www.jn.pt/sociedade/telemold-reduz-idas-ao-hospital-a-25-mil-doentes-1305664.html (Accessed: 7 February 2022).

Gordon, K. *et al.* (2020) 'Exploring an Innovative Care Model and Telemonitoring for the Management of Patients With Complex Chronic Needs: Qualitative Description Study', *JMIR Nursing*, 3(1), p. e15691. doi: 10.2196/15691.

Gordon, K. *et al.* (2022) 'Normalizing Telemonitoring in Nurse-Led Care Models for Complex Chronic Patient Populations: Case Study', *JMIR Nursing*, 5(1), p. e36346. doi: 10.2196/36346.

Goretzki, L. *et al.* (2018) 'Exploring the Persuasiveness of Accounting Numbers in the Framing of "Performance" – A Micro-Level Analysis of Performance Review Meetings', *European Accounting Review*, 27(3), pp. 495–525. doi: 10.1080/09638180.2016.1262273.

Gottlob, A. *et al.* (2025) 'Telemedicine in cancer care: lessons from COVID-19 and solutions for Europe', *European Journal of Public Health*. doi: 10.1093/eurpub/ckae206.

Greco, S. *et al.* (2019) 'On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness', *Social Indicators Research*, 141(1), pp. 61–94. doi: 10.1007/s11205-017-1832-9.

Greenhalgh, T. *et al.* (2017) 'Beyond Adoption: A New Framework for Theorizing and Evaluating Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability of Health and Care Technologies', *Journal of Medical Internet Research*, 19(11), p. e367. doi: 10.2196/jmir.8775.

Grigsby, J., Brega, A. G. and Devore, P. A. (2005) 'The Evaluation of Telemedicine and Health Services Research', *Telemedicine and e-Health*, 11(3), pp. 317–328. doi: 10.1089/tmj.2005.11.317.

Grover, V. *et al.* (2018) 'Creating Strategic Business Value from Big Data Analytics: A Research Framework', *Journal of Management Information Systems*, 35(2), pp. 388–423. doi: 10.1080/07421222.2018.1451951.

Grustam, A. S. *et al.* (2017) 'Care coordination in a business-to-business and a business-to-consumer model for telemonitoring patients with chronic diseases', *International Journal of Care Coordination*, 20(4), pp. 135–147. doi: 10.1177/2053434517747908.

Grustam, A. S. *et al.* (2018) 'Cost-Effectiveness Analysis in Telehealth: A Comparison between Home Telemonitoring, Nurse Telephone Support, and Usual Care in Chronic Heart Failure Management', *Value in Health*, 21(7), pp. 772–782. doi: 10.1016/j.jval.2017.11.011.

Guarini, M. R., Battisti, F. and Chiovitti, A. (2017) 'Public Initiatives of Settlement Transformation: A Theoretical-Methodological Approach to Selecting Tools of Multi-Criteria Decision Analysis', *Buildings*, 8(1), p. 1. doi: 10.3390/buildings8010001.

Guilcher, S. J. T. *et al.* (2013) 'Spanning Boundaries into Remote Communities: An Exploration of Experiences with Telehealth Chronic Disease Self-Management Programs in Rural Northern Ontario, Canada', *Telemedicine and e-Health*, 19(12), pp. 904–909. doi: 10.1089/tmj.2013.0057.

Gülmezoglu, A. M. *et al.* (2020) 'Self-care and remote care during pregnancy: a new paradigm?', *Health Research Policy and Systems*, 18(1), p. 107. doi: 10.1186/s12961-020-00627-4.

Haig, M. *et al.* (2023) 'A Value Framework to Assess Patient-Facing Digital Health Technologies That Aim to Improve Chronic Disease Management: A Delphi Approach', *Value in Health*, 26(10), pp. 1474–1484. doi: 10.1016/j.jval.2023.06.008.

Halwani, F. *et al.* (2016) 'A real-time dashboard for managing pathology processes', *Journal of Pathology Informatics*, 7(1), p. 24. doi: 10.4103/2153-3539.181768.

Harb, S. I. *et al.* (2021) 'Methodological options of the nominal group technique for survey item elicitation in health research: A scoping review', *Journal of Clinical Epidemiology*, 139, pp. 140–148. doi: 10.1016/j.jclinepi.2021.08.008.

Hebert, M. (2001) 'Telehealth Success: Evaluation Framework Development', *Studies in Health Technology and Informatics*, 84, pp. 1145–1149. doi: 10.3233/978-1-60750-928-8-1145.

Heinzelmann, P. J. *et al.* (2005) 'Clinical Outcomes Associated with Telemedicine/Telehealth', *Telemedicine and e-Health*, 11(3), pp. 329–347. doi: 10.1089/tmj.2005.11.329.

Hendricks, S. *et al.* (2018) 'A modified stakeholder participation assessment framework for design thinking in health innovation', *Healthcare*, 6(3), pp. 191–196. doi: 10.1016/j.hjdsi.2018.06.003.

Herkert, C. *et al.* (2020) 'Quality Assessment of an Integrated Care Pathway Using Telemonitoring in Patients with Chronic Heart Failure and Chronic Obstructive Pulmonary Disease: Protocol for a Quasi-Experimental Study', *JMIR Research Protocols*, 9(11), p. e20571. doi: 10.2196/20571.

Hernández-Quiles, C. *et al.* (2016) 'A randomized clinical trial for remote telemonitoring into an integrated care program for high complexity patients. Atlan-TIC project', *International Journal of Integrated Care*, 16(6), p. 154. doi: 10.5334/ijic.2702.

Hevner, A. and Gregor, S. (2022) 'Envisioning entrepreneurship and digital innovation through a design science research lens: A matrix approach', *Information & Management*, 59(3), p. 103350. doi: 10.1016/j.im.2020.103350.

Hilty, D. M. *et al.* (2021) 'Sensor, Wearable, and Remote Patient Monitoring Competencies for Clinical Care and Training: Scoping Review', *Journal of Technology in Behavioral Science*, 6(2), pp. 252–277. doi: 10.1007/s41347-020-00190-3.

Hincapié, M. A. *et al.* (2020) 'Implementation and Usefulness of Telemedicine During the COVID-19 Pandemic: A Scoping Review', *Journal of Primary Care & Community Health*, 11, p. 215013272098061. doi: 10.1177/2150132720980612.

Hirko, K. A. *et al.* (2020) 'Telehealth in response to the COVID-19 pandemic: Implications for rural health disparities', *Journal of the American Medical Informatics Association*, 27(11), pp. 1816–1818. doi: 10.1093/jamia/ocaa156.

Hogervorst, M. A. *et al.* (2022) 'Reported Challenges in Health Technology Assessment of Complex Health Technologies', *Value in Health*, 25(6), pp. 992–1001. doi: 10.1016/j.jval.2021.11.1356.

Hospital de Setúbal "quebrou barreiras". "O mais importante é o doente" (2020) *Diário de Notícias*. Available at: https://www.dn.pt/especiais/coracao-de-portugal/hospital-de-setubal-quebrou-barreiras-o-mais-importante-e-o-doente-13100040.html (Accessed: 7 February 2022).

Hospital Santa Marta. Na hora de medir corações, estar perto é estar longe (2020) *Diário de Notícias*. Available at: https://www.dn.pt/especiais/coracao-de-portugal/hospital-santa-marta-na-hora-de-medir-coracoes-estar-perto-e-estar-longe--12999610.html (Accessed: 7 February 2022).

Hou, C.-K. (2012) 'Examining the effect of user satisfaction on system usage and individual performance with business intelligence systems: An empirical study of Taiwan's electronics industry', *International Journal of Information Management*, 32(6), pp. 560–573. doi: 10.1016/j.ijinfomgt.2012.03.001.

Howard, R. A. (2004) 'Speaking of Decisions: Precise Decision Language', *Decision Analysis*, 1(2), pp. 71–78. doi: 10.1287/deca.1030.0005.

Iftikhar, A. *et al.* (2019) 'Role of dashboards in improving decision making in healthcare: Review of the literature', in *Proceedings of the 31st European Conference on Cognitive Ergonomics*. New York, NY, USA: ACM, pp. 215–219. doi: 10.1145/3335082.3335109.

Ignatenko, E., Ribeiro, M. and Oliveira, M. D. (2022) 'Informing the Design of Data Visualization Tools to Monitor the COVID-19 Pandemic in Portugal: A Web-Delphi Participatory Approach', *International Journal of Environmental Research and Public Health*, 19(17), p. 11012. doi: 10.3390/ijerph191711012.

Inácio, A. M. (2021) *Doentes com sequelas da covid tratados com telemonitorização em Lisboa*, *Diário de Notícias*. Available at: https://www.dn.pt/sociedade/doentes-com-sequelas-da-covid-tratados-com-telemonitorizacao-em-lisboa-13940006.html (Accessed: 7 February 2022).

International Association for Public Participation (2022) 'IAP2 Spectrum of Public Participation'. Available at: https://cdn.ymaws.com/www.iap2.org/resource/resmgr/pillars/Spectrum_8.5x11_Print.pdf (Accessed: 9 March

2023).

