UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

ANTONIJA SROK

ADVANCING ECONOMIC EVALUATION OF TELEMEDICINE TO STRENGTHEN EVIDENCE-BASED RESOURCE ALLOCATION IN HEART FAILURE CARE IN SLOVENIA

DOCTORAL DISSERTATION

Ljubljana, 2026

UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

ANTONIJA SROK

ADVANCING ECONOMIC EVALUATION OF TELEMEDICINE TO STRENGTHEN EVIDENCE-BASED RESOURCE ALLOCATION IN HEART FAILURE CARE IN SLOVENIA

DOCTORAL DISSERTATION

Ljubljana, 2026

AUTHORSHIP STATEMENT

The undersigned Antonija Srok, a student at the University of Ljubljana, School of Economics and Business, (hereafter: SEB LU), author of this written final work of studies with the title Advancing economic evaluation of telemedicine to strengthen evidence-based resource allocation in heart failure care in Slovenia, prepared under supervision of Associate Professor Petra Došenović Bonča, PhD.

D E C L A R E

1. this doctoral dissertation to be based on the results of my own research;
2. the printed form of this doctoral dissertation to be identical to its electronic form;
3. the text of this doctoral dissertation to be language-edited and technically in adherence with the SEB LU's Technical Guidelines for Written Works, which means that I cited and / or quoted works and opinions of other authors in this written final work of studies in accordance with the SEB LU's Technical Guidelines for Written Works;
4. to be aware of the fact that plagiarism (in written or graphical form) is a criminal offence and can be prosecuted in accordance with the Criminal Code of the Republic of Slovenia;
5. to be aware of the consequences a proven plagiarism charge based on this doctoral dissertation could have for my status at the SEB LU in accordance with the relevant SEB LU Rules;
6. to have obtained all the necessary permits to use the data and works of other authors which are (in written or graphical form) referred to in this doctoral dissertation and to have clearly marked them;
7. to have acted in accordance with ethical principles during the preparation of this doctoral dissertation and to have, where necessary, obtained permission of the Ethics Committee;
8. my consent to use the electronic form of this doctoral dissertation for the detection of content similarity with other written works, using similarity detection software that is connected with the SEB LU Study Information System;
9. to transfer to the University of Ljubljana free of charge, non-exclusively, geographically and time-wise unlimited the right of saving this doctoral dissertation in the electronic form, the right of its reproduction, as well as the right of making this doctoral dissertation available to the public on the World Wide Web via the Repository of the University of Ljubljana;
10. my consent to publication of my personal data that are included in this doctoral dissertation and in this declaration, when this doctoral dissertation is published;
11. that I have verified the authenticity of the information derived from the records using artificial intelligence tools.

Ljubljana, May 25th, 2026. Author's signature: _____

ACKNOWLEDGEMENTS

I am grateful to my supervisor, Associate Prof. Petra Došenović Bonča, for her guidance, encouragement, and patience throughout this work. I also extend my sincere appreciation to the members of the Doctoral Student Committee, Prof. Tjaša Redek, Assistant Prof. Aleša Lotrič Dolinar, and Associate Prof. Eva Turk, as well as to Prof. Valentina Prevolnik Rupel, who was involved during the proposal phase, for their careful reading, valuable comments, and thoughtful questions. Their insights and high academic standards played an important role in shaping and strengthening this dissertation.

I am also grateful to Prof. Borut Jug for his encouragement and kindness, for taking the time to discuss and comment on the statistical results, and for sharing his clinical expertise in heart failure. I am further grateful to him and to my supervisor for introducing this research direction and enabling access to the data used in the empirical analyses. I thank the Health Insurance Institute of Slovenia for providing the administrative data used in this dissertation, and the stakeholders who participated in the interviews and whose perspectives were central to its qualitative and policy-oriented aspects.

On a personal level, I am deeply grateful to my friends for their support and confidence in me throughout this journey. I am especially thankful to Ema and Ivana, who shared much of this path with me. Together, we navigated not only academic challenges but also years of uncertainty and growth. Their presence gave me stability and perspective during demanding periods and made this experience more manageable and more meaningful. I am especially grateful that, through this journey, Ema and Ivana became friends whose support and friendship remain an important part of my life. I am also grateful to Antonija for her optimism and warmth, which brought lightness when it was most needed. I am likewise grateful to my colleagues, especially Jelena and Ivana, for their encouragement along the way. I thank my family, especially my brother Martin and his wife Ivana, for their constant support.

Finally, my deepest gratitude and love go to my husband, Dorian. His presence, understanding, and belief in me have sustained me not only through this journey but also through life's broader challenges. I dedicate this work to him.

This work is also dedicated to the memory of my father, whose quiet strength and perseverance in the face of hardship remain a lasting influence on my life and continue to guide my path.

SUMMARY

In this dissertation, I focus on economic evaluations of digital health interventions, which represent a valuable tool for comparing digital health interventions with usual care, supporting healthcare decision-making and resource allocation, and facilitating the adoption and reimbursement of digital health interventions. However, despite the increasing adoption of digital health interventions in healthcare systems, economic evaluation evidence in this field remains methodologically heterogeneous and uneven in quality. Against this background, I provide a comprehensive examination of the current use of economic evaluations of digital health interventions, identify key challenges and existing recommendations for strengthening economic evaluation practices in digital health, explore the perspectives of different stakeholders on economic evaluations of digital health interventions, and conduct a statistical analysis and an economic evaluation of a specific telemedicine intervention for patients with heart failure in Slovenia.

In the first chapter, I introduce the research area and present the research questions addressed in the dissertation. In the second chapter, I examine the use of ICT in the healthcare sector, focusing on the development of ICT-enabled healthcare, changes in terminology, and the current state of digitalisation of the healthcare sector in Slovenia. In the third chapter, I present a bibliometric analysis of the existing literature to assess the current state of research on economic evaluations of digital health interventions, which remains limited in scope and variable in quality. In this chapter, I also include a narrative literature review of the methodological challenges associated with conducting economic evaluations of digital health interventions and summarise recent recommendations on how economic evaluation practices in this field may be improved. In the fourth chapter, I introduce heart failure as the clinical condition associated with the telemedicine intervention evaluated later in the dissertation. I present a systematic literature review of existing research, with a particular focus on the economic evaluation of teleconsultations for patients with heart failure, which constitute the specific telemedicine intervention analysed in the Slovenian context in subsequent chapters.

In the fifth chapter, I present a qualitative analysis of interviews that I conducted with relevant stakeholders regarding their experiences and perceptions of telemedicine and teleconsultations for patients with heart failure. The stakeholders include patients with heart failure, cardiologists, health economists, and digital health experts. Through these interviews, I explore perceived costs and benefits associated with teleconsultations, approaches to the economic evaluation of telemedicine, and challenges related to both the economic evaluation practice and the wider adoption of telemedicine in healthcare. The qualitative analysis comprises a thematic analysis, identifying eight main themes and thirty subthemes, alongside a decision-oriented framework analysis that structures stakeholder perspectives according to these themes. The subsequent analytical and empirical

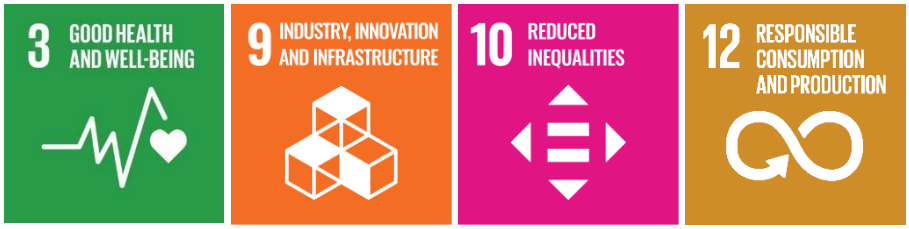
components of the dissertation build on the conceptual and methodological insights developed in the previous chapters.

In the sixth chapter, I examine the impact of teleconsultations for patients with heart failure in Slovenia during the period from 2020 to 2021. For this purpose, I use administrative data that I obtain from the Slovenian Health Insurance Institute, which include information on hospitalisations for heart failure, outpatient specialist visits, emergency department visits, prescribed pharmaceuticals, and other healthcare utilisation measures for the period 2015–2023. I employ a range of regression and time-to-event models to analyse these data. First, I estimate a logistic regression model to identify patient characteristics associated with assignment to teleconsultations. Based on the resulting propensity scores, I construct a matched cohort comprising patients assigned to teleconsultations and patients receiving in-person consultations, and I perform all subsequent analyses on this matched sample. I then apply negative binomial regression, composite Poisson–Gamma regression, Kaplan–Meier curves, and Cox proportional hazards models to assess the impact of teleconsultations on healthcare utilisation, healthcare expenditure, and mortality. To assess robustness and reduce confounding, I estimate all models in three specifications: unadjusted, adjusted for baseline covariates, and further adjusted using an autoregressive specification by including lagged outcomes from the preceding 1-year period. In the seventh chapter, I present an impact inventory matrix and an economic cost–consequence analysis that synthesise evidence that I generate across the preceding chapters and relevant prior research.

In the overall conclusion, I highlight the need for clearer methodological guidance and more standardised approaches to conducting economic evaluations of digital health interventions, as only robust evidence on both clinical effectiveness and economic viability can demonstrate the true value of digital health interventions to the healthcare system. By integrating bibliometric, qualitative, and quantitative approaches, I demonstrate how economic evaluations of digital health interventions can be methodologically strengthened and better aligned with healthcare decision-making.

KEY WORDS: economic evaluations, telemedicine, resource allocation, public healthcare

SUSTAINABLE DEVELOPMENT GOALS



POVZETEK

V tej disertaciji se osredotočam na presojo ekonomske upravičenosti digitalnih zdravstvenih intervencij, ki predstavljajo dragoceno orodje za primerjavo digitalnih zdravstvenih intervencij z običajno oskrbo, nudijo podporo pri odločanju v zdravstvu in dodeljevanju virov ter pospešujejo uvajanje in povračilo stroškov digitalnih zdravstvenih intervencij. Kljub vse pogostejšemu uvajanju digitalnih zdravstvenih intervencij v zdravstvene sisteme pa so dokazi o njihovi ekonomski upravičenosti metodološko heterogeni in kakovostno neenotni. Glede na to opravim celovito preučitev trenutne uporabe metod za ekonomsko vrednotenje digitalnih zdravstvenih intervencij ter opredelim ključne izzive in obstoječa priporočila za izboljšanje praks pri izvajanju ekonomskih vrednotenj na področju digitalnega zdravstva. Poleg tega raziščem stališča različnih deležnikov glede ekonomskih vrednotenj digitalnih zdravstvenih intervencij ter izvedem statistično analizo in ekonomsko vrednotenje konkretne telemedicinske intervencije za bolnike s srčnim popuščanjem v Sloveniji.

V prvem poglavju predstavim področje raziskave in raziskovalna vprašanja, ki jih obravnava disertacija. V drugem poglavju preučujem uporabo IKT v zdravstvenem sektorju, pri čemer se osredotočam na razvoj zdravstva, ki temelji na IKT, spremembe v terminologiji in trenutno stanje digitalizacije zdravstva v Sloveniji. V tretjem poglavju predstavim bibliometrično analizo obstoječe literature, da ocenim trenutno stanje raziskav o ekonomskih vrednotenjih digitalnih zdravstvenih intervencij; te so po obsegu še vedno omejene in kakovostno heterogene. Poglavje vključuje tudi narativni pregled literature o metodoloških izzivih pri izvajanju ekonomskih vrednotenj digitalnih zdravstvenih intervencij in povzema nedavna priporočila za izboljšanje praks na tem področju. V četrtem poglavju predstavljam srčno popuščanje kot klinično stanje, povezano s telemedicinsko intervencijo, ki jo ocenjujem v nadaljevanju disertacije. Poleg tega obravnavam sistematičen pregled obstoječih raziskav s posebnim poudarkom na ekonomskih vrednotenjih telekonzultacij za bolnike s srčnim popuščanjem, ki predstavljajo specifično telemedicinsko intervencijo. Telekonzultacije za bolnike s srčnim popuščanjem analiziram v slovenskem kontekstu v nadaljnjih poglavjih.

V petem poglavju predstavljam kvalitativno analizo intervjujev z ustreznimi deležniki o njihovih izkušnjah in dojemanju telemedicine in telekonzultacij za bolnike s srčnim popuščanjem. Med deležniki so bolniki s srčnim popuščanjem, kardiologi, zdravstveni ekonomisti in strokovnjaki za digitalno zdravje. Na podlagi intervjujev raziskujem zaznane stroške in koristi telekonzultacij, stališča do pristopov k ekonomskim vrednotenjem telemedicine ter izzive, povezane tako z ekonomskimi vrednotenji kot s širšim uvajanjem telemedicine v zdravstvo. Kvalitativna analiza vključuje tematsko analizo, ki opredeljuje osem glavnih tem in trideset podtem, ter sistematično matrično analizo za strukturiranje stališč deležnikov. Nadaljnji analitični deli disertacije temeljijo na teh konceptualnih in metodoloških spoznanjih.

V šestem poglavju preučujem vpliv telekonzultacij na bolnike s srčnim popuščanjem v Sloveniji v obdobju 2020–2021. Za ta namen uporabljam administrativne podatke, pridobljene od Zavoda za zdravstveno zavarovanje Slovenije, ki vključujejo informacije o hospitalizacijah zaradi srčnega popuščanja, ambulantnih obiskih pri specialistih, obiskih na urgenci, predpisanih zdravilih in drugih kazalnikih uporabe zdravstvenih storitev v obdobju 2015–2023. Za analizo teh podatkov uporabljam različne regresijske modele in modele preživetja. Najprej ocenim model logistične regresije, da identificiram značilnosti bolnikov, ki vplivajo na to, da so bili obravnavani s telekonzultacijo. Na podlagi dobljenih mer nagnjenosti sestavim ujemajočo se kohorto bolnikov, ki prejemajo telekonzultacije, in bolnikov, ki imajo neposredni stik z zdravstvenimi delavci v živo, ter na tej ujemajoči se vzorčni skupini opravim vse nadaljnje analize. Nato uporabim model negativne binomske regresije, model kompozitne Poissonove-Gamma regresije, Kaplan-Meierjeve krivulje in model Coxove regresije proporcionalnih tveganj, da ocenim vpliv telekonzultacij na uporabo zdravstvenih storitev, izdatke za zdravstvo in umrljivost. Za oceno robustnosti in zmanjšanje možnosti napačnih ocen povezanosti ocenim vse modele v treh specifikacijah: neprilagojene, prilagojene za osnovne kontrolne spremenljivke in dodatno prilagojene z uporabo avtoregresivne specifikacije, z vključitvijo odloženih vrednosti izidov iz preteklega leta.

V sedmem poglavju predstavljam analizo stroškov in posledic telekonzultacij za HF ter matriko vplivov ter analizo stroškov in posledic, ki združujeta dokaze iz prejšnjih poglavij in ustreznih predhodnih raziskav.

V sklepu izpostavljam potrebo po jasnejših metodoloških smernicah in bolj standardiziranih pristopih k izvajanju ekonomskih vrednotenj digitalnih zdravstvenih intervencij. Le trdni dokazi o klinični učinkovitosti in ekonomski upravičenosti lahko namreč dokažejo resnično vrednost digitalnih zdravstvenih intervencij za zdravstveni sistem. S kombiniranjem bibliometričnih, kvalitativnih in kvantitativnih pristopov pokažem, kako je mogoče ekonomska vrednotenja digitalnih zdravstvenih intervencij metodološko okrepiti in jih bolje uskladiti s procesi odločanja v zdravstvu.

KLJUČNE BESEDE: ekonomska vrednotenja, telemedicina, razporejanje virov, javno zdravstvo

CILJI TRAJNOSTNEGA RAZVOJA



TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Overview of the research area 1

1.2 Purpose of the study, research questions, methodology and data 5

1.3 Contribution of the dissertation 9

1.4 Structure of the dissertation 10

2 DIGITAL HEALTH INTERVENTIONS 11

2.1 Typology of ICT-enabled health interventions 11

2.2 Bibliometric analysis of the literature on ICT-enabled health interventions. 15

2.2.1 Data collection 15

2.2.2 Methodology 16

2.2.3 Results 16

2.2.3.1 Performance analysis 17

2.2.3.2 Analysis of keywords 18

2.2.4 Discussion and conclusions 21

2.3 Digital health interventions in Slovenia 22

2.3.1 Digitalisation of healthcare in Slovenia (2008–2022) 23

2.3.2 National strategy for the digitalisation of healthcare in Slovenia to 2027 24

2.4 Summary 25

3 ECONOMIC EVALUATION OF DIGITAL HEALTH INTERVENTIONS 26

3.1 Economic evaluation in healthcare 27

3.2 Bibliometric analysis of the literature on economic evaluation of digital health interventions 31

3.2.1 Data collection 31

3.2.2 Methodology 32

3.2.3 Results 33

3.2.3.1 Performance analysis 33

3.2.3.2 Analysis of leading countries and organisations 35

3.2.3.3 Analysis of leading journals 37

3.2.3.4 Bibliometric and content analysis of most influential individual publications *38*

3.2.3.5 Analysis of keywords *41*

3.2.4 Discussion and conclusions 42

3.3 Narrative review of methodological challenges and recommendations for the economic evaluation of digital health interventions 45

3.3.1 Challenges related to research questions, context, and intervention complexity 46

3.3.2 Methodological challenges and recommendations for economic evaluation 49

3.3.2.1 Impact inventory matrix *51*

3.3.2.2 Cost-consequence analysis *53*

3.3.3 Discussion and conclusions 55

3.4 Summary and implications 57

4 ECONOMIC EVALUATION OF TELEMEDICINE INTERVENTIONS FOR HEART FAILURE PATIENTS: A SYSTEMATIC REVIEW 60

4.1 Clinical background and management of heart failure 60

4.2 Systematic literature review of economic evaluations of telemedicine interventions including teleconsultations for heart failure patients 63

4.2.1 Data collection 64

4.2.2 Methodology 65

4.2.3 Results 67

4.2.4 Discussion and conclusions 71

4.3 Summary and implications 72

5 FRAMEWORK ANALYSIS OF STAKEHOLDER PERCEPTIONS OF ECONOMIC EVALUATION OF TELEMEDICINE INTERVENTIONS FOR HEART FAILURE PATIENTS 74

5.1 The role of qualitative research in informing economic evaluation 75

5.2 Study design 77

5.3 Data collection 78

5.4 Methodology 80

5.5 Results 81

5.5.1 Health-related clinical outcomes 82

5.5.2 Healthcare utilisation outcomes 85
5.5.3 Patient-centred outcomes and behaviours 88
5.5.4 Societal and equity outcomes 91
5.5.5 Organisational and technical outcomes 93
5.5.6 Economic and financial costs 95
5.5.7 Methodological aspects in economic evaluation 98
5.5.8 Challenges and risks 101
5.6 Discussion and conclusions 104
5.7 Summary and implications 107
6 ASSESSMENT OF THE EFFECTS OF TELECONSULTATIONS FOR HEART FAILURE PATIENTS IN SLOVENIA USING ADMINISTRATIVE DATA .. 110
6.1 Study design 112
6.2 Data collection 114
6.3 Methodology 118
6.3.1 Descriptive statistics and model specification 120
6.3.2 Generalised linear models 122
6.3.3 Logistic regression for binary outcomes 123
6.3.4 Propensity score matching and matched cohort construction 125
6.3.5 Negative binomial regression for count outcomes 128
6.3.6 Compound Poisson–Gamma regression for semi-continuous data 130
6.3.7 Logistic regression and time-to-event models for mortality analysis 132
6.4 Results 134
6.4.1 Descriptive statistics 135
6.4.2 Determinants of assignment to teleconsultations 136
6.4.3 Effects of teleconsultations on healthcare utilisation 138
6.4.4 Effects of teleconsultations on healthcare expenditure 141
6.4.5 Association between teleconsultation assignment and mortality 143
6.5 Discussion and conclusions 145
6.6 Summary and implications 149
7 COST-CONSEQUENCE ANALYSIS OF TELECONSULTATIONS FOR HEART FAILURE PATIENTS IN SLOVENIA 152

7.1 Study design 153

7.2 Data collection 153

7.3 Methodology 154

7.4 Results 155

7.4.1 Impact inventory matrix 156

7.4.2 Cost-consequence analysis 157

7.5 Discussion and conclusions 164

7.6 Summary and implications 166

8 CONCLUSIONS 169

REFERENCE LIST 177

APPENDICES 201

LIST OF TABLES

Table 1: Most frequently occurring keywords related to information and communication technology-enabled healthcare 21
Table 2: Key components of economic evaluations 30
Table 3: Performance indicators of publications on the economic evaluation of digital health interventions (2005–August 2023) 34
Table 4: Most productive countries 35
Table 5: Most cited organisations 36
Table 6: Most productive journals 37
Table 7: Most cited individual scientific publications 39
Table 8: Most occurring author keywords 41
Table 9: Contextual components of digital health interventions 47
Table 10: Description of impact inventory matrix components 52
Table 11: Characteristics of the included economic evaluation studies 68
Table 12: Characteristics of the included economic evaluations 68
Table 13: Cost categories considered in the included economic evaluations 69
Table 14: Summary of health-related effectiveness and economic outcomes in the included economic evaluation studies 69
Table 15: Health-related clinical outcomes theme with interview extracts 84
Table 16: Healthcare utilisation outcomes theme with interview extracts 86
Table 17: Patient-centred outcomes and behaviours theme with interview extracts 89
Table 18: Societal and equity outcomes theme with interview extracts 92

Table 19: Organisational and technical outcomes theme with interview extracts 95
Table 20: Economic and financial costs theme with interview extracts 96
Table 21: Methodological aspects in economic evaluation theme with interview extracts 99
Table 22: Challenges and risks theme with interview extracts 102
Table 23: Covariate balance before and after propensity score matching 128
Table 24: Results of logistic regression for the probability of teleconsultation assignment 137
Table 25: Results of negative binomial regression for count outcomes 139
Table 26: Results of zero-inflated negative binomial regression for count outcomes 140
Table 27: Results of compound Poisson–Gamma regression for expenditure data.....142
Table 28: Results of conditional logistic regression for mortality 143
Table 29: Results of Kaplan–Meier survival analysis at 365 days 144
Table 30: Results of stratified Cox proportional hazards regression 145
Table 31: Impact inventory matrix for teleconsultations for heart failure patients in Slovenia 158
Table 32: Cost-consequence analysis of teleconsultations for heart failure patients in Slovenia.....162

LIST OF FIGURES

Figure 1: Conceptual relationship between key terms used to describe information and communication technology-enabled healthcare……..14
Figure 2: Number of publications referring to different information and communication technology-enabled healthcare terms 17
Figure 3: Bibliometric network of keyword co-occurrence in telemedicine publications..19
Figure 4: Bibliometric network of keyword co-occurrence in telehealth publications.....19
Figure 5: Bibliometric network of keyword co-occurrence in eHealth publications.....20
Figure 6: Bibliometric network of keyword co-occurrence in digital health publications .20
Figure 7: Annual number of publications and citations on the economic evaluation of digital health interventions (2005–August 2023).....34
Figure 8: Clustered network of countries based on co-authorship analysis.....36
Figure 9: Clustered network of organisations based on co-authorship analysis 37
Figure 10: Trends in publishing journals based on bibliographic coupling analysis.....38
Figure 11: Clustered network of publications based on bibliographic coupling analysis...40
Figure 12: Clustered network of keywords based on keyword co-occurrence analysis 42
Figure 13: Preferred reporting items for systematic reviews and meta-analyses 2020 flow diagram of study selection for the systematic review 66
Figure 14: Overall study observation period.....112
Figure 15: Teleconsultations frequency over time.....117
Figure 16: Flow diagram of patient selection and cohort construction.....118

LIST OF APPENDICES

Appendix 1: Daljši povzetek (Extended summary in Slovene language) 1
Appendix 2: Supplementary overview of digital health projects in Slovenia (2022–2027) 11
Appendix 3: Classification of cardiovascular and non-cardiovascular comorbidities in heart failure 12
Appendix 4: Overview of analytical variables 13
Appendix 5: Qualitative study materials 14
Appendix 6: Supplementary tables 20
Appendix 7: Supplementary figures 29
Appendix 8: Data management plan 30

LIST OF ABBREVIATIONS

ACE – Angiotensin-converting enzyme

AIC – Akaike information criterion

ARNI – Angiotensin receptor-neprilysin

ASReview – Active learning for systematic reviews

ATC – Anatomical Therapeutic Chemical

AUC – Area under the receiver operating characteristic curve

BIC – Bayesian information criterion

CBA – Cost-benefit analysis

CCA – Cost-consequence analysis

CEA – Cost-effectiveness analysis

CI – Confidence interval

COPD – Chronic obstructive pulmonary disease

CUA – Cost-utility analysis

DALY – Disability-adjusted life years

DHI – Digital health interventions

ED – Emergency department

EE – Economic evaluation

EHDS – European Health Data Space

EPV – Events per variable

EU – European Union

GDP – Gross domestic product

GDPR – General Data Protection Regulation

GLM – Generalised linear models

HF – Heart failure

HIIS – Health Insurance Institute of Slovenia

HR – Hazard ratio

HTA – Health technology assessment

ICD – International statistical classification of diseases and related health problems

ICER – Incremental cost-effectiveness ratio

ICT – Information and communication technologies

ID – Identification number

IIM – Impact inventory matrix

IRR – Incidence rate ratio

ISPOR – International Society for Pharmacoeconomics and Outcomes Research

MRA – Mineralocorticoid receptor antagonists

NICE – National Institute for Health and Care Excellence

NN – Nearest neighbour

OLS – Ordinary least squares

OR – Odds ratio

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PSM – Propensity score matching

QALY – Quality-adjusted life years

QOL – Quality of life

RCT – Randomised controlled trial

SE – Standard error

SGLT2 – Sodium-glucose co-transporter 2

SMD – Standardised mean differences

UK – United Kingdom

USA – United States of America

VIF – Variance inflation factor

WHO – World Health Organisation

WoS CC – Web of Science Core Collection

1 INTRODUCTION

In this dissertation, I focus on economic evaluations (hereinafter EE) of digital health interventions (hereinafter DHI). EE represents a key analytical tool for comparing DHI with usual care and for supporting healthcare decision-making, resource allocation, and adoption and reimbursement decisions. However, the application of EE to DHI remains methodologically challenging due to the complexity of DHI, their contextual dependence, and the rapid pace of technological change. To address these challenges, I adopt a mixed-methods research design that integrates evidence from the literature, stakeholder perspectives, and administrative healthcare data. The empirical focus of the dissertation is a specific DHI, namely teleconsultations for patients with heart failure (hereinafter HF), and the analysis culminates in an EE of teleconsultations for patients with HF.

At the same time, this dissertation acknowledges that evaluating DHI, particularly those introduced during the COVID-19 pandemic, entails unavoidable methodological and contextual limitations. Teleconsultations are embedded in evolving care pathways and organisational practices, making it difficult to fully disentangle their effects from broader system-level changes. Accordingly, I adopt a pragmatic, policy-oriented perspective that aims to generate contextually relevant evidence to inform real-world healthcare decision-making. I argue that a central challenge in the EE of DHI is not the absence of methods, but the misalignment between traditional evaluative frameworks and the contextual, organisational, and multi-stakeholder nature of DHI. Rather than proposing a single methodological solution, I examine how existing approaches can be adapted, combined, and interpreted to better support real-world healthcare decision-making.

In Subchapter 1.1, I provide an overview of the research area. In Subchapter 1.2, I present the purpose of the study, research questions, methodology, and data. In Subchapter 1.3, I discuss the dissertation's contributions. In Subchapter 1.4, I outline the structure of the dissertation.

1.1 Overview of the research area

In the pre-modern, pre-digitalised world, life expectancy was well below 40 years. Improvements in living conditions, housing and sanitation, education and nutrition, and advances in medicine through the introduction of vaccines and antibiotics have all contributed to longer lives. In 2021, the average life expectancy at birth was 80.3 years (OECD, 2022), and in 2018, for the first time in history, the number of people over the age of 64 exceeded the number of children under the age of five (H. Ritchie & Roser, 2019). As a result of the growing world population and longer life expectancy, healthcare costs are steadily increasing worldwide and are forecast to continue to rise (OECD, 2021, 2022). From 2013 to 2019, healthcare costs in OECD countries amounted to around 8.8% of gross domestic product (hereinafter GDP). In 2021, the global health crisis caused by the COVID-

19 pandemic led to a sharp increase in healthcare costs to around 9.7% of GDP (OECD, 2022). In 2022, this figure fell to 9.2%, and in 2023, the share of GDP was expected to be between 9% and 10%, still above the pre-pandemic level (OECD, 2024).

Despite the increase in healthcare spending, healthcare systems around the world are facing a variety of problems, and solutions are constantly being sought to transform overburdened healthcare systems and mitigate serious health risks. During the global health crisis triggered by the COVID-19 pandemic, various weaknesses in the healthcare system became particularly apparent. The severe restriction of in-person contact during the COVID-19 pandemic highlighted the crucial role of information and communication technologies (hereinafter ICT) and accelerated their adoption, as remotely accessible healthcare became urgently necessary (Busso et al., 2022; Greiwe, 2022; Monaghesh & Hajizadeh, 2020). The pandemic enabled the rapid and, in some cases, mandatory adoption of certain forms of ICT, thereby partially alleviating barriers related to implementation costs and training requirements, previously identified as major obstacles. In addition, the widespread adoption of ICT services created opportunities to conduct more research and study the actual impact of ICT on health on a larger scale. The rapid diffusion of ICT and the partial substitution of traditional healthcare delivery models acted as a catalyst for broader transformation within healthcare systems.

Growing research on the use of ICT to augment traditional healthcare suggests that this approach is promising and has the potential to reshape healthcare delivery models to achieve greater health gains with limited resources. The World Health Organisation (hereinafter WHO) now considers the use of ICT in healthcare to be essential for the advancement of healthcare, as its use offers opportunities for progress in various clinical, behavioural, technical, and organisational values (Kolasa & Kozinski, 2020; WHO, 2021b). ICT can also address challenges related to the financial sustainability of healthcare systems. Improved disease management and treatment monitoring can lead to better clinical outcomes, including more accurate diagnosis and more effective treatment. Improved health outcomes and quality of care may result in fewer hospital admissions and shorter lengths of stay. Remote care reduces healthcare costs for patients through lower travelling costs, better follow-up, and availability in rural areas or among patients with limited mobility, and improves access to healthcare and patient equity. ICT can also be used to promote health and well-being, raise awareness of health-related issues, and facilitate health education. Greater efficiency and sustainability of the health system can be achieved through the use of various ICT for system integration, better communication between healthcare organisations, and better access to healthcare data. ICT can alleviate the increasing shortage of healthcare staff by contributing to better time management, such as reducing time lost due to missing appointments and improving work planning, thus reducing productivity losses. ICT also enables distance learning, meetings, supervision and presentations among clinicians, as well as online information and health data management (Busso et al., 2022; Greiwe, 2022; Huter et al., 2022; Kovačić et al., 2022; Monaghesh & Hajizadeh, 2020). The

impact of ICT therefore also extends to different needs of healthcare providers and users, different health conditions, different environments, and specific patient groups.

However, the integration of ICT into the healthcare system also faces challenges such as the complexity of implementation and training needs, the digital divide that excludes less tech-savvy patients, and barriers to integration into existing healthcare systems. Other concerns include hidden operational costs, equity and privacy risks, and difficulties in fully capturing the clinical and societal value of DHI in assessments.

Due to the diverse use of ICT in healthcare, there is also a wide range of terminology in the literature relating to the integration of ICT and healthcare. The terms telemedicine and telehealth refer to the delivery of healthcare services remotely, with telemedicine usually defined as including only clinical services (e.g., teleconsultations, telemonitoring, telerehabilitation), whereas telehealth includes non-clinical services (e.g., meetings, education). eHealth refers to the use of ICT both on site and remotely, and mHealth refers to the use of mobile technologies in healthcare. More recently, the term digital health has been seen as a broad umbrella term for the variety of ICT uses in healthcare (WHO, 2021b) and is considered a term that also encompasses other ICT uses and interventions in healthcare, which are summarised under terms such as telemedicine, telehealth, eHealth, and mHealth. Therefore, I use the term DHI in this dissertation when referring to various ICT applications in healthcare.

DHI can be seen as a complement to traditional in-person healthcare, referred to as usual care, but also as a substitute for usual care where appropriate. For this reason, DHI have the potential to be reimbursed and publicly funded from healthcare budgets. Reducing and controlling healthcare costs therefore represent a strong motivator for the introduction and funding of DHI. In order to provide evidence for public funding and reimbursement decisions, the economic burden of alternative interventions compared to usual care interventions must be determined, for which EE are used. EE play a central role in demonstrating the cost-effectiveness of DHI and are used to assess the costs and benefits with the aim of ensuring that the overall benefits of adopting digital health in healthcare are maximised (Benedetto et al., 2023; Gomes et al., 2022; Wilkinson et al., 2023). EE provides a valuable toolkit that can be used to compare DHI with usual care interventions and inform decision-making, including resource allocation decisions (e.g., Walker et al., 2019) and facilitates further adoption and reimbursement of digital health. However, the number of publications on EE of DHI remains very low, despite the fact that the further development and utilisation of DHI are highly dependent on public funding, which depends on evidence of economic efficiency and effectiveness.

Advancing EE of DHI is therefore crucial for strengthening evidence-based resource allocation within public healthcare systems. Existing research on the economic justifiability of DHI has often been criticised for inconclusive economic evidence, poor quality, substantial heterogeneity, and lack of generalisability (e.g., Eze et al., 2020; Hwang et al.,

2019; Snoswell, Taylor, et al., 2020). A number of evidence syntheses on EE of DHI, for various diseases and interventions, highlight the lack of economic evidence (Huter et al., 2022; Jankovic et al., 2021; Naoum et al., 2021; Valenzuela Espinoza et al., 2019). DHI tend to be complex interventions that evolve over time, involve multiple stakeholders such as patients, carers, and health professionals, are technologically diverse, are used in various contexts and for different health conditions, and may generate a variety of outcomes and spillover effects that are not necessarily health-related and that depend not only on the intervention itself but also on its users (Husereau et al., 2014; Petticrew et al., 2013). As such, they pose a particular challenge for EE, and special care is required when evaluating digital health, e.g., in the choice of comparator, the choice of perspective, the choice and assessment of costs and benefits, the selection of appropriate data sources (e.g., clinical trial data, administrative data) and also the choice of methodology (Benedetto et al., 2023; Bergmo, 2015; Gomes et al., 2022; Husereau et al., 2014; Jankovic et al., 2021; McNamee et al., 2016; Snoswell et al., 2017; Walker et al., 2019; Wilkinson et al., 2023). The commonly used methods for EE of healthcare interventions typically adopt a payer perspective and focus on health-related outcomes, such as quality of life (hereinafter QOL) in cost-utility analysis (hereinafter CUA) or clinical outcomes in cost-effectiveness analysis (hereinafter CEA; Drummond et al., 2005). However, considering only health-related outcomes and adopting a payer perspective cannot adequately capture the broad range of effects of DHI and provide sound economic evidence for decision-making (Benedetto et al., 2023; Bergmo, 2015; Gomes et al., 2022; Kolasa & Kozinski, 2020; Snoswell et al., 2017).

In view of the fact that many of the identified challenges for EE have not yet been resolved, there is still a lack of clear and comprehensive guidelines for EE of DHI (Gomes et al., 2022; Wilkinson et al., 2024). The few existing guidelines for evaluating DHI remain mostly general and do not provide a detailed analytical framework for estimating economic outcomes (Kolasa & Kozinski, 2020; Wilkinson et al., 2024). Cost-benefit analysis (hereinafter CBA) is often suggested together with cost-consequence analysis (hereinafter CCA) for evaluating DHI as they allow easier inclusion of diverse costs and benefits from the societal perspective and are also easily understood by decision-makers (Benedetto et al., 2023; Dobrev et al., 2008; Gomes et al., 2022; Snoswell et al., 2017). The CCA is also frequently performed when using administrative data in health EE (e.g., Gansen, 2018; Lemmon et al., 2021), which is relevant for DHI, for which not all relevant economic outcomes are often systematically collected in advance. Given the recent proliferation of DHI, particularly telemedicine, due to the COVID-19 pandemic and increasing pressures on the financial stability of public healthcare systems, improved EE of telemedicine and other DHI will play a critical role in demonstrating their economic viability and facilitate their wider adoption and use (Gomes et al., 2022). Only sound clinical and economic evidence can adequately inform resource allocation decisions and thus promote the adoption of DHI. For this reason, EE of telemedicine and other DHI is recognised as a rapidly emerging area of health economics.

1.2 Purpose of the study, research questions, methodology and data

The purpose of this doctoral dissertation is to critically review and assess existing EE of DHI, with a focus on telemedicine; to systematise key challenges and methodological recommendations; and to apply these insights to advance the EE of telemedicine and to an empirical case of teleconsultations for HF in Slovenia. To achieve this purpose, I pursue three objectives. First, I develop methodologically grounded recommendations for EE of DHI based on a critical appraisal of existing studies and the literature. Second, I conduct a qualitative analysis of stakeholders' perceptions of relevant costs, benefits, and key challenges associated with telemedicine interventions and DHI in general. Third, I conduct a statistical analysis and an EE of a specific telemedicine intervention, namely teleconsultations for patients with HF in Slovenia. Together, these objectives aim to strengthen evidence-based resource allocation within Slovenia's public healthcare system.

To operationalise these objectives, I formulate four research questions that structure the dissertation and guide the choice of methods and data. The first research question addressed is:

RQ1: *"What is the current state of research related to EE of DHI and, more specifically, telemedicine, globally and in Slovenia?"*

A review of existing research on the EE of telemedicine and other DHI provides the knowledge base for subsequent analyses. I quantitatively examine relevant publications related to EE of DHI using bibliometric methods, the usefulness of which several authors have acknowledged by several authors for mapping rapidly expanding research fields such as digital health (de las Heras-Pedrosa et al., 2022; dos Santos Silva et al., 2021; Sikandar et al., 2021; Uribe-Toril et al., 2021; Waqas et al., 2020; Zwack et al., 2024). Dos Santos Silva et al. (2021) identified limited cost-effectiveness evidence for newer interventions such as telemedicine, and Zwack et al. (2024) noted that EE of DHI has not yet emerged as a trending research area. Building on this work, I conduct a comprehensive bibliometric analysis using multiple analytical tools to examine publications on EE of DHI in greater depth.

I extract bibliographic data on publications from the Web of Science Core Collection (hereinafter WoS CC), which is widely used in bibliometric research and considered a reference database due to its coverage and data quality (Pranckutė, 2021; Visser et al., 2021). I examine (1) the share of research contributions addressing the economic justification of DHI within the broader digital health literature and their evolution over time; (2) the extent to which the COVID-19 pandemic stimulated research interest in EE of DHI; (3) the types of DHI evaluated, with particular attention to telemedicine interventions; (4) the main bibliometric characteristics of existing studies; and (5) the key economic and methodological issues addressed. This analysis allows me to assess whether the literature primarily highlights the lack of robust economic evidence or provides actionable

recommendations for overcoming key challenges in EE of DHI. The bibliometric analysis I conduct at the global level is complemented by a narrative literature review I provide of research on DHI in Slovenia, given that telemedicine and eHealth interventions expanded particularly during the COVID-19 pandemic.

The second research question addressed is:

RQ2: *"What are the key challenges in conducting EE of telemedicine interventions? Are they adequately addressed by existing, albeit scarce, guidelines for their EE?"*

As discussed in the overview of the research area, existing research identifies multiple substantive and methodological challenges in conducting EE of DHI (Bergmo, 2015; Gomes et al., 2022; Husereau et al., 2014; Jankovic et al., 2021; Kolasa & Kozinski, 2020; McNamee et al., 2016; Michie et al., 2017; Snoswell et al., 2017). The persistence of unresolved issues related to methodological choice, analytical perspective, and outcome measurement is reflected in the continued absence of comprehensive and tailored guidelines for EE of DHI (e.g., Ekeland et al., 2010; Gomes et al., 2022; Hall et al., 2015; Michie et al., 2017). Although several organisations have recently developed or updated frameworks with more explicit relevance to EE of DHI (e.g., NICE, 2022; Wilkinson et al., 2024), these remain general and do not provide sufficiently detailed guidance for empirical evaluation. Existing EE guidelines are largely designed for pharmaceuticals and medical devices, typically treating CUA as the reference standard and adopting a payer perspective (Sharma et al., 2021). A review of existing evaluation frameworks identifies eleven guidelines relevant to DHI; however, none provides a detailed analytical framework for estimating economic outcomes (Kolasa & Kozinski, 2020). Of these, three focus on telemedicine, four on mHealth, and four are generic. The latter group includes guidelines issued by the National Institute for Health and Care Excellence (hereinafter NICE), which recommend budget impact analysis, CUA, and CCA depending on the intended purpose of the intervention (NICE, 2018).

To systematise and critically appraise these challenges, I conduct a narrative literature review. In addition, I perform a qualitative analysis of stakeholder interviews to capture perceptions of relevant costs, benefits, and challenges. Qualitative research has proven useful for identifying underlying methodological and practical barriers to the use of EE in healthcare decision-making, illuminating processes shaping economic evidence, and eliciting stakeholder perspectives on relevant economic outcomes (Barnett et al., 2020; Dopp et al., 2019; Grove et al., 2019; van Dongen et al., 2013). The use of qualitative evidence is also emphasised in NICE guidance for evaluating DHI (NICE, 2018). Moreover, qualitative approaches are increasingly recommended to capture the complexity of telemedicine interventions (Caffery et al., 2017; Skivington et al., 2021), despite their relatively limited uptake in health economics (Coast & De Allegri, 2018; Dopp et al., 2019; Merlo et al., 2019).

My qualitative analysis also informs the third research question:

RQ3: *"How should EE of telemedicine interventions be approached in the case of chronic HF?"*

Telemedicine interventions are particularly relevant for chronic conditions, where ongoing healthcare utilisation generates substantial direct and indirect costs, including productivity losses (e.g., Akiyama & Yoo, 2016; Forouzanfar et al., 2016; Von Huben et al., 2021). Nevertheless, the evidence base on EE of telemedicine for chronic diseases remains limited (Ben-Assuli, 2022; Boodoo et al., 2020; Caillon et al., 2022; De Guzman et al., 2022; Frederix et al., 2019). Existing studies differ markedly in intervention type, evaluation method, time horizon, observed data, and cost components. Costs typically include equipment, implementation and operating expenses, training, and staff time, while benefits include improved clinical outcomes, QOL, reduced mortality, and lower healthcare utilisation, such as fewer emergency department (hereinafter ED) visits and hospitalisations (De Guzman et al., 2022; Eze et al., 2020; Klersy et al., 2011; Snoswell, North, et al., 2020; Taylor et al., 2021).

Although telemedicine interventions for chronic conditions such as HF have been implemented in Slovenia (Rudel et al., 2017), their uptake remains limited despite evidence of benefits, including reduced waiting times and hospitalisations (Rant, 2021). Barriers include funding constraints, outdated infrastructure, institutional rigidity, concerns regarding equity and data security, and the absence of standardised evaluation frameworks (Rant, 2021; Stanimirovic, 2015, 2021; Varnai et al., 2019; WHO, 2021a). The COVID-19 pandemic accelerated the deployment of DHI in Slovenia, particularly teleconsultations and telemonitoring, some of which were funded by the Health Insurance Institute of Slovenia (hereinafter HIIS) in 2020 and 2021 (Rant & Rudel, 2021). Future funding, however, remains contingent on robust economic justification.

Using a machine learning–assisted screening tool (van de Schoot et al., 2021), I conduct a systematic literature review of EE research of teleconsultations for patients with HF to identify the methodological characteristics of existing studies. I combine recommendations derived from the literature with insights from stakeholders to inform a context-sensitive evaluation framework. I also use the qualitative findings to inform the subsequent EE model with contextual information relevant for healthcare decision-making (Caffery et al., 2017; Coast & De Allegri, 2018; McGill et al., 2021; Skivington et al., 2021). I obtain qualitative data through semi-structured interviews with purposively selected stakeholders (Palinkas et al., 2015), including patients, cardiologists, representatives of healthcare organisations and digital health experts, and health economists. I prepare the interview guide in advance, including a list of key questions and prompts that I identify as important based on the literature on the key characteristics and challenges of EE of telemedicine interventions. I conduct interviews via videoconference when in-person meetings are not feasible, as this method has been shown to be effective in health research given the workload and

professional commitments of participants, thereby contributing to higher uptake and response rates (e.g., Archibald et al., 2019). I record, transcribe, and analyse the interviews using framework analysis, a structured form of thematic analysis that is suitable for describing and interpreting specific processes and for addressing predefined research questions (Coast & De Allegri, 2018; Gale et al., 2013; Murray et al., 2019; J. Ritchie & Spencer, 1994).

This research question therefore sits at the intersection of methodological guidance, empirical evidence, and contextual constraints specific to chronic HF care. The fourth research question addressed in the dissertation is:

RQ4: *"Is a telemedicine intervention in the form of teleconsultations for chronic HF in Slovenia economically viable?"*

To address this question, I conduct a statistical analysis and EE of teleconsultations for HF using administrative claims data that I obtained from the HIIS (contract no. 1721-13/2021-DI/1, Annex 1) and approval from the National Medical Ethics Committee (no. 0120-223/2021/4, Annex 1). I inform the data analysis using stakeholder inputs from the qualitative study, as well as methodological recommendations and evidence from comparable interventions in similar settings, as synthesised in earlier chapters. The administrative data provided by the HIIS constitute population-level data covering patients with cardiovascular diseases in the period 2015–2022 and include demographic information, healthcare utilisation, expenditures, and selected outcome indicators, such as hospital readmissions and mortality. Administrative data, often referred to as "real-world data", are increasingly used in health economics as systematically collected data on encounters within the healthcare system, allowing for a more comprehensive capture of costs and service utilisation than is typically available in clinical trial data (Gansen, 2018; Hanna et al., 2019; Hazra et al., 2019; Lemmon et al., 2021; Pongiglione & Torbica, 2022). However, the majority of administrative datasets include only direct costs from the payer perspective and information on healthcare utilisation, while lacking detailed clinical indicators that are usually contained in medical records.

Teleconsultation data are available for the COVID-19 pandemic period, from 2020 to 2022. I use the unique patient ID to identify patients assigned to teleconsultations and to merge datasets. I use propensity score matching (hereinafter PSM), a method commonly applied in health research using administrative data (e.g., Gansen, 2018), to construct a comparable control group of patients receiving usual care (in-person consultations) based on observed patient characteristics (e.g., Cheng et al., 2019; Pongiglione & Torbica, 2022). Given that administrative data do not include detailed clinical severity indicators, I approximate disease severity using prior utilisation patterns and readmissions. I compare healthcare utilisation and outcomes between the treatment group (teleconsultation) and the control group (in-person consultation) using appropriate statistical tests, regression models, and survival analysis, following comparable studies using administrative data (e.g., Chu et al., 2022;

Howe et al., 2022; Jit & Cook, 2024; Severino et al., 2022; Tan et al., 2019; Tsang et al., 2021). Across all empirical components, I interpret the analysis with caution in light of data limitations, including residual confounding, sample size constraints, and pandemic-specific time effects, which are explicitly discussed as part of the dissertation's limitations and directions for future research (e.g., Jit & Cook, 2024).

Given the available data, the selection of CCA from the payer perspective reflects both data availability and the need for a pragmatic evaluation framework capable of capturing multiple outcomes (e.g., Gansen, 2018; Lemmon et al., 2021). I discuss data requirements for extending the analysis towards a broader societal perspective, together with limitations related to currently unavailable data. These methodological choices reflect real-world health technology assessment (hereinafter HTA) constraints and are integral to the contribution of the dissertation. Based on these findings, I propose appropriate approaches to the evaluation of teleconsultations, clearly identifying the relevant data that need to be collected alongside telemedicine implementation to enable both improved ex-ante and in medias res EE and to continuously enhance healthcare delivery.

I address each research question in dedicated chapters, ensuring a coherent progression from conceptual analysis (RQ1) through methodological development (RQ2 and RQ3) to applied empirical analysis and EE (RQ4).

1.3 Contribution of the dissertation

I make three interrelated contributions to the field of health economics and digital health. First, I contribute at the descriptive and mapping level by systematically identifying the share of publications related to EE of DHI, examining the impact of the COVID-19 pandemic on publication growth, and analysing key bibliometric indicators such as the most influential journals, publications, and keywords. I provide a structured empirical overview of the scope, evolution, and intellectual structure of research on EE of DHI.

Second, I make a methodological contribution by providing a structured synthesis of evidence on the challenges of conducting EE of DHI as identified in the literature and critically assessing how these challenges are addressed in existing evaluation guidelines. By synthesising fragmented evidence and comparing it with current guidance, I advance understanding of persistent methodological gaps in the EE of DHI, with a particular focus on telemedicine interventions.

Third, I provide an empirical and integrative contribution by advancing the EE of telemedicine interventions through a combined qualitative and quantitative approach. Specifically, I evaluate the economic viability of teleconsultations for patients with HF in Slovenia using population-level administrative data, thereby generating context-specific evidence directly relevant for healthcare decision-making. At the same time, I systematically incorporate stakeholder perspectives into the EE framework, demonstrating

how qualitative insights can complement quantitative analyses when assessing complex DHI.

I provide a comprehensive and methodologically robust study that strengthens the methodological rigour and policy relevance of EE of telemedicine and other DHI by integrating bibliometric analysis, a narrative review of methodological challenges in EE of DHI, and a systematic, context-specific review of teleconsultations for HF, together with qualitative stakeholder analysis, a statistical analysis, and an EE of a specific telemedicine intervention. By combining general methodological insights with HF-specific and context-specific evidence, I contribute to a more nuanced understanding of how EE of complex DHI can be designed, interpreted, and applied in real-world healthcare settings.

In addition, by proposing practical recommendations for future data collection and analysis, I support the development of more robust evidence bases for EE and contribute to building capacity for evidence-based resource allocation in Slovenia's public healthcare system. By emphasising CCA and the Impact Inventory Matrix (hereinafter IIM) as transparent and flexible EE tools, I position these approaches as particularly suitable for real-world HTA and reimbursement deliberations, including settings characterised by data constraints and competing policy priorities. I situate these approaches within a rapidly evolving European policy context, including ongoing initiatives related to European Union (hereinafter EU) level HTA and digital health governance, which further reinforces the relevance of transparent and adaptable EE approaches, while remaining beyond the empirical scope of the present analysis. Accordingly, I make both theoretical and practical contributions, and I help bridge the gap between EE research and real-world healthcare decision-making.

1.4 Structure of the dissertation

The dissertation consists of eight chapters. Chapter 1 introduces the research area, outlines the purpose of the study, presents the research questions, and describes the overall structure of the dissertation. In Chapter 2, I give an overview of the broader research area of DHI, including key terminology and its use based on bibliometric analysis, and provide a description of DHI available in Slovenia. In Chapter 3, I provide an overview of EE in healthcare and conduct a bibliometric analysis of the existing literature to assess the current state of research on EE of DHI. Furthermore, I examine the methodological challenges faced in the EE of DHI and review recent methodological proposals and guidelines aimed at addressing these challenges. In Chapter 4, I introduce HF as the clinical condition of interest, given its relevance for teleconsultations in Slovenia. I present a narrative overview of telemedicine research and conduct a systematic literature review focusing specifically on teleconsultations for patients with HF. In Chapter 5, I present a qualitative analysis of interviews that I conducted with relevant stakeholders involved in DHI, with a particular focus on teleconsultations for patients with HF. In Chapter 6, I present the empirical analysis, conducting several statistical analyses using administrative data on

teleconsultations for patients with HF implemented during the COVID-19 pandemic in Slovenia. In Chapter 7, I conduct a IIM and CCA of teleconsultations for HF, synthesising evidence from the preceding chapters. In Chapter 8, I summarise the main findings, discuss their implications, address limitations, and present the overall conclusions of the dissertation.

2 DIGITAL HEALTH INTERVENTIONS

In this chapter, I examine DHI as the conceptual and empirical foundation for the subsequent economic analysis. Given the rapid expansion of ICT in healthcare, a clear understanding of how DHI are defined, categorised, and studied is essential for interpreting evidence on their effectiveness, costs, and overall value. In particular, inconsistent terminology and heterogeneous conceptualisations of ICT-enabled healthcare complicate the accumulation and comparison of evidence, including EE.

Accordingly, I provide the broader research context within which I examine the state of EE of DHI in later chapters, thereby laying the groundwork for addressing RQ1. In particular, this chapter serves three related purposes. First, it clarifies the evolution of ICT use in healthcare and the main terminological frameworks used to describe DHI. Second, it empirically maps the development of research on ICT-enabled healthcare to illustrate how different terms are associated with distinct research themes and trajectories. Third, it situates DHI within the Slovenian healthcare system, highlighting institutional, organisational, and data-related features that are directly relevant for later analysis and that inform subsequent analytical choices and interpretations.

In Subchapter 2.1, I provide a concise overview of the historical development of ICT use in healthcare and the progress enabled by these technologies. I then present a typology of ICT-enabled health interventions and outline the evolution of definitions and terminology in this field. In Subchapter 2.2, I employ a bibliometric analysis to illustrate patterns of research activity in this field, with particular attention to developments following the COVID-19 pandemic. By analysing the co-occurrence of keywords, I identify dominant research themes associated with different terminological frameworks, illustrating the evolution of this research area and the development of ICT-enabled healthcare. Finally, in Subchapter 2.3, I provide a brief introduction to the Slovenian healthcare system and outline the current position of DHI within the Slovenian context, focusing on digitalisation efforts, governance structures, and data infrastructure relevant for evaluation and policy decision-making.

2.1 Typology of ICT-enabled health interventions

The development of ICT has ensured that communication and information transmission are now faster, more accessible, and less constrained by geographical distance. Technologies and devices originally designed for voice communication now transmit video, images, data,

and software, and are used across most sectors. ICT is increasingly emphasised as a facilitator of global connectivity, with potential to bridge the digital divide, accelerate progress, and advance knowledge. As data transmission infrastructure has improved, ICT use in healthcare has become more widespread. According to the Global Digital Health Strategy for 2020–2025, ICT use in healthcare is considered essential for expanding access to healthcare and improving QOL (WHO, 2021b).

Overall, ICT use in healthcare has a longer history than is often assumed. Early applications were associated with telephone- and television-based communication. In the early twentieth century, heart rhythms were transmitted by telephone, and radio consultations were carried out in the 1920s. In the 1940s, medical records containing radiological images were electronically transmitted (Bashshur & Shannon, 2009). Contemporary ICT in healthcare extends beyond communication, encompassing data storage and exchange, smart medical devices, and advanced computational tools, including artificial intelligence, aimed at improving health outcomes at scale.

As technology has advanced and ICT use in healthcare has expanded, multiple terms have emerged to describe these applications[1]. Historically, the predominant term was telemedicine; however, in more recent literature, including that of the WHO, digital health has become increasingly prominent. Other commonly used terms include telehealth, eHealth, and mHealth (Burrell et al., 2022; Srok & Došenović Bonča, 2024, 2022). Persistent confusion surrounding these terms reflects the absence of universally accepted definitions. Definitions vary across policy documents, industry usage, scientific research, and healthcare practice, resulting in terminological inconsistency. While this diversity contributes to fragmentation and complicates implementation and evaluation, it also reflects the dynamic and evolving nature of ICT-enabled healthcare.

Telemedicine was the earliest term used to describe ICT applications in healthcare. It was first coined in the 1960s to describe the use of the telephone for medical purposes (Bird et al., 1969). The term "telemedicine" is derived from the Latin word "medicus" and the Greek word "tele" meaning "from a distance", and it is traditionally associated with healthcare activities conducted via telephone or television (Strehle & Shabde, 2006). Telemedicine was early recognised as a potential model of healthcare delivery, enabling access to care from home using available technologies (Heinzelmann et al., 2005).

With the development of technology and the adoption of new tools in healthcare, the definition of telemedicine has expanded. In 2007, 104 definitions were identified, reflecting the broad scope and complexity of the concept (Sood et al., 2007). These definitions focused on four core dimensions: (1) healthcare content, (2) technological tools for data transmission, (3) spatial distance between participants, and (4) intended benefits, such as

[1] A part of this chapter was published in: Srok, A. & Došenović Bonča, P. (2024). ICT-enabled healthcare and economic evaluations: a bibliometric analysis. Dealing with uncertainty: University of Rijeka, Faculty of Economics and Business, 197-218.

improved access when in-person care was not feasible. Telemedicine generally refers to three main modes of ICT use over distance. One widely discussed form is remote monitoring (telemonitoring), which involves biometric devices for continuous or periodic assessment of symptoms and vital signs, often in the home setting. Telephone and video consultations proved particularly valuable as real-time care modalities during the COVID-19 pandemic (Monaghesh & Hajizadeh, 2020). A third mode is store-and-forward telemedicine, involving the asynchronous exchange of pre-recorded data, such as laboratory results, radiological images, and expert opinions (Strehle & Shabde, 2006).

Telehealth is closely related to telemedicine and is generally understood as a broader concept. Telemedicine and telehealth are often differentiated by scope: telemedicine focuses on clinical services such as diagnosis, monitoring, or treatment, whereas telehealth also includes non-clinical activities, such as education, training, administration, patient support, and health promotion (WHO, 2010). This relationship is commonly summarised by the phrase that "telemedicine is to telehealth what medicine is to health" (Bashshur et al., 2011).

The WHO highlights shared elements of telemedicine and telehealth, including clinical support, remoteness, ICT use, and the aim of improving health outcomes, and therefore adopts a single general description for both. Accordingly, the WHO adopts the following general description: "The delivery of health care services, where distance is a critical factor, by all health care professionals using ICT for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities" (WHO, 2010). This overlap explains why the terms are often used interchangeably. Less commonly used related terms include telecare and telematics, the latter now rarely applied in healthcare contexts (WHO, 1998).

The term eHealth emerged in the late 1990s as ICT became mainstream across multiple sectors and more deeply integrated into healthcare. The prefix "e" was widely adopted to denote the growing use of electronic and internet-based technologies, which also led to the adoption of the term eHealth. In 2005, 51 unique definitions of eHealth had been identified (Oh et al., 2005). Similar to telehealth, eHealth refers to ICT use by healthcare professionals and non-professionals, including patients and the general public (Stevens et al., 2019). Most definitions extend beyond telehealth by explicitly including on-site ICT, such as electronic health records. The WHO defines eHealth concisely as "the use of ICT to support health and health-related areas" (WHO, 2016).

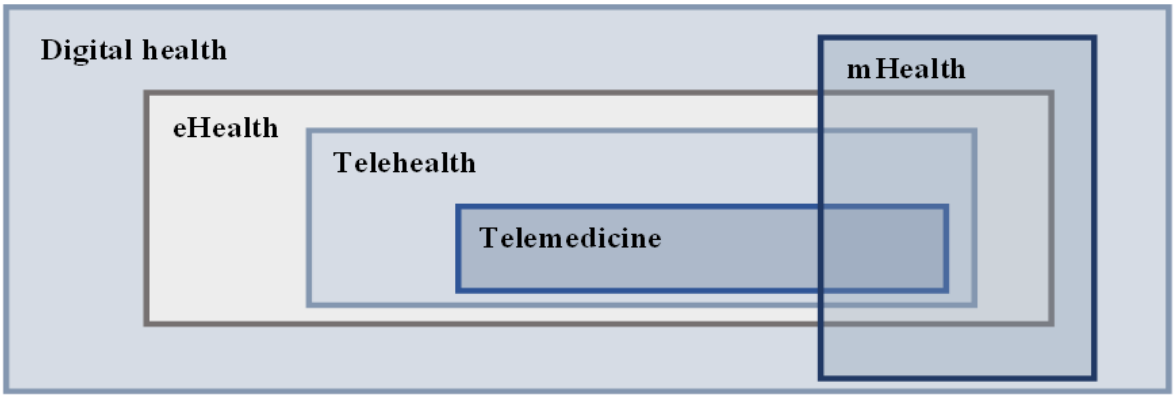
Digital health is the most recent and currently dominant term describing ICT use in healthcare. Although first mentioned in 1998 (D'Alessandro et al., 1998), it gained prominence during the COVID-19 pandemic. The WHO describes digital health as a broad umbrella term encompassing eHealth and advanced computing applications: "Today, the term 'digital health' is often used as a broad umbrella term that encompasses both eHealth and evolving areas such as the use of advanced computing sciences" (WHO, 2021b). A

review of 95 definitions highlights its population-level orientation, enabled by widespread use of smart devices and connected technologies (Fatehi et al., 2020). In line with this broader perspective, the WHO defines digital health as: "...the field of knowledge and practice associated with the development and use of digital technologies to improve health. Digital health extends the concept of eHealth to digital consumers with a wider range of smart devices and connected equipment. It also encompasses other applications of digital technologies for health such as the Internet of things, artificial intelligence, big data and robotics, and predictive and prescriptive analytics." (WHO, 2021b).

Other terms, such as mobile health (mHealth), are used less frequently. mHealth focuses on mobile and wireless technologies and is defined by the WHO as "the use of mobile wireless technologies for public health" (WHO, 2011). In practice, mHealth spans telemedicine, telehealth, eHealth, and digital health. Figure 1 illustrates the conceptual relationship between these terms.

ICT in healthcare can also be classified along functional dimensions, including synchronous versus asynchronous use, on-site versus remote applications, clinical versus non-clinical functions (Craig & Patterson, 2005; Monaghesh & Hajizadeh, 2020), and business-to-business versus business-to-consumer models (Rant, 2021).

Figure 1: Conceptual relationship between key terms used to describe information and communication technology-enabled healthcare



Source: Srok and Došenović Bonča (2024)

Finally, a distinction can be drawn between healthcare services and healthcare interventions. Health interventions are focused, evidence-based programmes designed to achieve specific objectives and are therefore amenable to evaluation, whereas healthcare services refer more broadly to systems supporting multiple functions (WHO, 2019). In the remainder of this dissertation, I use the overarching term digital health, with a specific focus on healthcare interventions (DHI), in line with WHO terminology.

2.2 Bibliometric analysis of the literature on ICT-enabled health interventions

In the previous subchapter, I presented the different terminologies and definitions used to describe DHI. Given the rapid technological development and the corresponding expansion of ICT use in healthcare, bibliometric analysis provides a systematic approach to mapping research activity, identifying trends, and visualising relationships within large bodies of literature. Bibliometric methods are widely used to examine research foundations, thematic evolution, and citation patterns across scientific fields. In recent years, several studies have applied bibliometric analysis to digital health research in order to structure and synthesise a rapidly growing and heterogeneous evidence base. Most bibliometric analyses of digital health have been conducted in the last five years, particularly during the COVID-19 pandemic, and differ in terms of topic focus, terminology, database coverage, and analytical methods (e.g., Sikandar et al., 2021; Uribe-Toril et al., 2021; Waqas et al., 2020). In this subchapter, I apply a bibliometric co-occurrence analysis of author keywords to examine the most frequently used terms and research themes across publications employing the four dominant terminologies used to describe ICT-enabled healthcare. This approach enables a comparative assessment of how research topics differ and evolve across terminological frameworks, thereby providing deeper insight into the structure and development of this research area. This mapping is particularly relevant for EE research, where fragmented terminology can obscure the accumulation and comparability of evidence.

2.2.1 Data collection

The data collection and analytical procedure follow established guidelines for conducting rigorous bibliometric research (e.g., Donthu et al., 2021). I obtained bibliographic data for the bibliometric analysis and network visualisation through an extensive literature search in the WoS CC (Visser et al., 2021). WoS CC is widely regarded as a reference database for bibliometric analysis due to its broad coverage of journals and multiple citation indexes (e.g., Pranckutė, 2021; Visser et al., 2021).

I conducted the bibliographic search using topic-based queries, targeting keywords in publication titles, abstracts, and author keywords. Search strings were constructed using Boolean operators (AND, OR) and include relevant terms and their synonyms. The primary objective of the data collection is to capture the state of research associated with different terminologies used to describe ICT use in healthcare. The same database is also used in Subchapter 3.2; however, that analysis focuses specifically on EE of DHI and applies a distinct search strategy. I collected bibliographic data separately for the four most commonly used terms describing ICT in healthcare (digital health, eHealth or e-health, telehealth, and telemedicine), resulting in four publication groups for subsequent analysis. I restricted the search to English-language journal articles and review papers, in line with bibliometric research recommendations (e.g., Donthu et al., 2021). I defined the publication period as 2000 to May 2022, capturing more than two decades of ICT-enabled healthcare

research. I subsequently updated descriptive publication counts to include full-year data for 2022 and 2023, where explicitly reported.

2.2.2 Methodology

Bibliometric analysis applies mathematical and statistical techniques to quantify patterns in scientific publications (Pritchard, 1969). Two broad categories of bibliometric techniques are commonly distinguished:

- performance analysis, and
- science mapping (Donthu et al., 2021).

I provide a detailed methodological description of these techniques in Subchapter 3.2.2, where I apply them to the bibliometric analysis of EE of DHI. In the present subchapter, I apply both performance analysis and science mapping exclusively through keyword co-occurrence analysis, with individual publications serving as the unit of analysis.

I conduct keyword co-occurrence analysis separately for publications associated with each of the four terminologies (telemedicine, telehealth, eHealth, and digital health). Performance analysis assesses publication activity based on selected terminology, using indicators such as the number of publications and annual research output. Science mapping visualises relationships between keywords, representing them as nodes within a bibliometric network (Donthu et al., 2021; van Eck & Waltman, 2014). Node size reflects keyword frequency, while links indicate co-occurrence strength, with thicker lines representing more frequent joint appearances. Keywords are grouped into clusters to highlight dominant thematic structures.

I conduct all performance and network analyses using VOSviewer, a widely used tool for bibliometric visualisation and science mapping (Aria & Cuccurullo, 2017; van Eck & Waltman, 2014).

2.2.3 Results

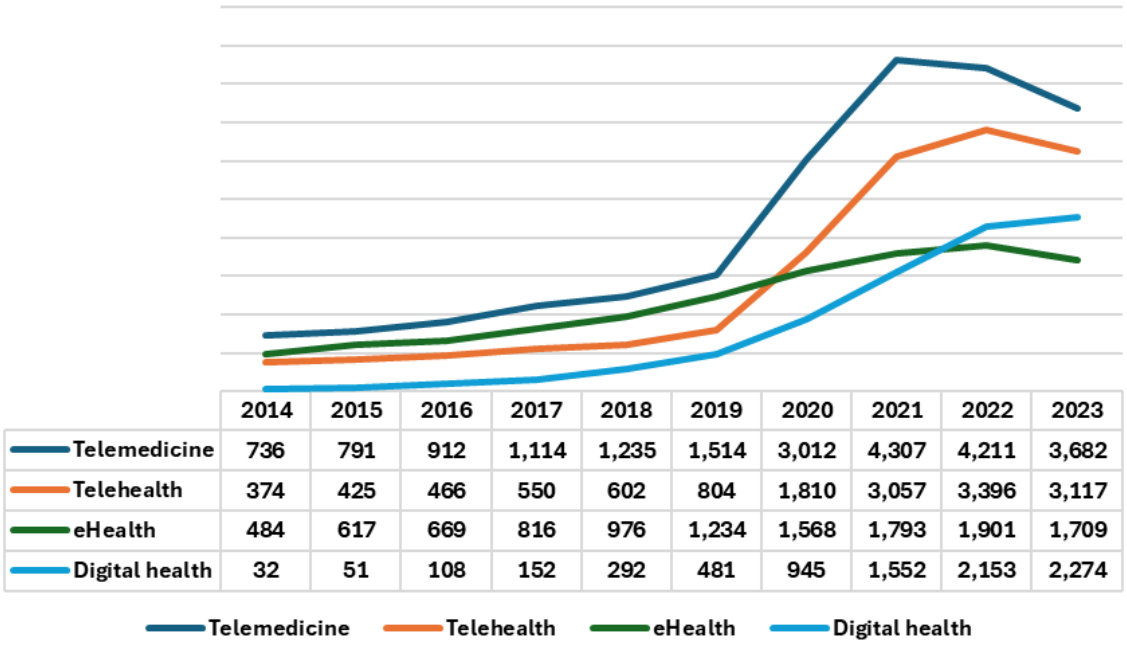
The results presented in this subchapter refer to the analysis of author keyword co-occurrence across the four groups of publications related to the terminology used to describe ICT in healthcare. The analysis relates observed keyword patterns to the conceptual distinctions introduced in Subchapter 2.1. Performance analysis and science mapping are used to assess publication volume across terminologies and to identify dominant research topics associated with each term.

2.2.3.1 Performance analysis

Based on the performance analysis of the bibliographic data, telemedicine is the earliest term recorded in the WoS CC database (1969), followed by telehealth (1985), digital health (1995), and eHealth (2000). The number of publications related to ICT use in healthcare increased steadily over the past two decades (see Figure 2). Telehealth exhibited slower growth than telemedicine and was overtaken by eHealth in 2011, while digital health remained relatively uncommon until the late 2010s. From 2018 onwards, publications using the term digital health increased markedly, a trend that intensified during the COVID-19 pandemic.

During the COVID-19 period, publications referring to telemedicine and telehealth increased substantially, followed by digital health. In 2020 alone, publications using telemedicine and telehealth more than doubled compared with the previous year (from 1,514 to 3,102 and from 804 to 1,810, respectively), while publications using digital health also increased sharply (from 945 to 1,552; Figure 2). By contrast, the use of the term eHealth declined after 2020. In 2021, more than 4,000 publications referred to telemedicine, while in 2023 publications using telemedicine and telehealth declined, whereas digital health continued to increase, reflecting its consolidation as an umbrella term.

Figure 2: Number of publications referring to different information and communication technology-enabled healthcare terms



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Telemedicine	736	791	912	1,114	1,235	1,514	3,012	4,307	4,211	3,682
Telehealth	374	425	466	550	602	804	1,810	3,057	3,396	3,117
eHealth	484	617	669	816	976	1,234	1,568	1,793	1,901	1,709
Digital health	32	51	108	152	292	481	945	1,552	2,153	2,274

Note: Publication counts for 2022 and 2023 were updated to include the full calendar year.

Source: Author's work

2.2.3.2 Analysis of keywords

I conduct keyword co-occurrence analysis separately for each terminology group to identify dominant topic structures associated with different conceptual frameworks (see Figures 3–6).

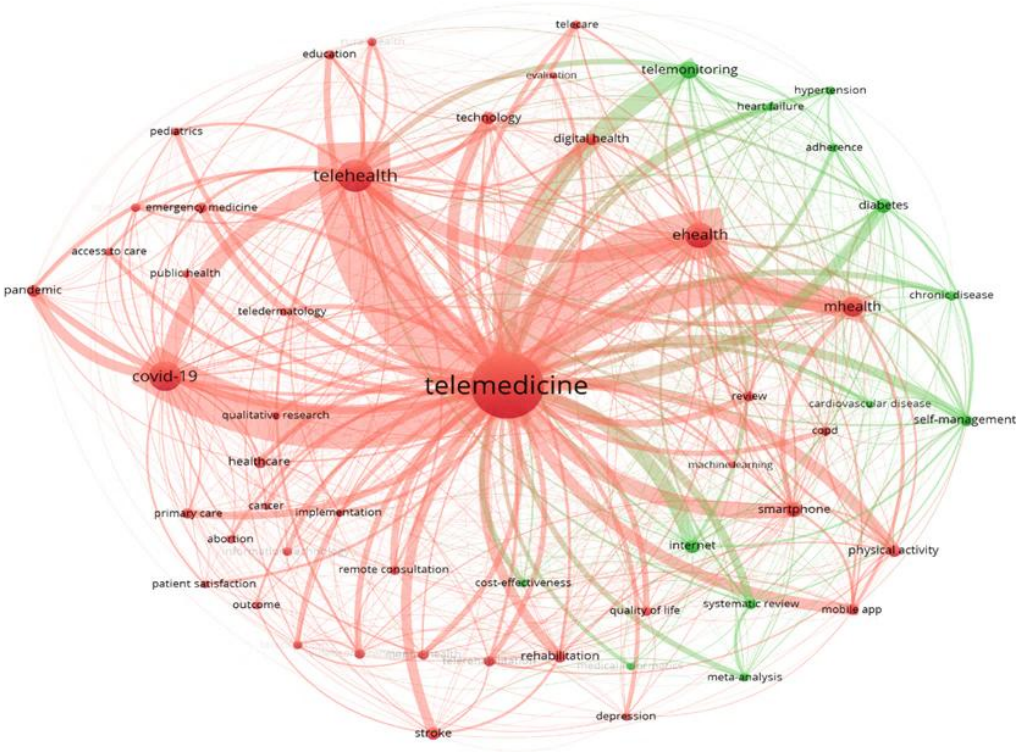
Telemedicine publications (see Figure 3) show strong associations with telehealth, eHealth, COVID-19, and mHealth, reflecting the extensive use of telemedicine and telehealth during the pandemic. Frequently occurring keywords include chronic conditions (e.g., cancer, chronic obstructive pulmonary disease, hereinafter COPD, stroke, HF, diabetes) and telemedicine-specific specialties (telerehabilitation, telepsychiatry, teledermatology). This pattern is consistent with the historical development of telemedicine, which initially focused on remote consultations and monitoring for chronic disease management. Cost-effectiveness appears among the most frequently occurring keywords, indicating early links between telemedicine and EE.

Telehealth publications (see Figure 4) display a keyword structure closely overlapping with telemedicine, with strong links to telemedicine and COVID-19. This overlap is consistent with the conceptual proximity of the two terms, as discussed in Subchapter 2.1. At the same time, telehealth-specific keywords emerge, including children, dementia, nursing, veterans, and virtual care, indicating a broader focus on care delivery contexts and population groups. Cost-effectiveness again appears among the most frequently occurring keywords, suggesting continued attention to economic considerations.

eHealth publications (see Figure 5) are strongly associated with telemedicine, telehealth, and mHealth, followed by internet and digital health. In contrast to telemedicine-focused publications, technology-oriented keywords such as artificial intelligence, blockchain, cloud computing, electronic health records, Internet of Things, and machine learning emerge more prominently. In addition, patient- and consumer-related themes (e.g., health literacy, privacy, behaviour change, adherence, safety, and social media) are frequently represented. This pattern is consistent with the definition of eHealth presented in Subchapter 2.1, as encompassing both on-site ICT use and patient-facing applications. No keywords explicitly related to EE or economics are observed in this group.

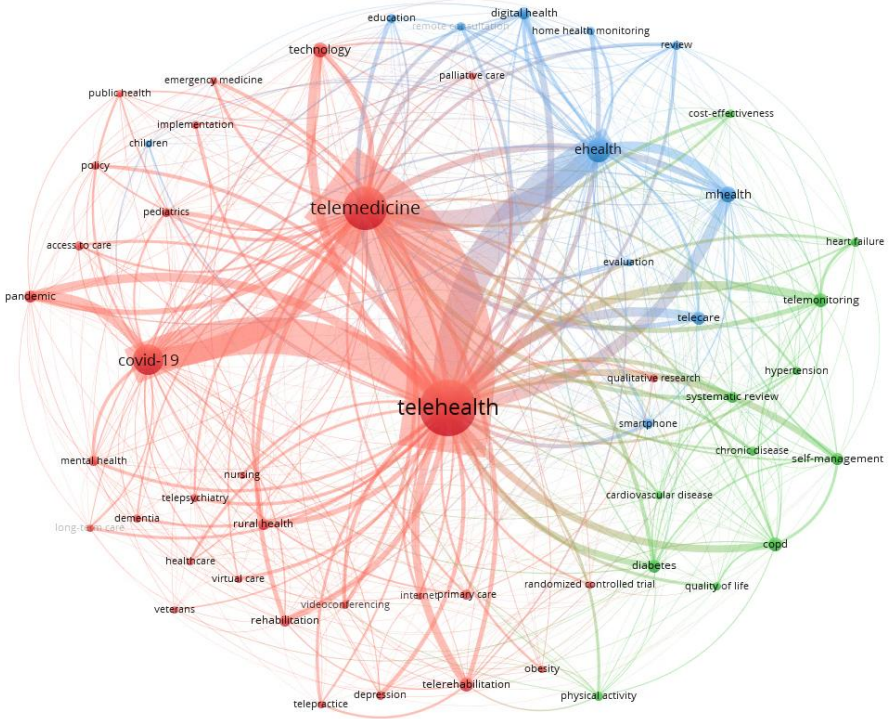
Digital health publications (see Figure 6) show strong associations with eHealth and mHealth, while links with telemedicine and telehealth are less pronounced, reflecting a conceptual shift away from exclusively remote care. New technology-driven keywords, including big data, deep learning, wearables, machine learning, and artificial intelligence, feature prominently, alongside terms emphasising digital innovation (e.g., digital health technology, digital medicine, precision medicine). Keywords related to patient-centred care, usability, health promotion, and infodemiology also emerge. As with eHealth, no keywords related to EE or economics appear among the most frequently occurring terms. Table 1 summarises the 15 most frequently occurring keywords for each terminology group.

Figure 3: Bibliometric network of keyword co-occurrence in telemedicine publications



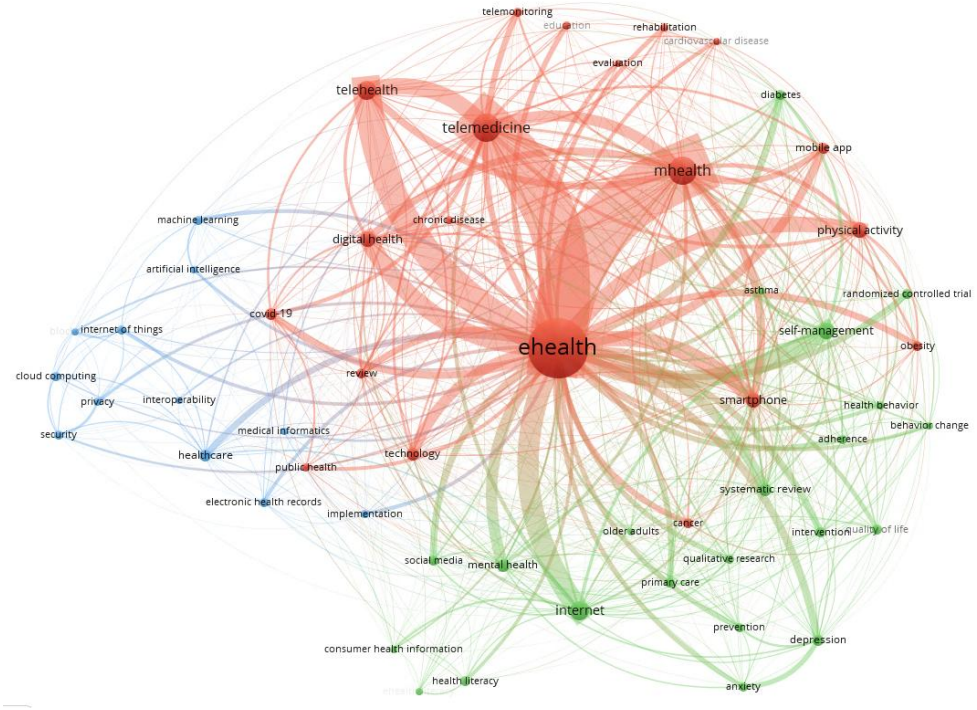
Source: Author's work

Figure 4: Bibliometric network of keyword co-occurrence in telehealth publications



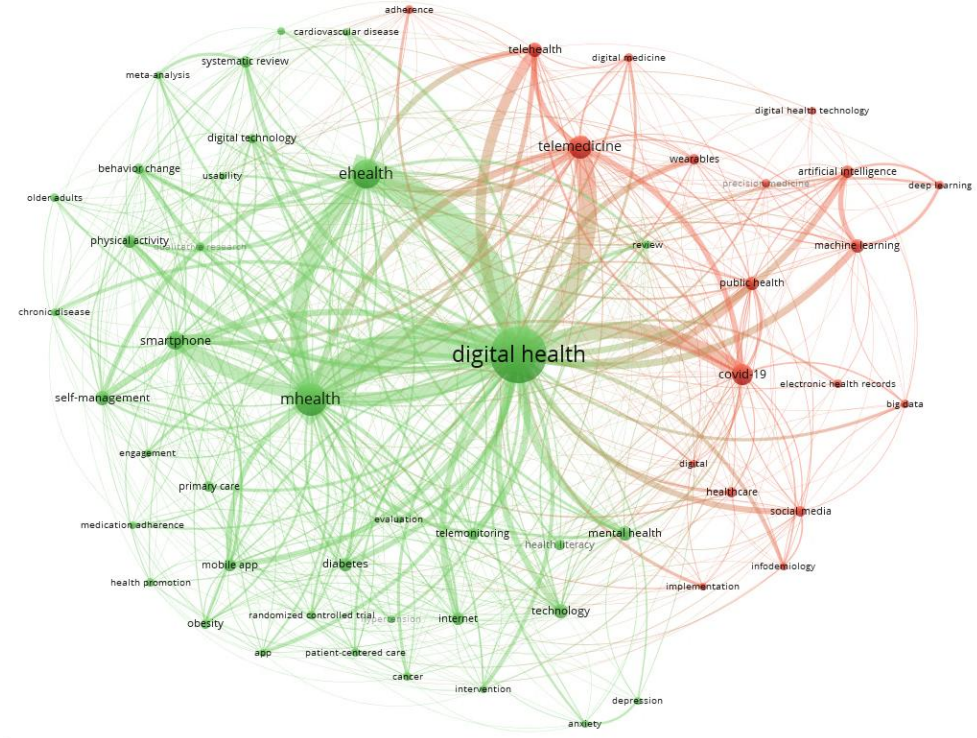
Source: Author's work

Figure 5: Bibliometric network of keyword co-occurrence in eHealth publications



Source: Author's work

Figure 6: Bibliometric network of keyword co-occurrence in digital health publications



Source: Author's work

Table 1: Most frequently occurring keywords related to information and communication technology-enabled healthcare

Telemedicine		Telehealth		eHealth		Digital health	
Keyword	**Nr**	**Keyword**	**Nr**	**Keyword**	**Nr**	**Keyword**	**Nr**
telemedicine	1,584	telehealth	873	ehealth	1,336	digital health	438
telehealth	386	telemedicine	523	telemedicine	300	mhealth	151
covid-19	338	covid-19	258	mhealth	288	ehealth	123
ehealth	259	ehealth	164	telehealth	144	telemedicine	81
mhealth	148	mhealth	68	internet	137	covid-19	66
telemonitoring	108	technology	61	self-management	102	smartphone	53
smartphone	79	copd	56	physical activity	95	telehealth	35
diabetes	78	telerehabilitation	55	digital health	91	mental health	33
internet	71	telemonitoring	54	smartphone	86	self-management	33
technology	62	diabetes	48	systematic review	65	technology	32
stroke	60	telecare	46	mental health	63	diabetes	30
physical activity	56	pandemic	44	technology	60	machine learning	28
self-management	53	digital health	41	covid-19	58	physical activity	28
pandemic	52	self-management	40	healthcare	54	public health	28
rehabilitation	52	systematic review	38	depression	50	artificial intelligence	26

Source: Author's work

2.2.4 Discussion and conclusions

The marked increase in publications observed in this subchapter reflects the expanding adoption of ICT in healthcare, with the COVID-19 pandemic acting as a major catalyst for research on remote healthcare delivery. Between 2020 and 2022, publications on telemedicine and telehealth increased sharply, followed by digital health, whose publication volume more than doubled between 2019 and 2020. In contrast, the use of the term eHealth has declined since 2019. In the final year of analysis (2023), publications using telemedicine and telehealth decreased, while digital health continued to grow, consistent with its consolidation as an umbrella term encompassing a broad range of ICT-enabled healthcare applications.

To capture shifts in research focus associated with evolving terminology, I apply bibliometric co-occurrence analysis across four publication groups. mHealth emerges as one of the most frequently occurring keywords across all groups, indicating its cross-cutting role across different conceptualisations of ICT use in healthcare. Telemedicine, telehealth, eHealth, and mHealth also consistently appear among the most frequent keywords, highlighting persistent overlap and conceptual ambiguity in the literature.

The topic focus differs across terminologies. Telemedicine and telehealth publications predominantly address chronic diseases, rehabilitation, and remote consultations, whereas eHealth and digital health publications more frequently emphasise mental health, wellbeing, and patient engagement. Keywords related to emerging technologies, including machine learning and artificial intelligence, are most prominent in digital health publications, reflecting a stronger orientation towards data-driven and consumer-facing technologies.

Overall, the keyword patterns align with the conceptual distinctions outlined in Subchapter 2.1. Notably, economic concepts remain weakly represented: cost-effectiveness appears primarily in telemedicine and telehealth publications, while EE is largely absent from eHealth and digital health-focused research, underscoring the need for a more systematic integration of EE within digital health research. Taken together, these findings highlight that while research on ICT-enabled healthcare has expanded rapidly, EE remains unevenly integrated across terminologies, motivating the focused examination of EE frameworks and methods in the next subchapter.

2.3 Digital health interventions in Slovenia

In this subchapter, I situate DHI in Slovenia within the institutional, technical, and data environment that shapes both their implementation and the feasibility of robust EE and HTA. In particular, this subchapter explains why fragmentation, limited interoperability, and uneven digital capacity directly affect data quality, comparability, and the practical use of evaluation tools such as CCA and the IIM.

ICT plays an important role in strengthening health systems, promoting public health, and improving equity in access to health services. ICT is also frequently presented as a potential solution to overburdened healthcare systems. However, the ability to translate this potential into measurable outcomes and economic evidence depends on governance arrangements, interoperable infrastructures, and the availability of standardised data across providers.

The Slovenian healthcare system faces several interrelated challenges that constrain the effective adoption and evaluation of DHI. First, governance and system fragmentation remain substantial. Although hospitals in Slovenia were established by the state and patients move through the same system from primary care to hospital treatment, there is no fully centralised management of the health information system, and ICT solutions are often procured and adapted locally (Kosednar, 2023; Ministry of Health, 2022).

Second, interoperability and data standardisation remain limited, affecting data quality and analytical usability. The healthcare system collects large amounts of data, yet data are frequently recorded inconsistently across providers, as clinics apply different reporting standards and use different local configurations. Data are not systematically verified, and recording practices are not fully standardised across primary and secondary care, which limits the production of accurate statistics and comparative analyses (Ministry of Health, 2022). The administrative burden is also substantial: data entry is time-consuming for patients and healthcare professionals, databases are not always connected, and patient status updates may need to be repeated across systems, resulting in lost time and reduced availability of usable clinical information (Kosednar, 2023; Ministry of Health, 2022).

Third, human capacity and adoption constraints remain salient. Slovenia faces a shortage of staff, including ICT specialists, and healthcare professionals and administrators may lack

key digital competences. In addition, adoption barriers include limited funding opportunities, insufficient stakeholder engagement, limited awareness among decision-makers of potential benefits, organisational rigidity in adopting new technologies, and the need for user training (Rant, 2021; Stanimirović & Matetić, 2020).

The National Institute of Public Health monitors, evaluates, and improves population health, and collects, manages, and analyses national health data to support evidence-based decision-making (Ministry of Health, 2022). However, existing standards are not yet implemented consistently, and adoption of standards remains challenging (Kosednar, 2023). Overall, a central digitalisation challenge is the standardisation of data collection and technical specifications, as well as the connectivity of ICT solutions across providers.

Operational fragmentation is visible across care levels. In primary care, centres are managed by municipalities, which are responsible for investments and decisions regarding ICT use. Primary care centres reportedly use more than 30 different ICT systems, which are not fully interconnected and are often adapted to local needs, including modifications that preserve existing workflows rather than optimising interoperability or data quality. This local tailoring contributes to heterogeneity in data capture and limits comparability across sites. At the secondary care level, hospital information systems are provided and managed by multiple companies and often include several components, such as administrative modules and clinical modules, plus specialty-specific systems (e.g., radiology information systems). Although core data needs overlap with primary care, local adaptation practices are similar: hospitals and individual clinics may customise systems to meet local requirements, producing inconsistent and non-comparable data while generating additional costs through uncoordinated change processes (Kosednar, 2023; Ministry of Health, 2022).

2.3.1 Digitalisation of healthcare in Slovenia (2008–2022)

Digitalisation of the Slovenian healthcare system began in 2008 through the eHealth (sl. eZdravje) programme. The project was led by the Ministry of Health from 2008 to November 2015, after which the National Institute of Public Health assumed responsibility for managing eHealth interventions. By 2022, more than 20 active digital health tools and DHI were operating under eHealth (Kosednar, 2023; National Institute of Public Health, 2021b). Selected DHI examples include: ePosvet (eConsultation), eTriaža (eTriage), TeleRadiology, and Telekap (TeleStroke). Key digital health tools and platforms include: eRecept (ePrescription), eNaročanje (eReferral), the Central Register for Patient Data, the zVEM patient portal, and the zVEMPlus portal for healthcare professionals (Kosednar, 2023; National Institute of Public Health, 2021b).

In the Digital Economy and Society Index Report 2019, Slovenia ranked sixth among EU countries regarding the development and use of eHealth solutions (European Commission, 2019; National Institute of Public Health, 2021b). Despite this relative performance, funding

levels remain constrained. The Ministry of Health invests less than 6 million euros per year from the national budget in eHealth, and the maintenance of ICT in healthcare is funded primarily through budget transfers. The National Institute of Public Health also acquires investment through EU projects, typically below 3 million euros per year. HIIS transfers almost 7 million euros to public healthcare providers for direct ICT investments, while healthcare providers spend less than 2% of revenues on ICT (Ministry of Health, 2022). By 2022, annual ICT investment remained far below the estimated 350 million euros per year that would be required if 6–10% of annual revenues were allocated to ICT development and maintenance, given that Slovenia spends more than 4 billion euros on healthcare annually (5.46 billion euros in 2022; 9.6% of GDP; Ministry of Health, 2022; Statistical Office of the Republic of Slovenia, n.d.). Industry planning often assumes substantial ongoing maintenance requirements relative to initial ICT investment (commonly estimated at around 20% annually over a multi-year period) to support long-term system sustainability and effective planning (Kosednar, 2023). This level of underinvestment is relevant for both implementation capacity and the availability of reliable, standardised data streams needed for EE and HTA.

2.3.2 National strategy for the digitalisation of healthcare in Slovenia to 2027

Further development of Slovenia's eHealth strategy forms part of a project supported under the European Commission's Structural Reform Support Programme, which aims to develop an eHealth strategy and investment plan for the period 2022–2027 (European Commission, 2023). The Ministry of Health is investing an estimated 101.3 million euros in the digital transformation of healthcare, with expected European funding from the Recovery and Resilience Plan amounting to 83 million euros (Ministry of Health, 2025).

The Ministry of Health participated in the creation of an eHealth strategy, which provides a technical basis for the Health Digitalisation Act. The Act follows the Strategy for the Digitalisation of Healthcare in Slovenia (2022–2027) and the Resolution on the National Healthcare Plan 2016–2025 "Together for a Healthy Society" (Ministry of Health, 2025). Planned legislative amendments are intended to strengthen oversight of eHealth and streamline data flows to support patient care and informed policymaking.

The Health Digitalisation Act aims to improve efficiency and digital data exchange. Its objectives include simplifying patient pathways through improved data integration and synchronisation between providers, strengthening information security, and reducing administrative burden for healthcare professionals through access to a single, interconnected system that supports workflow optimisation (Ministry of Health, 2025). A central policy objective is therefore the development of a central health information system capable of producing accurate, uniform, and reusable data that support research, official statistics, and health policy (Ministry of Health, 2025).

In addition to the strategy and legal framework, a strategic investment plan sets objectives and priorities for 2022–2027, including optimisation, integration, and connectivity of existing information systems and databases, strengthening management and control procedures, and improving data security (Ministry of Health, 2022). The Ministry of Health is also implementing several projects using European funds from the Recovery and Resilience Plan, spanning DHI, digital tools and platforms, data infrastructure and interoperability, and policy and operational transformation initiatives (Ministry of Health, 2025). Examples of digital health projects and implementation initiatives are reported in Appendix 2.

As part of the broader digital transformation, Slovenia adopted the Act on Quality Assurance in Healthcare in November 2024, aligned with EU Regulation 2021/2282 on HTA (European Commission, 2025; European Parliament, 2021a, 2023). Given the increasing complexity of health technologies, HTA has become more central for decisions on adoption, quality, and value. In March 2025, the government approved the establishment of an independent Slovenian Public Agency for Quality in Healthcare and its governing council. The Agency is tasked with monitoring healthcare quality, promoting patient safety, publishing annual quality reports, supporting advisory boards, and aligning national HTA processes with EU frameworks (Ministry of Health, 2024). This represents the first formal national regulation of HTA in Slovenia (Prelog et al., 2025; Prevolnik Rupel, 2017).

2.4 Summary

ICT is increasingly used across healthcare systems, as it offers opportunities to improve health outcomes, make more efficient use of scarce healthcare resources, and support the transformation of overburdened healthcare systems. Through remote access to health information, improved communication between providers, and more efficient service delivery, ICT applications are now embedded in everyday healthcare practice. As a result, the literature on digital health has expanded rapidly and is characterised by substantial conceptual and thematic diversity.

The rapid development of ICT over the past two decades has led to persistent terminological inconsistency, with several key terms (e.g., telemedicine, telehealth, eHealth, and digital health) used to describe ICT-enabled healthcare, as outlined in Subchapter 2.1. While telemedicine traditionally referred to remotely delivered clinical care, more recent literature, including WHO guidance, increasingly adopts the term digital health as a broad umbrella concept encompassing diverse ICT applications in healthcare. Despite this expansion, the adoption of ICT in healthcare has often been constrained by financial, regulatory, and organisational challenges, including limited interoperability, data privacy and security concerns, ethical considerations, and a lack of robust economic evidence to inform resource allocation decisions for DHI (Fernández Coves et al., 2022; Hong & Cho, 2023; Manteghinejad & Javanmard, 2021; Stanisavljevic & Tekić Sauerborn, 2024). The COVID-

19 pandemic temporarily alleviated some technological and financial barriers, as the provision of remote healthcare became essential. In the post-pandemic period, continued ICT adoption, positive stakeholder perceptions, and improved data sharing have reinforced the potential of digital health to support more person-centred and data-driven care pathways.

To assess the evolution of ICT-enabled healthcare research, I apply a bibliometric analysis structured around the terminology used to describe ICT in healthcare. During and after the COVID-19 pandemic, research output increased substantially across all terminological categories, reflecting accelerated adoption and scholarly interest. Keyword co-occurrence analysis indicates that dominant research themes align closely with the conceptual distinctions discussed in Subchapter 2.1: telemedicine and telehealth publications focus primarily on chronic disease management and remote consultations; eHealth and digital health research increasingly addresses mental health, wellbeing, and emerging digital technologies such as artificial intelligence and machine learning.

The growing global use of ICT in healthcare highlights both opportunities and structural constraints within the Slovenian healthcare system. Key challenges include insufficient standardisation of data collection, limited interoperability between information systems, fragmented technical solutions, and constraints related to funding, governance, and stakeholder engagement. Digitalisation of the Slovenian healthcare system began in 2008 and currently encompasses more than 20 active DHI and tools within the eHealth framework, with further expansion planned for the 2022–2027 period. The central policy objective is the development of an integrated health information system capable of producing accurate, standardised, and reusable data to support research, monitoring, and evidence-informed health policy.

As part of this digital transformation, the Act on Quality Assurance in Healthcare was adopted in 2024 in alignment with the EU Regulation 2021/2282 on HTA, and the establishment of an independent Public Agency for Quality in Healthcare was approved in 2025. The Agency is tasked with monitoring healthcare quality and patient safety, publishing annual reports, supporting advisory bodies, and harmonising national HTA processes with EU standards. The increasing diversity and complexity of healthcare technologies have thus positioned HTA as a central mechanism for ensuring the safety, quality, and cost-effectiveness of healthcare interventions in Slovenia, including DHI, providing an important institutional context for the EE frameworks examined in the following chapter.

3 ECONOMIC EVALUATION OF DIGITAL HEALTH INTERVENTIONS

In this chapter, I examine EE as a core analytical component of HTA and assess its applicability to DHI. Healthcare systems operate under conditions of resource scarcity and

must make informed decisions about how to allocate limited resources across interventions, services, and population groups in order to maximise health gains, reduce disease burden, and improve access to care. Within this context, EE provides a structured framework for comparing alternative healthcare interventions in terms of their costs and consequences, and for informing reimbursement, funding, and investment decisions (Drummond et al., 2005).

While EE is well established within HTA (particularly for pharmaceuticals and medical devices), its application to newer and more complex technologies**,** such as DHI, warrants closer examination. The increasing role of DHI in healthcare delivery raises questions about how extensively EE has been applied in this field and how existing evaluation frameworks address the specific characteristics of DHI. Against this background, I address the following research questions:

RQ1*: "What is the current state of research related to EE of DHI and, more specifically, telemedicine, globally and in Slovenia?",* and

RQ2*: "What are the key challenges in conducting EE of telemedicine interventions? Are they adequately addressed by existing, albeit scarce, guidelines for their EE?"*

To address these research questions, I proceed in three analytical steps. First, in Subchapter 3.1, I outline the conceptual foundations of EE in healthcare and its role within HTA, including key methodological components, analytical perspectives, and commonly used evaluation methods. This establishes the conceptual basis for how value is assessed in healthcare and how decision-making frameworks are structured.

Second, I empirically assess the current state of EE research on DHI through a bibliometric analysis in Subchapter 3.2. This analysis positions EE within the broader DHI research landscape and examines publication trends, dominant themes, and influential contributions, thereby characterising the extent and characteristics of existing EE research in this field.

Third, in Subchapter 3.3, I conduct a narrative review to identify challenges related to intervention complexity, context dependence, data availability, and outcome measurement. Building on this analysis, I examine emerging methodological responses and policy-relevant approaches, specifically CCA and the IIM, that offer pragmatic ways to support economic appraisal of DHI under real-world constraints. The chapter concludes by integrating findings from the bibliometric and narrative analyses and by discussing their implications for future EE research and evaluation practice in the context of DHI.

3.1 Economic evaluation in healthcare

EE is a comparative analytical framework used to assess alternative healthcare interventions in terms of their costs and consequences. The role of EE is grounded in the fact that healthcare systems operate under conditions of resource scarcity: available resources are

limited relative to population health needs, and allocating resources to one intervention necessarily implies forgoing other interventions. Within HTA, EE supports decisions on whether new interventions should supplement or replace existing care by providing structured evidence on value for money. Because resources are finite, funding one intervention inevitably implies that other interventions cannot be funded, giving rise to opportunity costs and requiring explicit allocation decisions. EE addresses this problem by comparing alternative uses of resources and assessing whether additional benefits justify additional costs. The central question is therefore not whether an intervention works in isolation, but whether it represents a better use of resources than available alternatives.

The primary objective of EE in healthcare is to support decisions that maximise health gains within existing budget constraints. By making trade-offs transparent, EE contributes to allocative efficiency and provides a structured basis for priority setting. This makes EE particularly relevant for publicly funded healthcare systems, where allocation decisions must be justified, consistent, and defensible (Drummond et al., 2015; ISPOR, n.d.; NICE, 2022). As part of HTA, EE complements clinical evidence by linking effectiveness to affordability and long-term sustainability. While EE does not capture all dimensions of value relevant to healthcare decision-making, such as safety or ethical considerations, it provides a systematic approach to quantifying trade-offs between costs and outcomes and is therefore integral to evidence-informed decision-making. In many healthcare systems, evidence from EE is therefore required to inform coverage decisions, reimbursement levels, pricing negotiations, and investment priorities.

At its core, EE is inherently comparative and incremental. Interventions are evaluated relative to one or more comparators, typically reflecting current standard practice. Analysis focuses on incremental differences in costs and outcomes, allowing decision-makers to assess whether observed improvements in outcomes warrant the additional resources required. This incremental perspective underpins all forms of EE and is essential for interpreting results in a policy context.