Ippolito, A. *et al.* (2022) 'How technological innovations in performance measurement systems overcome management challenges in healthcare', *International Journal of Productivity and Performance Management*. doi: 10.1108/IJPPM-11-2021-0664.

Isazad Mashinchi, M., Ojo, A. and Sullivan, F. J. (2020) 'Investigating Analytics Dashboards' Support for the Value-based Healthcare Delivery Model', in *Proceedings of the 53rd Hawaii International Conference on System Sciences*, pp. 3659–3668. doi: 10.24251/HICSS.2020.448.

Jain, S. *et al.* (2022) 'Remote Monitoring and Holistic Care of Home-Isolated COVID-19 Positive Healthcare Workers Through Digital Technology During the Omicron (B1.1.529) Wave: A Prospective Cohort Study From India.', *Frontiers in public health*, 10(July), p. 936000. doi: 10.3389/fpubh.2022.936000.

James, H. M. *et al.* (2021) 'Spread, Scale-up, and Sustainability of Video Consulting in Health Care: Systematic Review and Synthesis Guided by the NASSS Framework', *Journal of Medical Internet Research*, 23(1). doi: 10.2196/23775.

Kasparian, J. and Rolland, A. (2012) 'OECD's Better Life Index: can any country be well ranked?', *Journal of Applied Statistics*, 39(10), pp. 2223–2230. doi: 10.1080/02664763.2012.706265.

Keeney, R. L. (1982) 'Decision Analysis: An Overview', *Operations Research*, 30(5), pp. 803–838.

Keeney, R. L. (1996) 'Value-focused thinking: Identifying decision opportunities and creating alternatives', *European Journal of Operational Research*, 92(3), pp. 537–549. doi: 10.1016/0377-2217(96)00004-5.

Keeney, R. L. and Raiffa, H. (1993) *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. New York: Cambridge University Press. doi: 10.1017/CBO9781139174084.

Kerzner, H. (2017) *Project Management Metrics, KPIs, and Dashboards*. Hoboken, NJ, USA: John Wiley & Sons, Inc. doi: 10.1002/9781119427599.

van Kessel, R. *et al.* (2022) 'Is Europe prepared to go digital? Making the case for developing digital capacity: An exploratory analysis of Eurostat survey data', *PLOS Digital Health*. Edited by L. Sbaffi, 1(2), p. e0000013. doi: 10.1371/journal.pdig.0000013.

Khan, I., Pintelon, L. and Martin, H. (2022) 'The Application of Multicriteria Decision Analysis Methods in Health Care: A Literature Review', *Medical Decision Making*, 42(2), pp. 262–274. doi: 10.1177/0272989X211019040.

Khan, M. S. *et al.* (2024) 'Global epidemiology of heart failure', *Nature Reviews Cardiology*, 21(10), pp. 717–734. doi: 10.1038/s41569-024-01046-6.

Khan, S. *et al.* (2024) 'Implementing Autonomous Control in the Digital-Twins-Based Internet of Robotic Things for Remote Patient Monitoring', *Sensors*, 24(17), p. 5840. doi: 10.3390/s24175840.

Khanal, S. *et al.* (2024) 'Development of a Prioritization Framework to Aid Healthcare Funding Decision Making in Health Technology Assessment in Australia: Application of Multicriteria Decision Analysis', *Value in Health*, 27(11), pp. 1585–1593. doi: 10.1016/j.jval.2024.07.003.

Kidholm, K. *et al.* (2012) 'A model for assessment of telemedicine applications: MAST', *International Journal of Technology Assessment in Health Care*, 28(1), pp. 44–51. doi: 10.1017/S0266462311000638.

Kidholm, K. *et al.* (2017) 'The Model for Assessment of Telemedicine (MAST): A scoping review of empirical studies', *Journal of Telemedicine and Telecare*, 23(9), pp. 803–813. doi: 10.1177/1357633X17721815.

Kirk, A. (2012) *Data Visualization: a successful design process*. 1st edn. Birmingham: Packt Publishing, Ltd. Available at: https://www.packtpub.com/en-us/product/data-visualization-a-successful-design-process-9781849693462.

Kirkwood, C. W. and Sarin, R. K. (1980) 'Preference Conditions for Multiattribute Value Functions', *Operations Research*, 28(1), pp. 225–232. doi: 10.1287/opre.28.1.225.

Kishore, K. *et al.* (2021) 'Practical guidelines to develop and evaluate a questionnaire', *Indian Dermatology Online Journal*, 12(2), p. 266. doi: 10.4103/idoj.IDOJ_674_20.

Kitsiou, S., Paré, G. and Jaana, M. (2013) 'Systematic reviews and meta-analyses of home telemonitoring interventions for patients with chronic diseases: A critical assessment of their methodological quality', *Journal of Medical Internet Research*, 15(7). doi: 10.2196/jmir.2770.

Knegtmans, M. F. *et al.* (2020) ‘Home Telemonitoring Improved Pain Registration in Patients With Cancer’, *Pain Practice*, 20(2), pp. 122–128. doi: 10.1111/papr.12830.

Koehler, F., Koehler, K., Deckwart, O., Prescher, S., Wegscheider, K., Kirwan, B.-A., *et al.* (2018) ‘Efficacy of telemedical interventional management in patients with heart failure (TIM-HF2): a randomised, controlled, parallel-group, unmasked trial’, *The Lancet*, 392(10152), pp. 1047–1057. doi: 10.1016/S0140-6736(18)31880-4.

Koehler, F., Koehler, K., Deckwart, O., Prescher, S., Wegscheider, K., Winkler, S., *et al.* (2018) ‘Telemedical Interventional Management in Heart Failure II (TIM-HF2), a randomised, controlled trial investigating the impact of telemedicine on unplanned cardiovascular hospitalisations and mortality in heart failure patients: study design and description’, *European Journal of Heart Failure*, 20(10), pp. 1485–1493. doi: 10.1002/ejhf.1300.

Köksalan, M., Wallenius, J. and Zionts, S. (2011) *Multiple Criteria Decision Making: From Early History to the 21st Century*. Singapore: World Scientific Publishing Limited. doi: 10.1142/8042.

Kozłowska, J. (2022) ‘Methods of Multi-Criteria Analysis in Technology Selection and Technology Assessment: A Systematic Literature Review’, *Engineering Management in Production and Services*, 14(2), pp. 116–137. doi: 10.2478/emj-2022-0021.

Krenitsky, N. M. *et al.* (2020) ‘Primed for a pandemic: Implementation of telehealth outpatient monitoring for women with mild COVID-19’, *Seminars in Perinatology*, 44(7), p. 151285. doi: 10.1016/j.semperi.2020.151285.

Kronenfeld, J. P. and Penedo, F. J. (2021) ‘Novel Coronavirus (COVID-19): telemedicine and remote care delivery in a time of medical crisis, implementation, and challenges’, *Translational Behavioral Medicine*, 11(2), pp. 659–663. doi: 10.1093/tbm/ibaa105.

Kruglov, A., Strugar, D. and Succi, G. (2021) ‘Tailored performance dashboards—an evaluation of the state of the art’, *PeerJ Computer Science*, 7, p. e625. doi: 10.7717/peerj-cs.625.

Kumpunen, S. *et al.* (2021) ‘Transformations in the landscape of primary health care during COVID-19: Themes from the European region’, *Health Policy*. doi: 10.1016/j.healthpol.2021.08.002.

Kunjan, K., Doebbeling, B. and Toscos, T. (2019) ‘Dashboards to Support Operational Decision Making in Health Centers: A Case for Role-Specific Design’, *International Journal of Human–Computer Interaction*, 35(9), pp. 742–750. doi: 10.1080/10447318.2018.1488418.

Lago, P. P. *et al.* (2007) ‘Structuring group decision making in a web-based environment by using the nominal group technique’, *Computers & Industrial Engineering*, 52(2), pp. 277–295. doi: 10.1016/j.cie.2006.11.003.

Lampe, K. *et al.* (2009) ‘The HTA Core Model: A novel method for producing and reporting health technology assessments’, *International Journal of Technology Assessment in Health Care*, 25(S2), pp. 9–20. doi: 10.1017/S0266462309990638.

Lares portugueses recebem nova plataforma de telemonitorização da COVID-19 (2020) *NewsFarma*. Available at: https://www.newsfarma.pt/noticias/9949-lares-portugueses-recebem-nova-plataforma-de-telemonitorização-da-covid-19.html (Accessed: 7 February 2022).

Lau, M. K. *et al.* (2019) ‘Clinical dashboard development and use for academic detailing in the U.S. Department of Veterans Affairs’, *Journal of the American Pharmacists Association*, 59(2), pp. S96-S103.e3. doi: 10.1016/j.japh.2018.12.006.

Lee, J. Y. and Lee, S. W. H. (2018) ‘Telemedicine Cost–Effectiveness for Diabetes Management: A Systematic Review’, *Diabetes Technology & Therapeutics*, 20(7), pp. 492–500. doi: 10.1089/dia.2018.0098.

Leijten, F. R. M. *et al.* (2018) ‘The SELFIE framework for integrated care for multi-morbidity: Development and description’, *Health Policy*, 122(1), pp. 12–22. doi: 10.1016/j.healthpol.2017.06.002.

Li, Y. *et al.* (2023) ‘Toward a campus crisis management system amid the pandemic and beyond’, *Information & Management*, 60(8), p. 103883. doi: 10.1016/j.im.2023.103883.

Liao, Y. *et al.* (2019) ‘The Future of Wearable Technologies and Remote Monitoring in Health Care’, *American Society of Clinical Oncology Educational Book*, 39(39), pp. 115–121. doi: 10.1200/EDBK_238919.

Lilholt, P. H. *et al.* (2017) ‘Telehealthcare for patients suffering from chronic obstructive pulmonary disease: Effects on health-related quality of life: Results from the Danish ? € TeleCare North’ cluster-randomised trial’, *BMJ Open*, 7(5). doi: 10.1136/bmjopen-2016-014587.

List, C. (2012) ‘The theory of judgment aggregation: an introductory review’, *Synthese*, 187(1), pp. 179–207. doi:

10.1007/s11229-011-0025-3.

Liu, N., Prester, J. and Kim, J. (2024) ‘Patient Adaptation Processes in Remote Monitoring Environments: A Computational Analysis’, in *ICIS 2024 Proceedings*. Bangkok. Available at: https://aisel.aisnet.org/icis2024/ishealthcare/ishealthcare/17.

Lluch, M. and Abadie, F. (2013) ‘Exploring the role of ICT in the provision of integrated care—Evidence from eight countries’, *Health Policy*, 111(1), pp. 1–13. doi: 10.1016/j.healthpol.2013.03.005.

Lopes, D. F. *et al.* (2014) ‘Using MACBETH with the Choquet Integral Fundamentals to Model Interdependencies between Elementary Concerns in the Context of Risk Management’, in *Proceedings of the 3rd International Conference on Operations Research and Enterprise Systems*. SCITEPRESS - Science and and Technology Publications, pp. 116–126. doi: 10.5220/0004833701160126.

Lopez-Villegas, A. *et al.* (2018) ‘Health-related quality of life on tele-monitoring for users with pacemakers 6 months after implant: the NORDLAND study, a randomized trial’, *BMC Geriatrics*, 18(1), pp. 1–12. doi: 10.1186/s12877-018-0911-3.

Lopez-Villegas, A. *et al.* (2020) ‘Cost–utility analysis of telemonitoring versus conventional hospital-based follow-up of patients with pacemakers. The NORDLAND randomized clinical trial’, *PLOS ONE*. Edited by G. Andò, 15(1), p. e0226188. doi: 10.1371/journal.pone.0226188.

Ludlow, K. *et al.* (2021) ‘Co-designing a dashboard of predictive analytics and decision support to drive care quality and client outcomes in aged care: A mixed-method study protocol’, *BMJ Open*, 11(8). doi: 10.1136/bmjopen-2021-048657.

Lundell, S. *et al.* (2015) ‘Telehealthcare in COPD: A systematic review and meta-analysis on physical outcomes and dyspnea’, *Respiratory Medicine*, 109(1), pp. 11–26. doi: 10.1016/j.rmed.2014.10.008.

Lysdahl, K. B. *et al.* (2017) ‘Comprehensive Assessment of Complex Technologies: Integrating Various Aspects in Health Technology Assessment’, *International Journal of Technology Assessment in Health Care*, 33(5), pp. 570–576. doi: 10.1017/S0266462317000678.

Maguire, T. *et al.* (2022) ‘Using the Nominal Group Technique to determine a nursing framework for a forensic mental health service: A discussion paper’, *International Journal of Mental Health Nursing*, 31(4), pp. 1030–1038. doi: 10.1111/inm.13023.

Malviya, R. *et al.* (2023) ‘Blockchain with Artificial Intelligence for Healthcare’, *A synergistic approach*. IOP Publishing. doi: 10.1088/978-0-7503-5839-2.

Marsh, K. *et al.* (2016) ‘Multiple Criteria Decision Analysis for Health Care Decision Making—Emerging Good Practices: Report 2 of the ISPOR MCDA Emerging Good Practices Task Force’, *Value in Health*, 19(2), pp. 125–137. doi: 10.1016/j.jval.2015.12.016.

Martinez, D. A. *et al.* (2018) ‘An Electronic Dashboard to Monitor Patient Flow at the Johns Hopkins Hospital: Communication of Key Performance Indicators Using the Donabedian Model’, *Journal of Medical Systems*, 42(8), p. 133. doi: 10.1007/s10916-018-0988-4.

Martins, A. I. *et al.* (2015) ‘European Portuguese Validation of the System Usability Scale (SUS)’, *Procedia Computer Science*, 67, pp. 293–300. doi: 10.1016/j.procs.2015.09.273.

Martins, H. and Amorim, P. (2022) ‘TeleHealth Evolution in Portugal in the Last Century’, in *A century of telemedicine: Curatio Sine Distantia et Tempora, A World Wide Overview – Part V*, pp. 31–111.

Marttunen, M. *et al.* (2019) ‘Identifying relevant objectives in environmental management decisions: An application to a national monitoring program for river restoration’, *Ecological Indicators*, 101(November 2018), pp. 851–866. doi: 10.1016/j.ecolind.2018.11.042.

Mateus, R. J. G., Bana e Costa, J. C. and Matos, P. V. (2017) ‘Supporting Multicriteria Group Decisions with MACBETH Tools: Selection of Sustainable Brownfield Redevelopment Actions’, *Group Decision and Negotiation*, 26(3), pp. 495–521. doi: 10.1007/s10726-016-9501-y.

Matheus, R., Janssen, M. and Maheshwari, D. (2020) ‘Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities’, *Government Information Quarterly*, 37(3), p. 101284. doi: 10.1016/j.giq.2018.01.006.

McDonagh, T. A. *et al.* (2021) ‘2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure', *European Heart Journal*, 42(36), pp. 3599–3726. doi: 10.1093/eurheartj/ehab368.

McLean, S. *et al.* (2011) 'Telehealthcare for asthma: a Cochrane review (Structured abstract)', *CMAJ: Canadian Medical Association Journal*, 183(11), pp. E733-e742. Available at: http://onlinelibrary.wiley.com/o/cochrane/cldare/articles/DARE-12011005823/frame.html.

McLean, S., Protti, D. and Sheikh, A. (2011) 'Telehealthcare for long term conditions', *Bmj*, 342(7793), pp. 374–378. doi: 10.1136/bmj.d120.

Melchiorre, M. G. *et al.* (2018) 'eHealth in integrated care programs for people with multimorbidity in Europe: Insights from the ICARE4EU project', *Health Policy*, 122(1), pp. 53–63. doi: 10.1016/j.healthpol.2017.08.006.

Mentzakis, E., Tkacz, D. and Rivas, C. (2020) 'A proof-of-concept framework for the preference elicitation and evaluation of health informatics technologies: the online PRESENT patient experience dashboard as a case example', *BMC Medical Informatics and Decision Making*, 20(95), pp. 1–20. doi: 10.1186/s12911-020-1098-z.

Mettler, T. and Vimarlund, V. (2009) 'Understanding business intelligence in the context of healthcare', *Health Informatics Journal*, 15(3), pp. 254–264. doi: 10.1177/1460458209337446.

Mexia, F. R. M. de M. (2024) *Design and Development of a Decision Support System Integrating MACBETH-Voting for Use in Health Contexts*. Instituto Superior Técnico, University of Lisbon. Available at: https://fenix.tecnico.ulisboa.pt/cursos/mebiom21/dissertacao/1691203502345014.

Meyer, M. (2022) *Telehealth for heart patients*, *Siemens Healthineers*. Available at: https://www.siemens-healthineers.com/perspectives/telehealth (Accessed: 4 March 2022).

Miller, G. A. (1956) 'The magical number seven, plus or minus two: Some limits on our capacity for processing information.', *Psychological Review*, 63(2), pp. 81–97. doi: 10.1037/h0043158.

Ministério da Saúde (20AD) *Diário da República, 2.ª série - N.º 90 — 10 de Maio de 2018. Despacho n.º 4583/2018 do Gabinete do Secretário de Estado Adjunto e da Saúde*.

Ministério da Saúde (2013) *Diário da República, 2.ª série - N.º 46 — 6 de Março de 2013. Despacho n.º 3571/2013 do Gabinete do Secretário de Estado Adjunto do Ministro da Saúde*.

Ministério da Saúde (2018) *Diário da República, 2.ª série - N.º 191 — 3 de Outubro de 2018. Despacho n.º 9323-A/2018 do Gabinete da Secretária de Estado da Saúde*. Available at: https://dre.pt/home/-/dre/116587923/details/maximized.

Ministério das Finanças (2013) *Diário da República, 1.ª série - N.º 191 — 3 de Outubro de 2013. Decreto-Lei n.º 133/2013 do Ministério das Finanças*.

Miranda, R., Oliveira, M. D., Baptista, F. M., *et al.* (2023) 'Telemonitoring in Portugal: where do we stand and which way forward?', *Health Policy*, 131, p. 104761. doi: 10.1016/j.healthpol.2023.104761.