Guidelines for conducting EE in healthcare consistently emphasise a set of core design choices that determine how value is assessed and interpreted. These include the definition of the study perspective, the selection of appropriate comparators, the choice of time horizon, the identification and measurement of costs and outcomes, and the approach to handling uncertainty. Together, these components determine the scope, comparability, and policy relevance of an EE. The key components are summarised in Table 2.

The study perspective defines which costs and consequences are included in the analysis. Common perspectives include the healthcare system or provider perspective, the healthcare payer or insurer perspective, the patient perspective, and the societal perspective. The societal perspective is the broadest, as it encompasses costs and outcomes accruing to all stakeholders, including patients, providers, payers, and the wider economy. In practice, many HTA guidelines prioritise the payer or healthcare system perspective, sometimes

complemented by a societal perspective in sensitivity analyses, depending on the decision context (Aranda-Jan et al., 2014; Ekeland et al., 2010; Gomes et al., 2022; Michie et al., 2017; Snoswell et al., 2017).

Comparators usually reflect current usual care care and may include usual practice, an alternative intervention, or minimal care. The time horizon defines the period over which costs and outcomes are measured and should be long enough to capture all relevant consequences of an intervention. Depending on the decision context, analyses may adopt short-term, long-term, lifetime, or technology life-cycle horizons. Costs included in EE depend on the chosen perspective and may encompass direct healthcare costs, direct non-healthcare costs, indirect costs, and capital, implementation, and maintenance costs. Outcomes include both health effects, such as changes in mortality or QOL, and non-health effects, such as time savings, behavioural changes, or reductions in resource use (Aranda-Jan et al., 2014; Ekeland et al., 2010; Gomes et al., 2022; Hall et al., 2015; McNamee et al., 2016; Michie et al., 2017; Snoswell et al., 2017; Wootton, 2012).

Because costs and outcomes accrue over time, EE applies discounting in line with national or international guidelines. Uncertainty is unavoidable and arises from variability in data, modelling assumptions, and population heterogeneity. Sensitivity and uncertainty analyses are therefore essential for assessing the robustness of results and for informing decision-makers about the degree of confidence that can be placed in estimated cost-effectiveness (Drummond et al., 2015).

Several types of EE are used in healthcare decision-making (Drummond et al., 2005, 2015). CEA and CUA are the most widely applied methods. CEA measures outcomes in natural units, such as life years gained or hospitalisations avoided, and indicates which alternative is more efficient in achieving a given outcome (Drummond et al., 2005; Udeh, 2020). CUA adjusts outcomes for QOL, using quality-adjusted life years (hereinafter QALY) or disability-adjusted life years (hereinafter DALY) as outcomes (Udeh, 2020). Both approaches typically report results as incremental cost-effectiveness ratios (hereinafter ICER), which express the additional cost per additional unit of outcome gained compared with a comparator.

CBA values both costs and outcomes in monetary terms, enabling comparisons across sectors, but relying on valuation methods, such as willingness-to-pay, that may be challenging to apply in healthcare contexts (Drummond et al., 2005; Turner et al., 2021).

CCA presents costs alongside multiple disaggregated outcomes without aggregating them into a single summary measure, allowing decision-makers to weigh different dimensions of impact explicitly (Drummond et al., 2005). CCA is commonly used at an early stage of decision-making or when outcomes are difficult to combine across perspectives or stakeholder groups. Cost-minimisation analysis compares alternatives solely on the basis of cost under the assumption of equivalent outcomes, a condition that is rarely met in practice and that therefore limits its applicability (Dakin & Wordsworth, 2013).

Table 2: Key components of economic evaluations

Component	Description
Study perspective	Defines whose costs and outcomes are considered (e.g., healthcare system, payer, patient, societal).
Alternatives or comparators	Intervention(s) against which the technology of interest is compared (e.g., standard of care, no intervention, alternative technology).
Time horizon	Period over which costs and outcomes are measured (short-term, long-term, lifetime, or technology life cycle).
Costs	Resources consumed, depending on perspective (e.g., direct healthcare, direct non-healthcare, indirect, capital, implementation, maintenance, data-related costs).
Benefit or Outcome	Health and non-health effects of the intervention; can be measured in natural units (e.g., hospitalisations avoided), composite measures (e.g., QALY, DALY), or monetary terms.
Incremental analysis outcome or Value proposition	Comparison of incremental costs and outcomes between alternatives (e.g., ICER, net monetary benefit).
Discounting	Adjustment of future costs and outcomes to present value.
Sensitivity Analysis	Exploration of robustness of results under alternative assumptions (deterministic or probabilistic).
Uncertainty Analysis	Assessment of parameter, structural, methodological uncertainty, and heterogeneity.
Reporting and Transparency	Clear documentation of methods, data sources, assumptions, and limitations to support interpretation and comparability.

Source: adapted from Drummond et al. (2015)

To promote consistency and transparency, EE is guided by international and national methodological standards. These are often embedded in HTA guidelines or issued as standalone EE guidance (Drummond et al., 2008). Internationally recognised sources include guidelines developed by organisations such as the International Society for Pharmacoeconomics and Outcomes Research (hereinafter ISPOR), WHO, and the Society for Medical Decision Making, as well as national HTA bodies (Adeagbo et al., 2018; Caro et al., 2012; ISPOR, n.d.; NICE, 2022; WHO, 2003). Countries with more developed HTA systems, such as the UK, provide detailed guidance through institutions such as NICE, covering pharmaceuticals, medical devices, diagnostics, and DHI (NICE, 2018, 2022). While most countries have developed national guidelines that reflect local decision contexts, these frameworks have historically been designed for pharmaceuticals and medical devices (Sharma et al., 2021). As a result, their applicability to complex and rapidly evolving interventions, such as DHI, is not always straightforward.

Given the increasing policy relevance of DHI and their distinct characteristics, such as context dependence, multiple outcome domains, and evolving implementation pathways, it is necessary to examine how existing EE frameworks are applied in practice and where methodological challenges arise. In the following subchapter, I empirically examine the current state of EE research on DHI through a bibliometric analysis.

3.2 Bibliometric analysis of the literature on economic evaluation of digital health interventions

In the previous subchapter, EE was positioned as a core analytical component of HTA, supporting resource allocation under conditions of scarcity. Despite this central role, the application of EE to DHI remains limited. While the broader literature on DHI has expanded rapidly, particularly during the COVID-19 period, several studies indicate that economic evidence has developed more slowly and unevenly and that multiple methodological issues persist in the EE of DHI (e.g., Gomes et al., 2022; Huter et al., 2022; Jankovic et al., 2021; Zwack et al., 2024).

As outlined in Subchapter 2.2, bibliometric analysis provides a structured approach to mapping research activity and identifying influential contributions within large and heterogeneous literatures. In recent years, bibliometric methods have been widely applied to assess research on DHI, particularly during the COVID-19 pandemic (e.g., Sikandar et al., 2021; Uribe-Toril et al., 2021; Waqas et al., 2020), yet few studies have focused explicitly on EE. A recent bibliometric analysis focusing more broadly on EE in healthcare further indicates that research on new technologies, such as telemedicine, telehealth, artificial intelligence, and robotics, remains under-represented (dos Santos Silva et al., 2021).

Building on this methodological foundation, I apply a bibliometric analysis in this subchapter to assess the state of research on EE of DHI. In this analysis, I position EE within the wider DHI research landscape and examine publication trends, thematic structures, and influential research constituents. Against this background, I provide a focused examination of EE of DHI[2] as a distinct and policy-relevant research domain.

3.2.1 Data collection

I describe the data collection and general bibliometric procedure in detail in Subchapter 2.2.1. In line with the proposed steps for a bibliometric analysis (e.g., Donthu et al., 2021), I retrieved bibliographic data from WoS CC for the bibliometric analysis and network visualisation (Visser et al., 2021), using a topic search across titles, abstracts, and keywords.

In this subchapter, I designed the search strategy to capture publications that address both DHI-related terminology (Subchapter 2.1) and EE-related terminology (Subchapter 3.1), including relevant synonyms. I combined two topic-based queries using the AND operator:

- digital health OR e-health OR ehealth OR telehealth OR telemedicine,

[2]A part of this chapter was published in: Srok, A., & Došenović Bonča, P. (2025) Economic Evaluations of Digital Health Interventions: A Bibliometric Analysis and a Review of Methodological Challenges. Business Systems Research, 16(1), 284-303.

– cost-effectiveness OR cost-utility OR cost-benefit OR benefit-cost OR cost-consequences OR cost-minimisation OR cost analysis OR economic analysis OR economic evaluation OR health economics.

As described in Subchapter 2.2.1, I limited the database search to English-language journal articles and review articles. I defined the search period as 2005–2023 (August 2023 as the final extraction point). The year 2005 is selected as the base year because the World Health Assembly adopted a resolution on eHealth that recognised ICT use for health-related areas as cost-effective and called on Member States to develop long-term plans for ICT in health (World Health Assembly, 2005). The search identified 54,265 publications on DHI-related terminology, of which 2,308 publications also addressed EE-related terminology (4.25%), and I retained these for the bibliometric analysis. The 2,308 publications span 2005 to August 2023 and are analysed to identify influential countries, organisations, journals, and individual publications.

3.2.2 Methodology

The techniques for bibliometric analysis can be grouped into two categories:

– performance analysis, and
– science mapping (Donthu et al., 2021).

Performance analysis draws on a range of quantitative and qualitative publication- and citation-related indicators. Quantitative indicators capture research output, such as the number of publications or productivity over time, while qualitative indicators reflect impact, including total citations and average citations per year or per publication. I use this approach to assess the contributions of key research constituents, including publications, countries, organisations, and journals.

Science mapping examines relationships between research constituents using bibliometric network visualisations (Donthu et al., 2021; van Eck & Waltman, 2014). In these networks, constituents are represented as nodes, node size reflects weight (e.g., frequency or citations), and links represent association strength; thicker links indicate stronger relationships. Nodes can be coloured by cluster membership to highlight thematic groupings, or by average publication year (overlay visualisation) to distinguish older from more recent constituents (van Eck & Waltman, 2014).

I conduct the performance analysis and science mapping using VOSviewer and R software (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010). I carry out the performance analysis and science mapping as follows, with regard to the type of bibliometric analysis and the research constituents:

1. Co-authorship analysis of countries and organisations,

2. Bibliographic coupling analysis of journals,
3. Bibliographic coupling analysis of publications and journals, and
4. Co-occurrence analysis of author keywords.

I use co-authorship analysis to identify the countries and organisations with the most publications on EE of DHI, and to examine collaboration and co-authorship between authors. To examine the countries and organisations to which the authors belong, basic quantitative and qualitative indicators are coupled with the graphical representation of the bibliometric co-authorship network. In the co-authorship network, node weight indicates publications per country or organisation, while link thickness reflects the number of co-authored publications between constituents (van Eck & Waltman, 2014).

I use bibliographic coupling analysis to analyse influential individual publications and leading journals in the research area. In bibliographic coupling, links are determined by the number of shared references, while node weight reflects citations. Journal networks are coloured by average publication year (overlay visualisation), whereas publication networks are coloured by cluster membership (van Eck & Waltman, 2014).

I use co-occurrence analysis of keywords to identify the most frequently used author keywords across publications and their co-occurrence. By doing so, co-occurrence analysis can provide insight into relevant research topics related to EE and DHI. In the bibliometric network representation, the weight of the node represents the number of occurrences of each keyword. The strength of the link shows the number of publications in which the two keywords occur together (van Eck & Waltman, 2014). In addition, Keywords Plus are included, which are algorithmically generated from the titles of cited references and capture broader related topics that may not be stated explicitly in article keywords.

3.2.3 Results

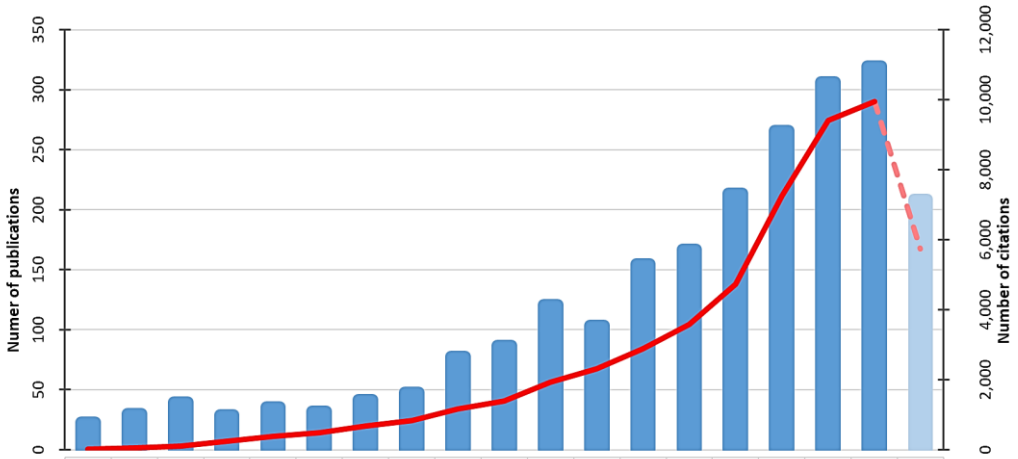
The results presented in this subchapter summarise several bibliometric analyses of publications related to EE of DHI, using terminology described in Subchapter 2.1 and Subchapter 3.1.

3.2.3.1 Performance analysis

The combined search strategy yields 2,308 publications for analysis. Figure 7 reports annual publications and citations for EE of DHI, alongside the overall publication growth in DHI. Publications on DHI increase steadily between 2005 and 2019, with a marked rise from 2020 onwards. In 2022, DHI publications reach 10,017, representing an increase of almost 150% compared with 4,062 publications in 2019. By contrast, publications on EE of DHI remain a small subset of the overall DHI literature: across the full period, the 2,308 publications represent less than 5% of DHI publications. Nevertheless, publications on EE

of DHI increase during the COVID-19 period, rising from 214 in 2019 to 266 in 2020, 307 in 2021, and 320 in 2022. This publication growth is accompanied by a sharper rise in citations, from an average of 22.11 citations per publication in 2019 to 31.13 citations per publication in 2022. The first half of 2023 includes 209 publications and 5,735 citations.

Figure 7: Annual number of publications and citations on the economic evaluation of digital health interventions (2005–August 2023)



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EE publications	23	30	40	29	36	32	42	48	78	87	121	104	155	167	214	266	307	320	209
EE citations	11	50	97	240	391	481	674	837	1,166	1,399	1,928	2,322	2,896	3,590	4,733	7,258	9,418	9,959	5,735
Total DHI publications	389	473	490	531	611	654	823	1,093	1,309	1,509	1,911	2,191	2,644	3,181	4,062	7,016	9,621	10,017	5,740
Share of EE	5.91%	6.34%	8.16%	5.46%	5.89%	4.89%	5.10%	4.39%	5.96%	5.77%	6.33%	4.75%	5.86%	5.25%	5.27%	3.79%	3.19%	3.19%	3.64%

Note: Data for 2023 reflect publications indexed up to August 2023 and therefore represent a partial year. The lighter shading indicates that 2023 values are not directly comparable with full-year counts.

Source: Author's work

Table 3: Performance indicators of publications on the economic evaluation of digital health interventions (2005–August 2023)

Number of publications on DHI	54,265
Number of publications on EE of DHI	2,308
Number of citations	53,186
Average number of citations per publication	23.04
H-index	101
Number of countries	108
Number of affiliations	3,957
Number of authors	12,527
Number of journals	850
Number of research areas	84
Number of keywords	4,414

Source: Author's work

Table 3 summarises additional performance indicators for the 2,308 publications, including total citations (53,186), an average of 23.04 citations per publication, and an H-index of 101, and the breadth of countries, affiliations, authors, journals, and research areas

represented. The publications span 84 research areas, with most outputs in Health Care Sciences Services, followed by Medical Informatics and Public Environmental Occupational Health, which reflects the interdisciplinary nature of EE of DHI. More than 4,400 author keywords are used across the dataset, indicating substantial thematic diversity within the literature.

3.2.3.2 Analysis of leading countries and organisations

Table 4 reports the most productive countries in terms of publication volume and citation impact for EE of DHI. The United States of America (hereinafter USA) ranks first with 769 publications, followed by England (361), Australia (310), the Netherlands (219), and Canada (197). Citation impact differs across these leading countries: citations per publication are highest for England (30.78), followed by Canada (27.61) and the USA (25.47). Other high-income countries, including Germany, Italy, Spain, China, and France, also contribute substantially, with citation impact ranging from 17.36 to 23.51 citations per publication.

Figure 8 presents country collaboration as a co-authorship network. Two main clusters are observed: one dominated by European countries and one centred on the USA, Canada, England, and Australia, with additional non-European linkages. Collaboration among European countries is particularly dense within the European cluster.

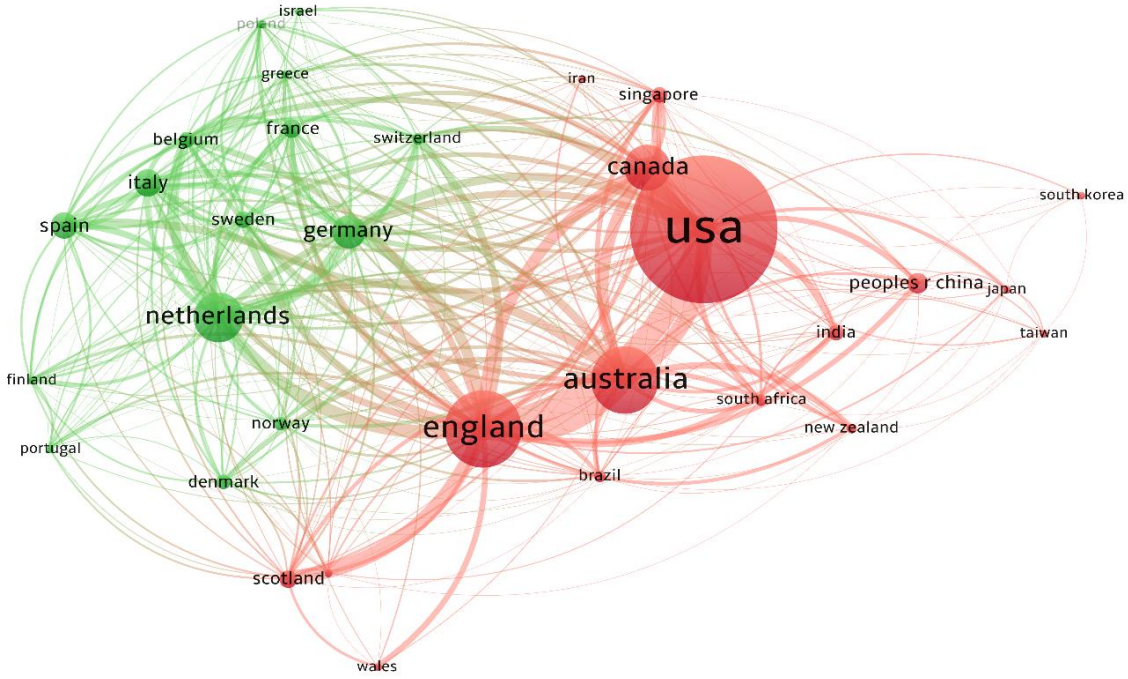
In addition to country-level patterns, organisational affiliations of authors are analysed. Table 5 reports the 10 most cited organisations publishing on EE of DHI. In terms of publication volume, the University of Queensland leads with 78 publications, followed by University College London (56) and Vrije University of Amsterdam (46). Citation impact per publication is highest for University Hospital of North Norway (119.38), Imperial College London (105.50), and the University of Southampton (84.25), indicating substantial variation in influence across organisations. Overall, English institutions account for half of the top ten most cited organisations.

Table 4: Most productive countries

Country	Total publications	Total citations	Citations per publication
USA	769	19,587	25.47
England	361	11,110	30.78
Australia	310	6,493	20.95
Netherlands	219	4,373	19.97
Canada	197	5,440	27.61
Germany	137	3,221	23.51
Italy	106	2,048	19.32
Spain	105	1,823	17.36
China	77	1,606	20.86
France	69	1,482	21.48

Source: Author's work

Figure 8: Clustered network of countries based on co-authorship analysis



Source: Author's work

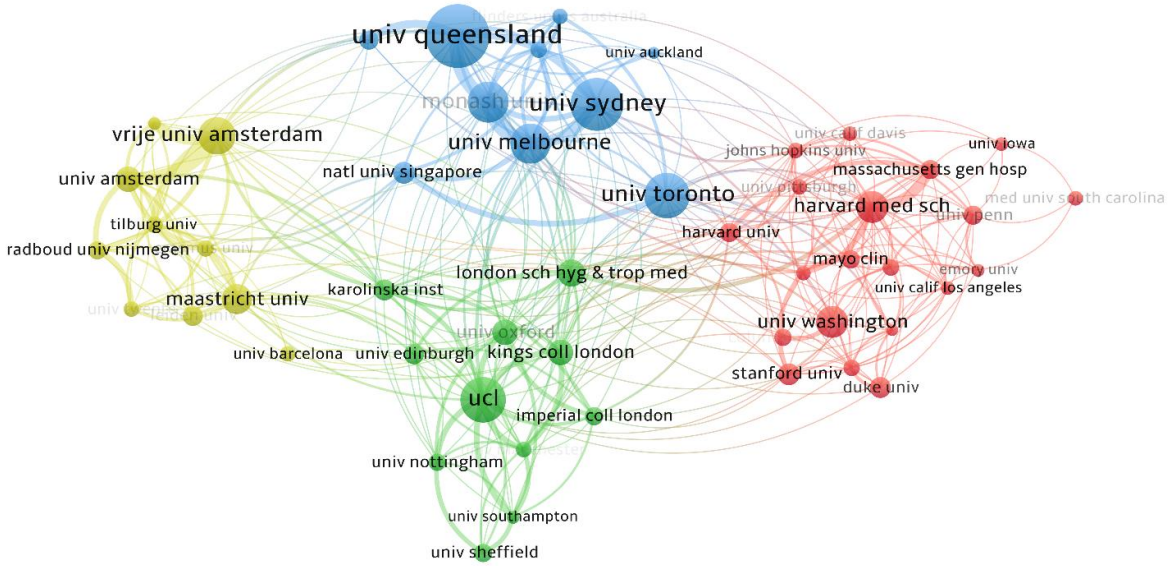
Table 5: Most cited organisations

Organisation	Country	Total publications	Total citations	Citations per publication
University College London	England	56	2,139	38.20
Oxford University	England	32	1,833	57.28
University of Queensland	Australia	78	1,723	22.09
University Hospital of North Norway	Norway	13	1,522	119.38
Imperial College London	England	14	1,477	105.50
University of Edinburgh	Scotland	25	1,395	55.80
University of Washington	USA	39	1,382	35.44
University of Manchester	England	20	1,378	68.90
University of Southampton	England	16	1,348	84.25
Vrije University of Amsterdam	Netherlands	46	1,237	26.89

Source: Author's work

Figure 9 presents the organisational co-authorship network. Four main clusters are observed, largely reflecting national collaboration patterns: Australian institutions (blue), organisations from the USA and Canada (red), United Kingdom (hereinafter UK) institutions (green), and Dutch institutions (yellow). Overall, organisational collaboration is predominantly concentrated within national boundaries.

Figure 9: Clustered network of organisations based on co-authorship analysis



Source: Author's work

3.2.3.3 Analysis of leading journals

Table 6 reports the most productive journals publishing on EE of DHI in terms of publication volume and citation impact.

Table 6: Most productive journals

Source	Total publications	Total citations	Citations per publication	Impact Factor (2021)	H index
Journal of Telemedicine and Telecare	142	3,836	27.01	6.34	80
Telemedicine and e-Health	132	3,724	28.21	5.03	81
Journal of Medical Internet Research	130	5,459	41.99	7.08	158
BMJ Open	88	683	7.76	3.01	121
BMC Trials	72	764	10.61	2.28	84
JMIR Research Protocols	59	543	9.20	-	33
JMIR mHealth and uHealth	46	808	17.57	4.95	68
PLOS One	34	1,048	30.82	3.58	367
International Journal of Environmental Research and Public Health	29	180	6.21	4.61	138
Contemporary Clinical Trials	24	205	8.54	2.26	65

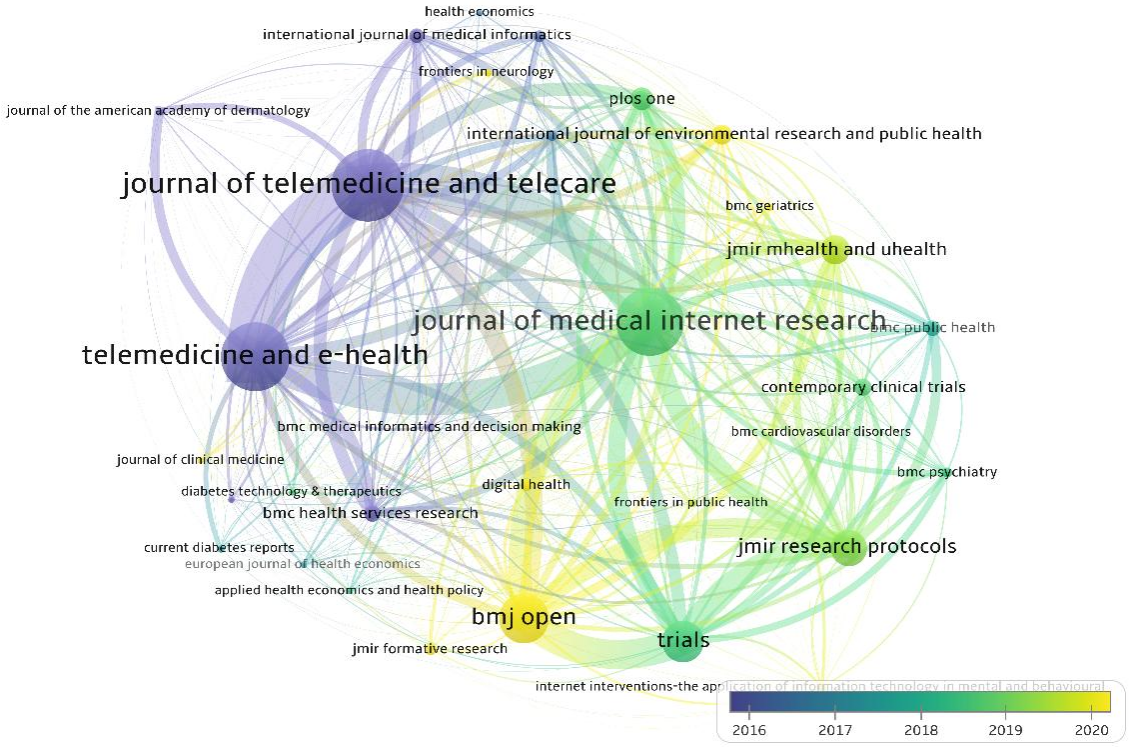
Source: Author's work

The Journal of Telemedicine and Telecare (142 publications), Telemedicine and e-Health (132), and the Journal of Medical Internet Research (130) account for the highest number of publications and also rank among the most cited journals. In terms of citation impact per

publication, the Journal of Medical Internet Research leads (41.99), followed by PLOS One (30.82), Telemedicine and e-Health (28.21), and the Journal of Telemedicine and Telecare (27.01). The listed journals span health informatics, medicine, and multidisciplinary research areas, and Table 6 reports their impact factors (2021) and H-indices, indicating variation in journal scope and influence.

Figure 10 presents a bibliographic coupling network of journals using overlay visualisation, with more recent publication activity highlighted in lighter colours. Journals with more recent publications include multidisciplinary outlets such as BMJ Open, International Journal of Environmental Research and Public Health, and JMIR mHealth and uHealth.

Figure 10: Trends in publishing journals based on bibliographic coupling analysis



Source: Author's work

3.2.3.4 Bibliometric and content analysis of most influential individual publications

The most frequently cited publications related to EE of DHI are listed in Table 7, together with their key methodological insights. Almost all highly cited publications are systematic reviews or evidence syntheses, as reflected in their titles. Half of these publications reach their highest annual citation counts within 2020–2022, indicating heightened attention to DHI and their evaluation during the COVID-19 period.

Table 7: Most cited individual scientific publications

Title	Author year	Total citat.	Citations per year	Best citation year (N)	Key points
The impact of ehealth on the quality and safety of health care: a systematic Overview	Black et al., 2011	769	59.15	2013 (90)	Lack of evidence on cost-effectiveness
Effectiveness of telemedicine: A systematic review of reviews	Ekeland et al., 2010	618	44.14	2021 (91)	Methodology issues, lack of evidence on cost-effectiveness, low quality evidence
The effectiveness of telemental health: a 2013 review	Hilty et al., 2013	572	52	2021 (111)	Heterogeneity of costs and types of EE used
Systematic review of home telemonitoring for chronic diseases: The evidence base	Paré et al., 2007	500	29.41	2015 (51)	Lack of economic evidence, lack of detailed analysis
Mobile text messaging for health: a systematic review of reviews	Hall et al., 2015	471	52.33	2019 (76)	Lack of cost-effectiveness and cost-benefit evidence
Interdisciplinary chronic pain management past, present, and future	Gatchel et al., 2014	415	41.5	2020 (75)	Lack of comprehensive reviews of costs and benefits
Developing and evaluating digital interventions to promote behavior change in health and health care: recommendations resulting from an international workshop	Michie et al., 2017	391	55.86	2022 (81)	Methodology for EE not appropriate for evaluation of DHI
Digital health interventions for children and young people with mental health problems - a systematic and meta-review	Hollis et al., 2017	347	49.57	2021 (88)	Lack of evidence on cost-effectiveness
Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa	Aranda-Jan et al., 2014	329	32.9	2019 (64)	Lack of evidence on cost-effectiveness
Twenty years of telemedicine in chronic disease management - an evidence synthesis	Wootton, 2012	320	26.67	2016 (49)	Lack of evidence on cost-effectiveness

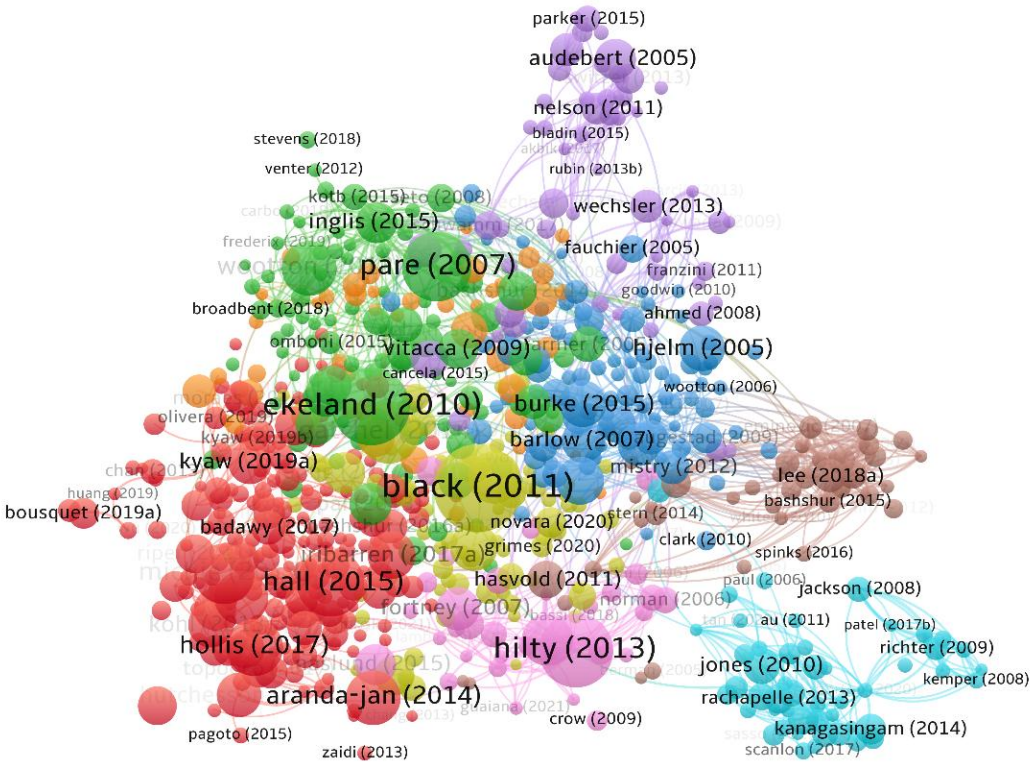
Source: Author's work

The most influential publications on EE of DHI predominantly focus on applications in chronic disease management, chronic pain, mental health, and well-being. Highly cited studies address DHI used in the management of chronic conditions and long-term care (Gatchel et al., 2014; Paré et al., 2007; Wootton, 2012), mental health interventions (Hilty et al., 2013; Hollis et al., 2017), and wellbeing and behaviour change (Hall et al., 2015).

Across clinical contexts, a recurring finding is the limited availability and quality of economic evidence. Several reviews explicitly report a lack of robust cost-effectiveness or

cost-benefit evidence, substantial methodological heterogeneity, and difficulties in capturing long-term costs and outcomes of DHI (Aranda-Jan et al., 2014; Hall et al., 2015; Michie et al., 2017). Content analysis of the most influential publications further reveals frequent methodological shortcomings, including unclear or inappropriate comparator selection, inconsistent definition of study perspective, limited outcome measurement, and insufficient consideration of time horizons required to capture all relevant costs and benefits of DHI. In addition, the publications highlight a limited understanding of economic evidence among decision-makers, alongside the absence of clear guidance to support both the conduct and interpretation of EE of DHI.

Figure 11: Clustered network of publications based on bibliographic coupling analysis



Source: Author's work

The bibliographic coupling analysis of publications (see Figure 11) reveals nine clusters largely organised around medical domains. The three clusters at the edges are related to specific medical fields and indicate an area of distinct and established research. The purple cluster includes publications in neurology, the brown cluster includes publications in dermatology, and the light blue cluster includes publications on ophthalmology and diabetes. Central clusters consist mainly of systematic reviews and broader evidence syntheses, indicating that methodological reflection on EE of DHI is concentrated within secondary research rather than primary economic studies. The green cluster represents publications on telemedicine and chronic diseases. The red cluster represents smartphone use and health-related behaviours, and the dark blue and yellow clusters include various

reviews and literature syntheses. The orange cluster in the middle includes publications related to rehabilitation, and the pink cluster includes publications mainly related to mental health.

3.2.3.5 Analysis of keywords

Analysis of author keywords identifies the 20 most frequently occurring terms across publications related to EE of DHI (see Table 8).

As expected, technology-related terms dominate, with telemedicine, telehealth, eHealth, and mHealth among the most frequent keywords. Cost-effectiveness ranks fifth overall, followed by health economics, economic evaluation, cost analysis, and cost-benefit. Keywords referring to specific EE approaches, such as cost-utility, cost-minimisation, and cost-consequence analysis, occur less frequently. The most frequently occurring Keyword Plus is cost-effectiveness, indicating that EE-related concepts are commonly present in cited references, even when not explicitly stated as author keywords. Among EE-related terms, CEA appears most frequently, while CBA and CUA are comparatively underrepresented. The term cost-effectiveness is often used interchangeably with EE or, in some cases, with CBA, suggesting potential ambiguity in how EE concepts are labelled and reported.

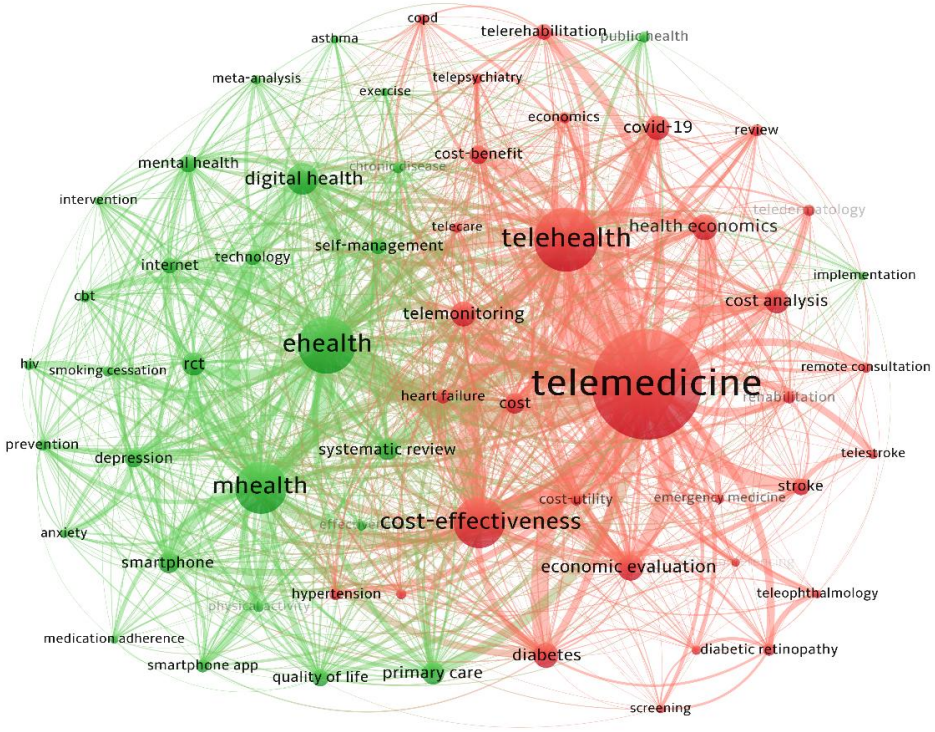
Table 8: Most occurring author keywords

Keyword	Number of occurrences	Keyword	Number of occurrences
telemedicine	741	cost-analysis	90
telehealth	343	covid-19	88
ehealth	299	rct	86
mhealth	260	primary care	82
cost-effectiveness	254	smartphone	74
digital health	130	systematic review	73
health economics	101	cost	69
economic evaluation	99	cost-benefit	61
diabetes	92	depression	57
telemonitoring	92	mental health	56

Source: Author's work

The clustered keyword co-occurrence network (see Figure 12) reveals two dominant thematic structures. One cluster centres on telemedicine and telehealth and contains the majority of EE-related keywords, alongside terms related to chronic diseases and clinical specialties (e.g., diabetes, HF, COPD, stroke, teledermatology, telerehabilitation). The second cluster emphasises eHealth, digital health, and mHealth and includes keywords related to self-management, mental health, public health, smartphone use, and behaviour change.

Figure 12: Clustered network of keywords based on keyword co-occurrence analysis



Source: Author's work

3.2.4 Discussion and conclusions

This bibliometric analysis provides a comprehensive overview of more than 15 years of research on the EE of DHI, explicitly accounting for both terminological diversity in digital health and methodological diversity in EE. The findings demonstrate a clear divergence between the rapid expansion of DHI research and the comparatively limited integration of EE. While overall DHI publications increased steadily between 2005 and 2019 and rose sharply during the COVID-19 period, publications explicitly addressing EE account for less than 5% of the total digital health literature. At the same time, the marked increase in citations per publication indicates growing recognition of the importance of economic evidence within the DHI research community.

The analysis further reveals a heterogeneous and interdisciplinary evidence base. Publications on EE of DHI span multiple research areas, most prominently Health Services, Medical Informatics, and Public Health, and appear in both specialised digital health journals and broader multidisciplinary outlets. This dispersion reflects the diverse contexts in which DHI are developed and applied but also contributes to variability in study designs, outcome measures, and evaluation approaches. Together, these patterns highlight both the expanding relevance of EE for DHI and the absence of a consolidated methodological core.

Country- and organisation-level analyses show that research output and citation impact are concentrated in a small number of high-income settings. The USA and England lead in both publication volume and citations, with additional contributions from Australia, Canada, and several European countries. The USA, which leads in publication volume, has the highest per capita healthcare spending and the largest share of GDP devoted to healthcare worldwide and operates a mixed public–private healthcare system supported by a strong biotechnology sector and internationally recognised universities (e.g., Stanford University and Harvard University). England likewise demonstrates a well-established academic and institutional infrastructure for health economics, including leading universities and organisations such as the London School of Economics, the University of York, and NICE, which provides extensive guidance for the evaluation of medical technologies, diagnostics, pharmaceuticals, and DHI (NICE, 2022). Australia and Canada, both early adopters of national HTA guidelines (Sharma et al., 2021), further illustrate the association between formal evaluation frameworks and research activity.

At the organisational level, influential research is concentrated within a limited number of institutions, with English universities accounting for half of the ten most cited organisations. The predominantly national collaboration patterns observed suggest that EE research on DHI remains closely embedded within country-specific academic and policy environments, reinforcing the link between healthcare expenditure levels, research capacity, and the presence of established HTA and EE infrastructures. The prominence of England, in particular, aligns with the role of NICE in developing and disseminating formal guidance for the EE of healthcare technologies, including DHI.

Journal-level findings provide additional insight into the evolution of the EE of DHI literature. Historically, EE of DHI has been concentrated in specialist journals focused on telemedicine and digital health, such as the Journal of Telemedicine and Telecare, Telemedicine and e-Health, and the Journal of Medical Internet Research. More recently, EE-related studies have increasingly appeared in multidisciplinary journals, including BMJ Open and the International Journal of Environmental Research and Public Health. This shift reflects the broader integration of DHI across healthcare settings and policy domains while also underscoring the methodological heterogeneity of the evidence base.

The most influential publications primarily address the effectiveness of different types of DHI across different clinical areas, including chronic disease management, mental health, and wellbeing (Black et al., 2011; Ekeland et al., 2010; Gatchel et al., 2014; Hilty et al., 2013; Hollis et al., 2017; Wootton, 2012). Across clinical areas, the content analysis results point to structural limitations in the existing evidence base on EE of DHI (Aranda-Jan et al., 2014; Hall et al., 2015; Michie et al., 2017). The repeated emphasis on poor quality, methodological heterogeneity, and inconsistent reporting suggests that EE has not yet been systematically embedded within DHI research. Notably, the dominance of systematic reviews among the most influential publications indicates that the EE of DHI literature is largely characterised by synthesis and critique rather than primary EE. Moreover, the

clustering of influential publications by medical domain further suggests that EE of DHI has evolved in fragmented, condition-specific settings rather than into a coherent methodological field. Together, these patterns highlight persistent challenges related to comparator selection, perspective definition, outcome measurement, and the assessment of long-term costs and benefits—issues that directly limit the usefulness of EE for decision-making. These observations underscore the need for clearer methodological guidance and more consistent application of EE frameworks, which I examine in detail in the following narrative review.

The keyword analysis confirms an uneven and selective integration of EE concepts within the DHI literature. While cost-effectiveness appears relatively frequently (particularly in telemedicine- and telehealth-focused publications), other EE approaches, such as CUA and CBA, are substantially less visible. Notably, EE-related keywords are largely absent from publications using broader terms such as eHealth and digital health. Terminology is also used inconsistently, with cost-effectiveness often employed interchangeably with EE or CBA (Husereau et al., 2014). This may partly explain the dominance of CEA-related terms, given that cost-effectiveness is commonly applied where outcomes can be expressed in natural units and closely aligned with clinical effectiveness. These findings are consistent with prior bibliometric research indicating growing attention to cost-effectiveness in DHI, alongside a continued lack of EE evidence for newer digital technologies, including telemedicine and artificial intelligence (dos Santos Silva et al., 2021; Waqas et al., 2020). Importantly, EE-related keywords cluster predominantly within telemedicine- and telehealth-oriented research and frequently co-occur with chronic disease terms. This pattern suggests that EE is most often applied in settings characterised by recurrent utilisation and longer time horizons, where economic consequences are more readily observable. In this context, the keyword structure reinforces the importance of core EE design choices, particularly perspective, comparator selection, and time horizon, in evaluating DHI for chronic disease management, directly linking these findings to the methodological challenges examined in the following subchapter.

Taken together, the analyses of influential publications and keyword structures reveal a strong and consistent thematic concentration on chronic disease management, mental health, and long-term care. Highly cited studies and dominant keyword clusters centre on telemedicine and related DHI applied to conditions such as HF, COPD, diabetes, stroke, and mental health disorders. Chronic diseases account for approximately 41 million deaths annually, representing 71% of global mortality, and are associated with frequent healthcare utilisation and sustained resource use. This thematic focus aligns with the broader role of DHI in supporting long-term disease management, continuity of care, and self-management, particularly in the context of increased demand for remote care during the COVID-19 pandemic (Goldberg et al., 2022; Seixas et al., 2021). From a health system perspective, this emphasis is highly policy-relevant. Conditions such as HF, which is the focus of later work in this dissertation, generate substantial healthcare expenditure due to repeated

hospitalisations and long-term outpatient management. Chronic disease settings are therefore particularly sensitive to EE design choices, including the selection of appropriate comparators, time horizons, and analytical perspectives capable of capturing downstream costs and benefits.

Despite this thematic concentration, both bibliometric strands point to persistent shortcomings in the evidence base. Influential publications repeatedly highlight limited and heterogeneous economic evidence, methodological weaknesses, and inconsistent reporting of costs and outcomes. At the same time, the scarcity of EE-related keywords beyond cost-effectiveness suggests that alternative evaluation approaches remain underused or insufficiently articulated. Together, these findings indicate that while EE of DHI is gaining visibility, it remains fragmented, methodologically inconsistent, and insufficiently aligned with decision-making needs. This convergence of evidence provides a clear rationale for the narrative review in the following subchapter, which examines in detail the methodological challenges and emerging recommendations for conducting EE of DHI. The prominence of HF-related and other chronic disease keywords within the EE-oriented DHI literature further reinforces the relevance of this dissertation's empirical focus and underscores the need for robust and methodologically sound economic evidence in this domain.

This bibliometric analysis follows established guidelines and applies multiple complementary bibliometric techniques. Nevertheless, the findings are subject to several limitations. These include the restriction to English-language publications, the focus on journal articles and review papers, and the reliance on a single bibliographic database, which may limit coverage of relevant grey literature, conference proceedings, and region-specific research outputs. While these limitations are common to bibliometric research, they are particularly relevant in the context of DHI, where evaluation practices and policy-relevant evidence may be reported outside traditional academic journals. Consequently, bibliometric analysis alone cannot fully capture the methodological depth or practical challenges associated with conducting EE of DHI. To address these limitations and to provide a more detailed and conceptually grounded assessment of how EE of DHI is currently conducted, the following subchapter presents a narrative literature review. This review systematically examines methodological challenges, recurring sources of bias, and emerging recommendations for the design and application of EE frameworks in the context of DHI, thereby directly building on the gaps and patterns identified in the bibliometric analysis.

3.3 Narrative review of methodological challenges and recommendations for the economic evaluation of digital health interventions

In Subchapter 3.2, the bibliometric analysis showed that only a small share of the DHI literature explicitly addresses EE, and the content analysis of influential publications repeatedly highlights methodological weaknesses in existing EE of DHI (e.g., Bergmo, 2015; Michie et al., 2017). Building on these findings, I synthesise the methodological

challenges and emerging recommendations for conducting EE of DHI through a narrative literature review.

Before 2020, the methodological debate on EE of DHI was limited, with only a small number of studies explicitly addressing how intervention complexity and context shaped economic methods (e.g., Husereau et al., 2014; McNamee et al., 2016; Murray et al., 2016; Snoswell et al., 2017; Wildman & Wildman, 2019). Since the COVID-19 pandemic, the rapid expansion of remote care has accelerated both empirical EE work and methodological discussion, including guidance-oriented contributions and evidence syntheses (Gega et al., 2022; Gomes et al., 2022; Huter et al., 2022; Jankovic et al., 2021; Kim & Neumann, 2020; Kolasa & Kozinski, 2020; Wildman & Wildman, 2019). Recent evidence syntheses, for example in secondary stroke prevention (Valenzuela Espinoza et al., 2019), palliative care (Naoum et al., 2021), nursing (Huter et al., 2022), and mental health (Jankovic et al., 2021), consistently report either a lack of economic evidence or low-quality and heterogeneous EE for DHI.

The literature diverges on whether DHI require fundamentally "new" EE methods or a more disciplined application of established approaches. A common position is that core economic principles remain unchanged, but that EE must be adapted to DHI-specific features, such as multi-stakeholder impacts, indirect costs, implementation dynamics, and spillovers, without losing comparability. Where these adaptations are not made transparently, the resulting heterogeneity reduces transferability, weakens synthesis, and increases uncertainty about cost-effectiveness, which can slow the implementation of ICT in healthcare (Aranda-Jan et al., 2014; Hall et al., 2015; Husereau et al., 2014; Jankovic et al., 2021).

A recurring explanation for these problems is the limited availability of detailed, DHI-specific methodological guidance. Existing guidance is often high-level and focused on subsets of DHI (e.g., telemedicine or mHealth), with limited direction on modelling clinical and economic outcomes across contexts (Kolasa & Kozinski, 2020). In response, several organisations have developed or updated frameworks with more explicit relevance to EE of DHI (NICE, 2022; WHO, 2019; Wilkinson et al., 2024).

Accordingly, I proceed in two steps in the remainder of this subchapter. First, I clarify why research questions, context, and intervention complexity are foundational considerations for EE of DHI (Subchapter 3.3.1). Second, I synthesise methodological challenges and pragmatic responses across core EE components (Subchapter 3.3.2), with particular attention to approaches, such as the IIM and CCA, that support transparent and feasible economic appraisal under real-world constraints.

3.3.1 Challenges related to research questions, context, and intervention complexity

A prerequisite for credible EE of DHI is a clear specification of the research question, the decision context, and the intervention under evaluation. Context and intervention

complexity are repeatedly identified as central methodological challenges because they influence all core elements of EE, including comparator selection, perspective, cost identification, outcome measurement, and time horizon (Garrison et al., 2018; Gomes et al., 2022; McNamee et al., 2016; Petticrew et al., 2013; Santos et al., 2026; Veijer et al., 2024; WHO, 2019; Wilkinson et al., 2023). I conceptualise context through four interrelated components: the stakeholders, the intervention itself, the implementation environment, and the intended impact, which together define the decision problem and constrain EE design choices (see Table 9).

Table 9: Contextual components of digital health interventions

Context component	List of factors/elements with brief description
Stakeholders	Decision-makers Users or population to be affected by the intervention
Intervention	Type of intervention Technical components Implementation details Description of usage User involvement
Environment	Country context Health system characteristics Digital environment characteristics
Impact	Main research question Effects intended to be achieved Time horizon to achieve the effects intended

Source: Author's work, partially adopted from Wilkinson et al. (2023)

Unlike many conventional healthcare interventions evaluated at a fixed point in time, DHI typically evolve across their life cycle, from development and pilot implementation to scaling and routine use. Changes in functionality, uptake, training requirements, and maintenance imply that both costs and effects vary over time. EE should therefore be explicitly aligned with the stage of the DHI life cycle and the specific implementation setting, including anticipated updates and changes in utilisation. Transparent reporting of these contextual features improves interpretability and transferability, allowing researchers and decision-makers to assess which elements are likely to change when an evaluation is applied in another setting and to identify both intended and unintended consequences, including spillover effects.

Stakeholders form a core contextual component and include both decision-makers and users. Decision-makers are particularly influential because they define the decision problem and determine key EE design choices, most notably the analytical perspective and the scope of relevant costs and consequences (Wilkinson et al., 2023). Depending on the setting, decision-makers may include governments, ministries, healthcare organisations, payers, or private investors, each of which may prioritise different outcomes and cost categories. Users represent the population affected by the DHI and may include patients, healthcare professionals, healthcare organisations, or the wider population. User involvement is central

to EE, as training, adoption, and long-term adherence shape both costs and realised benefits. In addition, DHI frequently generate spillover effects that extend beyond direct users, further broadening the set of stakeholders whose costs and consequences may need to be considered (Gega et al., 2022; Wilkinson et al., 2023).

The intervention itself must be described in sufficient detail to support interpretation and replication, including the type of DHI, its technical components, implementation and rollout processes, patterns of use, and levels of user engagement. Such detail is necessary to understand how the intervention interacts with the health system and how costs and effects arise (McNamee et al., 2016; Wilkinson et al., 2023). DHI are often characterised by high fixed implementation costs and low marginal costs, commonly described as "one installation with multiple users", and are frequently associated with spillover effects across patient groups and care settings (Gega et al., 2022; Wilkinson et al., 2023).

The environment in which the DHI is implemented constitutes a further contextual component, encompassing the country context, health system characteristics, and the surrounding digital environment. Regulatory frameworks, reimbursement arrangements, organisational capacity, and digital infrastructure all influence implementation costs, uptake, and achievable outcomes. As a result, EE findings for DHI are inherently context-dependent, and failure to describe environmental characteristics limits both comparability across studies and relevance for policy decision-making (Gega et al., 2022; Wilkinson et al., 2023).

Finally, the impact component links the intervention and its context to the research question and intended effects, including the time horizon over which these effects are expected to occur. DHI may generate immediate, delayed, or cumulative effects, affect multiple outcome domains, and produce both health and non-health consequences. Consequences may accrue at individual, organisational, or system levels and often extend over long periods, contributing to outcome complexity that is widely recognised as a major challenge for EE of DHI (Gomes et al., 2022; McNamee et al., 2016; Wilkinson et al., 2024).

Together, explicit specification of stakeholders, intervention characteristics, environment, and impact provides the foundation for addressing intervention complexity within EE. The complexity of DHI means that they usually consist of several interacting components and require a more comprehensive assessment of costs and impacts, including consideration of benefits and costs that are not directly health-related (Bergmo, 2015). Complexity is commonly described across three domains (McNamee et al., 2016; Petticrew et al., 2013): intervention complexity, causal pathway complexity, and outcome complexity.

Intervention complexity reflects interacting components and evolution over time, such as updates, training, user adoption, and long-term adherence (Gomes et al., 2022; McNamee et al., 2016; Petticrew et al., 2013; Wilkinson et al., 2024). Causal pathway complexity reflects how effects evolve from observed outputs to outcomes and impacts, shaped by

confounding factors and context dependence, including behaviour, clinical workflows, and interactions between patients and professionals (McNamee et al., 2016; Petticrew et al., 2013; Wilkinson et al., 2024). Outcome complexity reflects the breadth of health and non-health outcomes, spillovers, externalities, and consequences accruing over time, which may need both disaggregated and aggregated representation.

3.3.2 Methodological challenges and recommendations for economic evaluation

Once context and complexity are specified, core EE components can be defined more consistently, reducing avoidable heterogeneity and improving the credibility of results. The methodological challenges identified in the literature cluster around a common set of design choices, namely comparator choice, timing and time horizon, perspective, identification and valuation of costs and consequences, method selection, and uncertainty.

Comparator selection is particularly consequential for DHI because these interventions are frequently introduced as complements to existing pathways rather than substitutes. In practice, comparisons often involve digitally enabled care (e.g., video consultations) versus traditional in-person pathways, but alternative comparators may include hybrid or stepped-care models, competing DHI, or the absence of intervention (Gomes et al., 2022; Husereau et al., 2014; Huter et al., 2022; Jankovic et al., 2021). Where multiple comparators are plausible but infeasible to include, stakeholder-informed prioritisation has been proposed as a pragmatic approach to improve relevance and transparency (Harst et al., 2020). Nevertheless, limited data, time, and budget constraints mean that DHI are often evaluated against usual care only, which may limit interpretation and the generalisability of results.

Timing and time horizon are challenging because DHI often involve high upfront implementation costs and benefits that accrue over time with scale and repeated use. Evaluations conducted during pilot phases may therefore misrepresent long-run cost structures and effects, especially if uptake is low or workflows are unstable (Husereau et al., 2014). The literature consistently argues that time horizons should be sufficiently long to capture downstream costs and benefits, including diminishing marginal costs as user numbers increase and fixed costs are spread across larger populations (e.g., Gomes et al., 2022).

Perspective and method choice are closely interrelated and should be aligned with the decision-maker and the research question, yet this alignment is often difficult to achieve in the context of DHI. Unlike many conventional health interventions, DHI frequently generate costs and effects beyond the patient and payer, extending to carers, healthcare professionals, healthcare organisations, and, in some cases, other sectors (Bergmo, 2015). As a result, many authors recommend adopting a societal perspective, or at least including it as a complementary analysis, to avoid systematically excluding relevant impacts (e.g., Gomes et al., 2022; Sittimart et al., 2024; Snoswell et al., 2017; Walker et al., 2019). This

recommendation is further reinforced by the prevalence of spillover effects, such as reductions in caregiver burden, changes in professional workflows, improved access to care, and equity-related impacts.

DHI may improve clinical outcomes and reduce relevant costs for patients and payers, for example through fewer hospitalisations, reduced outpatient visits, and lower travel costs (Huter et al., 2022). However, a central methodological challenge is that many important benefits of DHI are non-health in nature, including time savings, workflow reorganisation, access, user experience, and equity effects, which are difficult to measure, value, and compare consistently across studies (Aranda-Jan et al., 2014; Ekeland et al., 2010; Kim & Neumann, 2020; Lakdawalla et al., 2018; Michie et al., 2017). These non-health benefits represent a defining feature of DHI, in contrast to pharmaceuticals or medical devices, and are therefore critical for comprehensive economic assessment (e.g., Gomes et al., 2022). The literature accordingly emphasises careful and transparent outcome selection across clinical, behavioural, technical, and organisational domains, alongside explicit reporting of which impacts are included or excluded (Kolasa & Kozinski, 2020).

Cost measurement poses parallel challenges. Implementation, training, maintenance, software updates, licences, and data management costs often dominate early phases of DHI deployment, while cost structures may change substantially over time as systems mature and scale (McNamee et al., 2016). Failure to account for these dynamic cost profiles risks biased estimates of cost-effectiveness and limits the usefulness of EE for policy and reimbursement decisions.

The features of DHI also shape the choice of EE method. CEA and CUA remain widely used, but are frequently criticised as too narrow when non-health outcomes and multi-stakeholder impacts are material (Garrison et al., 2018; Gomes et al., 2022; Lakdawalla et al., 2018; Snoswell et al., 2017). Because many DHI generate benefits beyond health status, such as time savings, access, workflow reorganisation, and equity effects, methods that restrict consequences to health gains alone may systematically underrepresent their value. CBA is therefore often presented as an appropriate option to capture broader societal value, particularly for population-level prevention, as it allows consequences to be expressed in monetary terms and facilitates policy translation. However, CBA also raises familiar valuation challenges, particularly related to willingness-to-pay and the monetisation of life and health outcomes (Dobrev et al., 2008; Gomes et al., 2022; Snoswell et al., 2017; Stroetmann et al., 2006). CCA is repeatedly proposed for DHI because it presents disaggregated costs and consequences side-by-side, enabling decision-makers to explicitly weigh multiple dimensions of impact, although it does not produce a single summary measure of value for money (Gomes et al., 2022; Snoswell et al., 2017). Consistent with this logic, NICE guidance remains anchored in standard EE principles, recommending CCA when financial commitment is low and CBA when commitment is high (NICE, 2018).

The existing literature identifies several additional challenges in EE of DHI. Uncertainty represents a further pervasive challenge in EE of DHI. Uncertainty is amplified by evolving technologies, context dependence, variable uptake and adherence, changing workflows, and limitations in data availability and quality (Bergmo, 2015; Drummond et al., 2005; Gomes et al., 2022; Jit & Cook, 2024; Kolasa & Kozinski, 2020; McNamee et al., 2016; Snoswell et al., 2017). Structural, parameter, and methodological uncertainty therefore require explicit consideration, particularly where consequences accrue over long time horizons or depend on behavioural change. At the same time, the diversity of outcome measures used across studies further limits comparability and synthesis of results (Hall et al., 2015; McNamee et al., 2016; Wootton, 2012). For this reason, several authors recommend combining aggregated outcomes with disaggregated reporting, supplemented by descriptive consequences where quantification is infeasible, in order to support transparency and interpretation (e.g., Wilkinson et al., 2024).

Taken together, these methodological challenges illustrate why existing EE approaches often struggle to fully capture the value of DHI and motivate the need for a structured synthesis of implications for research and policy. In response to these challenges, recent methodological work increasingly proposes the use of an IIM to structure the broad and heterogeneous impacts of DHI prior to formal EE. The IIM can be applied conceptually or operationally to support subsequent EE, most commonly CCA, which I discuss in the following subchapter (e.g., Benedetto et al., 2023).

3.3.2.1 Impact inventory matrix

The IIM is a structured reporting framework designed to improve transparency and completeness in EE. It is explicitly positioned as a scoping and transparency instrument rather than as a valuation method or decision rule (Kim & Neumann, 2020; Sanders et al., 2016). Its purpose is not to force monetisation, but to ensure that all relevant impacts across stakeholders are explicitly declared, including both health and non-health benefits as well as costs that cannot be quantified or monetised.

The primary function of the IIM is to systematically list cost and consequence categories across sectors, including the healthcare system, patients and families, and wider society. By doing so, it makes analytical perspective choices explicit and prevents silent omissions of non-health impacts such as patient time, informal care, productivity effects, access, or equity-related consequences. The IIM clarifies which elements are included, excluded, or acknowledged but not quantified, thereby strengthening interpretability, comparability, and transparency across studies. These features make the IIM particularly suitable for DHI where non-health impacts are often central but difficult to measure consistently. This need for structured, perspective-explicit reporting was further highlighted during the COVID-19 pandemic, where rapid decision-making and cross-sectoral impacts underscored the

importance of capturing both health and non-health consequences (Kim & Neumann, 2020; Podolsky et al., 2022; Veijer et al., 2024).

Early DHI-specific applications of the IIM organised impacts across dimensions such as accessibility, professional practice or care organisation, quality and safety, and cost (Bongiovanni-Delarozière & Le Goff-Pronost, 2017; Le Goff-Pronost & Sicotte, 2010). Subsequent adaptations expanded this structure to better reflect the patient-centred and societal dimensions of complex interventions such as DHI, resulting in the five-category framework presented in Table 10 (health, healthcare system, user experience, value of data, and cross-sectoral impact) and applied in recent studies (Benedetto et al., 2023; Gomes et al., 2022; Kim & Neumann, 2020; Wilkinson et al., 2023). This framework supports transparent identification of both positive and negative impacts across stakeholder groups and outcome types, and allows qualitative evidence to be incorporated where appropriate, particularly for user experience, which is widely recognised as a fundamental component of DHI impact (Wilkinson et al., 2023). Importantly, it also makes the value of data explicit as a distinct outcome domain and captures cross-sectoral spillovers and equity effects, which may simultaneously improve access for some groups while creating barriers for others with limited digital literacy (Benedetto et al., 2023; Wilkinson et al., 2023).

Table 10: Description of impact inventory matrix components

Component of impact inventory	Description
Health	Natural units, generalized units, and net health benefits that incorporate the opportunity cost of lost health
Healthcare system	Result of intervention implementation, includes direct measurable impacts and longer term predicted process changes or disruption potential
User experience	Impacts on patients, population and health workforce not represented within health or health system impact (e.g., privacy, data, satisfaction)
Value of data	The value represented by the availability of data gathered through the use of the DHI that is not represented in direct impacts on health, health system or user experience
Cross-sectoral impact	Impacts on non-health sector (e.g., in education, organisation)

Source: Adopted from Wilkinson (2023)

In resource-constrained systems, this transparency enables prioritisation and deliberation even when evidence is partial, thereby reducing barriers to the institutionalisation of HTA. The IIM is particularly well suited to decision-making environments characterised by limited analytical capacity, incomplete data, or uncertainty regarding the appropriate evaluative perspective, where confusion between payer, provider, and societal perspectives is common. By requiring explicit inclusion and exclusion decisions, even where quantification is infeasible, the IIM functions as a perspective transparency and completeness checklist rather than as a data-intensive modelling requirement.

In empirical research, the IIM is most often used as a supplementary reporting table accompanying CEA or CUA, particularly where societal impacts are relevant (e.g.,

McQueen & Slejko, 2021). In policy and HTA-adjacent settings, its role is predominantly infrastructural rather than evaluative (e.g., Institute for Clinical and Economic Review, 2025). Across these contexts, the IIM functions as a shared analytical language across economists, clinicians, and policymakers.

In practical terms, the IIM serves three core functions:

1. perspective transparency, by making the analytical viewpoint explicit;
2. completeness checking, by systematically identifying all relevant impact categories; and
3. clarification of inclusion and exclusion decisions, including explicit justification where impacts are omitted or not quantified.

By forcing explicit acknowledgement rather than monetisation, the IIM disciplines decision-making processes and requires institutions to articulate what they value, such as patient time, access, or equity, rather than allowing such considerations to remain implicit or politically invisible. For DHI characterised by multidimensional and partially non-quantifiable impacts, this transparency is critical for the legitimacy and trustworthiness of HTA decisions.

The IIM functions as a preparatory and structuring instrument. It can be applied in HTA conceptually or operationally to inform subsequent EE, most commonly CCA, by clarifying which costs and consequences are relevant and how they should be measured. In the following subchapter, I focus on CCA as an evaluative approach that operationalises the structure provided by the IIM (Benedetto et al., 2023).

3.3.2.2 Cost-consequence analysis

Building on its role outlined in Subchapter 3.1, CCA is particularly relevant in contexts where interventions generate heterogeneous effects that cannot be meaningfully reduced to a single outcome measure. Rather than producing a decision rule, CCA supports deliberation by presenting costs and multiple consequences side-by-side, enabling decision-makers to explicitly consider trade-offs across clinical, organisational, and system-level domains (Drummond et al., 2005). This feature makes CCA especially appropriate for public health, service delivery, and system-level interventions, where value extends beyond health gain alone.

CCA is especially well suited to the evaluation of DHI, where impacts are multidimensional and often extend beyond traditional health consequences. In this context, CCA enables joint presentation of healthcare costs, utilisation changes, clinical outcomes, and system-level consequences such as shifts in service delivery, staff workload, or resource intensity. Reliance on CUA alone in such settings risks underrepresenting important dimensions of value for money (Gomes et al., 2022; Snoswell et al., 2017). A further advantage of CCA is its relatively modest data and modelling requirements. Outcomes can be reported in natural

units and process measures, such as hospital admissions avoided, waiting time, travel time, or staff time, using administrative and clinical data. This makes CCA particularly attractive in resource-constrained settings, where local utility weights and cost-effectiveness thresholds may be unavailable, modelling capacity limited, and decisions must balance affordability, access, and feasibility. In such contexts, CCA enables informed decision-making without requiring full preference-based modelling or formal multi-criteria decision analysis.

Within HTA, CCA is positioned as a complementary analytic format rather than an alternative to CEA or CUA (Hartfiel & Edwards, 2019). Its primary role is to support appraisal and deliberation where aggregation risks obscuring important dimensions of value. This framing is explicitly recognised in HTA guidance, including by NICE, which identifies CCA as appropriate when multiple consequences matter or when monetisation or QALY-based aggregation is problematic (NICE, 2018). By presenting consequences transparently in disaggregated form, CCA allows policymakers to weight impacts according to local priorities rather than imposing a fixed valuation structure, which is particularly relevant where willingness-to-pay thresholds are uncertain, contested, or absent.

In practice, CCA is commonly used as a policy communication and decision-support tool, either alongside formal CEA or CUA or as a stand-alone summary when aggregation is inappropriate. It aligns naturally with programme budgeting, budget impact analysis, service planning, and procurement decisions, making it especially useful for DHI and innovations where scalability and affordability dominate decision criteria. Importantly, CCA does not replace formal economic modelling when required for pricing or reimbursement decisions. Instead, it structures deliberation by making trade-offs explicit and transparent, functioning as a decision dashboard rather than a valuation mechanism.

CCA may operate either as a stand-alone decision-support tool or as a foundation for more aggregated approaches, such as CBA, where appropriate. While aggregated outputs (e.g., ICER or monetised net benefits) facilitate comparison and communication, they may also compress contextual detail and increase the risk of misinterpretation when valuation assumptions are uncertain or contested. Wilkinson et al. (2023), for example, propose a CBA using a return-on-capital framing following an IIM-based structuring step, while explicitly acknowledging the persistent difficulty of valuing life and health outcomes for monetisation. More broadly, there is no consensus on a single EE or HTA framework for DHI, as relevant effects may be lost when diverse outcomes are translated into a single metric, nor is there agreement on which aggregate outcome is most appropriate for decision-making (Benedetto et al., 2023).

3.3.3 Discussion and conclusions

Producing credible EE of DHI is systemically difficult because DHI are complex interventions implemented in heterogeneous contexts and often generate impacts that extend beyond health outcomes alone (Gomes et al., 2022; Petticrew et al., 2013; Walker et al., 2019; Wilkinson et al., 2023). Across the literature, recurring challenges arise from this complexity, including defining appropriate comparators for interventions that complement rather than replace usual care, selecting perspectives that capture multi-stakeholder effects, choosing time horizons that reflect long-term and scale-dependent benefits, and identifying and valuing both health and non-health outcomes. These challenges are compounded by evolving technologies, behavioural responses, and implementation dynamics, meaning that costs and effects are neither static nor confined to a single setting or stakeholder group. As a result, conventional EE approaches developed for pharmaceuticals or medical devices often struggle to fully represent the value generated by DHI (Gomes et al., 2022; Kolasa & Kozinski, 2020; Snoswell et al., 2017; Wildman & Wildman, 2019).

Despite broad recognition of these challenges, the existing evidence base remains heterogeneous and difficult to synthesise. A central reason is the absence of detailed, widely adopted methodological guidance tailored to DHI, beyond high-level principles or intervention-specific recommendations (Gomes et al., 2022; Husereau et al., 2014; Jankovic et al., 2021; Kolasa & Kozinski, 2020; Snoswell et al., 2017; Wildman & Wildman, 2019). In practice, standard EE frameworks are applied inconsistently, with limited transparency regarding how context, implementation, and non-health impacts are incorporated. Recent methodological work therefore increasingly emphasises the need for clearer structuring of impacts prior to formal evaluation, recommending broader outcome sets, longer time horizons, explicit treatment of implementation and scale effects, and transparent handling of uncertainty. Tools such as the IIM and CCA are proposed to support this structuring by making costs and consequences visible across stakeholders, while acknowledging that they do not in themselves resolve valuation challenges or substitute for coherent guidance.

Recent methodological work converges on the need to structure impacts explicitly before aggregation, while recognising that no single EE method can fully resolve the challenges posed by DHI. In this context, the IIM functions primarily as a structuring and transparency device, rather than as a valuation method or decision rule. By systematically listing health and non-health impacts across stakeholder groups, it makes analytical perspective and scope explicit and clarifies which elements are included, excluded, or acknowledged but not quantified (Benedetto et al., 2023). Importantly, the IIM does not require full monetisation; instead, it reduces ambiguity and improves interpretability and comparability across assessments.

CCA complements the IIM by preserving disaggregation at the evaluation stage, enabling decision-makers to appraise multiple dimensions of impact where consequences are heterogeneous and valuation is contested (Benedetto et al., 2023; Gomes et al., 2022;

Wilkinson et al., 2023). This is particularly relevant for interventions such as DHI, where value is distributed across clinical outcomes, healthcare utilisation, access, patient time, and organisational processes. By presenting costs and consequences side by side rather than collapsing them into a single metric, CCA supports deliberative appraisal and explicit assessment of trade-offs, consistent with HTA practice in which affordability, feasibility, and service delivery considerations matter alongside health gains.

CCA may operate as a stand-alone decision-support tool or serve as an input to more aggregated approaches, such as CBA, where appropriate (e.g., Wilkinson et al., 2023). However, structuring alone is insufficient. Aggregation remains highly sensitive to valuation assumptions, perspective choice, and time horizon, and there is currently no consensus on a single preferred EE or HTA framework for DHI. This tension between transparency and contextual sensitivity on the one hand, and comparability and decision relevance on the other, emerges as a central challenge in EE of DHI.

This review synthesises methodological challenges and emerging recommendations from a still-developing and fragmented evidence base. While several organisations and research groups have begun to articulate principles, conceptual frameworks, and illustrative approaches relevant to EE of DHI (most notably ISPOR, NICE, and the World Bank; NICE, 2022; Wilkinson et al., 2023, 2024), these contributions primarily reflect exploratory guidance rather than fully developed, standardised methodological frameworks. Existing documents tend to outline challenges, propose structuring tools, or offer high-level recommendations. As a result, guidance remains partial, unevenly adopted, and in many cases still at an early stage of development. This lack of mature standardisation contributes to persistent heterogeneity in study design and quality, limiting transferability, synthesis, and policy uptake, particularly in lower-income European settings where data availability, comparator differences, and limited HTA capacity constrain the application and transfer of advanced HTA methods (e.g., Kaló et al., 2026).

These limitations increase the risk that relevant impacts, particularly non-health outcomes, are omitted or undervalued, and that efficiency results are misinterpreted, reducing dissemination and slowing implementation. Given that EE and HTA are increasingly central to reimbursement, investment, and scaling decisions for DHI, clearer methodological guidance and stronger reporting standards are required. In particular, EE of DHI must move beyond a narrow focus on health outcomes to systematically incorporate organisational, societal, technical, and developmental impacts in order to reflect how DHI create value in practice.

A limitation of this chapter is its reliance on a narrative synthesis of a rapidly evolving literature. Accordingly, in the next subchapter, I summarise the key methodological insights from this review and distil their implications for EE and HTA practice. In particular, this subchapter situates structuring approaches such as the IIM and CCA within policy-relevant decision-making, including their emerging role in European and national HTA systems that

increasingly assess digital and service-level interventions for which traditional cost-effectiveness frameworks are insufficient.

3.4 Summary and implications

As digital technologies are increasingly embedded in healthcare delivery, EE becomes central to decisions about adoption, reimbursement, and scaling. For many DHI, evidence of clinical effectiveness alone is insufficient, as decision-makers must also consider affordability, opportunity costs, organisational feasibility, and distributional effects. This chapter therefore focuses on how EE can be applied in a way that remains analytically credible while reflecting the complexity and context dependence that characterise DHI.

This chapter combines a bibliometric analysis with a narrative review of methodological challenges in EE of DHI. The bibliometric analysis shows that, despite rapid growth in digital health research, explicit EE remains a small and uneven component of the evidence base, concentrated mainly in telemedicine research. Influential publications repeatedly highlight limited robustness, heterogeneity, and inconsistent reporting, indicating that the availability of policy-relevant economic evidence lags behind the pace of digital health adoption. The narrative review complements these findings by clarifying why these limitations persist. DHI are complex interventions that are heterogeneous in design and implementation, evolve over time, and generate impacts that extend beyond health outcomes across diverse contexts. Credible EE therefore requires explicit consideration of context and intervention complexity to inform core design choices that pose challenges to EE of DHI, including comparator selection, time horizon, analytical perspective, and the identification of costs and consequences, as well as the handling of uncertainty, together with the need for improved reporting standards to enhance comparability and synthesis. This chapter further highlights the limited availability of concrete, standardised guidance for conducting and reporting EE of DHI, as existing frameworks and recommendations remain unevenly adopted and are often still under development.

Across the reviewed literature, several general methodological recommendations recur, including clearer specification of intervention context and complexity, explicit perspective definition, systematic identification of costs and consequences across stakeholders, and proportionate handling of uncertainty. Building on these general recommendations, I emphasise the value of structured approaches that make complexity and context explicit rather than obscuring them through premature aggregation. In this respect, the IIM and CCA are positioned as complementary tools that operationalise transparency and feasibility.

The IIM is proposed as a tool to explicitly and systematically identify and organise all potential impacts of DHI from a societal perspective, across stakeholders and outcome domains, including both health and non-health effects, user experience, and the value of data. The IIM also accommodates impacts that are relevant but not readily quantified,

alongside descriptive results, thereby providing a clear foundation for subsequent EE. CCA builds on the IIM structure by preserving disaggregation and allowing decision-makers to explicitly judge trade-offs across costs and consequences, presenting results transparently without collapsing them into a single summary metric. Where appropriate, this structured approach can be extended towards more aggregated methods, such as CBA, while recognising the sensitivity of results to data availability, valuation assumptions, and perspective choice.

Based on the synthesis I present in this chapter, I propose a five-step conceptual framework for EE of DHI, providing a structured way to apply EE more consistently to complex DHI:

1. Detailed specification of context and intervention complexity,
2. Transparent definition of EE characteristics,
3. Development of an IIM, capturing costs and consequences across stakeholders, including non-health and unquantified elements,
4. Populate a CCA, using the IIM structure to present disaggregated costs and consequences, and
5. Conditional extension to more aggregated EE, where decision context and evidence maturity justify aggregation.

Within this framework, CCA functions as the primary policy communication tool, while the IIM functions as the transparency device that ensures relevant impacts are declared even when they cannot be fully monetised or quantified. Together, IIM and CCA make all relevant costs and consequences explicit across sectors and support deliberative assessment without reliance on a single summary metric. Their combined use provides a practical bridge between methodological guidance and decision-making practice, particularly in constrained contexts where formal modelling capacity and data availability remain limited.

These methodological insights have direct implications for HTA and policy at both European and national levels. Current EU HTA arrangements increasingly coordinate clinical evidence, while EE, budget impact analysis, and reimbursement decisions remain nationally determined and context-specific (EU HTA Regulation 2021/2282; European Parliament, 2021b). As a result, decisions must be made under local budget constraints, service configurations, and heterogeneous care pathways. This reinforces the need for nationally feasible EE approaches, particularly for DHI, where multi-domain effects and context dependence limit the usefulness of fully standardised models of EE. Although interpretation of multi-dimensional results requires analytical capacity and careful presentation, IIM and CCA offer a pragmatic, evidence-informed, context-sensitive, transparent, and flexible decision-support framework that aligns with multi-objective health policy under resource and budget constraints.

Recent European initiatives addressing digital health further reinforce this direction. Earlier European collaboration through EUnetHTA explicitly recognised economic, organisational,

and patient dimensions as integral components of HTA, even though the current regulatory focus is primarily on clinical assessment (Kristensen et al., 2017; Schuster, 2024). This legacy supports a multi-domain conception of value and legitimises structured and transparent economic reporting at national level. The ongoing EDiHTA project, which is developing a Europe-oriented HTA framework tailored to digital health technologies and plans an open piloting phase in 2026, starts from the premise that conventional HTA and single-metric economic models often struggle to capture DHI value across contexts, perspectives, and stages of maturity (Tsiasiotis et al., 2025). Its emphasis on flexibility, multiple stakeholders, and staged evidence development aligns closely with the use of IIM and CCA as proportionate economic tools. The ongoing ASSESS-DHT project further reinforces the relevance of staged and proportionate evidence generation in digital health, highlighting the limitations of applying standard HTA and CUA approaches to early-stage and context-dependent DHI (ASSESS DHT, n.d.). Its emphasis on transparent scoping, consideration of broad outcome domains, and decision-facing evidence generation is conceptually aligned with the use of the IIM and CCA as pragmatic tools for HTA under uncertainty.

In parallel, the European Health Data Space (hereinafter EHDS) is expected to improve the conditions for EE over time, by strengthening real-world evidence for utilisation and outcomes, improving equity stratification, enhancing cross-country comparability of parameters, and enabling better linkage of datasets for budget impact and longer-term modelling (European Commission, 2022). This logic is particularly policy-relevant for Slovenia, which introduced HTA in 2025, as discussed in Chapter 2.3. As EU-level clinical assessments become available, Slovenia can draw on shared evidence while continuing to rely on national EE for reimbursement and service decisions.

During institutional development, building HTA capacity does not require immediate full-scale model-based CUA for every technology; instead, the IIM and CCA offer low-barrier, transparent methods that can be progressively upgraded as data infrastructure and analytical capacity strengthen. In practical terms, the IIM can be adopted rapidly as a standard reporting template that makes explicit which costs and consequences are included, excluded, or acknowledged but not quantified under payer, provider, and societal perspectives. This improves perspective discipline and prevents silent omissions at an early stage of HTA development. CCA then operationalises this scoping logic as a default decision-facing format for complex interventions, presenting costs and multiple consequences in parallel and supporting appraisal committees in weighing trade-offs and budget implications. Where decision stakes are higher or pricing negotiations require aggregation, this structured evidence base can be selectively extended to targeted CEA or CUA without requiring full model-based evaluation for every DHI.

In the remainder of this doctoral dissertation, I focus on the EE of teleconsultations for patients with HF in Slovenia. The next chapter therefore introduces HF as a clinical context,

reviews the existing economic evidence on teleconsultations in HF, and synthesises prior research approaches and findings to inform the empirical analyses that follow.

4 ECONOMIC EVALUATION OF TELEMEDICINE INTERVENTIONS FOR HEART FAILURE PATIENTS: A SYSTEMATIC REVIEW

In the previous chapters, I establish the conceptual, methodological, and policy foundations for the EE of DHI. Building on this foundation, this chapter narrows the focus to HF, which constitutes the empirical disease context of this dissertation. I provide a systematic review of EE of telemedicine interventions that include teleconsultations for patients with HF, as teleconsultations represent the specific intervention that I analyse statistically and assess economically in the subsequent empirical chapters.

Accordingly, this chapter contributes to the dissertation by situating HF teleconsultations within the existing EE evidence base and by identifying prevailing methodological choices, gaps, and limitations. In doing so, it addresses the following research questions:

RQ1: *"What is the current state of research related to EE of DHI and, more specifically, telemedicine, globally and in Slovenia?",* and

RQ3: *"How should the EE of telemedicine interventions be approached in the case of HF?"*

In Subchapter 4.1, I present the clinical background necessary to justify the selection of outcomes, covariates, and classifications applied in the empirical analyses in Chapter 6. I briefly describe HF diagnosis, treatment, and management, including relevant comorbidities and pharmaceuticals that influence disease severity and healthcare utilisation. The discussion is based on the European Society of Cardiology 2021 Guidelines for the Diagnosis and Management of Acute and Chronic Heart Failure (McDonagh et al., 2021).

In Subchapter 4.2, I present a systematic literature review of EE studies of telemedicine interventions involving teleconsultations for patients with HF, focusing on economic and clinical outcomes, study design, comparators, time horizons, and cost perspectives. The purpose of the review is not only descriptive but also methodological: to inform the empirical and analytical choices made in the remainder of the dissertation, consistent with the challenges discussed in Chapter 3.

4.1 Clinical background and management of heart failure

HF affects more than 64 million people worldwide and is associated with high rates of hospitalisation, mortality, and healthcare costs, particularly in older adults with comorbidities (WHO, 2019). HF accounts for approximately 1–2% of total healthcare

expenditure and is a leading cause of unplanned hospitalisation among older adults, with high mortality and rehospitalisation rates (e.g., Díez-Villanueva et al., 2021). Its substantial and widely distributed economic burden, exceeding $284 billion globally in 2021, underscores the need for robust EE to inform prioritisation and resource allocation, particularly as HF prevalence rises sharply with age and drives long-term healthcare utilisation (Darvish et al., 2025; Hessel, 2021; Shahim et al., 2023). Demographic analysis for Slovenia shows that gains in life expectancy have been driven primarily by reductions in mortality from cardiovascular diseases at older ages (Lotrič Dolinar et al., 2017). This pattern highlights the central contribution of cardiovascular conditions to national health outcomes and strengthens the policy rationale for examining HF as a major chronic manifestation of cardiovascular disease within the Slovenian healthcare context.

According to the 2021 European Society of Cardiology Guidelines, HF is defined as a clinical syndrome characterised by typical symptoms and signs resulting from structural and/or functional cardiac abnormalities (McDonagh et al., 2021). Clinically, HF is commonly classified into chronic and acute forms, with acute decompensation often leading to unplanned hospitalisation. HF is categorised into three phenotypes based on left ventricular ejection fraction: HF with preserved, mildly reduced, and reduced ejection fraction (McDonagh et al., 2021). While phenotype-specific treatment is clinically relevant, administrative data do not systematically distinguish between these phenotypes, which has important implications for empirical research based on healthcare utilisation data. At the population level, however, HF phenotypes are approximately evenly distributed, with around half of patients presenting with reduced ejection fraction and the remainder with preserved or mildly reduced ejection fraction (McDonagh et al., 2021).

In Slovenia, HF is recorded using the International Statistical Classification of Diseases and Related Health Problems (hereinafter ICD), 10th Revision, Australian Modification (ICD-10-AM, version 6). HF coding does not differentiate between phenotypes and is limited to a small number of diagnostic categories:

- I50 Heart failure,
- I50.0 Congestive heart failure,
- I50.1 Left ventricular failure, and
- I50.9 Heart failure, unspecified (National Institute of Public Health, 2021a).

In the absence of phenotype information, disease severity and quality of care must therefore be inferred indirectly, which motivates the use of comorbidity profiles, patterns of healthcare utilisation, and pharmacotherapy as analytical proxies in Chapter 6.

HF rarely occurs in isolation. Cardiovascular and non-cardiovascular comorbidities substantially influence disease progression, treatment decisions, healthcare utilisation, and outcomes. For empirical purposes, comorbidities serve as indicators of patient complexity and baseline risk, particularly in analyses relying on administrative data. Cardiovascular

comorbidities were grouped into clinically relevant categories (e.g., arrhythmias, atrial fibrillation, coronary syndromes, valvular disease, hypertension, and stroke), while non-cardiovascular comorbidities included conditions such as diabetes, renal dysfunction, anaemia, pulmonary disease, depression, and cancer, consistent with European Society of Cardiology guidance (McDonagh et al., 2021). Detailed ICD-10-AM codes for all comorbidity groups are reported in Appendix 3, and the classification was reviewed by a specialised cardiologist to ensure clinical validity.

Pharmacotherapy represents a central component of HF management, aiming to reduce mortality, prevent rehospitalisation, and improve patients' QOL. Treatment recommendations vary by HF phenotype, with disease-modifying therapies established primarily for HF with reduced ejection fraction, while HF with preserved ejection fraction management focuses on symptom control and the management of comorbidities. In this dissertation, I use pharmacotherapy analytically to characterise treatment intensity and adherence to guidelines, rather than to assess clinical effectiveness per se. Pharmaceuticals were identified using the Anatomical Therapeutic Chemical (ATC) classification system (WHO, 2025) and grouped into categories relevant for HF treatment and healthcare cost analysis, including beta-blockers, agents acting on the renin–angiotensin system, namely angiotensin-converting enzyme (hereinafter ACE) inhibitors and angiotensin receptor–neprilysin inhibitors (hereinafter ARNI), mineralocorticoid receptor antagonists (hereinafter MRA), sodium–glucose co-transporter 2 inhibitors (hereinafter SGLT2, namely dapagliflozin and empagliflozin), and diuretics (McDonagh et al., 2021). A full mapping of pharmaceuticals and ATC codes is provided in Appendix 6 (see Table A.1).

Effective HF management extends beyond acute treatment and requires structured follow-up, patient education, and multidisciplinary care. Regular monitoring and timely adjustment of therapy are particularly important in the period following hospital discharge, with follow-up recommended within three to six months after discharge and at intervals of no more than six months thereafter (McDonagh et al., 2021). These follow-up requirements create a clear rationale for telemedicine interventions, and teleconsultations in particular, as substitutes for or complements to in-person outpatient visits. The European Society of Cardiology guidelines explicitly recognise telemedicine as a tool to improve access, continuity of care, treatment adherence, and patient self-management (McDonagh et al., 2021). Telemedicine in HF may take various forms, including teleconsultations, remote monitoring, digital education tools, and hybrid care models (Singhal & Cowie, 2021). This dissertation focuses specifically on teleconsultations, as they represent the most directly comparable alternative to conventional outpatient follow-up and are observable within routine healthcare data.

The following subchapter therefore examines how teleconsultations for patients with HF have been evaluated economically in the existing literature and how these evaluations inform the empirical analyses that follow.

4.2 Systematic literature review of economic evaluations of telemedicine interventions including teleconsultations for heart failure patients

As discussed in Chapter 3, EE of DHI remains uneven in both volume and methodological consistency. Within the narrower domain of telemedicine, these challenges are particularly pronounced, reflecting a wide variation in intervention configurations, cost components, evaluation perspectives, and implementation contexts. Consequently, the evidence base remains weakly standardised and difficult to compare across studies.

Systematic reviews of EE of telemedicine have been published for more than two decades, yet they consistently report a fragmented and heterogeneous evidence base, with limited standardisation in methods, outcomes, and costing approaches (Bergmo, 2009; Dávalos et al., 2009; Mistry, 2012; Polisena et al., 2009; Seto, 2008; Whitten et al., 2002). Early reviews found little robust evidence of cost-effectiveness, while later work identified potential cost savings, most notably through reduced hospitalisations and travel, often offset by substantial upfront investment costs (Polisena et al., 2009; Seto, 2008). Across reviews, evaluations are predominantly conducted from a healthcare-sector perspective, rely on short time horizons, and rarely incorporate indirect or societal costs, limiting comparability and transferability across settings.

More recent systematic reviews continue to highlight declining technology costs and more favourable findings for selected applications, including remote monitoring, mHealth, and HF-related interventions, but report highly context-dependent and inconsistent results across populations and delivery models (Iribarren et al., 2017; Peretz et al., 2018; Sanyal et al., 2018). Reviews focusing on implementation and cost components document substantial variation in equipment, personnel, and service costs, incomplete cost inventories, and limited use of comprehensive EE frameworks (Kidholm & Kristensen, 2018; Michaud et al., 2018; Sülz et al., 2021). While some studies identify broader benefits, such as productivity gains and reduced secondary care use, these outcomes are unevenly captured and rarely integrated into standardised evaluations (Snoswell et al., 2020). Within this heterogeneous literature, chronic disease and cardiovascular applications occupy a central position, with HF frequently highlighted as a condition with high potential for economic benefit from telemedicine due to its burden of hospitalisation and long-term management needs (Peretz et al., 2018; Sülz et al., 2021). However, teleconsultations are commonly embedded within broader telemedicine or remote monitoring models, and published EE vary substantially in perspective, time horizon, outcome selection, and reporting transparency.

Against this background, a focused systematic literature review of EE of telemedicine interventions that explicitly include teleconsultations for patients with HF is required. Such a review provides a structured and transparent basis for identifying relevant studies, extracting methodological characteristics, and synthesising reported economic and health outcomes, thereby supporting comparison with the empirical analyses presented later in this dissertation. Accordingly, I conduct a systematic literature review to identify and synthesise

recent EE evidence on telemedicine interventions that include teleconsultations for patients with HF (Jahan et al., 2016; Munn et al., 2018; Page et al., 2021).

4.2.1 Data collection

In this subchapter, I describe the data collection process for the systematic literature review on EE of teleconsultations in patients with HF, including data sources, search strategy, search query, timeframe, and restrictions (e.g., Jahan et al., 2016).

I searched the WoS CC database and MEDLINE via the Web of Science platform for records on teleconsultations for HF, including telemedicine interventions involving teleconsultations. MEDLINE is the leading biomedical database and a standard source for systematic reviews in health research, while WoS CC provides complementary multidisciplinary coverage that captures relevant literature in health economics, policy, and the social sciences that may fall outside MEDLINE's scope. Combining MEDLINE with a multidisciplinary database is recommended for interdisciplinary fields such as telemedicine to improve search sensitivity and coverage (Ahmadi et al., 2015). Given this interdisciplinary scope, I combined MEDLINE with WoS CC to improve coverage of both clinical and economic evidence.

To identify relevant records, I searched for keywords related to telemedicine, telehealth, eHealth, mHealth, and digital health, and included common prefixes describing remote delivery (tele, video, virtual, remote, home). I then restricted the search to consultation-related terms (consult*, visit*, follow*) to capture heterogeneous descriptions of teleconsultations used in practice. For economic evidence, I followed a broad approach using cost* OR economic* (De Guzman et al., 2022). HF was included as the population term. I then applied the topic search to title, abstract, and keywords. The query included three parts: (1) identification of the type of intervention, (2) identification of studies related to HF, and (3) identification of studies related to EE:

1. ((telemedicine OR telehealth OR eHealth OR e-health OR (digital health) OR mhealth OR m-health) OR (video* OR tele* OR virtual* OR remote* OR home*))
   AND (*consult* OR *visit* OR follow*) AND
2. (heart failure*) AND
3. (cost* OR economic*).

The literature search was restricted to peer-reviewed English-language journal records published between 1 January 2020 and 1 January 2025, reflecting rapidly evolving technology and capturing evidence generated during and after the COVID-19 period (Auener et al., 2021; Mandrik et al., 2021). The initial search returned 1,494,360 results. Narrowing to consultation terms reduced the number to 223,819; restricting to HF returned 3,139 articles; and applying economic keywords returned 413 articles. I removed duplicate

entries using Mendeley (Mendeley, n.d.). These 413 records are included in the in-depth screening workflow described in Subchapter 4.2.2.

4.2.2 Methodology

In the previous subchapter, I described how the initial set of 413 records was identified. In this subchapter, I describe the screening workflow and eligibility assessment, following Jahan et al. (2016). I use the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (hereinafter PRISMA) 2020 statement (Page et al., 2021) as a guide for conducting the systematic literature review, and the screening workflow is summarised using a PRISMA flow diagram.

The intervention of interest was teleconsultation, defined as a synchronous telemedicine intervention delivered by telephone or video, with usual care (in-person consultations) as the comparator. Synonyms such as video consultation, virtual clinic, remote consultation, and virtual consultation were also considered where teleconsultations were embedded within broader telemedicine models. Articles focusing exclusively on telemonitoring without teleconsultations were excluded, but articles in which it was not clear whether teleconsultations were included were reviewed.

Eligible studies were required to:

- include patients with HF,
- include teleconsultations (as the main intervention or a clearly identifiable component), and
- report some form of EE or cost analysis (e.g., CUA, CEA, CBA).

No additional eligibility criteria were applied with respect to study design, effect direction, or EE conclusions. The reasons for excluding records were therefore:

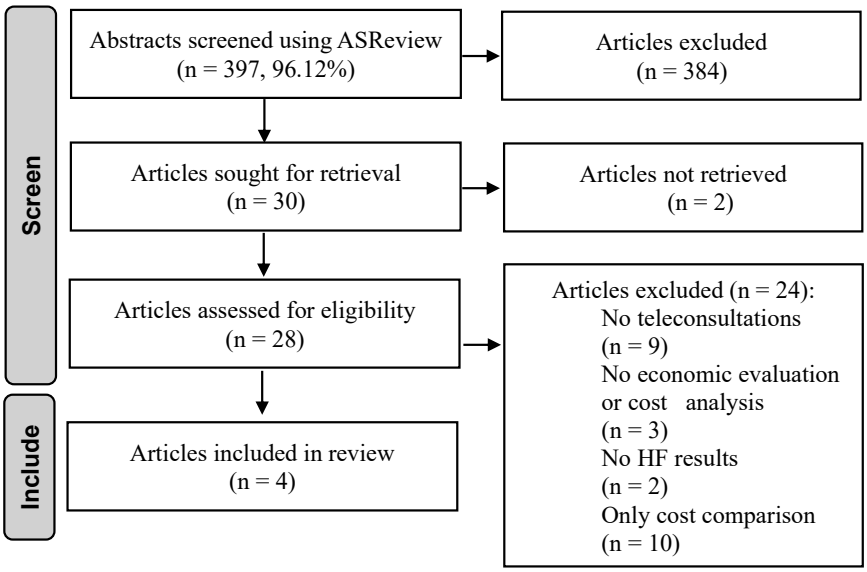
- no teleconsultation or intervention including teleconsultations,
- no HF disease,
- no cost analysis or EE, and
- literature reviews, protocols, study designs, or similar types of articles.

To screen the 413 records, I used a machine learning tool for systematic reviews (Active Learning for Systematic Reviews, hereinafter ASReview). ASReview is an open-source AI tool that uses active machine learning to prioritise articles for screening in systematic reviews based on selected preferences to reduce workload without compromising accuracy and supports multiple algorithms and benchmarks to ensure reproducibility (van de Schoot et al., 2021). I imported 413 RIS records (title, abstract, keywords, authors, journal, year) and used the ELAS Heavy model. I selected ELAS Heavy because the topic combines heterogeneous clinical and economic terminology (telemedicine, teleconsultation, HF, and

EE), and this model is designed to prioritise semantic relevance beyond simple keyword matching, which is advantageous in complex, multidisciplinary reviews (van de Schoot et al., 2020, 2021). The model was initiated using 15 clearly irrelevant and 8 clearly relevant records. In active-learning reviews, screening can be stopped based on predefined, data-driven criteria, most commonly a sustained sequence of consecutively irrelevant records and/or a high proportion of the total corpus screened, both of which indicate saturation and a low likelihood of identifying additional relevant studies (e.g., Boetje & van de Schoot, 2024; Campos et al., 2024; van de Schoot et al., 2021). I continued screening until saturation was reached and stopped after 397 records (96.12%) were screened, following 171 irrelevant records in a row. In total, 30 records were retained for full-text retrieval, and I identified one additional record through screening.

Of the 30 records retained, 28 full texts were retrieved, while two could not be accessed. Based on full-text assessment, 24 records were excluded because they did not explicitly include teleconsultations (9), did not report EE or cost analysis (3), reported only cost comparisons between groups (10), or did not report HF-specific results (2). One additional record was identified during screening. My supervisor reviewed 25% of the considered studies prior to the final inclusion decision, and uncertainties were resolved through discussion, consistent with Mandrik et al. (2021). Figure 13 presents the PRISMA flow diagram. Four studies met all inclusion criteria and were included in the synthesis.

Figure 13: Preferred reporting items for systematic reviews and meta-analyses 2020 flow diagram of study selection for the systematic review



Source: Author's work, adopted from Page et al. (2021)

4.2.3 Results

This subchapter presents the results of the systematic literature review of EE of telemedicine interventions that include teleconsultations for patients with HF. The findings are synthesised across the four included studies and complemented by structured study-level information presented in Tables 11–14. Overall, the included studies consistently report that teleconsultations, when embedded within broader telemedicine or integrated care models, are economically favourable compared with usual care, with stable or improved QOL and reductions in hospital utilisation (de Graaf et al., 2024; Pirhonen et al., 2020; Rasoul et al., 2025; Ziegler et al., 2023). However, these findings are derived from heterogeneous study designs and are subject to important methodological limitations, particularly short time horizons and restricted cost perspectives.

The included studies were conducted in diverse European settings, including the Netherlands, Germany, France, Sweden, and the UK, and differed substantially in design, scale, and patient populations (see Table 11). Two studies evaluated telemonitoring programmes that incorporated regular teleconsultations as part of structured follow-up care (de Graaf et al., 2024; Ziegler et al., 2023). One study examined a person-centred care model in which teleconsultations supplemented usual care through guided therapy and symptom management (Pirhonen et al., 2020). Another study evaluated a virtual ward model providing acute HF care at home, combining telemonitoring with diagnostic support, treatment, and daily nurse-led teleconsultations (Rasoul et al., 2025). The intensity and format of teleconsultations varied across studies, with reported consultation durations ranging from short telephone follow-ups to longer encounters such as home visits, reflecting differences in clinical objectives and care pathways. Rasoul et al. (2025) reported consultations lasting 45 minutes for home visits and 10 minutes for teleconsultations, while de Graaf et al. (2024) assumed a 15-minute duration per teleconsultation. In Pirhonen et al. (2020), patients received an average of three telephone calls over a six-month follow-up period.

Study size and design also varied markedly. Ziegler et al. (2023) reported a large randomised controlled trial (hereinafter RCT) with more than 400 patients per arm, while Pirhonen et al. (2020) conducted a smaller RCT involving approximately 100 patients per group. De Graaf et al. (2024) analysed smaller cohorts across three countries, and Rasoul et al. (2025) employed a matched cohort design in a UK virtual ward setting. Patient populations differed accordingly: while all studies included patients with HF, some focused on specific subgroups, such as patients with implantable defibrillators, or included additional chronic conditions such as chronic obstructive pulmonary disease. These contextual and design differences are reflected in substantial variation in reported outcomes and cost structures, driven by heterogeneity in national settings, clinical workflows, data collection, and teleconsultation delivery (e.g., routine versus alert-triggered, professional-led). Variation in sample size further influenced cost-effectiveness, as larger cohorts allowed fixed programme costs to be spread across more patients.