Miranda, R., Oliveira, M. D., Nicola, P., *et al.* (2023) 'Towards A Framework for Implementing Remote Patient Monitoring From an Integrated Care Perspective: A Scoping Review', *International Journal of Health Policy and Management*. doi: 10.34172/ijhpm.2023.7299.

Miranda, R. *et al.* (2024) 'Unlocking Continuous Improvement in Heart Failure Remote Monitoring: A Participatory Approach to Unveil Value Dimensions and Performance Indicators', *Telemedicine and e-Health*, 30(7), pp. e1990–e2003. doi: 10.1089/tmj.2023.0560.

Mitterer, S. *et al.* (2021) 'Measuring Financial Burden in Families of Children Living With Life-Limiting Conditions: A Scoping Review of Cost Indicators and Outcome Measures', *Value in Health*, 24(9), pp. 1377–1389. doi: 10.1016/j.jval.2021.03.015.

Modre-Osprian, R. *et al.* (2014) 'Closed-loop healthcare monitoring in a collaborative heart failure network', in Horbst, A and Hayn, D and Schreier, G and Ammenwerth, E. (ed.) *Studies in Health Technology and Informatics*. Netherlands: IOS Press (Studies in Health Technology and Informatics), pp. 17–24. doi: 10.3233/978-1-61499-397-1-17.

Mohebali, D. and Kittleson, M. M. (2021) 'Remote monitoring in heart failure: current and emerging technologies in the context of the pandemic', *Heart*, 107(5), pp. 366–372. doi: 10.1136/heartjnl-2020-318062.

Mokri, H., van Baal, P. and Rutten-van Mölken, M. (2024) 'The impact of different perspectives on the cost-effectiveness of remote patient monitoring for patients with heart failure in different European countries', *European Journal of Health Economics*. doi: 10.1007/s10198-024-01690-2.

Montignac, F., Noirot, I. and Chaudourne, S. (2009) ‘Multi-criteria evaluation of on-board hydrogen storage technologies using the MACBETH approach’, *International Journal of Hydrogen Energy*, 34(10), pp. 4561–4568. doi: 10.1016/j.ijhydene.2008.09.098.

Morgan, M. B. *et al.* (2008) ‘The Radiology Digital Dashboard: Effects on Report Turnaround Time’, *Journal of Digital Imaging*, 21(1), pp. 50–58. doi: 10.1007/s10278-007-9008-9.

Mühlbacher, A. C. and Kaczynski, A. (2016) ‘Making Good Decisions in Healthcare with Multi-Criteria Decision Analysis: The Use, Current Research and Future Development of MCDA’, *Applied Health Economics and Health Policy*, 14(1), pp. 29–40. doi: 10.1007/s40258-015-0203-4.

de Mul, M. *et al.* (2012) ‘Development of a clinical data warehouse from an intensive care clinical information system’, *Computer Methods and Programs in Biomedicine*, 105(1), pp. 22–30. doi: 10.1016/j.cmpb.2010.07.002.

Müller, A. *et al.* (2021) ‘Digital mHealth and Virtual Care Use in Pandemics: A Rapid Landscape Review of Interventions Used Internationally During COVID-19 in 4 Countries.’, *JMIR formative research*. doi: 10.2196/26041.

Nabyonga-Orem, J. *et al.* (2016) ‘Perspectives on health policy dialogue: definition, perceived importance and coordination’, *BMC Health Services Research*, 16(S4), p. 218. doi: 10.1186/s12913-016-1451-1.

Nangalia, V., Prytherch, D. R. and Smith, G. B. (2010) ‘Health technology assessment review: Remote monitoring of vital signs - current status and future challenges’, *Critical Care*, 14(5), p. 233. doi: 10.1186/cc9208.

National Quality Forum (2017) *Creating a Framework to Support Measure Development for Telehealth*. Washington, D.C. Available at: https://www.qualityforum.org/Publications/2017/08/Creating_a_Framework_to_Support_Measure_Development_for_Telehealth.aspx.

Ndwabe, H., Basu, A. and Mohammed, J. (2024) ‘Post pandemic analysis on comprehensive utilization of telehealth and telemedicine’, *Clinical eHealth*, 7, pp. 5–14. doi: 10.1016/j.ceh.2023.12.002.

Neely, A. *et al.* (2000) ‘Performance measurement system design: developing and testing a process-based approach’, *International Journal of Operations & Production Management*, 20(10), pp. 1119–1145. doi: 10.1108/01443570010343708.

Nelson, V. *et al.* (2022) ‘Using nominal group technique among resident physicians to identify key attributes of a burnout prevention program’, *PLOS ONE*. Edited by S. A. Useche, 17(3), p. e0264921. doi: 10.1371/journal.pone.0264921.

Nepal, S. *et al.* (2014) ‘A Framework for Telehealth Program Evaluation’, *Telemedicine and e-Health*, 20(4), pp. 393–404. doi: 10.1089/tmj.2013.0093.

Neumann, P. J. (2021) ‘Toward Better Data Dashboards for US Drug Value Assessments’, *Value in Health*, 24(10), pp. 1484–1489. doi: 10.1016/j.jval.2021.04.1287.

Newhouse, N., Farmer, A. and Whelan, M. E. (2020) ‘COVID-19: Needs-led implementation and the immediate potential of remote monitoring’, *BJGP Open*, 4(2), p. bjgpopen20X101093. doi: 10.3399/bjgpopen20X101093.

Niñerola, A., Hernández-Lara, A. and Sánchez-Rebull, M. (2021) ‘Improving healthcare performance through Activity-Based Costing and Time-Driven Activity-Based Costing’, *The International Journal of Health Planning and Management*, 36(6), pp. 2079–2093. doi: 10.1002/hpm.3304.

Nittari, G. *et al.* (2020) ‘Telemedicine Practice: Review of the Current Ethical and Legal Challenges’, *Telemedicine and e-Health*, 26(12), pp. 1427–1437. doi: 10.1089/tmj.2019.0158.

Nunes-Ferreira, A. *et al.* (2020) ‘Non-invasive telemonitoring improves outcomes in heart failure with reduced ejection fraction: a study in high-risk patients’, *ESC Heart Failure*, 7(6), pp. 3996–4004. doi: 10.1002/ehf2.12999.

Nunes, A. M. and Ferreira, D. C. (2019) ‘Reforms in the Portuguese health care sector: Challenges and proposals’, *The International Journal of Health Planning and Management*, 34(1). doi: 10.1002/hpm.2695.

O’Mara, B., Monani, D. and Carey, G. (2021) ‘Telehealth, COVID-19 and Refugees and Migrants in Australia: Policy and Related Barriers and Opportunities for More Inclusive Health and Technology Systems’, *International Journal of Health Policy and Management*, (x), pp. 1–5. doi: 10.34172/ijhpm.2021.31.

O’Rourke, B., Oortwijn, W. and Schuller, T. (2020) ‘The new definition of health technology assessment: A milestone in international collaboration’, *International Journal of Technology Assessment in Health Care*, 36(3), pp. 187–190. doi: 10.1017/S0266462320000215.

Ohinmaa, A., Hailey, D. and Roine, R. (2001) ‘Elements for assessment of telemedicine applications’, *International Journal of Technology Assessment in Health Care*, 17(2), pp. 190–202.

Oliveira Hashiguchi, T. C. (2020) ‘Bringing health care to the patient: An overview of the use of telemedicine in OECD countries’, *OECD Health Working Papers*, (116). doi: 10.1787/8e56ede7-en.

Oliveira, M. D. *et al.* (2022) *Sustainability and Resilience in the Portuguese Health System*. London: Partnership for Health Systems Sustainability and Resilience. Available at: https://www3.weforum.org/docs/WEF_PHSSR_Portugal_2022.pdf.

Oliveira, M. D., Mataloto, I. and Kanavos, P. (2019) ‘Multi-criteria decision analysis for health technology assessment: addressing methodological challenges to improve the state of the art’, *European Journal of Health Economics*, 20(6), pp. 891–918. doi: 10.1007/s10198-019-01052-3.

Oliveira, T. (2021) ‘SNS prepara futuro à distância para aliviar despesa’, *Expresso*, 22 January. Available at: https://expresso.pt/iniciativaseprodutos/projetos-expresso/2021-01-25-SNS-prepara-futuro-a-distancia-para-aliviar-despesa.

Opie, J. *et al.* (2021) ‘Requirements for a Dashboard to Support Quality Improvement Teams in Pain Management’, *Frontiers in Big Data*, 4(May), pp. 1–16. doi: 10.3389/fdata.2021.654914.

Orlando, T. M. and Sunindyo, W. D. (2017) ‘Designing dashboard visualization for heterogeneous stakeholders (case study: ITB central library)’, in *2017 International Conference on Data and Software Engineering (ICoDSE)*. IEEE, pp. 1–6. doi: 10.1109/ICODSE.2017.8285872.

Palacholla, R. S. *et al.* (2019) ‘Provider- and Patient-Related Barriers to and Facilitators of Digital Health Technology Adoption for Hypertension Management: Scoping Review’, *JMIR Cardio*, 3(1), p. e11951. doi: 10.2196/11951.