Table 11: Characteristics of the included economic evaluation studies

Author, year	Country	Study design	Number of patients	Data collected	Data year	Intervention description
de Graaf et al., 2024	Netherlands; Germany; France	Matched cohort	Intervention n=79; Control n=80	Healthcare utilisation, QALY, costs, length of stay, demographic data, disease severity, pharmaceutical use, selected comorbidities	2021 – 2022	Telemonitoring with integrated teleconsultations and nurse-led support in chronic HF patients
Pirhonen et al., 2020	Sweden	Matched cohort (PSM 1:10)	Intervention n=103; Control n=118	Healthcare utilisation, QALY, demographic data, pharmaceutical costs, mortality	2015 – 2016	Person-centred care model including teleconsultations for HF and COPD patients
Rasoul et al., 2025	UK	Matched cohort (PSM 1:1)	Total n=648	Healthcare utilisation and costs, length of stay, primary diagnosis	2022 – 2023	Virtual ward model with daily nurse-led teleconsultations
Ziegler et al., 2023	Germany	RCT	Intervention n=463; Control n=460	Patient demographics, primary diagnosis, selected comorbidities, QOL, QALY, healthcare costs, pharmaceuticals, length of stay	2017 – 2019	Integrated care model combining telemonitoring, teleconsultations, and guideline-based therapy

Source: Author's work

Table 12: Characteristics of the included economic evaluations

Author, year	EE Method	Comparator	Perspective	Time Horizon	ICER / Threshold	Final Result
de Graaf et al., 2024	CUA	Usual care	Healthcare system	1 year	< €20,000 per QALY	Cost-effective; potentially cost-saving
Pirhonen et al., 2020	CUA	Usual care	Healthcare system	6 months	500,000 SEK/QALY	Dominant; probability of cost-effectiveness 93%
Rasoul et al., 2025	CBA	Usual care	Healthcare system	30 days (extrapolated to 1 year)	Not reported	Cost-saving; positive net monetary benefit
Ziegler et al., 2023	CUA	Usual care	Payer	1 year	€10,652 per QALY (at 2,000 patients)	Cost-effective; probability of cost-effectiveness 97.5%

Source: Author's work

Table 13: Cost categories considered in the included economic evaluations

Author, Year	Direct	Indirect	Capital	Operational
de Graaf et al., 2024	Visit costs (outpatient, teleconsultations, ED visits), intensive care and ward stays, ambulance transport	Travel time, informal care	Equipment	Staff time, monitoring
Pirhonen et al., 2020	Primary care visit, specialist outpatient visit, inpatient care, pharmaceuticals	Productivity and household costs (acknowledged but not quantified)	Not reported (no new infrastructure required)	Nurse follow-up calls, education
Rasoul et al., 2025	Home visits, outpatient visits, teleconsultations, ED visits, prescriptions, hospital admissions	Not reported	Platform setup, remote monitoring equipment, patient setup	Staff time, management, maintenance, licencing, administration, ongoing education, staff travel
Ziegler et al., 2023	Hospitalisations, specialist visits, pharmaceuticals	Not reported	Programme and device costs, software	Training of nurses and cardiologists, annual infrastructure

Source: Author's work

Table 14: Summary of health-related effectiveness and economic outcomes in the included economic evaluation studies

Author, Year	Health-related effectiveness of intervention	Economic outcomes of intervention
de Graaf et al., 2024	Reduced length of stay, admissions, and unscheduled visits; mixed QALY effects (–0.003 to 0.086)	Telemonitoring with teleconsultations was cost-effective; −€1,041 (Netherlands) and −€2,865 (Germany); reduced travel and ambulance costs
Pirhonen et al., 2020	QALY gain of 0.018	Healthcare cost reduction of −12,434 SEK
Rasoul et al., 2025	Readmissions −50%; fewer ED visits; hospital stay −40%; improved mortality	Incremental net cost benefit of £1135 per patient per episode. Total annual cost: £721 virtual ward vs. £1,857 standard-of-care
Ziegler et al., 2023	Higher QOL; EQ-5D improvement; QALY gain of 0.031	Intervention cost €323 lower per patient/year, cost-effective at willingness-to-pay ~€10,652 per QALY

Source: Author's work

From a methodological perspective, three studies applied CUA using QALY as the primary outcome measure (de Graaf et al., 2024; Pirhonen et al., 2020; Ziegler et al., 2023), while one study conducted a CBA reporting net monetary benefit (Rasoul et al., 2025) (see Table 12). However, all three CUA studies labelled their analyses as CEA, and Rasoul et al. described the evaluation as a comprehensive cost comparison or health economic analysis.

This inconsistency in terminology and methodological labelling directly reflects the conceptual and reporting challenges in EE of DHI discussed in Chapter 3. All studies compare telemedicine interventions involving teleconsultations with usual care. The analytical perspective was predominantly limited to the healthcare system or payer, with only partial inclusion of societal cost components in one study. Time horizons are short, ranging from six to twelve months, except for Rasoul et al. (2025), who extrapolated results from a 30-day observation period to one year.

The scope of costs included in the EE varies substantially across studies (see Table 13). All studies incorporated direct healthcare costs, such as hospitalisations, outpatient visits, and pharmaceuticals. However, only some studies included indirect costs, such as travel time or informal care, and the treatment of capital and operational costs differed widely. Rasoul et al. (2025) provided the most detailed cost breakdown, explicitly distinguishing between fixed and variable programme costs, staff time, training, licensing, and travel. In contrast, other studies acknowledged but did not quantify productivity losses, household costs, or broader societal impacts, limiting comparability across evaluations.

Health outcomes are consistently favourable in the intervention groups. Reported QALY gains ranged from modest but positive effects to mixed results across countries, while monetary outcomes demonstrated reduced hospital utilisation, fewer ED visits, and shorter lengths of stay (see Table 14). Rasoul et al. (2025) did not report QALY but documented substantial reductions in readmissions and hospital days, alongside improved survival and positive net monetary benefits. Across all studies, QOL was either maintained or improved relative to usual care.

Economic results align with these clinical findings. Studies reporting ICERs found values well below commonly applied national thresholds, while one study demonstrated dominance, with lower costs and better outcomes, and another reported a substantial net monetary benefit. Where probabilistic analyses were conducted, the probability of cost-effectiveness exceeded 90%.

Despite these positive findings, the evidence base remains limited. Short time horizons, narrow cost perspectives, and heterogeneity in intervention design and costing approaches constrain the assessment of long-term sustainability and system-wide impacts. These limitations, which are further discussed in Subchapter 4.2.4, highlight the need for more comprehensive and methodologically consistent EE of teleconsultations for HF.

4.2.4 Discussion and conclusions

This systematic literature review synthesises the available evidence on the economic and clinical value of telemedicine interventions involving teleconsultations for patients with HF. Only four studies meet the inclusion criteria, highlighting a substantial evidence gap despite the widespread diffusion of DHI, particularly since the COVID-19 pandemic. This limited evidence base constrains generalisability and reflects the continued underrepresentation of robust EE in telemedicine research.

Across all included studies, teleconsultations integrated within broader telemedicine or care coordination models are associated with improved or stable QOL and reductions in hospital utilisation, and are reported as either cost-effective or cost-saving relative to usual care. These findings are consistent across different European healthcare systems and delivery models, suggesting that teleconsultations can contribute positively to HF management. However, the apparent consistency of results masks substantial contextual and methodological variation.

Context emerges as a central determinant of economic outcomes. Several studies explicitly demonstrate that cost-effectiveness depends on organisational factors such as programme scale, staffing models, and national care pathways. Cost savings are more pronounced in settings where fixed programme costs can be distributed across larger patient populations, and where teleconsultations substitute for, rather than duplicate, existing services. These findings underline that the value of teleconsultations is not intrinsic to the technology itself, but contingent on how and where it is implemented.

Methodologically, most studies rely on CUA using QALY, with one study adopting a CBA framework. While the predominance of favourable results is encouraging, their interpretation is limited by short time horizons and heterogeneous cost inclusion. Time horizons range from six months to one year, with one study extrapolating short-term outcomes, which are unlikely to capture the full trajectory of a chronic condition such as HF. Costing approaches also vary markedly. Some studies include indirect costs such as travel time or informal care, while others provide detailed breakdowns of capital and operational costs, including staff time and training. In contrast, several analyses focus narrowly on direct healthcare costs, acknowledging but not quantifying productivity losses, household costs, or organisational impacts.

Importantly, many studies explicitly identify relevant costs and consequences that remain unmeasured or only partially captured, including programme set-up, staff workload, training requirements, scalability, and organisational change. This recurrent pattern highlights a structural limitation of conventional EE approaches when applied to teleconsultations and implicitly motivates the need for structured frameworks that prioritise transparency and completeness over aggregation. In this respect, the reviewed literature aligns closely with the methodological challenges discussed in Chapter 3. Although QALYs provide a common

outcome metric in several studies, they are insufficient to reflect broader dimensions of value associated with teleconsultations, such as access to care, continuity, patient empowerment, and system-level effects. Equity considerations are largely absent, with limited attention to digital literacy, differential access, or patient subgroups. This omission risks overstating average benefits while obscuring distributional effects that are particularly relevant for digital interventions.

This systematic literature review has several limitations. Its focus on telemedicine interventions that explicitly include teleconsultations for patients with HF may exclude relevant studies in which teleconsultations are embedded but not clearly described. The chosen methodological approach and data collection strategy also shape the evidence base: restricting the search to two bibliographic databases and to peer-reviewed English-language articles published between 2020 and 2025 reflects recent technological developments but limits coverage of earlier studies with longer follow-up and increases the risk of publication bias. All included studies are European and mostly small-scale, which constrains generalisability beyond European health systems and limits transferability to Slovenia and other resource-constrained settings. In addition, the synthesis is constrained by reporting practices, as several studies acknowledge relevant costs and consequences, such as organisational change, staff workload, patient time, or equity effects, without quantifying them. Finally, the small number of eligible studies prevents quantitative synthesis and necessitates narrative comparison, reflecting a limited and still developing evidence base rather than a weakness of the review method.

Overall, the review suggests that teleconsultations for HF are clinically beneficial and economically promising, but that current evidence remains preliminary. The small number of studies, their European focus, short follow-up periods, and methodological heterogeneity limit both transferability and policy confidence. Taken together, these findings indicate that future EE should prioritise longer time horizons, broader cost perspectives, explicit treatment of scale and organisational effects, and transparent reporting of unquantified impacts. These insights directly inform the evaluative choices adopted in the empirical chapters of this dissertation.

4.3 Summary and implications

This chapter integrates the clinical context of HF with the existing EE evidence on telemedicine interventions involving teleconsultations and establishes the analytical foundation for the empirical chapters that follow. HF is selected as the empirical disease context of this dissertation because it combines high prevalence, substantial healthcare utilisation, and clearly defined follow-up requirements, making it particularly sensitive to changes in care delivery such as teleconsultations. In addition, HF management relies heavily on routine outpatient monitoring and pharmacotherapy that can be observed in

administrative data, enabling real-world evaluation of utilisation patterns, costs, and outcomes.

Subchapter 4.1 introduces HF as the empirical disease context and justifies the diagnostic, comorbidity, and pharmacological classifications applied in Chapter 6, including ICD-10-AM comorbidity groupings and ATC-based pharmaceutical categories. These classifications are not introduced for clinical interpretation per se, but to support outcome selection, covariate construction, and treatment characterisation in analyses based on administrative data. Subchapter 4.2 complements this clinical framing with a systematic literature review of EE of telemedicine interventions that explicitly include teleconsultations for patients with HF.

The systematic review identifies only four eligible studies, all conducted in European healthcare systems and largely at small to medium scale. Despite heterogeneity in study design, sample size, and intervention configuration, all studies report that teleconsultations are clinically beneficial and either cost-effective or cost-saving relative to usual care, with improvements in QOL and reductions in hospital utilisation. At the same time, the evidence base is constrained by short follow-up periods, heterogeneous costing approaches, and limited consideration of societal, organisational, and equity impacts. These features limit comparability and raise important concerns about generalisability, particularly for Slovenia and other resource-constrained health systems where care pathways, data capacity, economies of scale, and reimbursement and organisational arrangements differ from those assumed in published cost-effectiveness studies. International evidence can inform assumptions and parameter choices, but must be interpreted with caution and adapted to local assumptions, with explicit attention to costs and consequences that are excluded or remain not quantified.

Beyond headline cost-effectiveness results, the review provides important methodological insights into how teleconsultations are currently evaluated and where conventional EE approaches struggle. Across studies, authors consistently report descriptive outcomes and contextual information, such as consultation duration, staffing intensity, programme scale, training requirements, organisational change, patient time, access effects, and workload redistribution, while simultaneously acknowledging that many of these elements are not quantified or incorporated into aggregated economic outcomes. This recurring pattern reflects a structural limitation of conventional cost-utility frameworks when applied to complex, service-level digital interventions. Taken together, the reviewed literature therefore implicitly but clearly motivates the use of structured, disaggregated approaches that prioritise transparency and completeness over premature aggregation, such as the IIM and CCA, in which decision-relevant costs and consequences are made explicit even when full quantification or monetisation is not feasible.

Insights from the systematic review directly inform the application of the IIM and CCA in Chapter 7. Evidence reported in the reviewed studies, such as consultation duration, is used

to populate resource inputs in the CCA where national data are not available. Cost categories and consequences that cannot be robustly estimated using administrative data, including organisational change, staff training, patient time, access, and equity effects, are explicitly structured within the IIM rather than omitted. By doing so, the empirical analysis aligns EE with real-world decision constraints and reflects how teleconsultations are implemented and experienced in practice. This approach supports a pragmatic evaluation strategy that is sensitive to data limitations, institutional context, and policy relevance, particularly in smaller and resource-constrained health systems where HTA capacity, data availability, and service organisation differ from the settings assumed in many published studies.

From a policy perspective, the findings suggest that teleconsultations are a promising component of HF care, but that their economic value is inherently context-dependent. Adoption and scaling decisions therefore require careful consideration of programme design, staffing models, and service organisation, rather than reliance on the direct transfer of cost-effectiveness estimates alone. In such settings, the IIM and CCA can function as low-barrier HTA instruments that structure available evidence and support deliberative decision-making, even where full model-based CUA is not feasible.

By integrating clinical context, empirical classification choices, and a targeted synthesis of the EE literature, this chapter provides a coherent bridge between the methodological discussion in Chapter 3 and the empirical analyses in Chapters 6 and 7, supporting an evaluation strategy that is methodologically grounded, context-sensitive, and policy-relevant.

5 FRAMEWORK ANALYSIS OF STAKEHOLDER PERCEPTIONS OF ECONOMIC EVALUATION OF TELEMEDICINE INTERVENTIONS FOR HEART FAILURE PATIENTS

In Chapter 3, I discussed the various methodological and practical challenges in conducting EE of DHI, including telemedicine and teleconsultations. In Subchapter 4.2, I examined how these challenges are reflected in the existing empirical literature through a systematic review of EE of teleconsultations for patients with HF. While these analyses clarify what is currently measured and reported, they reveal less about how teleconsultations are experienced, implemented, and valued in practice.

This chapter therefore turns to primary qualitative evidence. I analyse interviews with stakeholders who are directly involved in, or have substantial expertise in, telemedicine interventions for HF, with a particular focus on teleconsultations. This includes patients and cardiologists engaged in teleconsultations, as well as digital health experts, health managers, medical informaticians, health economists, and researchers. Bringing these perspectives together allows me to examine not only perceived costs and benefits but also contextual

factors (such as organisational conditions, practical constraints, and methodological tensions) that shape the EE of teleconsultations and are not readily captured in administrative data or conventional EE models. Rather than treating EE as a purely technical exercise, the analysis situates it within the realities of clinical practice, service organisation, and patient experience. In doing so, it deepens the understanding of the following research question:

RQ3*: "How should the EE of telemedicine interventions be approached in the case of HF?"*

To address this question, I conducted 20 semi-structured interviews covering teleconsultation practice, perceived costs and benefits, and methodological as well as adoption-related challenges. The diversity of participants was intended to capture variation in experience and priorities across professional and patient groups, rather than to produce a consensus. Furthermore, this qualitative analysis aligns with the IIM, as explained in Subchapter 3.3.2. It enables a structured consideration of health, economic, organisational, societal, and methodological dimensions, including those that are difficult to quantify within conventional EE models. To analyse the data, I use framework analysis, a structured form of thematic analysis suited to applied health and policy research, which allows both deductive and inductive coding.

The structure of this chapter is as follows. In Subchapter 5.1, I situate the study within the broader discussion on the role of qualitative research in informing EE in health economics. In Subchapters 5.2–5.4, I describe the study design, data collection, and analytical procedures. Subchapter 5.5 presents the results of the framework analysis across the identified thematic domains. In Subchapters 5.6 and 5.7, I interpret these findings in relation to the existing literature and derive implications for the further development and application of EE for teleconsultations. The insights generated in this chapter are subsequently incorporated into the CCA in Chapter 7, together with evidence from Chapters 3 and 4, to inform a context-sensitive and practically grounded EE of teleconsultations for patients with HF.

5.1 The role of qualitative research in informing economic evaluation

In this subchapter, I provide an overview of qualitative research in health economics, particularly in relation to informing EE of DHI. Qualitative research addresses questions that differ fundamentally from those of quantitative studies. While quantitative methods measure magnitude, frequency, or distribution, they do not explain how and why phenomena occur (Silverman, 2017). Qualitative approaches instead explore mechanisms, contextual influences, and the conditions under which outcomes emerge, which is particularly relevant for complex interventions such as DHI (Silverman, 2017).

Semi-structured interviews and focus groups are commonly used to capture stakeholder experiences, attitudes, and perceived values (Palinkas et al., 2015). In healthcare decision-making, adoption depends not only on clinical effectiveness or cost-effectiveness, but also

on acceptability, feasibility, and equity. Stakeholder attitudes, ranging from patients and clinicians to managers and policymakers, therefore directly influence whether interventions such as DHI are implemented, sustained, or discontinued. Qualitative research is therefore not merely complementary to quantitative analysis but is central to understanding the processes and dynamics that shape health policy in complex systems such as telemedicine (Palinkas et al., 2015).

Qualitative research can complement EE by examining how economic models are developed, interpreted, and applied in practice (Coast & De Allegri, 2018). In the context of DHI, where implementation is organisationally and technologically complex, qualitative analysis can identify practical and contextual challenges such as limited awareness, insufficient expertise, data constraints, and financing arrangements that shape how EE is used in resource allocation and prioritisation (e.g., Almazrou et al., 2021; Alzarea et al., 2022; Barnett et al., 2020; Eckard et al., 2014; Flight et al., 2020; Grove et al., 2019; Kwon et al., 2021; Liu et al., 2018; Roseboom et al., 2017; van Dongen et al., 2013; Velayati et al., 2021). Qualitative evidence also supports the interpretation of quantitative findings by situating economic results within organisational and social realities (Noyes et al., 2019). For complex DHI, this may include identifying additional costs, unintended consequences, workflow disruptions, or savings that are not captured in routinely collected datasets or fully reflected in published EE (Dopp et al., 2019; Merlo et al., 2019; van Dongen et al., 2013). The relevance of qualitative evidence is also emphasised in the Medical Research Council guidance on complex interventions, including DHI (Skivington et al., 2021), and in NICE guidance recognising stakeholder perspectives in health technology decision-making (NICE, 2018).

Telemedicine, as a complex DHI, has frequently been examined using qualitative approaches, particularly during and after the COVID-19 pandemic. Thomas et al. (2024), for example, combined administrative data with stakeholder interviews to analyse telemedicine uptake and barriers to sustained adoption. Similarly, Kursīte et al. (2022) supplemented administrative data with clinicians' perspectives to explore appropriateness, usability, and sustainability of teleconsultations. These mixed-method approaches illustrate how qualitative insights can clarify and contextualise quantitative findings in complex healthcare systems.

Taken together, this literature supports the use of qualitative methods to inform and contextualise the EE of teleconsultations for HF. In the following subchapters, I apply framework analysis to semi-structured interviews with relevant stakeholders, focusing on dimensions relevant to the EE of teleconsultations for patients with HF that inform the subsequent analytical chapters.

5.2 Study design

In this subchapter, I outline the study design, including the research protocol, the theoretical paradigm, and, briefly, the data collection and methodology, which I discuss in more detail in later subchapters.

A clear research protocol is necessary to structure qualitative inquiry and to ensure transparency and coherence in addressing the research question. The research protocol for health and social science research can be summarised in several phases (e.g., Kaba et al., 2021):

- research topic,
- background and rationale for research,
- aims of the study,
- theoretical and philosophical framework,
- methodology,
- data analysis, and
- ethical considerations.

The research topic, the background, and the rationale are discussed earlier in this chapter. In Subchapter 5.1, I presented the relevant literature to situate qualitative research within health economics and telemedicine research. Within this structure, the present study focuses specifically on telemedicine interventions, which are complex healthcare interventions involving multiple stakeholders, technological diversity, different settings, and a variety of potential health and non-health outcomes. Due to this complexity, I select qualitative research to explore the experiences of stakeholders using or familiar with telemedicine interventions in HF, particularly teleconsultations, to deepen understanding of their implementation, identify omitted or unmeasurable outcomes, and inform methodological approaches to EE.

Another important step in qualitative research is the explicit articulation of the philosophical framework guiding the study. The research paradigm underpinning this analysis is critical realism, which is positioned between positivist and interpretivist traditions (Fletcher, 2016; Wells & Giacco, 2024). While positivism emphasises observable and measurable relationships, and interpretivism focuses on subjective meaning, critical realism seeks to explain underlying mechanisms while acknowledging that knowledge is shaped by context and perspective. Critical realism assumes that observable outcomes are generated by deeper mechanisms operating within specific contexts (Wells & Giacco, 2024), and is therefore suited to analysing complex DHI where measurable outcomes and stakeholder perceptions interact. Critical realism enables the identification of mechanisms, contextual influences, and both observed and unobserved costs and outcomes that may shape the EE of DHI (Sturgiss & Clark, 2020; Wells & Giacco, 2024). For this reason, critical realism provides a

foundation for analysing factors that influence the EE of DHI, including dimensions that are not directly observable in quantitative data.

I conducted semi-structured interviews in this study to capture stakeholder perceptions of key features relevant to EE of telemedicine, including cost and benefit components, methodological and practical challenges, and processes underlying economic outcomes. Contextual factors affecting adoption and scalability were also explored. The literature review informed the development of interview themes and guiding questions. In Subchapter 5.3, I describe the sampling strategy, recruitment procedures, and development of the interview guide in detail. I selected a relevant group of stakeholders with experience of telemedicine interventions for patients with HF through purposive sampling and snowballing. I collected data through interviews conducted via video conference or in person. All participants signed informed consent forms and granted permission for recording, ensuring adherence to ethical standards. I transcribed and anonymised the interviews prior to analysis.

I analyse the data using framework analysis, a structured and systematic form of thematic analysis designed to identify patterns and explanatory themes in qualitative data, as discussed in Subchapter 5.4. I develop codes to organise themes relating to stakeholder experiences and dimensions relevant to the EE of teleconsultations for patients with HF. The findings are presented and interpreted in Subchapters 5.5 and 5.6.

5.3 Data collection

In this subchapter, I describe the data collection process, including the study population, sampling strategy, recruitment procedures, interview guide development, ethical considerations, and summary characteristics of the interviews conducted.

I selected semi-structured interviews as the primary method of data collection, as they allow for a focused but flexible exploration of stakeholder perspectives. The interview guide contained predefined open-ended questions, supported by prompts to deepen discussion while allowing participants to elaborate on issues they considered relevant (DeJonckheere & Vaughn, 2019).

A key concern in qualitative research is sample size and data adequacy. Qualitative studies commonly include between six and 30 participants, depending on the research aim and data saturation (Coast & De Allegri, 2018; Kursīte et al., 2022). In this study, I determined the sample size by relevance to the research question and by theoretical saturation, that is, the stage at which additional interviews generate limited new insights.

Participants comprised four stakeholder groups. Participants were drawn from Slovenia and Croatia, reflecting both local implementation context and broader regional expertise in telemedicine and EE. The first group included cardiologists, and the second included patients

with HF, both directly involved in teleconsultations. The third group consisted of health economists, and the fourth comprised digital health experts (e.g., healthcare managers, medical informaticians, university lecturers, researchers, and decision-makers). I selected these participants to provide insight into dimensions relevant to the EE of teleconsultations for HF, as well as experiences related to implementation, adoption, and development. I used purposive sampling to identify stakeholders with relevant experience (Palinkas et al., 2015). I additionally employed snowball sampling, whereby participants recommended further eligible stakeholders.

I contacted potential participants via research networks and individual email invitations. The recruitment email described the purpose and design of the study, and confidentiality procedures (see Appendix 5.1). I provided interested participants with an informed consent form developed in accordance with WHO guidance for qualitative research (see Appendix 5.2). All participants provided written consent prior to the interview. In the consent form, participants were assured that the data collected would be kept confidential and anonymised.

I developed the interview guide using a standard interview template. The questions were formulated as briefly and simply as possible to avoid unnecessary bias in the data, using neutral terms and easy-to-understand language. Two research colleagues and three stakeholders reviewed the interview guide before the interviews began. I conducted a pilot interview to refine the guide. I shared the interview guide in advance. I informed the participants that preparation is optional and that there are no right or wrong answers. I anonymised transcripts using unique identification numbers (hereinafter ID). The study complies with the requirements of the General Data Protection Regulation (hereinafter GDPR) and does not require additional ethical approval from the Ethics Committee of the School of Economics and Business, University of Ljubljana, as no sensitive personal data are collected. The interview guide (see Appendix 5.3) was structured into six sections: demographic information; telemedicine and comparator; outcomes and benefits; costs; challenges for EE of telemedicine; and broader challenges to telemedicine. These sections reflect contextual, evaluative, and strategic dimensions relevant to the EE of teleconsultations (J. Ritchie & Spencer, 1994).

I conducted interviews between March 2023 and June 2025, primarily via video conference (e.g., Archibald et al., 2019), with several being conducted in person. Most interviews were conducted and recorded using Zoom, while in-person interviews were recorded using a mobile recording application (Easy Voice Recorder Pro). I audio-recorded all interviews with permission. During the interviews, the interview guide served as a framework, but participants were allowed and encouraged to bring up other topics that they felt were relevant to the discussion. I conducted all interviews as a single researcher to ensure consistency. I used an artificial intelligence transcription tool (Cockatoo Inc., 2025) to generate initial transcripts, which I manually reviewed and corrected. I deleted audio recordings after transcription. In total, I conducted 20 interviews. I categorised participants into four groups: cardiologists ($N = 4$), patients with HF ($N = 5$), health economists ($N = 4$), and digital health

experts ($N = 7$). Participants were between 26 and 78 years old (11 male, 9 female), with an average of 14 years of professional experience. Interviews lasted between 17 and 84 minutes (average 42 minutes). Thirteen interviews were conducted via video conference and seven in person. The full dataset comprised 275 pages of transcripts.

The next subchapter describes the analytical procedures applied to these interviews.

5.4 Methodology

In this subchapter, I describe the framework analysis used to examine stakeholder perceptions of the EE of teleconsultations for HF. Framework analysis, originally developed by Ritchie and Spencer (1994), is a structured form of thematic analysis tailored to applied research and is often a recommended approach in multidisciplinary and health-related research, as well as in practice- and policy-oriented research (Srivastava & Thomson, 2009). It allows both deductive and inductive coding and is particularly suitable for research with predefined research questions, conceptual frameworks, or policy relevance. Furthermore, it allows for a systematic and organised interpretation across multiple subgroups. In this study, I apply framework analysis to systematically code and compare perspectives both within and across the four stakeholder groups, ensuring comparability and analytical consistency in relation to the predefined research questions (Srivastava & Thomson, 2009). Given the policy-oriented nature of this research, framework analysis is particularly appropriate for context-sensitive analysis, linking empirical findings to practical implications for EE of complex DHI.

The analytical procedure followed the established stages of framework analysis (J. Ritchie & Spencer, 1994):

1. Familiarisation,
2. Identification of a thematic framework,
3. Indexing or coding,
4. Charting, and
5. Mapping and interpretation.

In the familiarisation phase, I re-read the transcribed data to gain an overview of the material and to identify initial patterns and recurring ideas related to EE and teleconsultation adoption. I recorded notes and memos to capture emerging themes and issues relevant to the research question.

Following familiarisation, I developed the thematic framework. This was an iterative process involving repeated reading of transcripts and refinement of preliminary categories. Themes were organised hierarchically into main themes, subthemes, and codes, representing progressively more specific analytical levels (e.g., patient-related outcomes → clinical events and disease progression → mortality).

I applied both deductive and inductive coding. Deductive codes were informed by prior research, including the systematic literature review on the EE of telemedicine (Subchapter 4.2) and the narrative review of methodological and implementation challenges (Subchapter 3.3). These informed the initial thematic structure, which included outcome categories, cost dimensions, stakeholder-related benefits, and common methodological or implementation challenges. I introduced inductive codes to capture themes emerging directly from the data. For example, several stakeholders highlighted environmental impacts of telemedicine, such as reduced travel and CO_2 emissions, which were not systematically addressed in the reviewed literature.

I refined the framework throughout the analysis to ensure alignment with the research questions and internal consistency. I systematically compared codes and themes across transcripts to identify similarities and differences between stakeholder groups. To increase reliability, my supervisor independently reviewed the coding structure, themes, and selected illustrative extracts.

The indexing and charting stages are distinctive features of framework analysis. In the indexing phase, I linked the interview extracts to codes within the thematic framework. In the charting phase, I organised the coded data into a matrix structured by themes and stakeholder groups. This matrix enabled structured comparison and provided a clear overview of how themes were supported by the interview extracts. The final stage involves mapping and interpretation. I synthesised the themes and subthemes in relation to the research question, with attention to patterns across stakeholder groups.

I present the mapping in a series of tables that provide a schematic overview of the interview extracts, themes, and subthemes. The framework matrix supported comparative analysis between both themes and stakeholder groups. I conduct all the coding and visualisation using MAXQDA 11 and MAXQDA 2024 (VERBI Software, 2011, 2024).

The next subchapter presents the findings structured according to the final thematic framework.

5.5 Results

This subchapter presents the results of the framework analysis.

In total, the framework analysis includes eight themes, comprising five outcome-related themes, one cost-related theme, one methodological theme related to EE, and one theme addressing broader challenges and risks associated with telemedicine. The eight themes comprise a total of 30 subthemes and 76 codes, which I develop through iterative inductive and deductive analysis. I nest all codes within subthemes and group them under overarching themes to capture hierarchical relationships. The complete structure of themes, subthemes, and codes is presented in Table A.2 in Appendix 6.

In each of the subsequent subchapters, I discuss each theme and subtheme in detail, along with the main findings that emerged from the interviews. To illustrate the points made, I include selected extracts from the interviews for each theme and subtheme. After the thematic overview, I discuss the framework analysis results, emphasising how the different stakeholder groups perceive the identified themes.

While interview extracts are organised thematically in the following subchapters, the comparative framework matrix summarising findings by stakeholder group and theme is presented in Table A.3 in Appendix 6. The framework matrix, structured by stakeholder group and main theme, helps to emphasise both general patterns and differences between stakeholder groups.

5.5.1 Health-related clinical outcomes

The first theme, *Health-related clinical outcomes*, summarises stakeholders' views on the impact of teleconsultations on patient health and disease management, particularly in terms of improved continuity of care, safety, and management of both chronic and acute conditions. This theme focuses on patient-level health effects and clinical trajectories rather than system-level resource allocation. Stakeholders emphasis that timely intervention, continuous monitoring, and adherence to treatment regimens, facilitated by teleconsultations and broader telemedicine approaches, are critical for preventing clinical deterioration and improving survival in HF (see Table 15). Stakeholders frequently link clinical effectiveness not to teleconsultations alone but to their integration with remote monitoring systems, suggesting that the perceived impact on early detection and prevention is contingent on broader telemedicine infrastructure rather than isolated video contact.

This theme includes the following subthemes:

- Clinical events and disease progression,
- Management effectiveness, and
- Patient safety and risk reduction.

Common codes within this theme include mortality, morbidity, chronic disease management, and prevention of adverse events (see Table A.2 in Appendix 6).

In the subtheme *Clinical events and disease progression*, stakeholders highlight the potential of teleconsultations to support early detection of health deterioration and complications, enabling proactive disease management and timely treatment adjustments and potentially reducing adverse events or mortality. One digital health expert notes that “saving even a single life through remote access to healthcare” justifies the adoption of telemedicine, particularly when patients would otherwise lack timely access to care. A cardiologist emphasises that teleconsultations allow patients to report warning symptoms (e.g., swelling), which may prompt a timely in-person visit or hospitalisation. Cardiologists and digital health

experts consistently underlined the clinical utility of telemedicine in detecting early signs of deterioration and reducing emergency events. Most stakeholders consider teleconsultations valuable for the management of stable chronic disease but express reservations regarding their use in acute health states, new symptoms, or initial diagnosis. Both patients and cardiologists favour in-person consultations for new or worsening symptoms and emphasise that teleconsultations should not replace physical examination in cases of acute exacerbation.

Under the subtheme *Management effectiveness*, teleconsultations are described as enhancing chronic disease management, particularly when integrated with remote monitoring systems. Stakeholders explained how alert-based interventions facilitate triage, prioritisation of urgent cases, and earlier clinical response. One cardiologist described how medication adjustments triggered by telemedicine alerts may reduce the risk of HF decompensation. Another noted that treatment delays increase hospitalisation rates and mortality risk, whereas telemedicine enables faster intervention. Several stakeholders also highlight administrative efficiencies associated with DHI, such as filtering normal results and flagging abnormalities, which streamline clinical workflows and reduce unnecessary workloads. Patients report that teleconsultations improved convenience and accessibility, allowing more active engagement in chronic disease management. Health economists emphasised potential long-term efficiency gains and prevention-related cost savings, while acknowledging the difficulty of quantifying these effects within conventional EE frameworks.

Within the *Patient safety and risk reduction* subtheme, stakeholders emphasised that teleconsultations reduce exposure to infections by limiting time spent in waiting rooms and hospitals. This was particularly salient during and after the COVID-19 pandemic, especially for elderly and immunocompromised patients. One cardiologist noted that reducing unnecessary specialist visits not only lowers infection risk but also improves QOL. Stakeholders broadly perceived the reduction of avoidable in-person visits as a key safety advantage of remote care models. Patients similarly emphasised convenience due to avoided travel and time spent in waiting rooms, as well as reduced exposure risk, as central benefits.

In summary, stakeholders identified multiple clinical benefits of teleconsultations for patients with HF, including:

- reduced burden of disease,
- improved continuity of care and disease management,
- earlier interventions,
- avoidance of complications and hospitalisation,
- more comfort and convenience through fewer unpleasant visits, and
- reduced risk of infection.

There was broad consensus regarding the value of teleconsultations in the management of stable chronic disease. At the same time, stakeholders consistently stressed that in-person consultation remains necessary for acute, complex, or new symptoms due to diagnostic

limitations. While most stakeholders expressed strong confidence in the clinical value of teleconsultations, several acknowledged that demonstrating long-term mortality reduction would require systematic longitudinal evidence, indicating a distinction between perceived clinical benefit and measurable clinical endpoints. The framework analysis therefore indicates that teleconsultations are not a universal substitute for in-person care, but offer clear clinical benefits within defined patient contexts. The integration of remote monitoring was repeatedly emphasised as central to achieving clinical effectiveness in HF management. These perceived clinical improvements are closely intertwined with patterns of healthcare utilisation discussed in the following subchapter, as earlier detection and proactive management are expected to influence hospital admissions and ED visits.

Table 15: Health-related clinical outcomes theme with interview extracts

Subtheme	**Interview extracts**
Clinical events & disease progression	"A single life saved is enough when you consider the effectiveness of telemedicine." *Health economist* "But in a patient who is in some kind of deterioration, some kind of acute exacerbation of their diseases or with some kind of new symptoms, I think that a clinical examination cannot really be avoided." *Cardiologist* "I am sure that at least some kind of insight can be recognised in patients who are monitored by teleconsultations. If you see that his legs are swollen, if he has HF, then you would invite him for a live examination, and he would be treated in-person." *Cardiologist*
Management effectiveness	"I provide you with a telemonitoring device and you get an alert that something has changed in the patient, and that's a great thing, but at the same time you have to monitor that and everything else from the side." *Cardiologist* "So with digitization you speed up processes, triage, the benefit to the patient increases." *Digital health expert* "…a general practitioner does not have to waste time every day looking at 100 normal findings, which is a waste of time, but the system only notifies him of the one that is not good." *Digital health expert* "In some cases, the waiting time for a specialist examination is months. Compared to an examination that could be carried out via a teleconsultation, the patient may receive medication sooner, which means an improvement in therapy and ultimately improves the patient's survival." *Cardiologist* "The most common reason for an ED visit for HF is decompensation. When I open my remotely monitored patients, I see which of them are green and doing well. I can see that everything is fine with them. There is the so-called orange alert, where I have to analyse a few things, but usually no intervention is required. And then there is the so-called red alert. The red alert that lights up tells me that this patient has a prognosis of decompensating in 14 days and will end up in the emergency room. My job is to call the patient or their family, find a contact person or a GP who can see the patient and consolidate their treatment in this way." *Digital health expert*
Patient safety & risk reduction	"It means that the patient is properly monitored, that his or her QOL is increased, that the number of hospital visits is reduced, where he or she can also contract some kind of hospital infection because he or she comes into a waiting room full of other people and catches the flu or gets Covid, as used to be the case. Avoiding situations like that is great." *Cardiologist* "Reduces the risk of exposure to potentially infectious diseases in all places where people come together, especially in hospitals, where there is an additional risk from resistant microorganisms." *Digital health expert*

Source: Author's work

5.5.2 Healthcare utilisation outcomes

The second theme addresses healthcare utilisation outcomes associated with teleconsultations for patients with HF. This theme discusses how teleconsultations shift care from resource-intensive settings, such as hospitals and ED, toward outpatient and community-based models. This shift illustrates how perceived clinical benefits translate into changes in service configuration, linking patient-level outcomes to system-level resource allocation. Whereas the previous theme addressed clinical effects at the patient level, this theme examines how teleconsultations influence patterns of service use and resource allocation across the healthcare system. This shift is particularly important in HF management, where ongoing follow-up, timely medication adjustments, and early detection of deterioration are critical. Stakeholders frequently describe the potential of teleconsultations to reduce unnecessary hospitalisations and emergency visits, enable timely care, and reduce systemic pressure on healthcare facilities (see Table 16). This theme includes the following subthemes:

- Hospital utilisation,
- ED utilisation,
- Outpatient and community care,
- Service continuity, and
- Medication use.

Some codes within this theme include length of stay, time to follow-up, pharmaceutical prescriptions, outpatient visits, and other (see Table A.2 in Appendix 6).

The subtheme of *Hospital utilisation* is discussed in the context of resource optimisation. Both cardiologists and digital health experts note that teleconsultations could reduce the burden on inpatient services by reserving in-person hospital resources for complex or urgent cases. For instance, one cardiologist highlighted how reducing unnecessary outpatient clinic obligations could free specialist time, thereby indirectly shortening time to follow-up and potentially reducing hospital length of stay by focusing specialist time on inpatient care. A digital health expert added that "the pressure on hospitals will be reduced, making room for urgent or complex cases," while a health economist emphasised that "it doesn't make sense for stable patients to take up time at the clinic when their issues can be handled remotely." A health economist further stressed that shifting follow-up care out of hospitals could reduce per-patient cost burdens: "Telemedicine avoids unnecessary contact with high-cost care settings. That's where the real savings start." While acute care costs may remain, improved chronic disease management was viewed as lowering cumulative costs over time. Teleconsultations were therefore described not only as clinical tools but also as mechanisms to improve capacity allocation and efficiency across hospital systems.

The *Emergency department utilisation* subtheme emerges as a critical point of concern. Several digital health experts emphasised that timely teleconsultations or digital triage could

prevent avoidable ED visits through earlier intervention and initial assessment. In urgent situations, video consultations were described as valuable for rapid first assessment or instructions before emergency medical services arrive, particularly in remote areas. One cardiologist added that earlier access to care could help patients "intervene before things spiral out of control." Stakeholders also referred to inappropriate use of emergency services contributing to overcapacity and resource misallocation. A health economist noted: "Preventing just 5% of avoidable ED visits would translate into significant annual savings." Thus, ED utilisation was framed both as a clinical and economic issue, closely linked to system efficiency and cost containment. At the same time, a small number of stakeholders cautioned that easier access to remote consultations may increase the total number of patient contacts, potentially offsetting efficiency gains if not accompanied by appropriate triage protocols and workflow integration.

Table 16: Healthcare utilisation outcomes theme with interview extracts

Subtheme	Interview extracts
Hospital utilisation	"We have a specialist who could realistically treat 5 patients in hospital whose length of stay in hospital is extended by 1-2 days because he is busy in a clinic where he has to deal with many patients who do not turn up or patients whose disease is stable." *Cardiologist* "The pressure on hospitals, clinics and healthcare facilities will be reduced and we can then make room for urgent or complex cases." *Digital health expert*
Emergency department utilisation	"Many people come to the emergency room unnecessarily." *Digital health expert* "A video call could help give first instructions before emergency services arrive." *Digital health expert* "It's not about replacing emergency care but about intervening earlier, before things spiral out of control." *Cardiologist* "Many people end up in the emergency room because they don't know where else to go. If they had easier access to a quick consultation, we could prevent that." *Digital health expert*
Outpatient & community care	"The aim is to reduce unnecessary visits and improve disease control." *Cardiologist* "It's much easier for my father, who has mobility issues." *Patient* "We're seeing better patient retention when they don't have to come in for every minor thing." *Cardiologist*
Service continuity	"Waiting times for specialist appointments, the number of patients that are waiting for certain services. This is really important." *Digital health expert* "Follow-up is accelerated by 65%." – *Digital health expert* "I now get follow-ups within days." *Patient* "The consistency in follow-up allows us to detect deterioration faster. It's not just reactive care anymore, it's proactive." *Cardiologist*
Medication use	"Medication titration fits well into the telemedicine model." *Cardiologist* "Renewing a prescription via phone is very convenient." *Patient* "Refills used to take so long. Now, I just request them digitally. I haven't missed a dose in months." *Patient* "Teleconsultations are ideal for medication titration in chronic patients. It saves time, reduces visits, and ensures adherence." *Cardiologist*

Source: Author's work

The subtheme of *Outpatient and community care* is consistently emphasised as a major benefit. Stakeholders view remote follow-ups as enhancing QOL by reducing travel burden, maintaining regular contact, and improving disease control. Routine follow-ups are considered well suited for remote management, freeing capacity for acute cases and reducing strain on hospital resources. A health economist described this shift as a "cost-effective

service substitution," replacing higher-cost in-person follow-up with lower-cost remote alternatives while maintaining care quality.

The *Service continuity* theme is repeatedly underscored, particularly by digital health experts. Teleconsultation platforms are reported to significantly accelerate follow-up times, with one stakeholder reporting reductions of up to 65%. Timely follow-up improved adherence and enabled earlier clinical intervention, thereby reducing downstream complications. A patient described receiving follow-up "within days" instead of waiting over a month. Cardiologists highlighted improved patient retention and the ability to transition from reactive to proactive care. From a health economics perspective, continuity was directly linked to avoided complications and reduced hospital admissions: "If follow-up is delayed, complications increase. Regular follow-up, even if remote, keeps people out of crisis and out of hospitals." A patient with mobility issues appreciated being able to access follow-ups from home, saying it "keeps him connected to his doctor without the stress of travel." Patients with mobility limitations emphasise that remote follow-ups maintain a connection with providers without the burden of travel.

The subtheme of *Medication use* highlight prescription renewal and titration as the most accepted use case for teleconsultations. Medication management thus intersects with both clinical effectiveness and healthcare utilisation, illustrating how outcome domains are analytically distinct but operationally interconnected. A cardiologist noted that therapeutic adjustments for long-term treatment "fall well within the scope of telemedicine." Nearly all stakeholders agreed on the efficiency and convenience of remote prescription management. Clinicians valued reduced administrative burden, while patients appreciated avoiding travel and delays. One patient described digital prescription renewal as "convenient" and "fast," and another noted that since digital prescriptions were introduced, they "haven't missed a dose in months." Medication management was therefore perceived as a low-risk, high-acceptance domain of teleconsultation use.

In summary, stakeholders identify several utilisation-related benefits of teleconsultations for patients with HF, including:

- reduced hospital utilisation,
- avoidance of unnecessary ED visits,
- improved outpatient and community-based care,
- enhanced service continuity, and
- improved medication management.

Most stakeholders agree that waiting times for follow-up consultations can be shortened. Additional perceived benefits included reduced workload, improved efficiency, faster access to medication and care, improved workflow, and capacity gains across care settings. Health economists emphasised cost-efficiency gains from reduced unnecessary service utilisation, particularly hospital and ED visits, and framed teleconsultations as preventive investments

that reduce downstream costs. Cardiologists stressed the ability to intervene earlier and avoid emergency visits and hospitalisations. Patients emphasised convenience, improved medication access, shorter waiting times, and increased trust in the system.

Overall, healthcare utilisation outcomes intersected with perceived system-level efficiency gains, especially reduced waiting times, improved access, and better prioritisation of care, all of which carry economic implications. These utilisation effects are closely connected to patient-centred outcomes, as shorter waiting times, improved access, and simplified medication management directly shape patient experience and adherence behaviours discussed in the next subchapter.

5.5.3 Patient-centred outcomes and behaviours

The *Patient-centred outcomes and behaviours* theme captures how teleconsultations affect patient experience, adherence to care, emotional wellbeing, and accessibility of services. However, digital literacy and personal preferences (especially among older adults) were identified as important moderating factors (see Table 17). The impact of teleconsultations on patient-centred outcomes therefore varies considerably across demographic and socio-technical contexts, reinforcing the need to interpret experiential benefits alongside structural and equity considerations. Stakeholders emphasised that beyond clinical outcomes and system-level efficiencies, teleconsultations influence patients' perceptions of convenience, autonomy, satisfaction, emotional security, and their ability to follow treatment plans. These outcomes are particularly relevant for patients with HF due to mobility limitations, complex pharmaceutical regimens, and the need for regular interaction with healthcare professionals. This theme includes the following subthemes:

- User experience,
- Adherence to care, and
- Self-managed care continuity and access to care.

Some of the code examples in this theme include satisfaction, convenience, and comfort, emotional impact, and related experiential dimensions (see Table A.2 in Appendix 6).

The first subtheme is *User experience*. Stakeholders underscore the convenience and emotional benefits of teleconsultations, particularly for patients with chronic diseases, those living in rural areas, or those balancing work responsibilities. Many described increased feelings of safety and satisfaction when access to medical advice was easier. Patients experienced better access to care, faster diagnosis and treatment, and cost savings related to travel and time management. Patients and cardiologists noted improved adherence to treatment plans and ongoing engagement, with teleconsultations supporting more active patient involvement in managing their conditions, as various DHI allow closer monitoring and reduced barriers to healthcare. Empowerment, however, is not uniformly experienced; it appeared contingent on digital competence, confidence, and prior familiarity with

technology. Concerns were raised about the perceived quality of remote interactions compared to in-person consultations. Some patients report not having full clinician attention during teleconsultations, feeling rushed and perceiving that symptoms are not adequately assessed remotely, which raises concerns about the depth of patient-clinician interaction. Moreover, some patients preferred in-person consultations due to personal preferences, values, and habits, stating that "going to the doctor is a kind of day trip... I like to talk to the doctor in person." Teleconsultations thus simultaneously increase emotional security for some patients through easier access, while reducing perceived relational depth for others who value in-person interaction. Physicians also acknowledged the limits of remote physical assessments compared to in-person examinations.

Table 17: Patient-centred outcomes and behaviours theme with interview extracts

Subtheme	Interview extracts
User experience	"For some chronic diseases, follow-up examinations, medication reviews, the patient feels comfortable with telemedicine. But the physical condition, I can't diagnose that. But for some kind of monitoring, it's definitely useful." *Cardiologist* "When you see someone in person, the doctor is dedicated only to you, and when he is on the phone, he is a little distracted." *Patient* "Now, as for the risks, I would never use telecommunications for some things that are really serious for me." *Patient* "We're seeing better patient retention when they don't have to come in for every minor thing." *Digital health expert* "I can ask small questions or request my referral from home. That makes a big difference." *Patient* "It's very convenient for me to apply for the renewal of the prescription via my mobile phone... I don't have to wait anymore." *Patient* "Some patients are very capable, they use smartphones, schedule everything themselves and are more independent." *Digital health expert* "For me, going to the doctor is a kind of day trip... I like to talk to the doctor in person." *Patient*
Adherence to care	"In addition to adherence to therapy and the effectiveness of therapy, there is also a valid response to therapy." *Cardiologist* "They can experience first-hand the patient satisfaction and adherence to care plans. So, they are able to monitor patients more closely and check if patients are sticking to the agreement." *Digital health expert* "Chronic patients, especially those stable on therapy, are easier to follow-up this way. You don't lose them in the system." *Cardiologist*
Self-managed care continuity & access to care	"Teleconsultation is certainly important for a patient to learn to live with their disease, to keep it under control and simply to know that they have access to information and expert opinion to guide them through the disease so that they can live a long life." *Cardiologist* "You have no absences with work, there is more time for the patient, the medical information is available, and it is quicker to get to the doctor" *Health economist* "Follow-up is accelerated by 65%." *Digital health expert* "If you offer both options – in-person and remote – patients feel more included and in control." *Digital health expert*

Source: Author's work

In the *Adherence to care* subtheme, teleconsultations were credited with improving pharmaceutical adherence and treatment engagement by simplifying follow-up, prescription renewal, and care reminders. Stakeholders noted that improved monitoring and increased contact may lead to better treatment effectiveness and earlier detection of non-compliance.

In the *Self-managed care continuity and access to care* subtheme, stakeholders report that teleconsultations empowered patients by providing more continuous access to care. Several stakeholders highlighted reductions in missed appointments and time savings for both patients and healthcare professionals. Particularly in rural settings or among working adults, reduced logistical barriers led to fewer missed appointments and improved disease understanding. One digital health expert noted that offering both remote and in-person access made patients feel "more included and in control."

In summary, this theme highlights the interplay between the convenience of telemedicine and the perceived quality of care, suggesting that evaluation frameworks should capture experiential depth, not only structural outcomes. These findings demonstrate that experiential outcomes extend beyond convenience and include relational, behavioural, and psychological dimensions that are rarely captured in conventional EE models. Stakeholders identified several key patient-centred outcomes and behaviours, including:

- increased convenience and comfort for routine care and administrative tasks,
- improved continuity of care, with reduced delays and enhanced provider contact,
- improved treatment adherence, especially among motivated patients and patients with higher digital affinity,
- reduced travel burden, which supports access for rural or mobility-limited patients,
- mixed emotional responses from patients based on personal preferences, and
- variations in care experienced by different patient groups as a consequence of the digital divide.

Cardiologists agreed that teleconsultations increase convenience, improve follow-up consistency and adherence, but expressed concern about potential oversights in fully virtual settings. Patients reported mixed emotional responses: some felt reassured and empowered, while others missed face-to-face interaction and perceived reduced emotional support. Preferences varied across patient groups. Some older patients experienced digital care as burdensome or impersonal and preferred in-person visits for sensitive or complex issues, while others embraced teleconsultations for their simplicity and speed. Health economists viewed patient-centred outcomes as important but under-measured in EE and stressed that user experience should be incorporated to capture the full value of the intervention. Furthermore, although improved access was emphasised for rural, remote, or working patients, individuals with limited digital skills or low digital literacy, particularly older adults, may experience reduced care quality if supportive measures are not implemented. Taken together with the clinical and utilisation themes, patient-centred outcomes illustrate how teleconsultations generate multidimensional value that spans health effects, system efficiency, and lived experience, thereby challenging narrow cost-effectiveness framings.

5.5.4 Societal and equity outcomes

The *Societal and equity outcomes* theme captures the broader impacts of teleconsultations on social determinants of health, inclusion, equity, environmental effects, and access to healthcare across different population segments (see Table 18). This theme comprises the following subthemes:

- improved spatial equity and inclusion,
- population-level benefits, and
- environmental impact.

Codes in this theme include improved access for rural and underserved populations, reduction of disparities across income, age, or ability, and environmental sustainability (see Table A.2 in Appendix 6).

In the first subtheme, *Improved spatial equity and inclusion*, stakeholders frequently highlight the potential of teleconsultations to improve healthcare access for patients in rural areas, those with disabilities, or individuals facing transportation barriers. For example, one cardiologist noted, “Some of our patients live more than 50 kilometres from the hospital, and teleconsultations make a huge difference.” A patient added, “I live in the countryside, and just the bus ride to the city can take over an hour. This [teleconsultation] saves me time, money, and stress.” However, stakeholders also emphasised that digital healthcare can reinforce existing inequalities through digital exclusion, particularly among older adults and those with limited digital literacy or access to technology. Some also noted that remote care may increase the burden on caregivers who must assist patients with technology. A digital health expert warned, “We are at risk of creating a two-tier system, namely those who can go digital, and those who cannot.” A health economist remarked: “We often forget that equity is not just about cost; it’s about access and outcomes. Teleconsultations have potential here, but only if we design them inclusively.” These accounts indicate that teleconsultations may reduce spatial barriers while simultaneously creating new digital barriers if inclusion strategies are not actively implemented.

In the *Population-level benefits* subtheme, several stakeholders argued that scaling teleconsultations can ease systemic burdens, reduce unnecessary hospital visits, and support broader population health goals, particularly during crises such as COVID-19. A digital health expert stated, “With digital tools, we can track health trends across patient groups and intervene earlier. This is public health.” By streamlining care and improving adherence, teleconsultations are perceived to benefit the population at large, especially in chronic disease management and prevention of deterioration. An important, yet often overlooked, dimension was the impact on caregivers. Several patient narratives revealed that teleconsultations reduced logistical stress for family members who would otherwise accompany patients to appointments. This caregiver perspective extends the societal impact

beyond individual patients and highlights time and productivity effects at household level, which are rarely captured in conventional EE.

Table 18: Societal and equity outcomes theme with interview extracts

Subtheme	Interview extracts
Improved spatial equity & inclusion	"If you're on an island, it's a great saving if the doctor can use some kind of video call" *Health economist* "And for a healthcare system to be credible it must first and foremost guarantee a high level of accessibility. And teleconsultations are one of the methods that can be used to increase accessibility." *Digital health expert* "Patients stop coming because they have difficulties organising everything and very often appointments have to be postponed" *Cardiologist* "So, these patients don't have to travel from islands, remote cities, towns, villages, rural areas" *Digital health expert* "For example, some excluded groups who are on islands or in mountainous regions and have internet access so that they can communicate easily with a doctor." *Digital health expert* "We are at risk of creating a two-tier system — those who can go digital, and those who cannot." *Digital health expert*
Population-level benefits	"On an island, where at some point the advice of a specialist is needed as to whether the patient in a particular condition should be taken to hospital or whether they should go to a secondary or tertiary centre. This consultation can certainly help the local doctor" *Cardiologist* "With digital tools, we can track health trends across patient groups and intervene earlier. This is public health." *Digital health expert*
Environmental impact	"There are environmental savings that healthcare and telemedicine can offer. The biggest traffic is around healthcare institutions. You can calculate exactly how much cardiology produces per day in paper or paper-based reports. These are things that could have an ecological and economic impact" *Digital health expert* "Environmental impact should not be overlooked. Fewer in-person visits mean less travel, lower emissions, and reduced burden on infrastructure." *Health economist*

Source: Author's work

The *Environmental* impact subtheme emerged less frequently but remained conceptually relevant. Several stakeholders noted that reducing patient travel and resource use contributes to healthcare sustainability. A health economist stated, "Environmental impact should not be overlooked. Fewer in-person visits mean less travel, lower emissions, and reduced burden on infrastructure." Although environmental effects were not central to all stakeholders, their inclusion broadens the evaluative scope beyond immediate clinical and utilisation outcomes toward long-term system sustainability.

In summary, this theme identified several societal and equity-related effects of teleconsultations for patients with HF, including:

- improved access for rural, remote, and immobile patients,
- potential disparities in care due to digital exclusion among older, low-income, or digitally less literate populations,
- uneven distribution of benefits across patient groups, raising equity concerns, and
- environmental gains through reduced travel and resource use.

Stakeholders generally agree that teleconsultations can enhance societal outcomes by improving access and reducing travel-related burdens. However, digital exclusion remains a central concern. While digital health experts and health economists emphasised broader equity and environmental implications, patients and clinicians focused more on individual-level access and usability. The overall consensus suggests that teleconsultations can support equity objectives, but only if digital inclusion is actively addressed through targeted support and infrastructure development.

Together with the clinical, utilisation, and patient-centred findings, these societal effects demonstrate that teleconsultations generate multidimensional value, but that this value is distributed unevenly across populations, reinforcing the need for equity-sensitive approaches in EE.

5.5.5 Organisational and technical outcomes

The *Organisational and Technical Outcomes* theme reflects stakeholder perceptions of how teleconsultations influence healthcare systems and organisational processes. Teleconsultations have the potential to enhance organisational efficiency, reduce workload, support continuity of care, and enable more flexible healthcare delivery. However, these benefits rely on supportive infrastructure, adoption strategies, and implementation planning. Stakeholders emphasised that without integration into existing healthcare workflows and platforms, teleconsultations risk remaining underused (see Table 19). This theme comprises the following subthemes:

- workforce efficiency and workflow improvements,
- adoption and changes in daily practice, and
- technical infrastructure, integration, and usability.

Some of the codes within this theme include sustainable long-term integration, improved provider productivity and scheduling, and flexible care delivery and task delegation (see Table A.2 in Appendix 6).

In the first subtheme, *Workforce efficiency and workflow improvements*, stakeholders frequently emphasis that teleconsultations could reduce inefficiencies in day-to-day healthcare delivery through improved triage, task delegation, continuous monitoring, reduced no-show rates, and shorter consultation times. A cardiologist stated that teleconsultations allow time to be allocated more efficiently: “You don’t need a cardiologist for everything. Let a nurse check and alert the doctor if needed.” A digital health expert highlighted the role of remote monitoring for chronic patients: “The system only notifies you when something is wrong and that’s a huge time saver.” Stakeholders also noted that telemedicine enabled continuity of care when in-person services were suspended during the

COVID-19 pandemic, strengthening system resilience during crisis periods. These findings indicate that organisational efficiency gains are closely linked to role reallocation, delegation, and structured monitoring rather than simply replacing in-person visits with remote ones.

The second subtheme, *Adoption and changes in daily practice*, highlights that successful implementation depends heavily on professional readiness and organisational culture. Some cardiologists acted as enthusiastic early adopters, while others resisted change due to unfamiliarity, perceived workflow disruption, additional workload, or personal preferences, particularly among older professionals. A digital health expert stated: "You need to give them time to try it out… and give them the support. Otherwise, they'll drop it." A health economist stressed that teleconsultations could scale nationally, especially in underserved areas, but only if supported by clear guidelines, structured implementation, sustainable financing, and coherent policy frameworks. Variation in uptake indicates that organisational transformation requires behavioural change strategies alongside technological investment.

The final subtheme, *Technical integration and usability,* primarily concerns barriers to adoption. Stakeholders frequently cited poor interoperability, fragmented platforms, multiple logins, and lack of system integration as major obstacles. Cardiologists and digital health experts emphasised the importance of user-friendly systems and seamless integration into daily clinical workflows. One cardiologist noted: "If I have to log into three systems just to do one consult, I won't use it." Digital health experts and health economists call for investment in interoperable systems integrated with national health information infrastructure, such as electronic health records, to enable sustainable implementation. Without interoperability and usability, efficiency gains may be offset by increased administrative and cognitive burden.

In summary, stakeholders identified several organisational and technical outcomes of teleconsultations for HF care:

- increased efficiency and prioritisation of clinical workloads,
- reduction in unnecessary in-person visits and no-shows,
- enhanced healthcare system resilience during crisis,
- potential decrease in care quality if uptake is limited by insufficient digital competence or support,
- potential underuse if integrated and user-friendly platforms are not provided, and
- potential decrease in usage due to technical barriers related to fragmented systems and poor interoperability.

Most stakeholders agreed that teleconsultations can improve organisational efficiency and system resilience when they are properly integrated into existing workflows. Remote consultations often take less time than in-person visits, which may allow providers to manage more patients per day. Time saved may be redirected to more complex cases or other

clinical tasks. However, stakeholders also emphasised that wider adoption would require investment in IT infrastructure, cybersecurity, technical support, and adjustments to organisational processes. Cardiologists focused on ease of use and time-saving potential, while digital health experts emphasised infrastructure, interoperability, and scalability. Health economists highlighted efficiency gains and potential economic returns. Patients valued smooth processes and rapid access to care.

Overall, organisational benefits appear achievable, but only if technical and procedural barriers are systematically addressed.

Table 19: Organisational and technical outcomes theme with interview extracts

Subtheme	Interview extracts
Workforce efficiency & workflow improvements	"When you have teleconsultations, there is less no-shows" *Digital health expert* "They are simply overwhelmed with all this mess of work. And as much as they could now, if they were given the opportunity to sort it out, they would certainly be relieved. But on the other hand, there must be reasons to motivate the change." *Health economist* "In addition, it reduces the administrative burden on services, is faster and possibly of better quality." *Digital health expert* "You don't need a cardiologist for everything. Let the nurse check-up and alert the doctor if needed." *Cardiologist* "The system only notifies you when something is wrong, that's a huge time saver." *Digital health expert*
Adoption and changes in daily practice	"The challenges are partly the same: GPs are very busy and don't have time for teleconsultations. There are often omissions in the sense that patients do not contact their GP because they cannot get the call through due to overwork." *Cardiologist* "You need to give them time to try it out… and the support. Otherwise, they'll drop it." *Digital health expert* "Some just say: I'm not doing it. And that's the end of the discussion." *Cardiologist* If you want this to be more than a pilot, you need a roadmap and sustainable resources." *Health economist*
Technical Integration & usability	"If I have to log into three systems just to do one consult, I won't use it." *Cardiologist* "We need a national infrastructure that speaks the same language across providers." *Digital health expert*

Source: Author's work

5.5.6 Economic and financial costs

The *Economic and financial costs* theme describes stakeholder perspectives on the direct and indirect costs associated with teleconsultations, as well as their potential for cost savings and resource optimisation. This theme reflects the need to balance long-term efficiency gains with caution regarding upfront implementation expenditures (see Table 20). This theme includes the following subthemes:

- direct healthcare costs,
- implementation and maintenance costs,
- direct non-healthcare costs, and
- indirect costs.

Some of the codes within this theme include cost of consultation, training, travel and transport, absenteeism, and related economic considerations (see Table A.2 in Appendix 6).

Table 20: Economic and financial costs theme with interview extracts

Subtheme	Interview extracts
Direct healthcare costs	"More than 30% of patients never show up for the scheduled check-ups." *Digital health expert* "I have 35% of patients who do not turn up for their scheduled appointment. 50% of patients do not turn up at the GP appointment." *Digital health expert* "It's a great saving if the doctor can use some kind of video call to establish whether the condition is a triviality that caused someone to call the emergency services." *Health economist* "I don't think physicians should care how much they spend. I don't care about the costs; I want to give the right quality of care that the patient needs." *Cardiologist* "Do you think that we should have mandatory cardiologists in every city, or can there be 3 or 4 regionally as needed? Can savings be made there using telemedicine?" *Digital health expert* "He charges 10 € for consultations in person. The telemedicine system can account for about 30% of the price and still make economic sense. He can read out the ECG from home, send it onwards, and then it costs 3 €." *Digital health expert* "If a patient avoids one hospitalisation a year because we caught deterioration early, that's a significant cost saving for the system." *Cardiologist*
Implementation & maintenance costs	"The challenge is to install a few additional application solutions that can be combined through IoT." *Digital health expert* "So, the cost advantage is entirely on the side of telemedicine, because the cost of the equipment is negligible when you consider what we can cumulatively gain." *Cardiologist* "We can't ignore the fact that software licences, maintenance, and IT staff cost money every year. These aren't one-off expenses." *Digital health expert* "There are lower operational costs. So, we need less physical space and resources if we can handle our patients through telemedicine and teleconsultation." *Digital health expert* "So, the hospital is a buyer and a payer of local information systems if the hospital wants to introduce a telecommunication or telemonitoring service." *Digital health expert* "At the same time, these telemedicine centres had to be set up, and this medical centre had to be connected to the Internet, acquire equipment, install the equipment, train the staff who would work with it and put it into operation." *Digital health expert* "If a doctor declares a need, we as a centre must provide the equipment in accordance with the telemedicine regulation, the doctor or the centre where the installation takes place is responsible for the equipment, and we maintain the equipment." *Digital health expert* "The acquisition of the devices themselves and the implementation of the information systems that will take care of them. This includes programmers, technical support and someone to ensure that the system is stable and working, as well as the education of users." *Cardiologist*
Direct non-healthcare costs (patient & caregiver)	"As for the patients, their personal costs would be the electricity consumption during the consultation, the purchase and maintenance of the equipment used for it." *Digital health expert* "For me, the biggest saving is not having to take a day off work to see the doctor for something simple." *Patient* "As for the patients, their personal costs would be the electricity consumption during the consultation, the purchase and maintenance of the equipment used for it." *Digital health expert* "We believe that everyone has devices that allow access to teleconsultations and that this does not entail any particular additional costs." *Digital health expert*
Indirect costs	"After all, time is money. So, both absence from work and some costs. There are no significant costs, but on the other hand, travelling and travel expenses and all that, but mainly time." *Patient* "On the other hand, we have more and more younger patients who are giving up work, adjusting their commitments, coming for check-ups, not missing a hard-to-get appointment, etc." *Digital health expert* "Indirect savings like reduced absenteeism aren't always counted in EE, but they are real." *Health economist*

Source: Author's work

Within the *Direct healthcare costs* subtheme, stakeholders consistently emphasise that the greatest cost-saving potential lies in avoiding expensive hospital-based care. Cardiologists explained that early intervention via teleconsultations may prevent admissions, shorten lengths of stay, and reduce reliance on ED. As one cardiologist noted, "If a patient avoids

one hospitalisation a year because we caught deterioration early, that's a significant cost saving for the system." Digital health experts linked these savings to improved triage and integration with remote monitoring, arguing that proactive management reduces high-cost acute episodes. One digital health expert estimated that the cost of a teleconsultation may be approximately 30% of an in-person consultation, suggesting potential substitution effects at the service level. However, several stakeholders also cautioned that cost savings depend on appropriate patient selection and substitution rather than additional parallel service use.

Under *Implementation and maintenance costs*, stakeholders repeatedly stressed that telemedicine requires substantial investment in hardware, software licences, cybersecurity, technical support, and staff training. As one digital health expert stated, "We can't ignore the fact that software licences, maintenance, and IT staff cost money every year. These aren't one-off expenses." Additional costs include system upgrades, integration with existing information systems, regulatory compliance, and long-term technical maintenance. At the same time, stakeholders note that once established, telemedicine infrastructure can serve a large patient population, potentially spreading fixed costs over time and generating scale efficiencies. This reflects a classic trade-off between fixed implementation costs and potential long-term marginal cost reductions.

In the *Direct non-healthcare costs* subtheme, patients highlighted savings related to reduced travel, parking expenses, and time away from work. One patient explained, "For me, the biggest saving is not having to take a day off work to see the doctor for something simple." These savings were described as particularly important for patients living in rural areas or with mobility limitations, where travel can be both financially and physically burdensome. Some stakeholders also noted minor patient-incurred costs (e.g., electricity, devices), although these were generally perceived as negligible relative to avoided travel and time costs.

The *Indirect costs* subtheme captured broader productivity effects. Health economists emphasised that avoiding time lost to travel and waiting rooms can improve labour force participation, especially among working-age patients and caregivers. As one health economist noted, "Indirect savings like reduced absenteeism aren't always counted in EE, but they are real." Digital health experts additionally highlighted societal benefits, such as reductions in caregiver burden and greater flexibility in managing work and family responsibilities. Several stakeholders therefore suggested that conventional healthcare-perspective EE may underestimate the societal value of teleconsultations.

In summary, stakeholders identified that teleconsultations can:

- reduce direct healthcare costs by preventing unnecessary hospitalisations and emergency visits,
- require substantial investment in infrastructure, maintenance, and training,
- lower patient-incurred costs such as travel, parking, and lost work time, and

– generate indirect economic benefits through improved productivity and reduced caregiver burden.

Cardiologists primarily focused on cost avoidance through early intervention and better prioritisation of patients. Digital health experts emphasised the realities of ongoing operational expenditures and warned that ignoring these costs risks unsustainable implementation. Health economists stressed the importance of incorporating indirect and societal costs, as conventional EE may underestimate total economic effects. Above all, patients perceived lower costs due to less travelling, lower expenditure, and fewer interruptions to work and daily life.

The overall conclusion is that teleconsultations involve a complex cost structure: potential savings in high-cost acute care must be weighed against recurring technological and organisational expenditures, with distributional implications across stakeholders.

5.5.7 Methodological aspects in economic evaluation

The *Methodological aspects in economic evaluation* theme captures stakeholder reflections on the design and conduct of EE for telemedicine, particularly teleconsultations in HF care (see Table 21). While Chapter 3 addresses these challenges conceptually, this theme presents how they are perceived in practice. This theme includes the following subthemes:

– perspective,
– time horizon,
– comparator, and
– data sources and quality.

Whereas outcomes and costs were addressed in previous themes, the focus here is on methodological choices shaping their evaluation. Codes within this theme include societal perspective, sufficiently long time horizon to capture downstream effects, usual care, interoperability, and related methodological concerns (see Table A.2 in Appendix 6).

Within the *Perspective* subtheme, several stakeholders emphasise that EE should extend beyond a narrow healthcare budget perspective to include patient and societal viewpoints. A health economist stated, “If you only look at the health system budget, you miss the real cost and benefit to patients and families.” Patients similarly stressed that their savings in time, travel, and productivity should be reflected in economic assessments. Health economists cautioned that excluding societal costs may underestimate the value of teleconsultations, particularly in chronic conditions such as HF. This concern links directly to the cost domains in Theme 5.5.6 and the equity considerations in Theme 5.5.4.

In the *Time horizon* subtheme, stakeholders agreed that short-term evaluations are likely to underestimate the benefits of teleconsultations, particularly in chronic disease management.

As one cardiologist noted, "If you follow a HF patient for only six months, you will not see the real effect on hospitalisations." Health economists and digital health experts suggested that evaluations should span at least three to five years to capture downstream effects, including avoided complications, readmissions, and long-term disease control. Several stakeholders note that high initial implementation costs may distort short-term findings, reinforcing the need for longer horizons in cost-effectiveness assessment.

Table 21: Methodological aspects in economic evaluation theme with interview extracts

Subtheme	Interview extracts
Perspective	"You need to take into consideration a wide perspective, especially because the contexts are different, the solutions are different, everything is very, very different." *Health economist* "If you only look at the health system budget, you miss the real cost and benefit to patients and families." *Health economist*
Time horizon	"If you follow a HF patient for only six months, you will not see the real effect on hospitalisations." *Cardiologist* "You can look at the use of a medical device for 2 months or 6 months or a year. Holistic interventions must be tested for a year." *Health economist* "It will take a long time, perhaps too long, but at least three years." *Health economist* "From an economic cost-benefit perspective, it is always best to start measuring from the beginning, from introduction, or rather, set some target values, go back to the beginning and measure for at least 5 years, in my opinion, to see some benefits. The first three years can be an indication of where things are going and whether something needs to be changed, but I think a five-year period is the minimum to see something." *Health economist* "I would recommend a period of several years if we want to measure the effect of complications, hospitalisation rates, readmission rates, different levels of chronic disease control. We also need to cover a number and type of teleconsultations and compare them to in-person visits. We need to monitor the number of cases admitted to emergency rooms and urgent care. We need to monitor the number of follow- up visits after teleconsultation. So, does this teleconsultation reduce the number of follow-up visits or does it cause a higher number? And also, we should monitor waiting times for appointments." *Digital health expert*
Comparator	"Mostly repetitive procedures and services can be completely replaced by teleconsultations, like, for example, prescription renewal, because that also saves time for both the patient and the physician or the nurse who handles such issues." *Digital health expert* "So does this teleconsultation reduce the number of follow-up visits or does it cause a higher number?" *Digital health expert* "Teleconsultation versus in-person is not reality. We need to measure the mixed models we actually use." *Digital health expert*
Data source & quality	"There is a lack of standardisation of healthcare data, such that if you want to use it, you cannot interpolate at intervals, and that is a very big problem that also needs to be solved." *Health economist* "If data from different hospitals doesn't speak the same language, your evaluation is flawed from the start." *Cardiologist* "And this data, and we use PDF that can handle everything and absolutely anything can be entered there, is secondarily unusable for any purpose." *Digital health expert* "All European countries have them to a greater or lesser extent, and I believe that electronic health records will become even more standardised across Europe, and their scope of application will expand as a result of the EHDS." *Digital health expert*

Source: Author's work

In relation to *Comparator*, stakeholders considered usual in-person care an appropriate baseline but emphasised that pure teleconsultation versus pure in-person consultation is rarely reflective of real-world practice. As one digital health expert stated, "Teleconsultation

versus in-person is not reality. We need to measure the mixed models we actually use." Stakeholders recommended evaluating hybrid care models that combine in-person visits, teleconsultations, and remote monitoring, aligning EE with actual service delivery rather than hypothetical extremes.

In the *Data sources and quality* subtheme, stakeholders expressed strong concerns about fragmented datasets, inconsistent data structures, lack of data standardisation, and limited interoperability across providers. A cardiologist remarked, "If data from different hospitals doesn't speak the same language, your evaluation is flawed from the start." Health economists similarly pointed to the lack of standardisation and structured electronic data as a major constraint. Digital health experts highlighted that poor interoperability and reliance on non-structured formats (e.g., PDFs) undermine both digitisation benefits and robust evaluation. Stakeholders repeatedly called for national interoperability standards and improved data integration as prerequisites for credible EE. These limitations directly constrain the measurement of clinical and utilisation outcomes identified in Themes 5.5.1 and 5.5.2.

In summary, stakeholders identified several methodological requirements for robust EE of teleconsultations:

- inclusion of multiple perspectives (health system, patient, and societal),
- use of sufficiently long time horizons to capture long-term effects,
- comparison against realistic hybrid care models, and
- improved data quality, standardisation, interconnectivity, and interoperability.

There was broad consensus that methodological clarity directly affects the credibility of evidence used for funding and reimbursement decisions. Health economists particularly emphasised the importance of adopting a societal perspective and long-term time horizons, as well as challenges related to limited data availability, inappropriate data use, insufficient capacity and funding, and the limited availability or application of methodological guidance. Cardiologists focused on clinically meaningful timeframes and warned that short-term analyses underestimate true effectiveness. Digital health experts stressed realistic comparators and interoperable data infrastructure, including lack of data standardisation and absence of a central database. Patients expressed concern that their lived costs and benefits are often excluded from formal evaluations. Some disagreement emerged regarding the feasibility of comprehensive societal-perspective evaluations under current budgetary and data constraints. Reported barriers included limited funding, insufficient collaboration between policymakers and health economists, lack of methodological capacity, and inadequate integration of EE into decision-making processes. Overall, stakeholders agreed that methodological rigour and context-sensitive design are essential to produce credible evidence capable of informing policy and investment decisions.

5.5.8 Challenges and risks

The last theme, *Challenges and risks,* captures stakeholder-identified barriers, uncertainties, and systemic constraints related to the adoption and use of teleconsultations in HF management. While teleconsultations were broadly viewed as beneficial, stakeholders consistently emphasised that these benefits could be undermined by systemic, organisational, technical, and patient-related challenges. These ranged from legal and regulatory gaps to digital literacy issues, infrastructure limitations, reimbursement problems, and risks to clinical quality in certain situations. Concerns also included the potential for widening health inequities, increased clinician workload, and insufficient integration with existing care pathways (see Table 22). This theme included the following subthemes:

- adoption and uptake risks,
- legal and regulatory barriers,
- technical risks, and
- incentive structure and mandates.

The codes in this theme include regulatory uncertainty and compliance barriers, technology failure, trust and privacy concerns, and lack of reimbursement and EE mandates (see Table A.2 in Appendix 6).

In the first subtheme, *Adoption and uptake risks,* stakeholders highlight that while teleconsultations have clear benefits, their adoption is uneven and dependent on patient characteristics and provider factors. As discussed earlier, digital literacy is important, and uptake varied across age, motivation, and familiarity with technology. As one cardiologist explained, “For some older patients, the technology is simply intimidating. They prefer the personal contact they have known for decades.”

Trust, motivation, and appropriate use criteria were cited as key barriers. Stakeholders stressed that teleconsultations are not suitable for every patient, particularly in cases involving acute deterioration or complex diagnostic uncertainty, as one digital health expert noted, “Depending on the health issues, teleconsultation is not always the best solution.” Patients expressed concerns about data security and privacy, which influenced their willingness to use digital services. This subtheme intersects with the equity and patient-centred themes, as digital inclusion and trust directly condition real-world effectiveness.

In the *Legal and regulatory barriers* subtheme, most stakeholders noted that there is a lack of a clear and comprehensive legal framework for telemedicine services. Legal and financial risks were cited as major deterrents for institutional adoption. Without addressing these foundational challenges, the potential of teleconsultations may remain underutilised. A digital health expert pointed out, “There is no definition of standards at the central level as minimum standards that everyone must adhere to.” Furthermore, another digital health expert highlighted the financial implications of legal compliance, noting the “initial

investment, especially in a good lawyer who will ensure that the application complies with the GDPR, Data Governance Act, EHDS and other European and national regulations, laws and ordinances. This is a very large initial investment." Cardiologists criticised the lack of appropriate professional guidelines to assess which patients are eligible for teleconsultation and which are not. Patients were particularly concerned about data security and data protection. GDPR compliance and liability were recurrent concerns. These findings reinforce earlier organisational and methodological themes, suggesting that regulatory clarity is a prerequisite for credible EE and sustainable implementation.

Table 22: Challenges and risks theme with interview extracts

Subtheme	Interview extracts
Adoption & Uptake Risks	"Depending on the health issues, teleconsultation is not always the best solution." *Digital health expert* "I have a trust in technology, so in my opinion, technology is able to offer us good quality services in telemedicine and teleconsultation." *Digital health expert*
Legal & Regulatory Barriers	"There is no definition of standards at a central level as minimum standards that everyone must adhere to." *Digital health expert* "…initial investment, especially in a good lawyer who will ensure that the application complies with the GDPR, Data Governance Act, EHDS, and other European and national regulations, laws and ordinances. This is a very large initial investment." *Digital health expert*
Technical Risks	"The traditional healthcare system can no longer function without technology and IT." *Digital health expert* "Data protection, I think there should be some kind of stronger software so not everyone can get hold of that information because it's sensitive information." *Health economist*
Incentive Structure & Mandates	"The health insurance company tolerates and considers it normal that 20% of patients do not turn up for examinations, and on the other hand they ask why our waiting lists are getting longer and longer." *Digital health expert* "Telemedicine is invisible, so to speak. So, you still have the same obligations as before, and nobody sees telemedicine. Nobody gives you any extra time. I want to tell you that telemedicine is a good thing, but you need time for everything." *Cardiologist* "So, some part of the financing is coming from the health insurance company and there also it is possible to have some other financing, some project financing or European Commission financing, so some funds that can be accessed. So, when considering the total cost, we also must think about the source of the financing, and we must ensure that we have financing for every next year." *Digital health expert* "A huge investment of time and money would have to come from this first institution, which would have to initiate some changes in the regulations and the legal framework in the Ministry, which would have to go to the Health Insurance Institute and change some price lists. So, I think everyone who is involved in any kind of health management realises how much effort, time, money and nerves have to be spent to implement it, and once one institution has done it, the others can copy it very quickly and implement it themselves with minimal investment of time, money and other things." *Digital health expert*

Source: Author's work

In the *Technical risks* subtheme, data protection, interoperability, and system stability were recurring concerns. Stakeholders emphasised the importance of secure software, reliable platforms, and adequate cyber protection. Several stressed the need for national-level leadership and investment to harmonise standards and ensure equitable implementation. Although most stakeholders acknowledged that healthcare can no longer function without technology, as one digital health expert stated: "The traditional healthcare system can no longer function without technology and IT", technical limitations still present a significant barrier. Fragmented systems, inconsistent data standards, and unstable platforms were seen as risks to both clinical quality and EE. This subtheme connects closely with the methodological theme, as data fragmentation and poor interoperability directly affect the validity of cost and outcome measurement.

In the final subtheme, *Incentive structure and mandates*, stakeholders criticised the lack of reimbursement models and formal recognition of teleconsultation work. Administrative burden without clear incentives was perceived to undermine motivation. Without structured incentives, health professionals often face the same workload pressures as before. As one cardiologist stated, "Telemedicine is actually invisible… You still have the same obligations as before, and nobody sees telemedicine. Nobody gives you any extra time. I want to tell you that telemedicine is a good thing, but you need time for everything." A digital health expert emphasised the complexity of policy reform: "A huge investment of time and money would have to come from this first institution to initiate regulatory changes and a legal framework at the Ministry, then go to the Health Insurance Institute and change price lists. I think everyone who is involved in any kind of health management realises how much effort, time, money and nerves have to be spent to implement it… once one institution has done it, the others can copy it very quickly." Another issue highlighted was tolerance for systemic inefficiencies, as illustrated by the observation that "the health insurance company tolerates and considers it normal that 20% of patients do not turn up for examinations." These findings suggest that without reimbursement reform and institutional alignment, teleconsultations will remain peripheral rather than structurally embedded within healthcare delivery.

In summary, stakeholders note that addressing the challenges and risks of teleconsultations in HF management requires the following:

- ensuring suitability according to patient condition and context,
- establishing clear national standards and regulatory guidance,
- strengthening technical infrastructure and cybersecurity, and
- aligning incentives and financing mechanisms.

All stakeholder groups agreed that the current environment lacks the structural readiness needed for large-scale, sustainable teleconsultation adoption. Cardiologists emphasised time pressures, workflow integration, and limitations in complex or acute cases. Patients focused on usability and trust. Digital health experts highlighted systemic and interoperability gaps. Health economists stressed that without appropriate incentives and policy alignment, potential cost savings and productivity gains will remain unrealised. Across groups, there was agreement that without addressing structural, legal, technical, and incentive-related barriers, previously identified benefits cannot be fully realised. Stakeholders emphasised that coordinated action at policy, organisational, and individual levels is required, alongside robust evaluation of costs and effects. Many observed that technological capacity has advanced faster than policy, infrastructure, and training, creating a mismatch that threatens sustainability and scalability.

This theme consolidates the tension between demonstrated potential and implementation reality and provides a direct bridge to the subsequent discussion and policy analysis.

5.6 Discussion and conclusions

This study provides a structured stakeholder-based examination of teleconsultations for HF using a framework analysis organised across eight thematic domains. The rapid expansion of teleconsultations during the COVID-19 pandemic exposed patients, cardiologists, digital health experts, and health economists to digital care delivery at scale, shaping their experiences and, in turn, their views on its benefits, limitations, and long-term sustainability. I find that teleconsultation effectiveness depends not only on clinical appropriateness but also on organisational redesign, institutional alignment, and user readiness. These factors are crucial for understanding its real-world value, which cannot be fully captured by conventional cost-effectiveness metrics. By integrating clinical, healthcare utilisation, patient-centred, societal, organisational, economic, methodological, and implementation dimensions, I show that teleconsultations operate as a complex intervention. Clinical value, efficiency gains, and economic consequences are closely interconnected rather than analytically separable. Consistent with the argument advanced in Chapter 3 (Skivington et al., 2021), value emerges from system reconfiguration rather than from the digital format itself.

Across stakeholder groups, I find that teleconsultations are perceived as most effective when implemented within a hybrid care model that complements in-person care. Early detection of deterioration, medication titration, continuity of care, and prevention of unnecessary hospital and ED visits are repeatedly identified by stakeholders as core mechanisms of value (Donaghy et al., 2019). These mechanisms are associated with downstream cost avoidance and productivity gains by preventing acute episodes and reallocating resources within capacity-constrained systems. However, I find that the central finding of this chapter is that teleconsultation value is conditional rather than intrinsic. Realisation of benefits depends on patient selection, digital literacy, workflow integration, interoperability, reimbursement alignment, and organisational readiness. Where these enabling conditions are weak, teleconsultations may increase administrative burden or fail to substitute high-cost services. Stakeholders rarely question the potential of teleconsultations themselves. Instead, their concerns focus on the organisational and regulatory environment in which they are implemented. This conditionality explains why anticipated savings do not automatically materialise. Poor digital integration can increase provider workload, and some patients continue to require frequent in-person visits despite remote options. Economic value therefore arises not from the consultation modality alone but from care pathway redesign. Stakeholders describe teleconsultations as shifting care away from inpatient and emergency settings towards more structured outpatient and community-based models of management. I show that this finding reinforces the argument in Chapter 3 that EE of DHI must account for system-level reallocation effects and dynamic implementation processes rather than evaluate isolated service substitutions.

Patient-centred findings introduce distributional and preference-sensitive dimensions. Many patients value convenience, reduced travel, faster access, and fewer work absences (Coast &

De Allegri, 2018), while others prefer in-person consultations for reassurance or perceived thoroughness (Imlach et al., 2020). Digital literacy, connectivity, and age function as moderators of benefit realisation. Teleconsultations therefore generate both equity gains and equity risks. Improved spatial access for remote and mobility-limited populations may coexist with digital exclusion among older or technologically disadvantaged groups. I argue that failure to address digital divide effects may not only widen disparities but also bias EE results if utilisation and outcomes differ systematically across patient subgroups. I show that these findings strengthen the methodological case for explicitly documenting distributional and non-health impacts through structured impact mapping such as the IIM before aggregation into summary cost-effectiveness metrics.

Organisational and technical readiness further mediates value realisation. Stakeholders associate improved triage, task delegation, reduced no-shows, and structured monitoring with efficiency gains (Maria et al., 2022). At the same time, fragmented systems, poor interoperability, multiple logins, and lack of workload recognition are major constraints. Stakeholders frequently describe teleconsultations as "invisible work" within existing reimbursement and staffing structures. Adoption often relies on professional goodwill rather than systemic support. I show that these organisational consequences, though difficult to monetise, are materially relevant for decision-making. Transparent reporting of such consequences through CCA, without forcing premature monetisation, reflects the implementation-sensitive evaluation logic developed in Chapter 3.

Economic discussions reinforce the multidomain character of teleconsultation value. While hospital avoidance and triage optimisation are viewed as principal sources of savings, implementation costs, training requirements, cybersecurity investments, and maintenance burdens are consistently emphasised. Stakeholders perceive indirect benefits such as caregiver burden reduction, reduced absenteeism, productivity gains, and environmental effects as meaningful yet insufficiently captured in conventional EE models. Health economists explicitly argue that narrow healthcare-budget perspectives risk systematic undervaluation of DHI. Suggested analytic horizons of three to five years reflect the chronic trajectory of HF and the delayed realisation of benefits.

The empirical findings substantiate the conceptual challenges identified in Chapter 3. Stakeholders question narrow perspectives, short time horizons, unrealistic comparators, and fragmented data infrastructures. Hybrid care models are viewed as more appropriate comparators because they better reflect actual service delivery. Data fragmentation undermines both clinical quality and evaluation validity. Rather than rejecting EE, stakeholders call for approaches that better reflect complexity, implementation variability, and cross-sectoral impacts. Environmental and sustainability impacts, though not dominant, further broaden the evaluative space. Researchers rarely incorporate these impacts, such as reduced travel and infrastructure use, in conventional EE (Thomas et al., 2024), yet these impacts conceptually align with societal perspective expansion. Their relative absence in standard CUA illustrates blind spots identified in Chapter 3.

Across stakeholder groups, emphasis differs systematically. Cardiologists prioritise clinical safety and workflow feasibility; patients foreground access, reassurance, convenience, and reduced logistical burden; digital health experts focus on interoperability, infrastructure, and scalability; health economists emphasise evaluative perspective, time horizon, and inclusion of indirect and societal costs. I show that these differences illuminate distinct but complementary dimensions of value, confirming that teleconsultation effectiveness is multidimensional and distribution-sensitive. I argue that failure to address digital exclusion may generate inequities and bias EE results if utilisation and outcomes differ across patient subgroups. Similarly, misaligned reimbursement structures may distort observed service patterns, complicating interpretation of administrative cost data. Because several relevant domains, such as caregiver burden, environmental impacts, and organisational workload shifts, are not captured in administrative datasets, quantitative analyses alone risk underrepresenting teleconsultation value. I argue that this heterogeneity further justifies structured multidomain mapping through IIM and transparent presentation through CCA prior to aggregation into summary cost-effectiveness metrics.

Persistent structural barriers remain. Legal uncertainty, fragmented reimbursement models, limited HTA guidance, lack of national standards, insufficient interoperability, low organisational readiness, and misaligned incentives constrain large-scale integration. Technological capacity has advanced faster than regulatory and financial alignment, which may explain why teleconsultations remain partially unrealised despite recognised benefits. I show that this tension between demonstrated potential and institutional constraint reinforces the conclusion that evaluation must consider context and implementation capacity alongside clinical effectiveness (Kim et al., 2018), as argued in Chapter 3. This systemic conditionality provides the analytical foundation for the methodological conclusions that follow.

Taken together, I show that these findings provide an empirical validation of the methodological argument developed in Chapter 3. I show that teleconsultation value is multidimensional, conditional, and closely tied to implementation context. For this reason, I identify and structure impacts across clinical, organisational, societal, and distributional domains before they are aggregated into single summary measures. The IIM operationalises this structured mapping, while CCA enables transparent multidomain presentation under conditions of heterogeneity and uncertainty. In this sense, the framework analysis goes beyond synthesising stakeholder perspectives. It also offers empirical support for more proportionate and context-sensitive approaches to EE of DHI. Furthermore, the analysis clarifies which domains matter, corroborates the methodological concerns identified in Chapter 3, and identifies concrete design adjustments that enhance policy relevance and analytical validity in the subsequent quantitative analyses.

Overall, this discussion underscores that teleconsultations should be conceptualised not as digital substitutes, but as components of hybrid care redesign whose value depends on organisational integration, incentive alignment, equity safeguards, and appropriate methodological framing. I show that incorporating stakeholder perspectives enhances

contextual validity and policy relevance by ensuring that EE reflects implementation realities rather than abstract service substitution models. The dissertation combines qualitative structuring, quantitative analysis, and multidomain mapping into a coherent and integrated evaluation framework.

Importantly, several domains identified in this framework analysis (caregiver burden, organisational workload shifts, environmental impacts, and user experience) are not observable in administrative data. The quantitative analysis in Chapter 6 therefore captures only measurable system-level outcomes reflected in utilisation, expenditure, and mortality records. In Chapter 7, I integrate complementary structured approaches (IIM and CCA) to ensure that broader domains not visible in administrative datasets are not excluded from policy-relevant evaluation.

I acknowledge several limitations. The purposive sample of 20 stakeholders does not permit statistical generalisation. While stakeholder diversity I ensured, perspectives are context-specific and may not fully capture heterogeneity across health systems. Experiences during and after the COVID-19 pandemic may have shaped perceptions. This finding aligns with Slovenian evidence from cardiac rehabilitation populations during COVID-19, where patients reported that their primary cardiac condition affected their lives more than pandemic-related stress and that they perceived care environments as safe and trustworthy (Jug, Sedlar Kobe, et al., 2024). Nevertheless, my aim is analytical generalisation, generating transferable insights for EE of DHI.

In the following chapters, I examine whether observed utilisation patterns, cost structures, and outcome trajectories align with stakeholder-identified mechanisms of value, thereby testing coherence between experiential evidence and quantitative system-level findings.

5.7 Summary and implications

I show that the findings of this framework analysis have direct implications for clinical practice, health system organisation, digital health policy, and the design of EE. They also reinforce the methodological issues discussed in Chapter 3, and I show how EE of DHI should be applied in practice when interventions are complex and context-dependent.

Across stakeholder groups, I find that teleconsultations are consistently framed as a complementary rather than a substitutive model of care. Their value lies in supporting routine follow-up, pharmaceutical adjustment, and early detection of deterioration in stable chronic patients with HF, while in-person visits remain essential for complex, acute, or diagnostically uncertain cases. Policy frameworks should therefore formalise hybrid care models. Clear clinical guidelines should define eligibility criteria, triage protocols, and appropriate use cases, incorporating patient preference, clinical complexity, and digital competence to operationalise a hybrid, patient-centred care model. I find that without defined boundaries and decision rules, teleconsultations risk either inappropriate expansion

or systematic underutilisation due to professional uncertainty. Formal institutionalisation of hybrid care pathways, including workload recognition and reimbursement alignment, is necessary to ensure that teleconsultation becomes structurally embedded rather than episodic. In capacity-constrained settings, even marginal efficiency gains may translate into meaningful access expansion, but only when hybrid care pathways are formally embedded and supported within routine financing and workforce structures.

From a healthcare system perspective, stakeholders emphasise the potential to reduce pressure on hospital and outpatient services, optimise clinic capacity, and improve efficiency, particularly in underserved or capacity-constrained settings. However, these gains depend on workflow redesign, clinical training, interoperability, and IT support. Stakeholders frequently describe teleconsultation as "invisible work" when not recognised in reimbursement or staffing structures. Leadership, organisational readiness, and incentive alignment are therefore as important as the technology itself. Technological readiness alone is insufficient. I identify four priority areas for policy action: regulatory clarity, payment reform, interoperable data standards, and workforce recognition. Sustainable integration requires regulatory clarity, interoperable infrastructure, financing reform, and formal workload recognition. I therefore argue that organisational reform should be treated as a precondition for economic realisation rather than a secondary implementation detail.

I show that equity considerations require explicit policy attention. Teleconsultations can improve access for rural, mobility-limited, and underserved populations, yet digital exclusion remains a substantial risk. Limited digital literacy, poor connectivity, restricted access to devices, and trust concerns may reinforce rather than reduce disparities. National digital strategies should embed equity safeguards at the design stage, including targeted literacy programmes, device access support, assisted digital pathways, and infrastructure investment. Distributional consequences should be treated as core evaluation criteria rather than secondary outcomes in both implementation and EE design.

The implications for EE are substantial. Conventional narrow cost-effectiveness approaches risk misrepresenting teleconsultation value if multidomain and distributional effects are omitted. For decision-makers, I identify the following core design requirements:

- broader evaluative perspectives, including patient-incurred costs, caregiver burden, productivity effects, and environmental impacts,
- longer analytic time horizons (e.g., three to five years) reflecting the chronic trajectory of HF,
- realistic hybrid comparators rather than artificial teleconsultation-versus-usual-care extremes,
- robust and interoperable data infrastructures to ensure credible outcome and cost measurement,
- reimbursement and incentive alignment, so that identified efficiency gains translate into system-level effects.

Importantly, some consequences identified in the framework analysis are descriptive or directional rather than being fully monetised. They nevertheless indicate potential cost shifts, resource reallocations, or distributional implications. Excluding such domains would systematically narrow the evaluative lens and risk undervaluation.

These implications directly substantiate the methodological argument that I develop in Chapter 3. They do not replace conventional CEA but instead structure it more transparently. They operationalise a staged logic in which multidomain impacts are first identified and documented (IIM), then transparently presented (CCA), and only subsequently aggregated where appropriate. In Chapter 7, I use IIM to map clinical, organisational, societal, environmental, and distributional domains identified in this framework analysis, including effects that are descriptive or not yet fully quantifiable. I then use CCA to present these domains in a structured format before any aggregation is undertaken. I explicitly link qualitative structuring (Chapter 5), quantitative estimation (Chapter 6), and multidomain mapping (Chapter 7) as complementary components of the evaluation rather than as separate analytical exercises.

I argue that future research needs to combine administrative data with qualitative evidence to capture contextual moderators of effectiveness, implementation fidelity, and sustainability. Furthermore, evaluation frameworks for DHI should routinely incorporate organisational workload shifts, user experience, distributional effects, and long-term system impacts alongside conventional cost-effectiveness metrics. I show that strengthening analytic capacity and data infrastructure remains essential to avoid systematic undervaluation of DHI.

In summary, I identify that successful integration and meaningful evaluation of teleconsultations in HF care require:

- clear clinical eligibility and triage guidelines,
- formal institutionalisation of hybrid care pathways,
- investment in interoperable digital infrastructure and workforce training,
- reimbursement reform and workload recognition mechanisms,
- explicit equity safeguards addressing digital divide risks,
- structured data systems and national standards,
- broader evaluative perspectives and extended time horizons in EE,
- realistic hybrid comparators reflecting routine practice, and
- systematic multidomain impact mapping and transparent presentation through structured approaches such as IIM and CCA.

In the next chapter, I present a quantitative analysis of teleconsultations for patients with HF in Slovenia using administrative data. These analyses capture measurable utilisation, expenditure, and mortality outcomes only. Broader domains, such as caregiver burden, organisational consequences, equity effects, and environmental impacts, cannot be fully

assessed within administrative datasets and I therefore integrate them in Chapter 7 through structured application of the IIM and CCA. This staged design ensures coherence between stakeholder-informed structuring, empirical estimation, and multidomain evaluation.

6 ASSESSMENT OF THE EFFECTS OF TELECONSULTATIONS FOR HEART FAILURE PATIENTS IN SLOVENIA USING ADMINISTRATIVE DATA

In Chapter 4.2, I present the results of a systematic literature review on the EE of teleconsultations in patients with HF. The studies to date have varied substantially in outcomes, costing approaches, and analytical methods, reflecting both the complexity of DHI and the methodological challenges outlined in Subchapter 3.3. In Chapter 5, I conduct qualitative research with relevant stakeholders to examine perspectives on teleconsultations for HF, with particular emphasis on EE-relevant costs, benefits, and implementation challenges.

Building directly on these conceptual and stakeholder findings, I now examine the empirical effects of teleconsultations for patients with HF in Slovenia, using administrative data. In this chapter, I move from conceptual and qualitative analysis to quantitative assessment, providing patient-level evidence on healthcare utilisation, hospitalisations, healthcare expenditure, and mortality. In this chapter, I assess the association between teleconsultation assignment and subsequent healthcare utilisation, expenditure, and mortality using regression and time-to-event models.

Teleconsultations were introduced in outpatient cardiology clinics in Slovenia in March 2020, initially without dedicated billing codes. Formal service codes for shorter and longer teleconsultations were implemented in December 2020 and remain in use. The introduction of teleconsultations thus coincides with substantial pandemic-related changes in healthcare organisation and patient behaviour, which complicate causal inference and which are discussed explicitly in the methodological and limitations sections below.

The research question addressed in this chapter is:

RQ4*: "Is a telemedicine intervention in the form of teleconsultations for chronic HF in Slovenia economically viable?"*

To answer the research question, I conduct a retrospective observational cohort study based on HIIS administrative data, including data on hospitalisations, outpatient visits, and medication prescriptions. The total observation period spans three years, consisting of a 2-year baseline period (pre-treatment) before the index consultation (index treatment date) and a 1-year follow-up period (post-treatment) after the index consultation. Given the non-random assignment to teleconsultations and the observable baseline differences between patients, the empirical strategy combines multivariable regression with PSM to construct a comparable matched cohort. Residual confounding inherent in observational administrative data cannot be fully excluded.

To investigate the effect of teleconsultations on healthcare utilisation, healthcare expenditure, and mortality, I divide the main research question into a series of targeted

subquestions, which I analyse using appropriate statistical methods. The first subquestion addresses determinants of assignment to teleconsultations:

RQ4.1: *"Which patient characteristics during the two years prior to the consultation increase the likelihood of receiving a teleconsultation rather than an in-person consultation following hospitalisation for HF?"*

I model assignment using logistic regression based on pre-treatment characteristics, including health status, demographics, and prior healthcare utilisation. I then use the estimated propensity scores to construct a matched cohort of comparable patients. The following research subquestions address the effects of teleconsultations in the year following the index consultation:

RQ4.2: *"What is the effect of teleconsultation, relative to in-person consultation, on 1-year post-consultation healthcare expenditures in a propensity-score matched cohort of HF patients?",*

RQ4.3: *"What is the effect of teleconsultation, relative to in-person consultation, on 1-year post-consultation healthcare utilisation in a propensity-score matched cohort of HF patients?",* and

RQ4.4*: "What is the association between teleconsultations and mortality in a propensity-score matched cohort of HF patients?",* with additional subquestions

> RQ4.4.1: *"Which patient characteristics are associated with an increased likelihood of 1-year mortality following teleconsultation, in a propensity-score matched cohort of HF patients?",* and
>
> RQ4.4.2: *"Do teleconsultations influence the time to death within one year, compared to matched controls, in a propensity-score matched cohort of HF patients?"*

The empirical strategy applies outcome-specific regression and survival models within the matched cohort, accounting for the matched design through appropriate stratification, conditioning, or robust standard errors (hereinafter SE). Model choice reflects the distributional properties of the outcomes (e.g., semi-continuous expenditure data and count-based utilisation measures). I develop the model specifications in consultation with a specialised cardiologist to ensure clinical plausibility while maintaining statistical parsimony.