Pare, G., Jaana, M. and Sicotte, C. (2007) ‘Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base’, *Journal of the American Medical Informatics Association*, 14(3), pp. 269–277. doi: 10.1197/jamia.M2270.

Park, K. W. *et al.* (2010) ‘The Operating Room Dashboard’, *Journal of Surgical Research*, 164(2), pp. 294–300. doi: 10.1016/j.jss.2009.09.011.

Patel, G. M. *et al.* (2024) ‘Examining medical urgent and patient precedence within the telemedicine landscape with its infrastructure and policies: A comprehensive review’, *Multidisciplinary Reviews*, 6, p. 2023ss017. doi: 10.31893/multirev.2023ss017.

Patel, S. *et al.* (2022) ‘Using Participatory Design to Engage Physicians in the Development of a Provider-Level Performance Dashboard and Feedback System’, *The Joint Commission Journal on Quality and Patient Safety*, 48(3), pp. 165–172. doi: 10.1016/j.jcjq.2021.10.003.

Pauwels, K. *et al.* (2009) ‘Dashboards as a Service’, *Journal of Service Research*, 12(2), pp. 175–189. doi: 10.1177/1094670509344213.

Pelletier, A. C. *et al.* (2011) ‘Implementing a Web-Based Home Monitoring System within an Academic Health Care Network: Barriers and Facilitators to Innovation Diffusion’, *Journal of Diabetes Science and Technology*, 5(1), pp. 32–38. doi: 10.1177/193229681100500105.

Peretz, D., Arnaert, A. and Ponzoni, N. N. (2018) ‘Determining the cost of implementing and operating a remote patient monitoring programme for the elderly with chronic conditions: A systematic review of economic evaluations’, *Journal of Telemedicine and Telecare*, 24(1), pp. 13–21. doi: 10.1177/1357633X16669239.

Perry, L. M. *et al.* (2022) ‘Patient-Reported Outcome Dashboards Within the Electronic Health Record to Support Shared Decision-making: Protocol for Co-design and Clinical Evaluation With Patients With Advanced Cancer and Chronic Kidney Disease’, *JMIR Research Protocols*, 11(9), pp. 1–18. doi: 10.2196/38461.

Peters, M. D. *et al.* (2016) ‘Business intelligence systems use in performance measurement capabilities: Implications for enhanced competitive advantage’, *International Journal of Accounting Information Systems*, 21, pp. 1–17. doi: 10.1016/j.accinf.2016.03.001.

Petrazzuoli, F. *et al.* (2021) ‘COVID-19 pandemic and the great impulse to telemedicine: the basis of the WONCA Europe Statement on Telemedicine at the WHO Europe 70th Regional Meeting September 2020’, *Primary Health Care Research & Development*, 22, p. e80. doi: 10.1017/S1463423621000633.

Phillips-Wren, G. *et al.* (2015) 'Business Analytics in the Context of Big Data: A Roadmap for Research', *Communications of the Association for Information Systems*, 37. doi: 10.17705/1CAIS.03723.

Phillips-Wren, G., Daly, M. and Burstein, F. (2021) 'Reconciling business intelligence, analytics and decision support systems: More data, deeper insight', *Decision Support Systems*, 146, p. 113560. doi: 10.1016/j.dss.2021.113560.

Phillips, L. D. (1984) 'A theory of requisite decision models', *Acta Psychologica*, 56(1–3), pp. 29–48. doi: 10.1016/0001-6918(84)90005-2.

Phillips, L. D. (2007) 'Decision Conferencing', in Edwards, W., Miles, R. F., and von Winterfeldt, D. (eds) *Advances in Decision Analysis: From Foundations to Applications*. Cambridge University Press, pp. 375–399. Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ba3add45e426a577fd8fb6e6c48aa5d2a97ca081.

Pinto Saraiva, A., Castelo-Branco, M. and Nunes, J. (2017) 'The ideal profile of the telemedicine user - Experience from Portugal', *Journal of the International Society for Telemedicine and eHealth*, 5, p. e49.

Porter, M. (2010) 'What is value in helath care?', *The New England Journal of Medicine*, 363(26), pp. 2477–2481. doi: 10.1056/NEJMp1011024.

Presidência do Conselho de Ministros (2016) *Diário da República, 1.ª série - N.º 206 — 26 de Outubro de 2016. Resolução do Conselho de Ministros n.º 67/2016*.

Qlik (2024) *Qlik Help: Visualization types*. Available at: https://help.qlik.com/en-US/sense-developer/February2024/Subsystems/Mashups/Content/Sense_Mashups/Create/Visualizations/visualization-types.htm (Accessed: 27 March 2024).

Quintal, C. *et al.* (2023) 'Socioeconomic Factors Associated with the Use of Telehealth in Primary Care Services During the COVID-19 Pandemic', *SSRN*. doi: 10.2139/ssrn.4603859.

Rabiei, R. *et al.* (2024) 'Developing public health surveillance dashboards: a scoping review on the design principles', *BMC Public Health*, 24(1), p. 392. doi: 10.1186/s12889-024-17841-2.

Rabiei, R. and Almasi, S. (2022) 'Requirements and challenges of hospital dashboards: a systematic literature review', *BMC Medical Informatics and Decision Making*, 22(1), p. 287. doi: 10.1186/s12911-022-02037-8.

Radice, L. (2020) 'Medical devices: Design, manufacturing, evaluation, and control', in Iadanza, E. (ed.) *Clinical Engineering Handbook*. 2nd edn. Florence: Elsevier, pp. 427–475. Available at: https://linkinghub.elsevier.com/retrieve/pii/B9780128134672001103.

Rajnoha, R. *et al.* (2016) 'Business intelligence as a key information and knowledge tool for strategic business performance management', *E a M: Ekonomie a Management*, 19(1), pp. 181–203. doi: 10.15240/tul/001/2016-1-013.

Randall, M. H. *et al.* (2020) 'The effect of remote patient monitoring on the primary care clinic visit frequency among adults with type 2 diabetes', *International Journal of Medical Informatics*, 143(July), p. 104267. doi: 10.1016/j.ijmedinf.2020.104267.

Raposo, V. L. (2016) 'Telemedicine: The legal framework (or the lack of it) in Europe.', *GMS Health Technology Assessment*, 12, p. Doc03. doi: 10.3205/hta000126.

Rasmussen, N. H., Bansal, M. and Chen, C. Y. (2009) *Business Dashboards: A Visual Catalog for Design and Deployment*. John Wiley & Sons. Available at: https://www.wiley.com/en-ie/Business+Dashboards%3A+A+Visual+Catalog+for+Design+and+Deployment-p-9780470413470.

Rattray, J. and Jones, M. C. (2007) 'Essential elements of questionnaire design and development', *Journal of Clinical Nursing*, 16(2), pp. 234–243. doi: 10.1111/j.1365-2702.2006.01573.x.

Realdon, O. *et al.* (2018) 'The Technology-Enhanced Ability Continuum-of-Care Home Program for People with Cognitive Disorders: Concept Design and Scenario of Use', in P., C. et al. (eds). Università degli Studi di Milano-Bicocca, P.zza Ateneo Nuovo, 1, Milan, 20126, Italy: Springer Verlag, pp. 64–73. doi: 10.1007/978-3-030-01093-5_9.

Reddel, H. K., Jenkins, C. R. and Partridge, M. R. (2014) 'Self-management support and other alternatives to reduce the burden of asthma and chronic obstructive pulmonary disease', *The International Journal of Tuberculosis and Lung Disease*, 18(12), pp. 1396–1406. doi: 10.5588/ijtld.14.0371.

Ricci, R. Pietro and Morichelli, L. (2013) 'Workflow, time and patient satisfaction from the perspectives of Home Monitoring', *Europace*, 15(suppl 1), pp. i49–i53. doi: 10.1093/europace/eut113.

Rigueira, J. *et al.* (2021) 'Heart and brain interactions in heart failure: Cognition, depression, anxiety, and related outcomes', *Revista Portuguesa de Cardiologia*, 40(8), pp. 547–555. doi: 10.1016/j.repc.2020.09.009.

Roberts, N., Campbell, D. E. and Vijayasarathy, L. R. (2016) 'Using Information Systems to Sense Opportunities for Innovation: Integrating Postadoptive Use Behaviors with the Dynamic Managerial Capability Perspective', *Journal of Management Information Systems*, 33(1), pp. 45–69. doi: 10.1080/07421222.2016.1172452.

Rodrigues, D. M. F. (2023) *Developing a framework for collaborative development of multidimensional management dashboards: A use case for remote patient monitoring in heart failure*. Instituto Superior Técnico. Available at: https://fenix.tecnico.ulisboa.pt/cursos/meic-a/dissertacao/1972678479055753.

Rodrigues, T. *et al.* (2023) 'The value of multiparametric prediction scores in heart failure varies with the type of follow-up after discharge: a comparative analysis', *ESC Heart Failure*, 10(4), pp. 2550–2558. doi: 10.1002/ehf2.13949.

Rodrigues, T. C. *et al.* (2017) 'Modelling multicriteria value interactions with Reasoning Maps', *European Journal of Operational Research*, 258(3), pp. 1054–1071. doi: 10.1016/j.ejor.2016.09.047.