Subchapters 6.1 and 6.2 describe the study design and data sources. Subchapter 6.3 outlines the empirical strategy. Subchapter 6.4 presents the results, followed by a discussion of findings and limitations (6.5) and policy-relevant implications (6.6). The findings of this chapter are subsequently integrated into the CCA in Chapter 7, together with the conceptual and qualitative evidence presented earlier in the thesis.

6.1 Study design

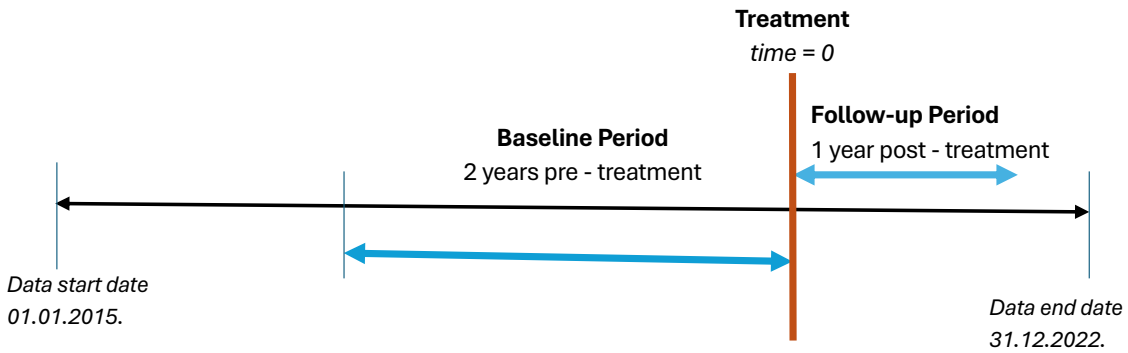
In this subchapter, I describe the study design, data source, cohort construction, and observation period.

This is a retrospective observational study using a matched cohort design based on anonymised administrative patient-level data. HIIS provided the data (contract no. 1721-13/2021-DI/1, Annex 1). The relevant ethics committee approved the study (no. 0120-223/2021/4, Annex 1). The dataset includes administrative records of patients with HF from 2015 to 2023. The data include hospitalisation records (primary and secondary diagnoses, procedures, previous admissions), outpatient specialist cardiology visits, ED visits, and prescription data for included patients. While these records provide detailed utilisation and diagnostic information, they do not contain granular clinical measures (e.g., functional status or ejection fraction), limiting adjustment for disease severity.

I define two cohorts of patients with HF based on outpatient specialist visits with a specialised cardiologist or cardiac surgeon. Patients who receive a teleconsultation form the treatment group, and those who receive an in-person consultation form the control group. The total observation period spans three years. The pre-treatment (baseline) period covers two years prior to the index consultation, and the post-treatment (follow-up) period covers one year after the index consultation (see Figure 14).

Information on health status, demographics, and healthcare utilisation included in hospital admission data was not available for patients who were never hospitalised. Therefore, to be included in the analysis, patients had to have at least one hospitalisation during the 2-year baseline period to allow adjustment for prior health status. I excluded patients with hospitalisations recorded before the baseline window to ensure a uniform observable history and reduce heterogeneity in prior disease history within the available data window.

Figure 14: Overall study observation period



Source: Author's work

In addition, patients had to receive a teleconsultation or an in-person consultation in 2020 or 2021 to allow a complete 1-year follow-up, as data were available until 31 December 2022.

Therefore, the inclusion criteria are:

- patients with at least one hospitalisation during the 2-year baseline period,
- patients with no hospitalisations recorded before the start of the baseline period, and
- patients with a complete 1-year follow-up after consultation.

For statistical analysis, I created a binary variable, "treatment", coded 1 for teleconsultation and 0 for in-person consultation. Given the non-random assignment to teleconsultations, I estimate propensity scores using logistic regression based on pre-treatment characteristics and construct a matched cohort of comparable patients. I conduct all subsequent analyses within this matched cohort. Residual confounding due to unobserved factors inherent in administrative data cannot be fully excluded.

I apply outcome-specific regression and survival models within the matched cohort, reflecting the distributional properties of utilisation, expenditure, and mortality outcomes. Detailed model specifications are provided in Subchapter 6.3. I estimate alternative specifications (unadjusted, covariate-adjusted, and autoregressive models incorporating lagged outcomes) to assess robustness. All statistical regression and time-to-event models that I present take into account the matching design, either by stratification, conditioning, or robust SE based on the matching group ID. The 1-year post-consultation outcomes examined are:

1. Healthcare utilisation, including
    a. number of hospitalisations,
    b. number of ED visits,
    c. number of outpatient cardiology visits,
    d. number of procedures during hospitalisations,
    e. number of secondary diagnoses during hospitalisation, and
    f. number of prescriptions by pharmaceutical group,
2. Healthcare expenditures, including
    a. expenditure on hospitalisation,
    b. expenditure on ED visits,
    c. expenditure on outpatient cardiology visits,
    d. expenditure on prescribed pharmaceuticals,
3. Mortality and time to death.

I perform all statistical analyses using R version 4.2.2 (RStudio Team, 2022) and Stata versions 15 and 17 (StataCorp, 2015, 2021).

6.2 Data collection

In this subchapter, I describe the administrative data source, classification systems, construction of analytical variables, and the cohort selection process. The administrative data obtained from the HIIS are reported to be of high quality, with minimal deviations and a high degree of compliance with coding standards and data integrity protocols (Bijec, 2024).

The administrative dataset covers patients with HF from 2015 to 2023 and includes hospitalisation records, outpatient cardiology visits (including teleconsultations), ED visits, and pharmaceutical prescription records.

I classify disease diagnoses using ICD-10-AM to identify HF and relevant comorbidities (see Subchapter 4.1 and Appendix 3). Therapeutic and diagnostic procedures performed during hospitalisation are recorded using the National Classification of Therapeutic and Diagnostic Procedures. Pharmaceuticals are classified according to ATC codes (see Subchapter 4.1 and Table 1 in Appendix 6). Outpatient specialist visits and inpatient visits are coded using SKD codes, the Slovenian version of the EU Statistical Classification of Economic Activities (NACE Rev.2; Statistical Office of the Republic of Slovenia, 2008), and the Classification of Types of Healthcare Activities, which specify the hospital department or specialised clinic (National Institute of Public Health, 2022; see Table A.4 in Appendix 6).

Teleconsultations are delivered within specialised outpatient cardiology clinics, and I identify them using the following service codes:

- 11604: Consultations with specialist,
- 91103: Teleconsultations – short (ePosvet – krajši), and
- 91104: Teleconsultations – long (ePosvet – daljši).

Hospitalisation data include admission and discharge dates, primary and secondary diagnoses, procedures, length of stay, diagnosis-related group codes, and associated expenditure. Diagnosis-related group codes are determined based on the primary diagnosis, secondary diagnoses and recorded procedures, and are used administratively for reimbursement. Patient characteristics such as age at admission and gender are also recorded. Outpatient data include visit dates, recorded diagnoses, services provided, and associated expenditure. Prescription data include referral diagnoses, ATC codes, drug names, issue dates, and expenditure. All datasets contain a unique patient ID used to merge records at the patient level. I standardised date formats, removed duplicates, and performed internal consistency checks to ensure accurate linkage and coherence of longitudinal records.

I next describe the construction of analytical variables used in the empirical analysis. I constructed a range of derived variables to operationalise treatment exposure, baseline characteristics, and outcomes. Variable construction is informed by prior literature, clinical

relevance, and the structure of the available administrative data. Aggregate measures include counts (e.g., number of hospitalisations, ED visits, and cardiology visits) and total expenditure over defined time windows. Indicator variables capture binary events or conditions, such as teleconsultation assignment, the presence of specific comorbidities, or receipt of prescriptions from defined pharmaceutical groups. Time-related variables define pre- and post-treatment periods and measure time to death.

I developed composite variables to approximate illness burden using administrative proxies. I used the average number of secondary diagnoses per hospitalisation as a proxy for overall health status, reflecting the burden of chronic disease and multimorbidity. Similarly, I used the average number of procedures per hospitalisation as an indicator of treatment intensity and clinical complexity. To approximate disease severity using available administrative data, I constructed a patient-level hospital severity score defined as the mean of two components: (1) the mean number of secondary diagnoses per hospitalisation and (2) the mean number of procedures per hospitalisation, calculated across all hospital admissions observed in the 2-year baseline period. This composite measure represents a pragmatic methodological solution to the absence of detailed clinical severity indicators in administrative data and enables a structured approximation of baseline illness burden within the constraints of the available dataset. Although HF severity is clinically classified using the New York Heart Association system (hereinafter NYHA; McDonagh et al., 2021), such data are not available. The composite score therefore serves as an administrative proxy for illness burden.

I defined mortality as all-cause death within one year of the treatment date. I calculated time-to-death (in days) for the survival analyses. I derived healthcare expenditures from HIIS reimbursement data for hospitalisations, outpatient visits, ED visits, and prescriptions, aggregated per patient over the relevant observation periods. All expenditure values are expressed in euros.

I next operationalised treatment exposure and defined the baseline and follow-up observation windows. The first step in data preparation was to define the treatment and control groups. I derived the treatment indicator from outpatient cardiology visit records by identifying whether patients received a teleconsultation or an in-person consultation. I defined the index consultation as the date of the first cardiology consultation within the eligible treatment years. This index consultation determined the 2-year baseline and 1-year follow-up periods and was used to calculate age at treatment and to generate an indicator for the year of treatment (2020 or 2021), reflecting differing pandemic conditions.

Based on the defined pre- and post-treatment windows, I aggregated utilisation and expenditure variables at the patient level. For each observation period, I calculated the total number of hospitalisations, ED visits, and specialist cardiology visits, as well as corresponding expenditure totals. For each hospitalisation, multiple secondary diagnoses are recorded. I used these diagnoses to construct binary indicators for cardiovascular and non-cardiovascular comorbidities (see Subchapter 4.1). In addition, I calculated the total

comorbidity counts per patient, both overall and within specific groups. The hospitalisation dataset also includes detailed procedure records, which I incorporated into severity and utilisation measures. I defined binary indicators for prescriptions within each relevant pharmaceutical group (see Subchapter 4.1.2 and Table 1 in Appendix 6). In addition, I calculated the total number of pharmaceutical groups from which a patient received prescriptions during the observation period. These derived variables enable longitudinal tracking at the patient level and facilitate consistent aggregation of utilisation and outcomes across baseline and follow-up periods.

Before proceeding to cohort selection, I applied additional data cleaning procedures to ensure the internal consistency of hospital episodes. I identified same-day transfers and treated them as a single hospitalisation episode using the unique hospital ID and admission and discharge dates. I aggregated the associated variables, including length of stay and expenditure, accordingly. Length of stay was recalculated based on admission and discharge dates to ensure internal consistency.

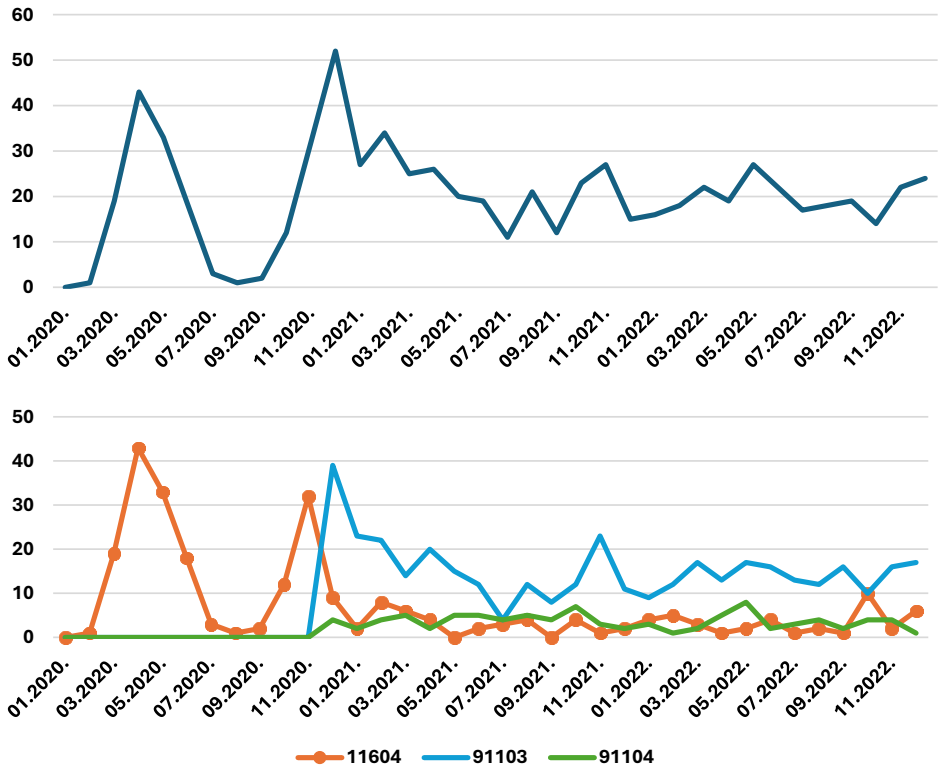
In addition to patient-level clinical and utilisation variables, I incorporated contextual socioeconomic and pandemic-related indicators. I extracted the municipality of residence using the municipality ID provided by the HIIS. For patients who changed residence during the observation period, I used the most recent municipality. I linked the municipality ID to average monthly income per 1,000 inhabitants and the municipal development index (National Institute of Public Health, 2020; Statistical Office of the Republic of Slovenia, 2022). To account for systemic pressures during the COVID-19 pandemic, I incorporated the Oxford COVID-19 Government Response Stringency Index (Hale et al., 2021). This index provides a standardised daily measure of policy intensity and was included as a time-dependent variable in selected models. A detailed overview of all constructed and extracted variables, grouped by category, is provided in Appendix 4.

After constructing the analytical variables, I restricted the dataset to patients who fulfilled the predefined inclusion criteria. As explained at the beginning of this chapter, teleconsultations were rarely used in Slovenia before the outbreak of the COVID-19 pandemic in March 2020, when routine implementation began. During the primary observation period (2020–2022), teleconsultations were introduced for both cardiology and cardiac surgery consultations, although uptake in cardiac surgery remained limited. Teleconsultation volume increased sharply during the initial pandemic period, declined during periods of relaxed restrictions (summer months), and stabilised in 2021 with observable seasonal variation (see Figure 15). The highest monthly volume was recorded in December 2020 (52 teleconsultations). These seasonal trends indicate that the use of teleconsultations is closely linked to pressure on the healthcare system and pandemic-related policy measures.

Teleconsultations were initially recorded under the general specialist consultation code (11604). In December 2020, two dedicated teleconsultation codes were implemented: 91103

(short teleconsultation) and 91104 (long teleconsultation). Following their introduction, use shifted progressively towards the new codes, particularly for shorter teleconsultations. The transition in coding practice is visible in Figure 15.

Figure 15: Teleconsultation frequency over time



Source: Author's work, based on HIIS data

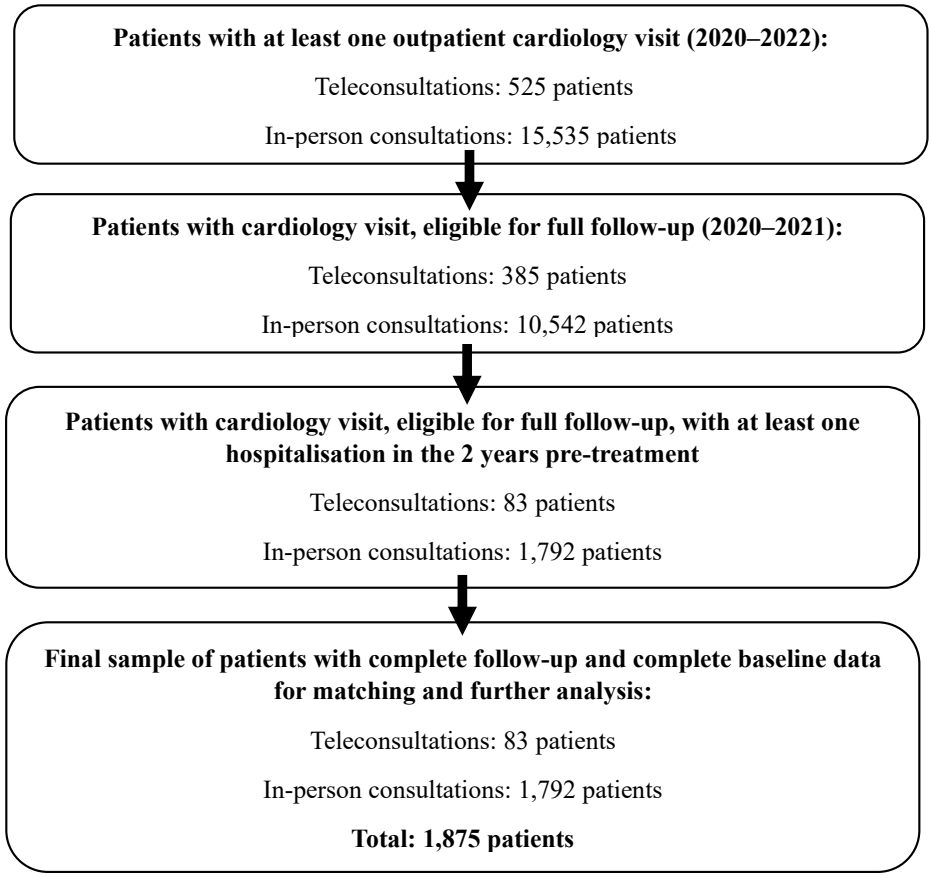
Between January 2020 and December 2022, 525 patients received at least one teleconsultation (714 teleconsultation episodes). In contrast, 15,535 patients received 29,218 in-person specialist cardiology consultations during the same period. To ensure a complete observation window comprising a 2-year baseline period and a 1-year follow-up period, only patients who received a teleconsultation or in-person consultation in 2020 or 2021 are eligible for inclusion (follow-up data are available until 31 December 2022). Based on this criterion, I reduced the sample to 385 teleconsultation patients (73.33% of all teleconsultation patients) and 10,542 in-person consultation patients (67.86% of all in-person consultation patients).

However, not all eligible patients had hospitalisation records within the 2-year baseline period. Because hospitalisation data contain key variables required for assessing baseline health status and constructing severity indicators, and because these variables are essential for the matching procedure, patients without hospitalisations during the baseline window could not be included in the analytical cohort. After applying this additional inclusion criterion (at least one hospitalisation in the 2-year baseline period), the final pre-matching

sample comprised 83 teleconsultation patients (21.56% of the initially eligible teleconsultation group) and 1,792 in-person consultation patients (17.00% of the initially eligible control group). These patients had complete baseline information on healthcare utilisation, demographic characteristics, diagnostic profiles, and prescriptions and were included in subsequent analyses. The flow of patient selection and cohort construction is illustrated in Figure 16.

In summary, by integrating hospital, outpatient, prescription, and contextual data, I constructed a comprehensive patient-level analytical dataset. This dataset captures healthcare utilisation (inpatient and outpatient), pharmaceutical use, healthcare expenditure, mortality, demographic characteristics, and contextual socioeconomic and pandemic-related factors. It provides the foundation for robust multivariable modelling of treatment effects while accounting for baseline illness burden and systemic influences.

Figure 16: Flow diagram of patient selection and cohort construction



Source: Author's work, based on HIIS data

6.3 Methodology

To answer the research questions outlined at the beginning of this chapter, I apply a structured empirical strategy based on regression modelling tailored to the distributional

properties of each outcome variable. I conduct analyses using the final pre-matching sample of 1,875 patients with complete baseline and follow-up data, and I subsequently restrict the analysis to the matched cohort. I select covariates to capture demographic characteristics, baseline health status, and prior healthcare utilisation, while preserving model parsimony given the limited number of treated observations.

In Subchapter 6.3.1, I present the approach used to generate summary statistics and to compare patient cohorts prior to matching. Due to the relatively small number of treated patients (83 in the treatment group and 1,792 in the control group before matching), the number of covariates that can be included in multivariable models is constrained. In line with the events per variable (hereinafter EPV) principle, I restrict the number of predictors, given the limited number of outcome events (e.g., deaths) and the small treated sample. Subchapter 6.3.1 therefore outlines the covariate screening and dimensionality reduction strategy. Covariate selection is both data-based and clinically sound, as I base it on prior literature, clinical input from a specialised cardiologist, and empirical diagnostics, with the aim of balancing statistical robustness, clinical relevance, and model parsimony.

The modelling strategy proceeds sequentially. First, I examine determinants of assignment to teleconsultation, defined as patient characteristics observed in the pre-intervention period, using logistic regression. Second, I use the estimated propensity scores to construct a matched cohort of treated and control patients with comparable baseline characteristics. Third, I estimate outcome-specific regression models within the matched cohort to evaluate the association between teleconsultation assignment and healthcare utilisation, expenditure, and mortality. All regression models applied (with the exception of survival models) belong to the class of generalised linear models (hereinafter GLM), selected according to the distributional properties of the respective outcomes.

To assess which pre-intervention characteristics are associated with assignment to teleconsultation, I estimate a logistic regression model in Subchapter 6.3.3. After estimating the logistic regression model and assessing its adequacy, I construct a matched cohort using PSM. The objective is to reduce observable confounding and improve balance between the treatment group (teleconsultation) and the control group (in-person consultation). I compare alternative matching specifications and select the preferred approach based on balance diagnostics and model evaluation criteria. In Subchapter 6.3.4, I describe the matching procedure and the comparison of baseline characteristics before and after matching.

Within the matched cohort, I estimate outcome-specific regression models. For each outcome category, I estimate three model specifications:

1. an unadjusted model,
2. a covariate-adjusted model, and
3. a model further adjusted using an autoregressive specification by including lagged outcomes from the preceding 1-year period, where feasible.

I assess model adequacy using diagnostics appropriate to each modelling framework.

For healthcare utilisation outcomes, such as counts of hospitalisations, specialist visits, and prescriptions, I use negative binomial regression models. I present the model diagnostics and specification tests in Subchapter 6.3.5, with results reported in Subchapter 6.4.3. When healthcare expenditure is the outcome of interest, I use a compound Poisson–Gamma (Tweedie) regression model to account for semi-continuous, right-skewed data with a substantial mass at zero and a heavy upper tail. I present the model diagnostics in Subchapter 6.3.6, and results in Subchapter 6.4.4.

For mortality, I first estimate a logistic regression model for the binary outcome of death within one year. I present the model specification and diagnostics in Subchapter 6.3.7, and results in Subchapter 6.4.5. To analyse time to death, I estimate Cox proportional hazards models, with assumptions and specification discussed in Subchapter 6.3.7 and results reported in Subchapter 6.4.5.

6.3.1 Descriptive statistics and model specification

I begin this methodology subchapter by presenting summary statistics of the sample of 1,875 patients included in the analysis, identifying the types of outcome variables considered, and outlining the structured approach to covariate selection and model specification. The development and evaluation of the models proceed as follows (e.g., Dyer, 2025; Sauerbrei et al., 2020):

1. Descriptive analysis
    a. summary statistics for all variables, and
    b. stratification by treatment group (treated vs. control),
2. Conceptual relevance (theory-driven selection)
    a. inclusion of variables based on prior evidence, and
    b. inclusion of clinically relevant variables,
3. Empirical screening (data-driven selection)
    a. univariate screening (model specific), and
    b. removal of variables with low variance across groups,
4. Redundancy and multicollinearity assessment,
    a. correlation matrix for continuous variables, and
    b. variance inflation factor (hereinafter VIF),
5. Parsimonious model building
    a. stepwise regression (model specific), and
    b. model evaluation (model specific).

First, I conduct a descriptive analysis. I generate summary statistics for relevant variables and compare them between the treatment group (teleconsultation) and the control group (in-person consultation). I select statistical tests according to variable type and distribution.

Continuous variables are assessed for normality using the Shapiro–Wilk test and skewness/kurtosis diagnostics. For approximately normally distributed variables, I report means and standard deviations (hereinafter SD), and group differences are assessed using Student's *t*-test (Mishra et al., 2019). For non-normally distributed variables, I report medians and interquartile ranges (hereinafter IQR) and groups are compared using the Mann–Whitney test. For binary categorical variables, I present contingency tables with frequencies and percentages, and group differences are tested using the χ^2 test or Fisher's exact test where appropriate. I summarise discrete count variables using medians and IQR, reflecting their typically skewed distribution in healthcare data, and compare them using the Mann–Whitney U test (Mishra et al., 2019).

Second, covariate selection follows a theory-driven approach. I include variables based on prior research, the relevant theoretical framework, and clinical relevance discussed with a specialised cardiologist.

Third, I conduct empirical screening within each regression model. I consider excluding variables exhibiting minimal variability (defined as less than 2.5% variation across the sample) because they contribute limited explanatory information. For example, depression and cancer are present in a small proportion of patients, and frailty-related comorbidity is absent; these variables are therefore excluded. I perform univariate regression analyses for each model specification. I consider predictors with *p*-values greater than 0.25 for removal, while I retain those below this threshold for further consideration to avoid excluding potentially relevant covariates (Heinze et al., 2018). The final selection for each model is described in the respective subchapters.

Fourth, I assess redundancy and multicollinearity. Correlation coefficients exceeding 0.6 are considered indicative of potential redundancy (Heinze et al., 2018). In cases of high correlation, I prioritise clinically and conceptually interpretable measures. For example, average monthly income per municipality is retained over the composite development index due to interpretability and comparable explanatory content. Similarly, I reduce highly correlated indicators of hospitalisation burden to a single summary severity score. Multicollinearity is further evaluated using the VIF, with values exceeding 5 considered indicative of problematic collinearity. Where I detect substantial overlap, I do not retain conceptually related and highly correlated variables simultaneously. Instead, I retain more parsimonious aggregate indicators, while redundant or nested components are excluded to improve model stability and avoid overparameterisation (J. Cheng et al., 2022).

Fifth, I apply a data-driven stepwise variable selection procedure to achieve a parsimonious specification while limiting overfitting. Stepwise elimination begins with the full set of candidate covariates and sequentially removes the least significant predictors, subject to model-specific thresholds (Hosmer, Lemeshow & Sturdivant, 2013). Clinically established predictors are retained irrespective of statistical significance and of the results of the stepwise selection. Where appropriate, right-skewed variables are log-transformed using $\ln(x + 1)$ to

reduce the influence of extreme values, approximate normality where relevant, and retain zero observations (e.g., Zuur et al., 2010).

Finally, I perform model evaluation using diagnostics appropriate to each regression model. In the subsequent subchapters, I report detailed diagnostic results together with the corresponding models.

6.3.2 Generalised linear models

In classical linear regression, or ordinary least squares (hereinafter OLS) regression, the model is linear in parameters and requires the absence of perfect multicollinearity and a zero conditional mean of the error term; homoscedastic and independent errors ensure efficiency, while normality is needed only for exact small-sample inference (e.g., Wooldridge, 2019). These assumptions are often violated in healthcare data, where outcomes are frequently binary, count, or right-skewed.

GLM provide a flexible framework for such settings by allowing the conditional mean to be linked to the covariates through non-identity link functions and by specifying distributional families beyond the normal (McCullagh & Nelder, 1989). In this study, the outcomes include binary assignment and mortality indicators, overdispersed count variables, and skewed expenditure measures; these characteristics motivate the use of GLM specifications tailored to their underlying distributional properties.

Conceptually, a GLM consists of a distributional family for the outcome, a linear predictor, and a link function connecting the conditional mean to covariates. In applied terms, the key requirement is correct specification of the conditional mean structure, including the functional form of the linear predictor, the distributional family of the outcome, and the link function (McCullagh & Nelder, 1989). In addition, valid inference requires independence of observations (or appropriate correction when dependence is present) and absence of severe multicollinearity. Other model-specific assumptions are discussed in the respective subchapters below.

I estimate all GLM models in this chapter by maximum likelihood (McCullagh & Nelder, 1989; Wooldridge, 2019). Model comparison across alternative specifications relies on the log-likelihood, Akaike Information Criterion (hereinafter AIC), and Bayesian Information Criterion (hereinafter BIC), which balance model fit and parsimony by penalising excessive model complexity. Lower AIC or BIC values indicate relatively better fit among models I estimate on the same dataset (McCullagh & Nelder, 1989). I additionally report deviance statistics where appropriate (McCullagh & Nelder, 1989).

I interpret regression coefficients in the various models according to the chosen link function. I report confidence intervals (hereinafter CI) alongside regression coefficients to reflect statistical uncertainty and the range of plausible parameter values. Unlike reliance on *p*-

values alone, CI provide information about both magnitude and precision of estimated effects (e.g., Wooldridge, 2019).

Within this framework, logistic regression is used for binary outcomes, negative binomial regression for overdispersed counts, and compound Poisson–Gamma regression for semi-continuous expenditure outcomes. I discuss time-to-event models separately, as they belong to a different modelling class.

Across all regression models used in this chapter, model specification follows a consistent structure. For each outcome type, I do the following:

- define the distributional assumptions,
- specify the link function and interpret the coefficients,
- outline key identifying assumptions, and
- assess model adequacy using diagnostics appropriate to the respective framework.

In Subchapter 6.4, I present detailed diagnostic results together with the empirical results. The next subchapter introduces logistic regression, which is first applied to analyse assignment to teleconsultations.

6.3.3 Logistic regression for binary outcomes

In this subchapter, I introduce the logistic regression model for binary outcomes used in this study. The specification follows the general modelling strategy outlined above and established in the literature (e.g., Agresti, 2003; Hosmer et al., 2013), and I apply it to both assignment to teleconsultations (Subchapter 6.4.2) and the binary mortality outcome (Subchapter 6.4.5.1).

Logistic regression is a statistical model for estimating the probability of a binary outcome conditional on one or more predictor variables. For each observation i, the outcome $Y_i \in \{0,1\}$ follows a Bernoulli distribution with probability $\mu_i = \mathbb{P}(Y_i = 1)$. The model links the conditional probability μ_i to covariates through the logit (canonical) link function:

$$\log\left(\frac{\mu_i}{1-\mu_i}\right) = x_i{}^{\top}\beta$$

The regression coefficients β_j represent the change in the log-odds of the outcome associated with a one-unit increase in predictor x_j, holding other variables constant (Hosmer et al., 2013). Coefficients are exponentiated and reported as odds ratios (hereinafter OR), $\mathrm{OR} = \mathrm{e}^{\beta_j}$, interpreted as multiplicative changes in the odds of the outcome associated with a one-unit increase in the predictor (Hosmer et al., 2013).

Key assumptions include a binary outcome, conditional independence of observations, linearity between continuous predictors and the logit of the outcome, and absence of perfect separation. I assess linearity using the Box–Tidwell test (Hosmer et al., 2013), and where necessary, I apply transformations (e.g., logarithmic). The model must be correctly specified and free from severe multicollinearity. I evaluate multicollinearity using the VIF and address problematic values through variable reduction or consolidation (J. Cheng et al., 2022; see Subchapter 6.3.1).

I evaluate the model using multiple complementary diagnostics structured along four dimensions (e.g., Boateng & Abaye, 2019; Fawcett, 2006; Hosmer et al., 2013; Menard, 2000):

1. Overall specification and fit
    a. Link test,
    b. McFadden's pseudo-R^2
    c. AIC and BIC,
    d. VIF
2. Calibration
    a. Hosmer–Lemeshow test,
    b. sensitivity, specificity, accuracy,
3. Discrimination
    a. area under the receiver operating characteristic curve (hereinafter AUC),
4. Stability and overfitting assessment
    a. training/test comparison,
    b. bootstrap.

In addition to AIC and BIC, I use the link test to assess potential functional form misspecification. McFadden's pseudo-R^2 summarises the proportional improvement in log-likelihood of the fitted model relative to the intercept-only model. I evaluate calibration using the Hosmer–Lemeshow test, which compares observed and expected event rates across risk subgroups. I summarise classification performance using sensitivity, specificity, and overall accuracy at the selected probability threshold. I assess discrimination using the AUC, which measures the model's ability to distinguish between outcome states across all classification thresholds (Fawcett, 2006). Importantly, AUC remains a reliable diagnostic tool, even in the presence of rare events, as is the case for being assigned to teleconsultations (Hosmer et al., 2013). To assess predictive stability and potential overfitting, I partition the dataset into training and test subsets and compare AUC values. I additionally use bootstrap resampling to examine coefficient stability and sampling variability. This validation framework allows me to assess model adequacy in terms of specification, calibration, discrimination, and predictive robustness.

I first apply logistic regression to model assignment to teleconsultation as a function of observed baseline characteristics during the 2-year pre-treatment period. Candidate covariates include demographic variables, comorbidities, prior utilisation, and prescription patterns, consistent with relevant literature and available administrative data (see Subchapter 6.2).

Variable refinement follows a structured selection strategy described in Subchapter 6.3.1 (e.g., Fawcett, 2006; Heinze et al., 2018; Hosmer et al., 2013; Menard, 2000). This approach balances model parsimony and adherence to the EPV principle. The final assignment model includes nine covariates, all statistically significant at conventional levels ($p < 0.10$). Model performance diagnostics indicate adequate calibration and discrimination. Out-of-sample AUC values in the test subset and bootstrap estimates further confirm the stability of the model coefficients and predictive performance. I subsequently use the estimated propensity scores to construct the matched cohort via PSM, as described in Subchapter 6.3.4.

6.3.4 Propensity score matching and matched cohort construction

Having established a well-performing logistic regression model for treatment assignment, I proceed to estimate propensity scores and construct a matched cohort of patients with HF.

Patient pre-treatment characteristics represent potential confounders that influence both treatment allocation and outcomes. This is typical in observational health data and must be addressed to reduce bias in estimated treatment effects. The idea behind PSM is to approximate selected features of a randomised comparison by creating a subsample in which the covariates are similar in the treated and control groups. In this subchapter, I discuss the following components, drawing on established frameworks (Austin, 2014; Leite, 2019; Rosenbaum & Rubin, 1985; Stuart, 2010):

1. PSM model specification
    a. matching method,
    b. caliper width, and
    c. exclusion of unmatched units,
2. Assessment of matching quality
    a. covariate balance diagnostics,
    b. variance ratios, and
    c. graphical diagnostics,
3. Evaluation statistics
    a. pseudo-R^2,
    b. likelihood ratio χ^2 and p-value, and
    c. reduction in standardised mean differences (hereinafter SMD).

PSM is a statistical technique used to reduce confounding by observed variables and selection bias in observational studies where treatment assignment is not randomised (Stuart,

2010). More specifically, treated patients are matched with control patients who have similar estimated probabilities of receiving treatment, thereby improving balance in observed baseline characteristics.

Formally, let $T_i \in \{0,1\}$ denote treatment status and X_i denote the vector of observed pre-treatment covariates for patient i. The propensity score is defined as:

$$\mathrm{e}(X_i) = \mathbb{P}(T_i = 1|X_i).$$

In this study, propensity scores are estimated using the logistic regression model described in Subchapter 6.3.3:

$$\log\left(\frac{\mathbb{P}\,(\,T_i = 1 \mid X_i\,)}{1 - \mathbb{P}\,(\,T_i = 1 \mid X_i\,)}\right) = {X_i}^{\top}\beta.$$

After estimating the regression coefficients $\hat{\beta}$, predicted probabilities $\hat{e}(X_i)$ are obtained and used for matching (Austin, 2011; Stuart, 2010).

Propensity scores can be used for matching, weighting, or stratification (Stuart, 2010). Two key assumptions underlie PSM. First, conditional independence (unconfoundedness), meaning that, given observed covariates X_i, treatment assignment is independent of potential outcomes. Second, common support (overlap), meaning that for each treated unit there is a sufficiently similar control unit.

Based on the well-specified and evaluated logistic regression model from the previous subchapter, I use the estimated propensity scores to match patients in the treatment group (teleconsultation) and the control group (in-person consultation) with the aim of balancing observed baseline covariates (Leite, 2019). The objective is to construct two comparable groups such that for each treated unit $i \in \{i: T_i = 1\}$, there exists at least one control unit $j \in \{j: T_j = 0\}$ with a similar distribution of observed covariates:

$$X_i|T_i = 1 \approx X_j|T_j = 0.$$

I implement matching using nearest neighbour (hereinafter NN) matching combined with a caliper restriction (Leite, 2019; Stuart, 2010). Specifically, NN(k) matching allows each treated patient to be matched with up to k control patients with the closest propensity scores, while the caliper imposes a maximum allowable distance:

$$|\hat{\mathrm{e}}(X_i) - \hat{\mathrm{e}}(X_j)| < \delta$$

where δ denotes the caliper width. The choice of k involves a trade-off between bias and variance: 1:1 matching prioritises match quality and may reduce bias, whereas 1:k matching improves precision but may introduce poorer matches. The caliper further restricts poor matches and reduces residual imbalance (Rosenbaum & Rubin, 1985; Stuart, 2010). In

settings with relatively rare treatment or substantial baseline imbalance, combining NN matching with a caliper restriction helps enforce closer matches within the region of common support. The commonly suggested caliper width is $0.2 \times \text{SD}$ of the logit of the propensity score (Austin, 2011). In this dataset, this value equals 0.3612. However, given the relatively large pool of controls (1,792 controls for 83 treated patients), I select a more restrictive caliper to prioritise match quality over sample size retention.

I perform matching without replacement, meaning that each control patient is used at most once. This avoids repeated use of controls across matched sets, simplifies interpretation of matched groups, and reduces the risk of artificially deflated SE. Given the large control-to-treatment ratio (more than 21:1), matching without replacement was feasible. To determine the optimal specification, I evaluate NN(5), NN(6), and NN(7) combined with calipers of 0.2, 0.25, and 0.3.

I assess matching quality using:

1. SMD,
2. variance ratios, and
3. graphical diagnostics (love plots).

Following established benchmarks, SMD < 0.10 was considered ideal and SMD < 0.20 acceptable (Leite, 2019). In addition, pseudo-R^2 and likelihood ratio χ^2 statistics from the treatment assignment model were compared before and after matching. A substantial reduction in pseudo-R^2 and a non-significant likelihood ratio test after matching indicate that covariates no longer strongly predict treatment assignment (e.g., Stuart, 2010).

After evaluating all candidate specifications, I select NN(6) with a caliper of 0.25. Before matching, several covariates exhibit substantial imbalance, with the largest SMD observed for prior cardiologist visits (ln-transformed). After matching, seven covariates achieve SMD < 0.10 and the remaining two achieve SMD < 0.11. The pseudo-R^2 decreases from 0.3178 to 0.0430, and the likelihood ratio χ^2 decreases from 215.97 ($p < 0.001$) to 15.36 ($p = 0.0815$), indicating substantial improvement in covariate balance and near-complete removal of the predictive power of covariates for treatment assignment (see Table 23 and Figure A.1 in Appendix 7).

The final matched sample consists of 70 patients in the treatment group (teleconsultation) and 295 in the control group (in-person consultation). I excluded 13 treated patients and 1,497 control patients due to insufficiently close matches. In 40 of the 70 matched sets, one treated patient was matched to six controls.

Because matched patients are no longer independent, all subsequent outcome models account for the matched design. Specifically, I cluster SE at the matched-group level or stratify/condition models on matched-group ID, depending on the model specification. This adjustment prevents underestimated SE and inflated type I error rates by accounting for

within-matched-group correlation (Stuart, 2010). Clustering does not alter coefficient estimates but yields robust *p*-values and CI that properly reflect the matched structure.

Table 23: Covariate balance before and after propensity score matching

Variable	SMD before matching	SMD after matching	Threshold
Obesity diagnosis, 2y pre-treatment	0.0399	0.0048	< 0.1
Gout or arthritis diagnosis, 2y pre-treatment	0.0497	-0.0607	< 0.1
Stroke diagnosis, 2y pre-treatment	-0.0339	0.0000	< 0.1
HF hospitalisations, 2y pre-treatment (ln-transformed)	-0.0615	-0.0699	< 0.1
Cardiologist visits, 2y pre-treatment (ln-transformed)	0.9185	-0.0704	< 0.1
ED visits, 2y pre-treatment (ln-transformed)	0.2850	-0.1089	< 0.2
Stringency index (%)	1.1785	0.1050	< 0.2
Year (binary; $1 = 2020$)	-0.0819	-0.0402	< 0.1
Hospitalisation severity score, 2y pre-treatment	0.4958	0.0686	< 0.1
Model evaluation			
Pseudo-R^2	0.3178	0.0430	
Likelihood ratio χ^2, *p*-value	215.9651, 0.000	15.3603, 0.0815	

Source: Author's work

After constructing a balanced matched cohort, I perform subsequent GLM analyses within this sample to estimate associations between teleconsultations and healthcare utilisation, expenditure, and mortality outcomes. In the following subchapter, I outline the analysis of the effect of teleconsultations on count outcomes.

6.3.5 Negative binomial regression for count outcomes

This subchapter presents the negative binomial and zero-inflated negative binomial models used for count outcomes. Model specification and evaluation follow established frameworks (e.g., Hilbe, 2011, 2014; Lee et al., 2023). The results are presented in Subchapter 6.4.3.

This subchapter addresses:

1. Model selection (negative binomial or zero-inflated negative binomial)
    a. dispersion assessment, and
    b. zero inflation diagnostics,
2. Model specification and goodness-of-fit
    a. AIC and BIC, and
    b. log-likelihood.

Count data, defined as non-negative integer values representing the frequency of events, are a common outcome type in health research, for example the number of hospitalisations or specialist visits per patient. Statistical methods such as Poisson regression and negative binomial regression are commonly used to model such outcomes (Hilbe, 2014).

Poisson regression assumes equality of the conditional mean and variance. This assumption is frequently violated in healthcare utilisation data due to overdispersion, where the conditional variance exceeds the conditional mean. Negative binomial regression relaxes this assumption by introducing an additional dispersion parameter, allowing the variance to exceed the mean (Hilbe, 2011). This flexibility makes the negative binomial model particularly suitable for healthcare utilisation data characterised by heterogeneous event frequencies.

For each observation i, the outcome Y_i follows the negative binomial distribution, parametrised by mean $\mu_i = \mathbb{E}(Y_i)$ and a dispersion parameter $\theta > 0$ (Hilbe, 2011), with variance defined as $\mathrm{Var}(Y_i) = \mu_i + \frac{{\mu_i}^2}{\theta}$. The model links the conditional mean μ_i to covariates using a log link:

$$\log(\mu_i) = {X_i}^\top \beta.$$

In negative binomial regression, coefficients are typically presented as incidence rate ratios (hereinafter IRR). A coefficient β_j represents the log-change in the expected count associated with a one-unit increase in predictor X_j, while all other covariates remain constant. Exponentiating β_j yields the IRR, $\mathrm{IRR} = \exp(\beta_j)$, which represents the multiplicative change in expected event counts (Hilbe, 2011).

However, in many healthcare datasets, count outcomes exhibit an excess of zero values beyond what standard count models would predict. These zeros may arise from two distinct processes: a structural zero process, where some patients are not at risk of the event during the observation period, and a standard count process governing event frequency among at-risk individuals (Hilbe, 2011). To account for this, I consider zero-inflated negative binomial (hereinafter ZINB) models. The ZINB model introduces a two-part mixture structure (Hilbe, 2011), consisting of:

1. a negative binomial regression model accounting for the standard count process, and
2. a binary process that accounts for structural zeros, with patient i having probability $0 < \pi_i < 1$ of always having zero events.

Formally, the probability of being a structural zero is:

$$\pi_i = \mathbb{P}(Y_i \text{ is a structural zero}) = \frac{\exp({Z_i}^\top \gamma)}{1 + \exp({Z_i}^\top \gamma)}$$

where Z_i are covariates predicting structural zeros and γ the coefficients for predicting structural zeros.

In ZINB regression, IRR from the count component represent multiplicative effects on the expected counts conditional on belonging to the count-generating process, while the inflation component yields OR for membership in the structural-zero group.

Negative binomial regression assumes a non-negative integer count outcome, conditional independence of observations, overdispersion, that is, $\mathbb{E}(Y_i) < \mathrm{Var}(Y_i)$, and a log-linear relationship between predictors and the expected count (Hilbe, 2011). As with other GLM, correct functional form and absence of severe multicollinearity are required (Hilbe, 2011).

To evaluate the association between teleconsultation and count outcomes, I consider two modelling strategies:

1. Standard negative binomial regression when zero proportions are moderate,
2. Zero-inflated negative binomial regression when zero counts are substantial (e.g., exceeding 50%) and structural mechanisms are plausible.

I examined outcome distributions descriptively prior to model estimation to guide specification choice. For each outcome, I estimate three model specifications: the unadjusted model, the covariate-adjusted model, and a further adjusted autoregressive specification including lagged outcomes from the preceding 1-year period, as discussed in Subchapter 6.3. I assessed dispersion descriptively and formally evaluated it by estimating the dispersion parameter. I then evaluated model adequacy using information criteria and log-likelihood comparisons, as discussed in Subchapter 6.3.2. Lower AIC/BIC values indicate better relative fit among competing specifications.

As described in Subchapter 6.3.4, I conduct the analyses within the matched cohort. To account for within-matched-group dependence introduced by the matching procedure, I estimate all negative binomial and ZINB models with SE clustered by match group ID (Stuart, 2010). Clustering adjusts inference for within-cluster correlation without altering coefficient estimates and ensures valid SE and CI.

The results of the count outcome analyses, including dispersion diagnostics and model fit comparisons, are presented in Subchapter 6.4.3. The following subchapter addresses semi-continuous expenditure outcomes, which are characteristic of healthcare expenditure data.

6.3.6 Compound Poisson–Gamma regression for semi-continuous data

This subchapter presents the compound Poisson–Gamma (Tweedie) regression model used for semi-continuous outcomes, following established frameworks (e.g., Bonat et al., 2017; Dunn & Smyth, 2005; Kurz, 2017). The model is applied to semi-continuous healthcare

expenditure outcomes, and alternative specifications are presented together with the results in Subchapter 6.4.4.

This subchapter addresses:

1. Model selection
    a. comparison between Poisson, Gamma, and compound Poisson–Gamma specifications, and
    b. estimation of the index parameter p,
2. Model specification and goodness-of-fit
    a. AIC, and
    b. deviance.

Dependent variables may be semi-continuous, with many zeros and positive values, often highly skewed and characterised by a heavy right tail. Such distributions are common in healthcare expenditure data, where some patients incur no costs during the observation period while others generate very high expenditures. Compound Poisson–Gamma regression provides an appropriate approach for modelling healthcare cost data with these characteristics (Basu & Manning, 2009; Kurz, 2017).

Both Poisson regression and Gamma regression are special cases of the GLM, each suitable for different types of outcome distributions. Poisson regression is typically used to model count data including zeros, whereas Gamma regression is designed for strictly positive, right-skewed continuous outcomes and cannot accommodate zero values. The compound Poisson–Gamma model combines features of both by assuming that the outcome arises from a compound process: a Poisson-distributed number of events with Gamma-distributed positive amounts. This structure simultaneously accommodates the probability of zero outcomes and the continuous distribution of positive values (Dunn & Smyth, 2005).

For each observation i, the outcome Y_i follows the Tweedie distribution with $\mathbb{E}(Y_i) = \mu_i$, $\mathrm{Var}(Y_i) = \phi\mu_i{}^p$ and $1 < p < 2$. In this specification, ϕ is the dispersion parameter and p is the index parameter governing the mean–variance relationship. For $p = 1$, the variance reduces to the Poisson case; for $p = 2$, it corresponds to Gamma. For $1 < p < 2$, the model represents a compound Poisson–Gamma process suitable for semi-continuous data (Dunn & Smyth, 2005).

In applied analysis, the conditional mean $\mu_i = \mathbb{E}(Y_i)$ is linked to covariates through a specified link function. With the log link, the model is specified as:

$$\log(\mu_i) = X_i{}^{\top}\beta.$$

Under the log link, coefficients are interpreted multiplicatively: exponentiated coefficients represent relative changes in expected outcome associated with each predictor, with values

greater than 1 indicating an increase in the expected outcome, values less than 1 indicating a decrease, and a value of 1 indicating no association (Dunn & Smyth, 2005).

With the identity link, the model is specified as:

$$\mu_i = X_i^{\top}\beta$$

Under the identity link, the coefficients represent additive changes in expected outcomes on the original outcome scale. A coefficient β_i represents the additive change in expected outcome associated with a one-unit increase in predictor X_i, holding other variables constant. A positive β_i indicates that higher values of the predictor are associated with an increase in expected expenditure, while a negative coefficient indicates a decrease in the expected outcome. Because EE focuses on incremental cost differences expressed in absolute monetary terms, I select the identity link for the primary specification to facilitate policy interpretation of treatment effects (Kurz, 2017).

Compound Poisson–Gamma regression requires correct specification of the mean–variance relationship, conditional independence given covariates (with appropriate adjustment if dependence is present), a valid link function, and correct specification of predictors. I estimate the index parameter p empirically (Mihaylova et al., 2011). In this study, I estimate p in the fully adjusted model and subsequently hold it constant across alternative specifications to ensure comparability. I added a small constant to the outcomes solely to address numerical optimisation issues in the estimation routine; this adjustment does not affect substantive interpretation (McCullagh & Nelder, 1989). All outcomes are non-negative.

I assess model adequacy using deviance statistics and AIC, consistent with the general GLM framework described in Subchapter 6.3.2. As described in Subchapter 6.3.4, I conduct the analyses within the matched cohort. Because cluster-robust SE are not directly available for this specification in the software used, I interpret the inference cautiously and assess robustness through alternative specifications.

The compound Poisson–Gamma regression results and associated diagnostics are presented in Subchapter 6.4.4. The next subchapter addresses time-to-event (survival) models for analysing mortality outcomes.