Rybnicek, R. and Königsgruber, R. (2019) 'What makes industry – university collaboration succeed? A systematic review of the literature', *Journal of Business Economics*, 89(2), pp. 221–250. doi: 10.1007/s11573-018-0916-6.

Sá, C. and Lopes, V. P. (2019) 'The use of wearable technology in a sample of Portuguese population', in *CIDESD 2019 International Congress*, p. 191.

Safwan, E. R., Meredith, R. and Burstein, F. (2016) 'Towards a business intelligence systems development methodology: Drawing on decision support and executive information systems', *Pacific Asia Conference on Information Systems, PACIS 2016 - Proceedings*.

Sakellarides, C. (2020) 'Serviço Nacional de Saúde: Dos Desafios da Atualidade às Transformações Necessárias', *Acta Médica Portuguesa*, 33(2), p. 133. doi: 10.20344/amp.12626.

Salgado, M. *et al.* (2020) 'Selecting Indicators to Monitor and Assess Environmental Health in a Portuguese Urban Setting: A Participatory Approach', *International Journal of Environmental Research and Public Health*, 17(22), p. 8597. doi: 10.3390/ijerph17228597.

Salgado, M. *et al.* (2022) 'Setting Requirements for a Dashboard to Inform Portuguese Decision-Makers About Environment Health in an Urban Setting', *Frontiers in Public Health*, 10(June), pp. 1–11. doi: 10.3389/fpubh.2022.837433.

Sampurno, F. *et al.* (2018) 'Quality Indicators for Global Benchmarking of Localized Prostate Cancer Management', *Journal of Urology*, 200(2), pp. 319–326. doi: 10.1016/j.juro.2018.02.071.

Sanchez-Lopez, R., Bana e Costa, C. A. and De Baets, B. (2012) 'The MACBETH approach for multi-criteria evaluation of development projects on cross-cutting issues', *Annals of Operations Research*, 199(1), pp. 393–408. doi: 10.1007/s10479-011-0877-4.

Sardain, A., Tang, C. and Potvin, C. (2016) 'Towards a dashboard of sustainability indicators for Panama: A participatory approach', *Ecological Indicators*, 70, pp. 545–556. doi: 10.1016/j.ecolind.2016.06.038.

Sarri, G. *et al.* (2021) 'The Role of Patient Experience in the Value Assessment of Complex Technologies – Do HTA Bodies Need to Reconsider How Value is Assessed?', *Health Policy*, 125(5), pp. 593–601. doi: 10.1016/j.healthpol.2021.03.006.

Schenkel, F. A. *et al.* (2020) 'Use of a Bluetooth tablet-based technology to improve outcomes in lung transplantation: A pilot study', *American Journal of Transplantation*, 20(12), pp. 3649–3657. doi: 10.1111/ajt.16154.

Schlieter, H. *et al.* (2022) 'Scale-up of Digital Innovations in Health Care: Expert Commentary on Enablers and Barriers', *Journal of Medical Internet Research*, 24(3), p. e24582. doi: 10.2196/24582.

Schmidt, C. *et al.* (2018) 'A novel integrated care concept (NICC) versus standard care in the treatment of chronic cardiovascular diseases: protocol for the randomized controlled trial CardioCare MV', *Trials*, 19(1), p. 120. doi: 10.1186/s13063-018-2502-1.

Schmier, J. K., Ong, K. L. and Fonarow, G. C. (2017) 'Cost-Effectiveness of Remote Cardiac Monitoring With the CardioMEMS Heart Failure System', *Clinical Cardiology*, 40(7), pp. 430–436. doi: 10.1002/clc.22696.

Scott Kruse, C. *et al.* (2018) 'Evaluating barriers to adopting telemedicine worldwide: A systematic review', *Journal of Telemedicine and Telecare*, 24(1), pp. 4–12. doi: 10.1177/1357633X16674087.

Scott, R. E. *et al.* (2003) *National Telehealth Outcome Indicators Project [NTOIP] - Project Information Document and a Synthesis of Telehealth Outcomes Literature*. Calgary. doi: 10.11575/PRISM/10618.

Sedrakyan, G., Mannens, E. and Verbert, K. (2019) 'Guiding the choice of learning dashboard visualizations: Linking dashboard design and data visualization concepts', *Journal of Computer Languages*, 50, pp. 19–38. doi: 10.1016/j.jvlc.2018.11.002.

Seferovic, P. M. *et al.* (2019) 'Clinical practice update on heart failure 2019: pharmacotherapy, procedures, devices and patient management. An expert consensus meeting report of the Heart Failure Association of the European Society of Cardiology', *European Journal of Heart Failure*, 21(10), pp. 1169–1186. doi: 10.1002/ejhf.1531.

Sekhon, M., Cartwright, M. and Francis, J. J. (2017) 'Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework', *BMC Health Services Research*, 17(1), p. 88. doi: 10.1186/s12913-017-2031-8.

Serviços Partilhados do Ministério da Saúde (2022) *Telemonit SNS 24*. Available at: https://play.google.com/store/apps/details?id=pt.minsaude.spms.telemonitsns&hl=pt&gl=US (Accessed: 6 May 2022).

Sheeran, T. *et al.* (2011) 'Feasibility and Impact of Telemonitor-Based Depression Care Management for Geriatric Homecare Patients', *Telemedicine and e-Health*, 17(8), pp. 620–626. doi: 10.1089/tmj.2011.0011.

Shi, C. *et al.* (2024) 'Inpatient-level care at home delivered by virtual wards and hospital at home: a systematic review and meta-analysis of complex interventions and their components', *BMC Medicine*, 22(1), p. 145. doi: 10.1186/s12916-024-03312-3.

Shi, Y., Cui, T. and Kurnia, S. (2023) 'Value co-creation for digital innovation: An interorganizational boundary-spanning perspective', *Information & Management*, 60(5), p. 103817. doi: 10.1016/j.im.2023.103817.

Siegel, S. *et al.* (2024) *2024 Global Health Care Sector Outlook: Navigating transformation*. Available at: https://www.deloitte.com/global/en/Industries/life-sciences-health-care/analysis/global-health-care-outlook.html.

Siemens Healthineers (2023a) *About Siemens Healthineers*. Available at: https://www.siemens-healthineers.com/pt/about (Accessed: 5 April 2023).

Siemens Healthineers (2023b) *Insights: Thought leadership platform for healthcare executives*. Available at: https://www.siemens-healthineers.com/en-us/insights (Accessed: 5 April 2023).

Siemens Healthineers (2023c) *We pioneer breakthroughs in healthcare. For everyone. Everywhere.* Available at: https://www.siemens-healthineers.com/company (Accessed: 5 April 2023).

da Silva Etges, A. P. B. *et al.* (2019) 'An 8-step framework for implementing time-driven activity-based costing in healthcare studies', *The European Journal of Health Economics*, 20(8), pp. 1133–1145. doi: 10.1007/s10198-019-01085-8.

Silva, P. *et al.* (2023) 'Telemonitoring in Heart Failure Patient Management', in, pp. 228–245. doi: 10.4018/978-1-6684-9251-2.ch011.

Silvério, R. M. P. (2022) *Developing a data visualisation tool to support the monitoring of remote care management programs: An integrative approach*. Instituto Superior Técnico, University of Lisbon. Available at: https://scholar.tecnico.ulisboa.pt/records/liK39V9nNQNOo62xWL9nq524rt5E7hS0Q6xs.

Simões, J., Augusto, G. F. and Fronteira, I. (2017) 'The portuguese health system in the aftermath of austerity', *Quarterly of the European Observatory on Health Systems and Policies*, 23(4), pp. 30–33. Available at: http://www.lse.ac.uk/lsehealthandsocialcare/publications/eurohealth/eurohealth.aspxhttp://www.healthobservatory.euhttp://www2.lse.ac.uk/LSEHealthAndSocialCare/aboutUs/LSEHealth/home.aspx.

Simões, J. de A. *et al.* (2017) *Portugal: Health system review*, *Health Systems in Transition*.

Simon, H. A. (1957) *Models of Man, Social and Rational: Mathematical Essays on Rational Human Behavior in Society Setting*. New York: John Wiley & Sons, Inc.

Singer, C. *et al.* (2024) ‘Computed tomography referral guidelines adherence in Europe: insights from a seven-country audit’, *European Radiology*. doi: 10.1007/s00330-024-11083-x.

Singh, R. *et al.* (2011) ‘Dynamic Capabilities in Home Health: IT-Enabled Transformation of Post-Acute Care’, *Journal of the Association for Information Systems*, 12(2), pp. 163–188. doi: 10.17705/1jais.00257.

Sistema Nacional de Saúde (2021) *Utilizar a aplicação móvel Telemonit SNS 24*. Available at: https://www.sns24.gov.pt/guia/utilizar-a-aplicacao-movel-telemonit-sns-24/ (Accessed: 6 May 2022).

Sistema Nacional de Saúde (2022) *Hospital Distrital de Santarém arranca projeto para doentes com DPOC*. Available at: https://www.sns.gov.pt/noticias/2021/03/01/telemonitorizacao-domiciliaria/ (Accessed: 7 February 2022).

Smaradottir, B. F. *et al.* (2017) ‘Telemedicine Follow Up of Chronic Obstructive Pulmonary Disease Integrated into a Patient-Centered Health Care Team-Setting Impacts on Patient Empowerment and Safety’, in Arabnia, HR and Deligiannidis, L and Tinetti, FG and Tran, QN and Yang, M. (ed.) *2017 International Conference on Computational Science and Computational Intelligence (CSCI)*. 345 E 47TH ST, NEW YORK, NY 10017 USA: IEEE, pp. 1779–1781. doi: 10.1109/CSCI.2017.311.

Smith, E. M. *et al.* (2022) ‘Assistive Technology Use and Provision During COVID-19: Results From a Rapid Global Survey’, *International Journal of Health Policy and Management*, 11(6), pp. 747–756. doi: 10.34172/IJHPM.2020.210.

Stensgaard, T. and Sørensen, T. (2001) ‘Telemedicine in Greenland - The Creation of an Evaluation Plan’, *Journal of Telemedicine and Telecare*, 7(1), pp. 37–38. doi: 10.1177/1357633X010070S115.

Struckmann, V. *et al.* (2018) ‘Relevant models and elements of integrated care for multi-morbidity: Results of a scoping review’, *Health Policy*, 122(1), pp. 23–35. doi: 10.1016/j.healthpol.2017.08.008.

Tahan, H. M. (2020) ‘Essential Case Management Practices Amidst the Novel Coronavirus Disease 2019 (COVID-19) Crisis: Part 1 Tele-Case Management, Surge Capacity, Discharge Planning, and Transitions of Care’, *PROFESSIONAL CASE MANAGEMENT*, 25(5), pp. 248–266. doi: 10.1097/NCM.0000000000000454.

Takahashi, E. A. *et al.* (2022) ‘An Overview of Telehealth in the Management of Cardiovascular Disease: A Scientific Statement From the American Heart Association.’, *Circulation*, 146(25), pp. e558–e568. doi: 10.1161/CIR.0000000000001107.

Tengblad, O. and Vallo Hult, H. (2023) ‘Exploring socio-technical challenges in patient self-monitoring: a qualitative case study’, in *9th International Conference on Socio-Technical Perspective in Information Systems Development, STPIS 2023*. Portsmouth, pp. 121–130.

Tersalvi, G. *et al.* (2020) ‘Telemedicine in Heart Failure During COVID-19: A Step Into the Future’, *Frontiers in Cardiovascular Medicine*, 7. doi: 10.3389/fcvm.2020.612818.

Thokala, P. *et al.* (2016) ‘Multiple Criteria Decision Analysis for Health Care Decision Making—An Introduction: Report 1 of the ISPOR MCDA Emerging Good Practices Task Force’, *Value in Health*, 19(1), pp. 1–13. doi: 10.1016/j.jval.2015.12.003.

Thomas, E. E. *et al.* (2024) ‘Beyond forced telehealth adoption: A framework to sustain telehealth among allied health services’, *Journal of Telemedicine and Telecare*, 30(3), pp. 559–569. doi: 10.1177/1357633X221074499.

Timóteo, A. T. *et al.* (2020) ‘Heart failure units: State of the art in disease management’, *Revista Portuguesa de Cardiologia*, 39(6), pp. 341–350. doi: 10.1016/j.repc.2020.02.007.

Tomé, J. (2020) *A telesaúde e teleassistência já podiam ter poupado muitas vidas em Portugal*, *Dinheiro Vivo*. Available at: https://www.dinheirovivo.pt/empresas/tecnologia/a-telesaude-e-teleassistencia-ja-podiam-ter-poupado-muitas-vidas-em-portugal-13130468.html (Accessed: 7 February 2022).

Torrini, I., Grassetti, L. and Rizzi, L. (2023) ‘Under-spending, over-spending or substitution among services? Spatial patterns of unexplained shares of health care expenditures’, *Health Policy*, 137, p. 104902. doi: 10.1016/j.healthpol.2023.104902.

Tricco, A. C. *et al.* (2018) ‘PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation’, *Annals of Internal Medicine*, 169(7), pp. 467–473. doi: 10.7326/M18-0850.

TSF Rádio Notícias (2020) *Controlo remoto de sintomas ajuda doentes com insuficiência cardíaca*. Available at: https://www.tsf.pt/especiais/coracao-de-portugal/controlo-remoto-de-sintomas-ajuda-doentes-com-insuficiencia-cardiaca-13004326.html (Accessed: 7 February 2022).

Turvey, C. (2016) 'Personal health records, patient portals, and mental healthcare', in *Career Paths in Telemental Health*. Department of Psychiatry, University of Iowa, Iowa City, IA 52245, United States: Springer International Publishing, pp. 115–121. doi: 10.1007/978-3-319-23736-7_10.

Udsen, F. W. *et al.* (2014) 'Effectiveness and cost-effectiveness of telehealthcare for chronic obstructive pulmonary disease: study protocol for a cluster randomized controlled trial', *Trials*, 15(1), p. 178. doi: 10.1186/1745-6215-15-178.

ULS de Castelo Branco inicia projeto de telemonitorização em diálise peritoneal domiciliária (2019) *NewsFarma*. Available at: https://www.newsfarma.pt/noticias/8159-uls-de-castelo-branco-inicia-projeto-de-telemonitorização-em-diálise-peritoneal-domiciliária.html (Accessed: 7 February 2022).

Vaismoradi, M., Lillo Crespo, M. and Turjamaa, R. (2024) 'Nurse-Led Medication Management for Older People in Home Care: A Systematic Review of Evolving Nurse Responsibilities in Technology-assisted Care', *Home Health Care Management & Practice*. doi: 10.1177/10848223241283415.

Valks, B. *et al.* (2021) 'Towards Smart Campus Management: Defining Information Requirements for Decision Making through Dashboard Design', *Buildings*, 11(5), p. 201. doi: 10.3390/buildings11050201.

Vallurupalli, V. and Bose, I. (2018) 'Business intelligence for performance measurement: A case based analysis', *Decision Support Systems*, 111(2017), pp. 72–85. doi: 10.1016/j.dss.2018.05.002.

Vegesna, A. *et al.* (2017) 'Remote Patient Monitoring via Non-Invasive Digital Technologies: A Systematic Review', *Telemedicine and e-Health*, 23(1), pp. 3–17. doi: 10.1089/tmj.2016.0051.

Velayati, F. *et al.* (2022) 'Telehealth Business Models and Their Components: Systematic Review', *Journal of Medical Internet Research*, 24(3), p. e33128. doi: 10.2196/33128.

Vestergaard, A. S. *et al.* (2020) 'Is telehealthcare for heart failure patients cost-effective? An economic evaluation alongside the Danish TeleCare North heart failure trial', *BMJ Open*, 10(1), p. e031670. doi: 10.1136/bmjopen-2019-031670.

Vieira, A. C. L., Oliveira, M. D. and Bana e Costa, C. A. (2020) 'Enhancing knowledge construction processes within multicriteria decision analysis: The Collaborative Value Modelling framework', *Omega*, 94, p. 102047. doi: 10.1016/j.omega.2019.03.005.

Vigiado 24 Horas por dia, José ajuda os médicos a tratar a sua doença (2020) *Diário de Notícias*. Available at: https://www.dn.pt/especiais/coracao-de-portugal/vigiado-24-horas-por-dia-jose-ajuda-os-medicos-a-tratar-a-sua-doenca--13122807.html (Accessed: 7 February 2022).

Vis, C. *et al.* (2020) 'Health technology assessment frameworks for eHealth: A systematic review', *International Journal of Technology Assessment in Health Care*, 36, pp. 204–216. doi: 10.1017/S026646232000015X.

Vitacca, Michele and Vitacca, Mauro (2019) 'Proposal of a multidimensional strategic-management dashboard for use in a rehabilitation respiratory unit', *Medicine*, 98(20), p. e15728. doi: 10.1097/MD.0000000000015728.

Vodafone Portugal (2020) *Vodafone disponibiliza solução de monitorização remota para ajudar no combate à pandemia*. Available at: https://www.vodafone.pt/press-releases/2020/6/vodafone-disponibiliza-solucao-monitorizacao-remota-ajudar-combate-pandemia.html (Accessed: 7 February 2022).

Voinov, A. *et al.* (2018) 'Tools and methods in participatory modeling: Selecting the right tool for the job', *Environmental Modelling & Software*, 109, pp. 232–255. doi: 10.1016/j.envsoft.2018.08.028.

Vos, T. *et al.* (2020) 'Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019', *The Lancet*, 396(10258), pp. 1204–1222. doi: 10.1016/S0140-6736(20)30925-9.

Vukovic, V. *et al.* (2018) 'Health technology assessment evidence on e-Health/m-Health technologies: Evaluating the transparency and thoroughness', *International Journal of Technology Assessment in Health Care*, 34(1), pp. 87–96. doi: 10.1017/S0266462317004512.

Vukšić, V. B., Bach, M. P. and Popovič, A. (2013) 'Supporting performance management with business process management and business intelligence: A case analysis of integration and orchestration', *International Journal of*

Information Management, 33(4), pp. 613–619. doi: 10.1016/j.ijinfomgt.2013.03.008.

Vuorinen, A.-L. *et al.* (2014) 'Use of Home Telemonitoring to Support Multidisciplinary Care of Heart Failure Patients in Finland: Randomized Controlled Trial', *Journal of Medical Internet Research*, 16(12), p. e282. doi: 10.2196/jmir.3651.

Wang, J. *et al.* (2023) 'Developing policy-ready digital dashboards of geospatial access to emergency obstetric care: a survey of policymakers and researchers in sub-Saharan Africa', *Health and Technology*, (0123456789). doi: 10.1007/s12553-023-00793-9.

Ware, P. *et al.* (2020) 'Outcomes of a Heart Failure Telemonitoring Program Implemented as the Standard of Care in an Outpatient Heart Function Clinic: Pretest-Posttest Pragmatic Study', *Journal of Medical Internet Research*, 22(2), p. e16538. doi: 10.2196/16538.

Watson, A. R., Wah, R. and Thamman, R. (2020) 'The Value of Remote Monitoring for the COVID-19 Pandemic', *Telemedicine and e-Health*, 26(9), pp. 1110–1112. doi: 10.1089/tmj.2020.0134.

Wilkes, M. *et al.* (2024) 'Hospital Is Not the Home: Lessons From Implementing Remote Technology to Support Acute Inpatient and Transitional Care in the Home in the United States and United Kingdom', *Journal of Medical Internet Research*, 26, p. e58888. doi: 10.2196/58888.

Willemse, E. *et al.* (2014) 'Do telemonitoring projects of heart failure fit the Chronic Care Model?', *International Journal of Integrated Care*, 14(3), p. e023. doi: 10.5334/ijic.1178.

Von Winterfeldt, D. and Edwards, W. (1986) *Decision analysis and behavioral research*. Cambridge University Press.

de Wit-de Vries, E. *et al.* (2019) 'Knowledge transfer in university-industry research partnerships: a review', *Journal of Technology Transfer*, 44, pp. 1236–1255. doi: 10.1007/s10961-018-9660-x.

World Health Organization (2022) *Noncommunicable diseases*. Available at: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases (Accessed: 9 January 2023).

Woudstra, K. *et al.* (2022) 'An Overview of Stakeholders, Methods, Topics, and Challenges in Participatory Approaches Used in the Development of Medical Devices: A Scoping Review', *International Journal of Health Policy and Management*, 12, pp. 1–8. doi: 10.34172/ijhpm.2022.6839.

Xu, S. *et al.* (2021) 'Impact of the COVID-19 Pandemic on Health Care Utilization in a Large Integrated Health Care System: Retrospective Cohort Study', *Journal of Medical Internet Research*, 23(4), p. e26558. doi: 10.2196/26558.

Yadav, S. (2024) 'Transformative Frontiers: A Comprehensive Review of Emerging Technologies in Modern Healthcare', *Cureus*. doi: 10.7759/cureus.56538.

Yigitbasioglu, O. M. and Velcu, O. (2012) 'A review of dashboards in performance management: Implications for design and research', *International Journal of Accounting Information Systems*, 13(1), pp. 41–59. doi: 10.1016/j.accinf.2011.08.002.

Zamith, M. *et al.* (2009) 'Home telemonitoring of severe chronic respiratory insufficient and asthmatic patients', *Revista Portuguesa de Pneumologia (English Edition)*, 15(3), pp. 385–417. doi: 10.1016/S2173-5115(09)70120-4.

Zanaboni, P. *et al.* (2013) 'Cost-Utility Analysis of the EVOLVO Study on Remote Monitoring for Heart Failure Patients With Implantable Defibrillators: Randomized Controlled Trial', *Journal of Medical Internet Research*, 15(5), p. e106. doi: 10.2196/jmir.2587.

Zhang, M. *et al.* (2022) 'What Is Value in Health and Healthcare? A Systematic Literature Review of Value Assessment Frameworks', *Value in Health*, 25(2), pp. 302–317. doi: 10.1016/j.jval.2021.07.005.

APPENDIX

Final Subject-Matter Appreciation (Chapter 5)

The information provided in Table 3, value dimensions and indicators descriptions and the comments left by the participants during the web-Delphi process constituted the starting point for the in-depth analysis with the subject-matter expert (CP). Noteworthy participants' commentaries are provided below, grouped by value dimension, and associated with the indicator under assessment:

Access

- *Number of program dropouts*
  - ”It would be more appropriate to consider this indicator in the acceptability dimension.”
- *Number of hospital readmissions* | *Length of stay in intensive care* | *Length of stay in ward*
  - ”For HF-related causes. Otherwise, the result may be influenced by other morbidities, clouding the assessment of the value of the intervention of remote monitoring for HF.”
  - ”Only those related to the clinical condition in program”
- *Number of scheduled teleconsultations* | *Number of scheduled face-to-face consultations*
  - ”This indicator is relevant for what? What do you want to measure? Why does having more or fewer teleconsultations define access?”

Clinical Aspects

- *All-cause mortality*
  - ”If it is not related to HF, it is not relevant.”
- Comorbidities
  - ”Not as an indicator, but as information for the construction of a case-mix and clinical profile.”
- *NT-ProBNP level (pg/ml)* | *Left ventricular Ejection Fraction (LVEF)* | *NYHA classification* | *Classification of HF according to LVEF*
  - ”I do not have the clinical knowledge about HF to be able to assess what is important to monitor.”

Costs

- *Costs of hospitalization in intensive care* | *Hospital admission costs* | *Teleconsultation costs* | *Face-to-face consultations costs* | *Emergency service admission costs*
  - ”For HF-related causes. Otherwise, the result may be influenced by other morbidities, clouding the assessment of the value of the intervention of remote monitoring for HF.”
- *Costs for the patient*
  - ”Remote monitoring programs for HF have no costs for patients”

Aside from the comments above, there were others suggesting small changes in the description of the indicators and some other informative comments rather than suggesting modifications.

CP agreed with all of the comments left in the *Access* dimension. He agreed that *Number of program dropouts* was more concerned with the program's acceptability, so it should be shifted to *Acceptability*. Besides that, he agreed that given the purpose of this work, which is focused on HF, all the indicators where it is possible to assign a condition should be specific to HF, e.g., *Number of hospital readmissions*, *Length of stay in intensive care*, *Length of stay in ward*, and *Number of emergency visits*. Considering *Number of scheduled teleconsultations* and *Number of scheduled face-to-face consultations*, CP did not have a clear opinion regarding their selection. He referred that from an operational standpoint, those indicators are important to know because, for example, if a patient requests a lot of unscheduled (tele)consultations, it maybe be better to change the care plan and adjust the number of scheduled (tele)consultations which may result in lower costs. However, this information may not be relevant to include in a dashboard solution.

When it came to the analysis of the comments left about *Clinical aspects* indicators, CP was very sure that *NT-ProBNP level (pg/ml)* and *Left ventricular Ejection Fraction (LVEF)* should be selected to monitor an HF remote program, because those are HF-specific indicators, that are commonly used in clinical settings to detect the status of a patient. Furthermore, *All-cause mortality* also generated doubts about not being specific to HF. In this case, it was suggested to present a ratio indicator like *HF-related mortality/All-cause mortality*. Knowing the number of patients admitted to the program would allow us to have the same information as with the separated indicators (*HF-related mortality* and *All-cause mortality*), without the bias that could result from the individual assessment of *All-cause mortality*. Another topic discussed was the need to have a case mix. This need had been raised in the semi-structured interviews by one of the experts and, in the web-Delphi process, a comment was also left regarding the same issue. According to CP, it is also essential to have a case mix and present it in the visualisation tool because that information is vital to analyse the other data presented in the dashboard accurately. Besides that, if the goal is to, in the future, compare the program with other alternatives, a case mix is needed. Parameters such as age, sex, level of education and race should be included. Previously considered indicators such as *Comorbidities*, *NYHA classification*, and *Classification of HF according to LVEF* should also be considered in the case mix because these are parameters that give important clinical information about the patients that are needed to inform the analysis of the indicators' results and the assessment of the overall program.

Regarding *Acceptability* indicators, there were no comments worth mentioning. Only the indicator *Users with weight registered on half of the year's days*, that did not achieve agreement, was worth discussing. According to CP, this indicator is not relevant to monitor because we already consider indicators such as *Patient adherence to the program* and *Level of self-care*, which also give notice of how compliant the patient is being with the tasks he is asked to do. Furthermore, if a patient forgets to weigh himself, he should be contacted or phoned immediately because this might indicate an issue with the device or, worse, the patient. According to CP, no patient should be able to reach that number of days without weighing himself.

When it came to analysing the *Cost*s indicators that generated more doubts (i.e., *Patient travel costs to scheduled appointments*), CP expressed a similar viewpoint as before, stating that this topic was already considered in the indicator also suggested by participants *Costs for the patient*. Regarding the expense issue (the last comment presented), he was unsure if it was true for all programs, even though he was aware that some cover patient fees.