6.3.7 Logistic regression and time-to-event models for mortality analysis

This subchapter presents the modelling strategy for 1-year mortality, using conditional logistic regression and stratified Cox proportional hazards models within the matched cohort. I use two complementary approaches: logistic regression for the probability of the event within one year and time-to-event (survival) models for analysing time until the event occurs. I refer to the logistic regression specification described in Subchapter 6.3.3 and

outline the survival modelling framework, including key assumptions, model specification, and diagnostic considerations, following established frameworks (Faraway et al., 2015; Hosmer et al., 2008). I present the model specifications and results in Subchapter 6.4.5.

This subchapter describes the following models:

1. Conditional logistic regression for 1-year mortality,
2. Kaplan–Meier estimator and survival curves, and
3. Stratified Cox proportional hazards models for time to event (strata = match group ID).

During the 1-year follow-up period, 54 out of 365 patients (14.79%) died (i.e., experienced the event). Among these, 11 died in hospital (7 in the control group and 4 in the treated group), with no significant difference between the groups (Fisher's exact test, $p = 0.233$). This test provides an initial descriptive comparison of mortality patterns between treated and control patients prior to multivariable modelling. Given this number of events, I restrict model complexity in line with the EPV principle. I select covariates using the univariate screening and stepwise procedure described in Subchapter 6.3.1. I estimate only unadjusted and covariate-adjusted specifications, as no prior 1-year mortality outcome is available for adjustment.

The logistic regression model is explained in detail in Subchapter 6.3.3. Because the analysis is conducted within a matched cohort, I analyse 1-year mortality using conditional logistic regression to respect the matched design and estimate treatment associations through within-group comparisons. Conditional logistic regression conditions on matched-group ID and thereby accounts for residual baseline-risk heterogeneity across matched sets.

In addition to modelling mortality as a binary endpoint, I analyse time-to-event using survival analysis. Survival analysis comprises statistical methods for analysing the time from a defined origin to the occurrence of an event (e.g., death, hospitalisation; Faraway et al., 2015). To define time-to-event models, let $T \geq 0$, where T denotes the time from a defined origin to a specified event. Survival data are subject to right censoring, as some individuals do not experience the event during the follow-up period. Two key functions characterise survival data:

$$S(t) = \mathbb{P}(T > t)$$

and the hazard function:

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{\mathbb{P}\left(t \leq T < t + \Delta t | T \geq t\right)}{\Delta t}.$$

The survival function represents the probability that the event will not have occurred by time t, while the hazard function captures the instantaneous rate at which events occur at time t, conditional on survival up to time t (Hosmer et al., 2008).

The Kaplan–Meier estimator provides a non-parametric estimate of the survival function:

$$\hat{S}(t) = \prod_{t_i \leq t} \left(1 - \frac{d_i}{n_i}\right)$$

where t_i is the time of the event, d_i is the number of events at time t_i, and n_i is the number of patients at risk shortly before t_i. I evaluate group differences using the log-rank test. Because this approach does not adjust for covariates, I use it primarily for descriptive comparison of survival curves (Faraway et al., 2015).

To assess covariate effects on the hazard rate, I use the semi-parametric Cox proportional hazards model:

$$\lambda(t|X) = \lambda_0(t)\exp(\beta^\top X),$$

where $\lambda\,(t|X)$ is the hazard function for a patient with the covariates X, where λ_0 is an unspecified baseline hazard function, and β is the vector of regression coefficients (Faraway et al., 2015). I present the results as hazard ratios (hereinafter HR), representing the ratio of hazard rates between groups at any given time, adjusted for the covariates. An HR greater than one indicates increased hazard, and an HR less than one indicates decreased hazard, an HR equal to one indicates no difference. The Cox model assumes proportional hazards, independent censoring, and log-linearity of continuous covariates, which I assess using standard diagnostic procedures (Faraway et al., 2015).

Because the analysis is conducted within a matched cohort, I analyse survival using a Cox proportional hazards model stratified by matched-group ID. Stratification respects the matched design by allowing the baseline hazard to vary across matched groups and estimating treatment effects through within-group comparisons. I present the results of the logistic and time-to-event analyses, together with model diagnostics, in Subchapter 6.4.5.

6.4 Results

In this subchapter, I present the empirical results. First, I present summary statistics for the unmatched cohorts: patients assigned to a teleconsultation (treatment group; N = 83) and those assigned to an in-person consultation (control group; N = 1,792), highlighting baseline differences before matching. I then present the results of a logistic regression model estimating the probability of teleconsultation assignment, together with selected model evaluation statistics. Using the resulting propensity scores, I construct a matched cohort with 70 patients in the treatment group (teleconsultation) and 295 in the control group (in-person consultation), with comparable baseline characteristics. The remainder of the subchapter focuses on analyses using the matched cohort, based on the GLM approaches described in Subchapter 6.3: negative binomial models for count outcomes, compound Poisson–Gamma models for semi-continuous outcomes, and logistic regression and time-to-event models for

mortality. For each modelling framework, I report unadjusted, covariate-adjusted, and, where feasible, fully adjusted estimates, together with corresponding model evaluation statistics.

6.4.1 Descriptive statistics

I first present summary statistics for the unmatched patient cohorts (N = 1,875), assigned to teleconsultations (N = 83) and in-person consultations (N = 1,792), highlighting baseline differences prior to matching. I provide the summary table in Appendix 6 (see Table A.5), and I describe the methodology in Subchapter 6.3.1.

The dataset contains binary, count, and semi-continuous variables (primarily expenditure outcomes). Most expenditure outcomes are right-skewed with a long upper tail, a common feature in healthcare datasets (Mihaylova et al., 2011), and they include structural zeros. Age at treatment and the hospitalisation severity score are not normally distributed, but I retain them in their raw form to maintain interpretability. Median monthly income is log-transformed to better satisfy linearity assumptions, while other variables, such as the number of secondary diagnoses and procedures, are also non-normally distributed.

The median age at treatment is the same in both groups (75 years; $p = 0.633$), but patients in the teleconsultation group have a slightly higher median monthly net income than the control group (€1,158.4 vs. €1,126.3; $p = 0.082$). Exposure to COVID-19 restrictions differs significantly, with the treatment group exhibiting a significantly higher median stringency index than the control group (69.4 vs. 43.9; $p < 0.001$). The hospitalisation severity score in the two years prior to treatment is also higher in the treatment group than in the control group (0.38 vs. 0.00; $p = 0.0001$).

In terms of healthcare utilisation in the pre-treatment period, patients in the treatment group undergo more procedures per hospitalisation both one year before treatment (10.8 vs. 6.4; $p = 0.0002$) and two years before treatment (10.5 vs. 6.5; $p < 0.001$). In addition, the total number of hospital procedures during the 2-year pre-treatment period is higher in the teleconsultation group (13.0 vs. 9.0; $p = 0.002$).

Outpatient and emergency utilisation also differ significantly between groups. Patients in the teleconsultation group have more cardiology outpatient visits both one and two years prior to treatment (both $p < 0.001$). ED visits in the 2-year pre-treatment period are also more frequent in the teleconsultation group ($p = 0.0002$).

Comorbidity profiles also differ between the treatment and control groups. Gout or arthritis (8.4% vs. 3.5%; $p = 0.019$), hypertension (62.7% vs. 49.4%; $p = 0.019$), obesity (7.2% vs. 3.2%; $p = 0.050$), and hyperlipidaemia (28.9% vs. 21.2%; $p = 0.095$) are more common in the treatment group. In addition, patients in the treatment group exhibit a higher burden of

cardiovascular morbidity, with a greater number of cardiovascular comorbidities ($p = 0.012$) and clinically relevant cardiovascular comorbidities ($p = 0.042$).

In terms of mortality, in-hospital deaths within one year of treatment are more frequent among patients in the teleconsultation group (7.2% vs. 2.7%; $p = 0.015$), while all-cause mortality at one year (both in-hospital and out-of-hospital) does not differ significantly between the treatment and control groups ($p = 0.412$). These post-treatment comparisons are descriptive and do not adjust for baseline differences.

Additional differences with p-values between 0.05 and 0.10 (e.g., slightly higher income, more additional diagnoses per hospitalisation, and a higher prevalence of obesity) suggest residual baseline imbalance prior to matching. Full descriptive statistics and significance tests are provided in Appendix 6, Table A.5.

Overall, the descriptive analysis reveals substantial baseline imbalances in healthcare utilisation, cardiovascular morbidity burden, and exposure to pandemic-related restrictions between groups. These differences justify the subsequent use of PSM to improve comparability.

In the next subchapter, I present logistic regression results estimating the probability of teleconsultation assignment using these baseline characteristics as potential predictors.

6.4.2 Determinants of assignment to teleconsultations

While the descriptive statistics in the previous subchapter show differences between patients in the treatment and control groups, they do not indicate which characteristics are independently associated with treatment assignment. To investigate this, I estimate a logistic regression model in which the dependent variable indicates whether a patient was assigned to a teleconsultation. The model includes demographic, clinical, and utilisation variables measured in the pre-treatment period. This analysis identifies patient characteristics associated with teleconsultation assignment and provides the propensity scores that I use for matching. The specified logistic regression model includes nine covariates, as described in Subchapter 6.3.3, all statistically significant at the 10% level or better (see Table 24).

The COVID-19 stringency index (OR = 1.05; $p < 0.001$) is positively associated with teleconsultation assignment (per a one-point increase in the stringency index), indicating that stricter pandemic measures are associated with a higher likelihood of remote consultations. Patients are less likely to be assigned to teleconsultations in 2020 (OR = 0.27; $p < 0.001$), the first pandemic year.

Obesity (OR = 2.22; $p = 0.064$) shows a positive association at the 10% level. Gout or arthritis (OR = 3.02; $p = 0.012$) is significantly associated with higher odds of teleconsultation. Stroke in the baseline period (OR = 0.25; $p = 0.042$) is associated with

lower odds of assignment. These associations suggest selective allocation patterns related to comorbidity profiles but should be interpreted cautiously, given the observational design.

Table 24: Results of logistic regression for the probability of teleconsultation assignment

Variable	OR (95% CI)	*p*-value
Obesity diagnosis (2-year pre-treatment)	2.221 (0.955–5.167)	0.064*
Gout or arthritis diagnosis (2-year pre-treatment)	3.022 (1.273–7.174)	0.012**
Stroke diagnosis (2-year pre-treatment)	0.253 (0.067–0.950)	0.042**
HF hospitalisations (2-year pre-treatment, ln-transformed)	0.507 (0.267–0.962)	0.038**
Cardiology outpatient visits (2-year pre-treatment, ln-transformed)	8.979 (5.501–14.657)	<0.001***
ED visits (2-year pre-treatment, ln-transformed)	2.740 (1.394–5.387)	0.003***
Stringency index (%)	1.055 (1.041–1.069)	<0.001***
Year of treatment (binary; 1 = 2020)	0.274 (0.135–0.558)	<0.001***
Hospitalisation severity score (2-year pre-treatment)	2.054 (1.508–2.798)	<0.001***
Intercept	0.002 (0.001–0.005)	<0.001***
Model evaluation		
Pseudo-R^2	0.318	
AIC	483.81	
BIC	539.18	
AUC	0.892	

*Note: Odds ratios (OR) with 95% confidence intervals (CI) are reported in parentheses. Pseudo-R² refers to McFadden's pseudo-R². AIC and BIC denote information criteria; lower values indicate better relative fit. AUC denotes the area under the receiver operating characteristic curve. ln-transformed variables are transformed using the natural logarithm of (x+1), where applicable. N=1,875 (full unmatched analytical sample). *p<0.10; **p<0.05; ***p<0.01.*

Source: Author's work

Previous HF hospitalisations (ln-transformed) are negatively associated with teleconsultation assignment (OR = 0.51; $p = 0.038$). Hospitalisation severity (OR = 2.05; $p < 0.001$) is positively associated. ED visits (OR = 2.74; $p = 0.003$) and cardiology outpatient visits (OR = 8.98; $p < 0.001$) in the baseline period show strong positive associations.

I summarise the model evaluation metrics in Table 24. The pseudo-R^2 is 0.318. This value reflects a substantial improvement in model fit relative to the null model, though it should not be interpreted as a proportion of variance explained in the OLS sense. AIC (483.81) and BIC (539.18) serve as comparative criteria across specifications. The AUC value is 0.892, indicating strong discrimination between treated and control patients (Hosmer et al., 2013). The relatively high AUC combined with the strong discrimination of prior cardiology visits is consistent with concentrated predictors of assignment. To assess internal validity, I perform bootstrapping with 500 replications. Coefficient signs, magnitudes, and significance levels remain stable across replications. I also conduct an 80–20 training–test split. The AUC is 0.897 in the training sample and 0.862 in the test sample, indicating good generalisability with limited overfitting. The link test indicates no evidence of misspecification, as the predicted value is statistically significant ($p < 0.001$) while the squared term is not. Given the low prevalence of teleconsultations (4.4%), I evaluate classification using a 0.04 probability threshold rather than the conventional 0.5. The Hosmer–Lemeshow test with four

and five groups is non-significant (p = 0.609; p = 0.695), indicating good calibration (Hosmer et al., 2013). At this cutoff, sensitivity is 80.72%, specificity 78.85%, and overall accuracy 78.93%, indicating balanced classification performance (Hosmer et al., 2013).

Overall, diagnostic results indicate that the model discriminates well, is adequately calibrated, and shows no evidence of severe misspecification or overfitting. The model is therefore suitable for generating propensity scores. Based on these estimated propensity scores, I construct a matched cohort as described in Subchapter 6.3.4. The final matched sample consists of 70 patients in the treatment group (teleconsultation) and 295 patients in the control group (in-person consultation). Although matching substantially improves observed covariate balance, residual confounding due to unmeasured variables cannot be excluded. Subsequent outcome analyses are therefore presented in unadjusted and adjusted forms to further improve robustness.

In the next subchapter, I examine healthcare utilisation outcomes within the matched sample.

6.4.3 Effects of teleconsultations on healthcare utilisation

Having outlined the modelling framework in Subchapter 6.3.5, I now apply standard and zero-inflated negative binomial models across all three model specifications to estimate the association between teleconsultation assignment and healthcare utilisation outcomes within the matched cohort, consistent with the underlying distributional properties (see Appendix 6, Table A.5).

In the standard negative binomial model without excess zeros, teleconsultation assignment is consistently associated with fewer cardiology outpatient visits across all specifications in the year following treatment (see Table 25). In the fully adjusted model, the IRR is 0.33 (p < 0.001), indicating approximately a 67% reduction in cardiology visits relative to the control group. The association remains statistically significant across all model specifications with similar IRR ranges, suggesting robustness to covariate adjustment and the inclusion of lagged utilisation. The magnitude and consistency of the IRR across specifications indicate a robust association between teleconsultation assignment and fewer in-person cardiology visits during follow-up.

For ACE inhibitor/ARNI prescriptions, results differ across specifications. The covariate-adjusted model shows a statistically significant increase (IRR = 1.43; p = 0.032), indicating 43% more prescriptions in the treatment group, whereas the fully adjusted model is not significant (IRR = 1.07; p = 0.649). The loss of significance in the fully adjusted model suggests that the observed association is driven by prior ACE inhibitor/ARNI prescribing, indicating model sensitivity and warranting cautious interpretation. A marginal association is detected for the number of HF prescription groups per patient in the fully adjusted model (IRR = 0.91; p = 0.091), but the magnitude is small and only weakly significant. For other prescription groups (beta-blockers, MRA, and diuretics), no statistically significant

associations are observed across specifications (see Table 25). Information criteria (AIC, BIC) and log-likelihood values consistently favour the fully adjusted model specifications (Model 3), indicating improved relative model fit when baseline covariates and lagged outcomes are included.

Table 25: Results of negative binomial regression for count outcomes

Variable	Model	IRR (95% CI)	*p*-value	AIC	BIC	Log-likelihood
Cardiology visit (1-year post-treatment)	1	0.392 (0.263–0.584)	<0.001***	1,164.71	1,176.41	-579.35
	2	0.379 (0.258–0.557)	<0.001***	1,092.71	1,139.51	-534.36
	3	0.330 (0.223–0.488)	<0.001***	1,070.37	1,121.07	-522.18
Beta-blocker prescriptions (1-year post-treatment)	1	0.973 (0.795–1.192)	0.793	1,647.52	1,659.20	-820.76
	2	0.972 (0.798–1.186)	0.782	1,655.31	1,702.04	-815.65
	3	0.941 (0.794–1.114)	0.477	1,566.91	1,617.54	-770.46
ACE inhibitor/ARNI prescriptions (1-year post-treatment)	1	1.312 (0.981–1.753)	0.067*	1,432.37	1,444.06	-713.19
	2	1.428 (1.031–1.978)	0.032**	1,442.86	1,489.59	-709.43
	3	1.068 (0.804–1.420)	0.649	1,296.11	1,346.73	-635.05
MRA prescriptions (1-year post-treatment)	1	0.797 (0.573–1.108)	0.176	1,385.10	1,396.78	-689.55
	2	0.771 (0.548–1.084)	0.134	1,396.34	1,443.07	-686.17
	3	0.758 (0.533–1.076)	0.121	1,283.07	1,333.70	-628.54
Prescriptions in HF medication group (1-year post-treatment)	1	0.947 (0.833–1.077)	0.408	1,055.92	1,063.72	-525.96
	2	0.925 (0.813–1.053)	0.237	1,069.61	1,112.51	-523.81
	3	0.905 (0.806–1.016)	0.091*	1,027.12	1,073.92	-501.56
Diuretic prescriptions (1-year post-treatment)	1	0.894 (0.745–1.073)	0.229	1,974.30	1,985.98	-984.15
	2	0.907 (0.749–1.098)	0.316	1,966.89	2,013.62	-971.44
	3	0.883 (0.756–1.031)	0.115	1,843.27	1,893.90	-908.64

Note: Incidence rate ratios (IRR) with 95% confidence intervals (CI) are reported. Models 1–3 represent increasing levels of adjustment (see Subchapter 6.3). Standard errors are clustered at the match-group level. N=365 (70 treated; 295 controls). AIC and BIC denote information criteria; lower values indicate better relative fit. Log-likelihood values reflect model fit, with higher (less negative) values indicating better fit. *p<0.10; **p<0.05; ***p<0.01.

Source: Author's work

I estimate zero-inflated negative binomial models for outcomes with substantial excess zeros (see Table 26). Among these outcomes, I observe a consistently statistically significant association between teleconsultation assignment and post-treatment healthcare utilisation only for the number of procedures during hospitalisation.

In the fully adjusted count component, teleconsultation assignment is associated with a higher number of procedures per hospitalisation (IRR = 1.57; p = 0.020), indicating approximately 57% higher expected number of procedures relative to the control group. This association is statistically significant at the 5% level only in the fully adjusted model specification. In the less adjusted model specifications, this association is weaker or non-significant. The inflate component for procedures is marginally significant ($p \approx 0.09–0.10$), indicating a lower probability of belonging to the structural-zero group among patients in

the treatment group and thus a higher likelihood of undergoing at least one procedure. For other outcomes, the inflate component is generally non-significant.

Table 26: Results of zero-inflated negative binomial regression for count outcomes

Variable	**Model**	**IRR / OR (95% CI)**	***p*-value**	**AIC**	**BIC**	**Log-likelihood**
HF hospitalisation (1-year post-treatment)	1. Count	0.971 (0.534–1.766)	0.924	438.18	457.68	-214.09
	1. Inflate	0.591 (0.186–1.876)	0.372			
	2. Count	1.190 (0.465–3.044)	0.717	437.00	491.60	-204.50
	2. Inflate	0.626 (0.098–4.011)	0.621			
Number of additional diagnoses during hospitalisation (1-year post-treatment)	1. Count	0.937 (0.672–1.306)	0.700	845.95	865.45	-417.98
	1. Inflate	0.600 (0.327–1.100)	0.099*			
	2. Count	1.170 (0.928–1.473)	0.184	805.50	860.10	-388.75
	2. Inflate	0.634 (0.350–1.150)	0.134			
	3. Count	1.168 (0.926–1.475)	0.190	807.50	866.10	-388.75
	3. Inflate	0.634 (0.350–1.149)	0.133			
Number of procedures during hospitalisation (1-year post-treatment)	1. Count	1.172 (0.841–1.635)	0.349	1,014.84	1,034.34	-502.42
	1. Inflate	0.607 (0.341–1.080)	0.089*			
	2. Count	1.393 (0.966–2.009)	0.076*	1,016.17	1,070.77	-494.09
	2. Inflate	0.610 (0.343–1.084)	0.092*			
	3. Count	1.574 (1.073–2.310)	0.020**	1,010.69	1,069.19	-490.34
	3. Inflate	0.616 (0.346–1.094)	0.098*			
ED visits (1-year post-treatment)	1. Count	0.785 (0.166–3.712)	0.760	251.86	271.35	-120.93
	1. Inflate	2.45×10^{-7} (7.36×10^{-10} – 8.15×10^{-5})	<0.001***			
	2. Count	1.372 (0.463–4.065)	0.568	208.34	262.93	-90.17
	2. Inflate	6.24×10^{-8} (2.83×10^{-21} – 1.38×10^{6})	0.290			

*Note: Zero-inflated negative binomial (ZINB) models include: a count model (reported as incidence rate ratios, IRR) and an inflation model (reported as odds ratios, OR). Models 1–3 represent levels of adjustment (see Subchapter 6.3). Standard errors are clustered at the match-group level. AIC and BIC denote information criteria; lower values indicate better relative fit. Log-likelihood values reflect model fit, with higher (less negative) values indicating better fit. Some fully adjusted model specifications did not converge and are therefore not reported. N=365 (70 treated; 295 controls). *p<0.10; **p<0.05; ***p<0.01.*

Source: Author's work

For HF hospitalisations, additional diagnoses during hospitalisation, and ED visits, I observe no statistically significant treatment effects in the count component across specifications. In most cases, the inflate component is also not statistically significant, with the exception of ED visits in the unadjusted model, where excess zeros are evident. Because ED visits are rare, the inflation model almost perfectly predicts zeros, producing an implausibly small OR, which reflects model instability rather than a true treatment effect.

Model fit statistics (AIC, BIC, log-likelihood) generally favour the fully adjusted specification, particularly for procedures during hospitalisation, indicating improved relative fit when covariates and lagged outcomes are included.

Overall, the results indicate a robust reduction in cardiology outpatient visits following teleconsultation assignment, a statistically significant increase in procedures during hospitalisation in the fully adjusted model specification, and limited and model-specification-sensitive effects on medication prescribing. Other utilisation outcomes do not show significant associations.

In the next subchapter, I examine semi-continuous healthcare expenditure outcomes using compound Poisson–Gamma regression models.

6.4.4 Effects of teleconsultations on healthcare expenditure

I describe the compound Poisson–Gamma regression model in Subchapter 6.3.6. In this subchapter, I analyse the association between teleconsultation assignment and semi-continuous healthcare expenditure within the matched cohort during the first year after treatment. I estimate three model specifications for each outcome considered. Coefficients represent additive differences in expected expenditure in euros. Although statistically significant, the absolute magnitude of some estimated differences is small (see Table 27).

For HF hospitalisation expenditure, I observe higher expenditure in the treatment group across all three model specifications. The estimated increase relative to the control group ranges from €1,131 in the fully adjusted model ($p = 0.034$) to €1,288 in the unadjusted model ($p = 0.061$). This pattern is consistent with greater inpatient treatment intensity among patients during follow-up.

Expenditure on outpatient cardiology visits is significantly lower in the treatment group across all three models, with estimated reductions ranging from €45.9 to €51.6 (all $p < 0.001$). For ED visit expenditure, no statistically significant association is observed in the fully adjusted model. The covariate-adjusted specification shows a marginal increase of €0.04 ($p = 0.071$), but I do not confirm this in the fully adjusted model.

Table 27: Results of compound Poisson–Gamma regression for expenditure data

Variable	Parameter p: $1 < p < 2$	Model	Estimate, SE	p-value	AIC	Deviance
HF hospitalisation expenditure (1-year post-treatment)	1.8	1	1,287.9 (684.0)	0.061*	-457.46	8,201.8
		2	1,232.0 (586.5)	0.036**	-514.41	7,264.4
		3	1,131.0 (532.0)	0.034**	-547.25	6,862.4
Cardiology outpatient visit expenditure (1-year post-treatment)	1.843	1	-45.9 (6.616)	<0.001***	3,423.75	1,313.9
		2	-51.6 (5.969)	<0.001***	3,394.27	1,193.9
		3	-49.7 (6.060)	<0.001***	3,390.19	1,174.4
ED visit expenditure (1-year post-treatment)	1.7	1	0.152 (6.798)	0.982	-1,913.05	5,980.6
		2	0.041 (0.023)	0.071*	-2,028.04	4,781.9
		3	0.015 (0.019)	0.428	-2,026.68	4,776.7
Beta-blocker prescription expenditure (1-year post-treatment)	1.771	1	-5.4 (4.624)	0.246	3,063.58	1,367.8
		2	-7.9 (4.686)	0.093*	3,076.03	1,355.6
		3	-2.5 (0.410)	<0.001***	2,947.30	1,058.0
ACE inhibitor/ARNI prescription expenditure (1-year post-treatment)	1.7	1	8.0 (6.615)	0.225	1,329.47	3,371.3
		2	26.1 (8.263)	0.002**	1,327.50	3,252.6
		3	-0.019 (0.013)	0.162	1,200.33	2,568.2
MRA prescription expenditure (1-year post-treatment)	1.8	1	-4.5 (8.971)	0.614	1,477.47	3,525.6
		2	-4.7 (8.195)	0.569	1,483.03	3,448.2
		3	-0.318 (0.053)	<0.001***	1,393.26	2,921.4
Expenditure of all categorised HF medications (1-year post-treatment)	1.720	1	-1.9 (12.443)	0.882	4,089.88	1,081.0
		2	-4.9 (12.473)	0.694	4,097.43	1,067.9
		3	-20.3 (9.297)	0.029**	4,018.26	897.7
Diuretic prescription expenditure (1-year post-treatment)	1.769	1	-11.1 (11.956)	0.352	3,751.51	1,417.3
		2	-11.2 (11.239)	0.322	3,750.97	1,385.3
		3	-10.7 (2.270)	<0.001***	3,620.29	1,085.0

*Note: Compound Poisson–Gamma (Tweedie) regression models with an identity link are estimated for semi-continuous expenditure outcomes. Coefficients are reported with standard errors (SE) in parentheses. Clustering by matched-group ID is not available in this model. The index parameter p is estimated in the fully adjusted specification for each outcome and applied consistently across model specifications (see Subchapter 6.3.6). Models 1–3 represent increasing levels of adjustment (see Subchapter 6.3). AIC and deviance statistics are reported for model comparison; lower values indicate better relative model fit. N=365 (70 treated; 295 controls). *p<0.10; **p<0.05; ***p<0.01.*

Source: Author's work

Prescription expenditure shows heterogeneous patterns across drug groups. In the fully adjusted model, expenditure on beta-blockers is lower in the treatment group (–€2.5; $p < 0.001$), as is expenditure on MRA prescriptions (–€0.32; $p < 0.001$), diuretics (–€10.7; $p < 0.001$) and total expenditure on all categorised HF medications (–€20.3; $p = 0.029$). In contrast, ACE inhibitor/ARNI expenditure is higher in the covariate-adjusted model by €26.1 ($p = 0.002$) but is not statistically significant in the unadjusted or fully adjusted specifications, mirroring the instability observed in the count models.

Model fit statistics generally favour the fully adjusted model across outcomes, indicating improved relative fit when covariates and lagged expenditure are included.

Overall, the compound Poisson–Gamma models indicate higher HF hospitalisation expenditure and lower outpatient cardiology expenditure associated with teleconsultation assignment, while prescription expenditure effects vary across prescription groups and model specifications.

In the next subchapter, I examine the association between teleconsultation assignment and mortality using logistic regression and time-to-event models.

6.4.5 Association between teleconsultation assignment and mortality

Using the logistic regression and time-to-event models described in Subchapter 6.3.7, I analyse the association between teleconsultation assignment and 1-year mortality. For each framework, I estimate unadjusted and covariate-adjusted specifications. I present results for conditional logistic regression, Kaplan–Meier survival analysis, and stratified Cox proportional hazards models.

Because mortality is a relatively rare event within the matched cohort, I specify a reduced logistic model in accordance with the EPV rule outlined in Subchapter 6.3 and estimate conditional logistic regression stratified by match-group ID.

Table 28: Results of conditional logistic regression for mortality

Variable	Model 1		Model 2	
	OR (95% CI)	***p*-value**	**OR (95% CI)**	***p*-value**
Treatment (binary, teleconsultation=1)	1.342 (0.638–2.824)	0.438	1.552 (0.697–3.457)	0.282
HF hospitalisations (2-year pre-treatment, ln-transformed)			2.060 (0.864–4.912)	0.103
ED visits (2-year pre-treatment, ln-transformed)			2.539 (1.193–5.404)	0.016**
Hospitalisation severity score (2-year pre-treatment)			1.522 (1.028–2.254)	0.036**
Model evaluation				
AIC	156.37		149.64	
BIC	159.78		163.29	
Log pseudo-likelihood	–77.19		–70.82	

*Note: Odds ratios (OR) with 95% confidence intervals (CI) are reported from conditional logistic regression models, conditional on match-group ID. Models 1–2 represent increasing levels of adjustment (see Subchapter 6.3). AIC and BIC denote information criteria; lower values indicate better relative fit. N=244 observations included in the conditional likelihood estimation; strata without within-group outcome variation are excluded. *p<0.10; **p<0.05; ***p<0.01.*

Source: Author's work

Teleconsultation assignment is not statistically significant in either specification, suggesting no evidence that teleconsultation assignment is associated with 1-year mortality (see Table 28). HF hospitalisations in the pre-treatment period are not statistically significant (p =

0.103). ED visits in the 2-year pre-treatment period are positively associated with mortality (OR = 2.54; $p = 0.016$), indicating that higher prior emergency utilisation is associated with substantially higher odds of death. The hospitalisation severity score is also positively associated with mortality (OR = 1.52; $p = 0.036$), indicating that each one-unit increase in the score is associated with a 52% increase in the odds of death.

The significantly lower AIC value (149.64 vs. 156.37) indicates better relative fit of the adjusted conditional logistic regression model, as does the log-likelihood value (–70.82 vs. –77.19). However, the BIC is slightly higher (163.29 vs. 159.78), reflecting a stronger penalty for additional parameters in the adjusted specification.

I next examine the survival patterns using time-to-event methods, as described in Subchapter 6.3.7.I estimate Kaplan–Meier curves over the 365-day follow-up period (see Figure A.2, Appendix 7). The figure displays the cumulative probability of death (failure function), which increases over time as events occur. Although at one year the corresponding survival probabilities differ numerically (86.1% vs. 81.4%; see Table 29), the log-rank test indicates no statistically significant difference in survival between the treatment and the control groups (χ^2 (1) = 1.23; $p = 0.267$).

Table 29: Results of Kaplan–Meier survival analysis at 365 days

	Events observed	**Events expected**	**Estimated survival probability (95% CI)**
Treatment = 0	41	44.15	0.861 (0.816–0.896)
Treatment = 1	13	9.85	0.814 (0.702–0.888)
Model evaluation			
Log-rank test	1.23; $p = 0.267$		

Note: Kaplan–Meier survival estimates are evaluated at 365 days. "Events expected" refers to the number of events expected under the null hypothesis of equal survival functions, as used in the log-rank test.

Source: Author's work

As outlined in Subchapter 6.3.7, I select covariates for the Cox proportional hazards models in accordance with the EPV rule. I estimate stratified Cox models by match group ID, with both unadjusted and covariate-adjusted model specifications.

Teleconsultation assignment is not statistically significant in either specification (see Table 30). In the adjusted model, ED visits (ln-transformed) are positively associated with mortality (HR = 2.48; $p = 0.025$), indicating that higher prior ED utilisation is associated with a markedly higher hazard of death. The hospitalisation severity score shows a marginal association (HR = 1.42; $p = 0.099$), with each one-point increase associated with a 42% higher hazard of death. HF hospitalisations are not statistically significant ($p = 0.155$).

Model evaluation indicates improved relative fit and discrimination in the adjusted specification. The likelihood-ratio test is statistically significant ($\chi^2 = 13.19$, $p = 0.010$), and AIC decreases, suggesting better relative fit despite a modest increase in BIC.

Discrimination improves (Harrell's C = 0.657), and the global proportional hazards test is non-significant, indicating no evidence against the proportional hazards assumption.

Table 30: Results of stratified Cox proportional hazards regression

Variable	Model 1		Model 2	
	HR (95% CI)	***p*-value**	**HR (95% CI)**	***p*-value**
Treatment (binary, teleconsultation=1)	1.466 (0.756–2.845)	0.257	1.593 (0.793–3.199)	0.191
HF hospitalisations (2-year pre-treatment, ln-transformed)			1.821 (0.798–4.158)	0.155
ED visits (2-year pre-treatment, ln-transformed)			2.481 (1.119–5.503)	0.025**
Hospitalisation severity score (2-year pre-treatment)			1.420 (0.936–2.154)	0.099*
Model evaluation				
Log pseudo-likelihood	-87.69		-81.70	
AIC	177.38		171.40	
BIC	181.28		187.00	
Harrell's C (Somers' D)	0.544 (0.089)		0.657 (0.315)	
LR χ^2	1.21 (p = 0.271)		13.19 (p = 0.010)	
PH test	0.191		0.492	

*Note: Hazard ratios (HR) with 95% confidence intervals (CI) are reported from stratified Cox proportional hazards models. Models 1–2 represent increasing levels of adjustment (see Subchapter 6.3). AIC and BIC denote information criteria; lower values indicate better relative fit. N=365; Events=54. *p<0.10; **p<0.05; ***p<0.01.*

Source: Author's work

6.5 Discussion and conclusions

This chapter provides patient-level evidence on the association between teleconsultation assignment and subsequent healthcare utilisation, expenditure, and mortality among patients with HF in Slovenia, using matched administrative data from the COVID-19 period.

I observe substantial baseline imbalance prior to matching. Compared with patients receiving in-person consultations, patients in the treatment group show higher exposure to pandemic restrictions (as measured by the stringency index), higher hospitalisation severity, and more intensive pre-treatment healthcare utilisation (including cardiology outpatient visits and ED visits). They also exhibit greater inpatient procedural intensity (reflected in a higher number of procedures per hospitalisation) and a higher burden of cardiovascular and non-cardiovascular comorbidity, both in terms of the total number of comorbid conditions and specific diagnoses such as hypertension, gout or arthritis, obesity, and hyperlipidaemia. Average monthly income differs modestly, and dispersion is wider in the teleconsultation group, indicating greater socioeconomic heterogeneity. Taken together, these patterns indicate that, at baseline, the teleconsultation group represents a clinically more complex and more intensively managed subgroup, which reinforces the need to address confounding before comparing post-treatment outcomes. Given that statistical models are necessarily

simplified representations of complex systems, and given the baseline differences between cohorts, I interpret the estimated effects as matched associations rather than causal effects. Matching improves comparability in observed covariates, but it does not eliminate the possibility of residual confounding due to unmeasured clinical severity, behavioural factors, or provider decision-making. Moreover, the pandemic context and the selective deployment of teleconsultations for higher-risk patients limit the external validity of these findings beyond this implementation setting.

The logistic assignment model reinforces this picture and clarifies which baseline characteristics independently structure teleconsultation assignment. Strong predictors, particularly prior cardiology outpatient visits, ED visits, hospitalisation severity, and the stringency index, indicate that teleconsultations are selectively allocated rather than randomly assigned during the pandemic. Assignment rises with higher stringency, which is consistent with system-level constraints and infection-risk mitigation shaping care modality. At the same time, assignment is lower in 2020 relative to later periods, consistent with gradual implementation and institutionalisation, including organisational adaptation and the introduction of dedicated billing codes in December 2020 (see Subchapter 6.2). Clinical selection also appears targeted rather than uniform. Patients are more likely to be assigned to teleconsultations when they have higher hospitalisation severity and mobility-related or inflammatory comorbidity (gout or arthritis, obesity), which is consistent with triage towards remote follow-up in higher-risk patients during COVID-19 and with stakeholder accounts in Chapter 5. By contrast, prior stroke is associated with lower odds of teleconsultation assignment, suggesting that teleconsultations are not uniformly suitable across clinical profiles and potentially reflecting digital or functional constraints, competing specialist pathways, or clinician preference for in-person assessment in patients with cerebrovascular complexity.

Prior utilisation structures teleconsultation assignment, but not uniformly. Intensive pre-treatment cardiology follow-up substantially increases the likelihood of teleconsultation, indicating that teleconsultations are primarily embedded within established specialist follow-up pathways rather than initiated de novo. This pattern is consistent with selective deployment among clinically complex but relatively stable patients, as suggested by stakeholders in Chapter 5. Patients with more prior ED visits are also more likely to receive teleconsultations, which may reflect a need for closer post-acute monitoring, heightened clinical vigilance during the pandemic, or follow-up arrangements after HF-related emergency encounters. In this sense, ED utilisation may function as an acuity signal triggering remote follow-up rather than as an independent treatment pathway. By contrast, more frequent prior HF hospitalisations reduce the likelihood of teleconsultation assignment, aligning with a preference for in-person assessment in patients with recent, unstable, or recurrent admissions due to HF.

Model diagnostics support the use of the logistic model for propensity score estimation, showing good discrimination and stability, and that matching substantially improves balance

in observed covariates. Based on the observed selection mechanisms, I interpret post-treatment differences: in this setting, teleconsultations function as a selectively deployed modality under system pressure rather than a universal substitute for in-person care.

Within the matched cohort, the most consistent healthcare utilisation finding is a marked reduction in total cardiology outpatient visits following teleconsultation assignment. This reduction reflects a decrease in overall specialist contact frequency rather than simple substitution of visit modality. This pattern aligns with the consistent reduction in outpatient cardiology expenditure in the compound Poisson–Gamma models. One possible interpretation is that teleconsultations alter follow-up intensity, potentially consolidating care or reducing the need for additional specialist encounters during the first post-treatment year. However, given the selective assignment patterns, the pandemic context, and residual confounding, this finding should be interpreted as an association rather than as definitive evidence of efficiency gains. In contrast, inpatient intensity and related expenditure move in the opposite direction. Teleconsultation assignment is associated with a higher number of procedures per hospitalisation, and the expenditure models indicate higher HF hospitalisation expenditure across specifications. Taken together, I interpret these results as indicating higher inpatient resource intensity among patients in the treatment group (teleconsultation) during follow-up. Given the documented baseline imbalance and structured assignment during COVID-19, the most plausible interpretation is patient selection rather than a treatment effect. Teleconsultations were disproportionately used for clinically more complex and higher-risk patients. The observed increase in inpatient procedures and hospitalisation expenditure therefore likely reflects underlying patient severity rather than a direct effect of teleconsultations. At the same time, the reduction in outpatient cardiology visits suggests a reallocation in where care is delivered. Taken together, this pattern indicates a redistribution of care across settings, rather than a simple cost-saving effect or uniform reduction in resource use. Similar pandemic-associated shifts in HF care have been documented elsewhere: during the first wave of COVID-19, hospital admissions for HF declined substantially, while community and short-term post-discharge mortality increased, indicating broader disruptions in care pathways rather than isolated intervention effects (Shoaib et al., 2021).

The medication-related results are mixed and depend on the model specifications. For ACE inhibitor/ARNI prescriptions, effects appear in some intermediate models but disappear once prior prescribing is included, suggesting that baseline prescribing patterns explain much of the association. For other drug groups, expenditure reductions are observed mainly in the fully adjusted models, but the effects are small and not consistently replicated across outcomes. I therefore interpret medication effects as less consistent and less robust than the outpatient–inpatient redistribution pattern, and I avoid drawing strong causal conclusions.

Across logistic regression and time-to-event analyses, teleconsultation assignment is not significantly associated with 1-year mortality. Conditional logistic regression shows no association between teleconsultation assignment and mortality after matching, and this

finding is consistent with the Kaplan–Meier survival curves and stratified Cox proportional hazards models. Instead, mortality risk is strongly associated with baseline patient characteristics. Pre-treatment emergency visits and hospital severity are consistent predictors of death across models. Each increase in emergency visits is associated with a substantially higher probability and hazard of death, while higher hospital severity scores also increase mortality risk. These findings indicate that pre-existing clinical burden, rather than teleconsultation assignment, drives short-term mortality outcomes. Survival probabilities remain high in both groups, with no statistically significant difference in 1-year mortality between patients in the treatment group (teleconsultation) and the control group (in-person consultation). Overall, the results suggest neither harm nor survival benefit attributable to teleconsultation assignment within one year in this matched cohort. Similar nationwide analyses of HF care across the COVID-19 period have shown that, despite substantial system disruption, in-hospital mortality remained stable and discharge prescribing of guideline-directed therapy was maintained or even improved, while longer-term outcomes worsened during the pandemic and subsequently improved in the post-COVID period (Cannata et al., 2023). This further supports the interpretation that pandemic-related system dynamics, rather than teleconsultation assignment per se, may shape observed mortality and utilisation patterns.

Several limitations constrain the interpretation. First, the analysis is observational and conducted during substantial pandemic-related disruption. Independent Slovenian evidence using linked national databases indicates that the COVID-19 pandemic altered acute coronary syndrome admission patterns and was associated with a negative time trend in secondary preventive medication uptake, despite stable short-term mortality (Furlan et al., 2023). This supports the interpretation that system-level strain and behavioural responses during the pandemic affected care pathways more broadly, beyond HF alone. Even after matching and adjustment, I cannot exclude residual confounding, particularly because administrative data lack granular HF severity measures (e.g., NYHA class, ejection fraction phenotype) and reflect care-seeking behaviour only indirectly. Second, I consider selection bias plausible: clinicians may assign teleconsultations based on unobserved factors (e.g., digital capacity, caregiver support, perceived adherence, symptom stability), and these factors may also influence subsequent utilisation and outcomes. Third, the treated sample is small and treatment prevalence is low, which constrains model complexity under EPV considerations, limits power for some outcomes, and increases sensitivity to specification choices. Fourth, measurement and coding limitations affect exposure classification: teleconsultations were implemented without fully stable coding early in the pandemic, and coding practices may vary over time and across providers, introducing potential misclassification of assignment and follow-up utilisation. Fifth, the pandemic context introduces time-varying confounding: system strain, restricted access, and behavioural changes may shift both assignment and outcomes in ways that are only partially captured by observed covariates. Sixth, expenditure results require cautious inference because software limitations prevented the use of cluster-robust SE under the chosen specification. I therefore

treat these findings as indicative and interpret them alongside the utilisation results. Taken together, these limitations imply that the results should be interpreted as decision-relevant empirical signals under real-world pandemic implementation conditions, rather than as definitive causal estimates of teleconsultation effects. In particular, the observed reduction in total cardiology outpatient visits, combined with greater inpatient intensity, is consistent with selective deployment of teleconsultations among more clinically complex patients during COVID-19 and with shifts in care pathways under constrained access.

These findings highlight the importance of clearly defining patient selection and care pathways when implementing teleconsultations. Outside a pandemic context, utilisation and cost patterns may differ if teleconsultations are deployed among more stable patients and embedded in structured follow-up protocols. Accordingly, I motivate further research and evaluation in more stable delivery conditions. Based on these findings, I suggest that future studies should examine teleconsultations outside the COVID-19 context and test hybrid care pathways that combine teleconsultations with structured monitoring, clear escalation criteria, and rapid in-person assessment when deterioration is suspected, as suggested in Chapter 5. EE should explicitly account for patient selection, the implementation stage, and the balance between reduced follow-up intensity and potential shifts towards more intensive inpatient care.

6.6 Summary and implications

This matched cohort analysis of patients with HF in Slovenia during the COVID-19 period shows that teleconsultations are selectively allocated to a more clinically complex and actively managed subgroup and that they are embedded within established cardiology follow-up pathways. Teleconsultation assignment is structured by baseline utilisation, severity, and pandemic stringency, confirming non-random allocation. These selection patterns underscore the need for careful pre-treatment adjustment when evaluating DHI using observational data, as unadjusted comparisons would otherwise be biased. I show that including contextual and utilisation variables strengthens internal validity and reflects the real-world complexity of DHI implementation. Within this constrained context, the chapter contributes rare patient-level economic evidence on teleconsultations in HF (see Subchapter 4.2), moving beyond trial-based or simulation-based estimates and demonstrating how implementation context and patient selection shape observed utilisation and cost patterns.

The key empirical findings are:

1. Selective assignment:

   – Teleconsultations are preferentially allocated to patients with higher prior utilisation and greater illness severity, are positively associated with the stringency index, and are integrated into existing specialist follow-up pathways.

2. Outpatient cardiology:

   – A robust reduction in total post-treatment cardiology visits (≈30–35%) and corresponding expenditure, indicating reduced overall specialist follow-up intensity rather than simple substitution of in-person visits.

3. Inpatient care:

   – A higher number of procedures per hospitalisation (≈50–60% increase in fully adjusted models) and consistently higher HF hospitalisation expenditure, indicating greater inpatient resource intensity during follow-up.

4. Medication outcomes:

   – No uniform pattern across drug groups. Small expenditure reductions are observed for some medications (e.g., diuretics, MRA, total HF prescriptions), while ACE inhibitor/ARNI effects are specification-sensitive and attenuate after adjusting for prior prescribing.

5. ED visits and HF hospitalisations:

   – No consistent association with event counts; zero-inflation diagnostics do not support a distinct structural-zero ED subgroup.

6. Mortality (1-year):

   – No significant association with teleconsultation assignment. Mortality is consistently driven by baseline emergency utilisation and hospitalisation severity.

Overall, the evidence points to a redistribution of care across settings rather than a net cost reduction. Teleconsultation assignment is associated with lower outpatient specialist utilisation but higher inpatient procedural intensity and HF hospitalisation expenditure during follow-up. Importantly, the increase in inpatient expenditure should not be interpreted as an adverse effect of teleconsultations. Triangulation of baseline severity indicators, higher pre-treatment utilisation, and stakeholder findings from Chapter 5 supports the interpretation of selective implementation among clinically more complex and higher-risk patients during the pandemic. The observed shift in resource use therefore reflects patient selection and contextual factors rather than adverse intervention effects.

From a methodological perspective, the analysis demonstrates the necessity of:

- controlling for prior utilisation and baseline severity,
- modelling count outcomes with structural zeros appropriately,
- applying suitable models for semi-continuous expenditure, and
- accounting for matched designs in inference.

The construction of severity proxies from administrative data illustrates how I achieve meaningful adjustment despite the lack of granular clinical information. The heterogeneous and multidomain effects observed reinforce the relevance of the IIM and CCA frameworks, which support transparent reporting across outcome domains rather than reliance on a single aggregated metric.

From a clinical and policy perspective, teleconsultations function as a complementary modality within established cardiology pathways rather than as a universal substitute for in-person care. While outpatient reductions suggest lower follow-up intensity, these are offset by higher inpatient HF hospitalisation expenditure and procedural intensity. Economic conclusions must therefore consider both reduced outpatient follow-up intensity and changes in inpatient care intensity.

The absence of a mortality effect indicates that teleconsultations do not compromise short-term survival within the matched cohort, supporting their use as an alternative modality of follow-up without detectable short-term safety concerns. I find that mortality remains primarily determined by baseline risk structure, reinforcing the importance of appropriate risk adjustment in evaluating DHI. The small and marginally significant income difference may tentatively suggest a socioeconomic dimension to teleconsultation uptake, consistent with stakeholder concerns raised in Chapter 5; however, this cannot be established conclusively with the available data.

From a policy and methodological perspective, the results underscore four points:

- clear patient selection criteria and explicit specification of the intended care pathway are essential when implementing teleconsultations outside crisis conditions,
- baseline risk structure and patient selection must be explicitly accounted for when interpreting DHI effects in observational data,
- outpatient efficiency gains should be evaluated alongside inpatient intensity to avoid incomplete economic conclusions, and
- evaluations conducted during pandemic implementation may not generalise to stable settings.

This multidomain and context-dependent pattern illustrates why structured approaches such as IIM and CCA are particularly suitable for evaluating DHI under real-world implementation constraints.

Because these findings arise from a pandemic-specific implementation context, future evaluations would benefit from several methodological and data-related enhancements. First, causal inference could be strengthened by linking administrative data to richer clinical data (e.g., HF registries, LVEF, NYHA class, laboratory and frailty measures), allowing more precise adjustment for disease severity beyond the hospitalisation proxy used in Chapter 6. Second, larger multicentre datasets and longer follow-up periods would increase

statistical power, particularly for rare outcomes such as 1-year mortality, and improve precision of effect estimates. Third, quasi-experimental designs and more granular temporal modelling approaches, including provider-level adoption timing, could further reduce residual confounding and better isolate intervention effects from pandemic-related system dynamics.

Beyond methodological refinement, future evaluations should more explicitly model care pathways and patient selection. I argue that teleconsultations should be analysed as components of broader HF management strategies rather than as isolated treatment events. In particular, hybrid care models that combine teleconsultations with structured monitoring and timely in-person escalation warrant investigation to clarify the clinical contexts in which teleconsultations provide the greatest value and to distinguish genuine substitution effects from broader organisational change.

7 COST-CONSEQUENCE ANALYSIS OF TELECONSULTATIONS FOR HEART FAILURE PATIENTS IN SLOVENIA

This chapter builds on the evidence developed across the preceding chapters to deliver an EE of teleconsultations for HF in Slovenia. In Chapter 3, I discuss the methodological challenges of conducting EE of DHI and introduce structured frameworks, notably the IIM and CCA, to map and transparently report multidomain impacts. Chapter 4 presents a systematic review of existing EE of telemedicine interventions that incorporate teleconsultations for HF. Chapter 5 presents qualitative insights from patients, cardiologists, digital health experts, and health economists. Chapter 6 analyses Slovenian administrative claims data to provide real-world quantitative evidence on the association between teleconsultations and HF care outcomes. Together, these chapters establish the conceptual, qualitative, and quantitative foundation for the EE presented here, progressing from domain identification to empirical estimation and integrative assessment in a manner consistent with the complexity of DHI.

In this chapter, I address the following research questions:

RQ3*: "How should the EE of telemedicine interventions be approached in the case of chronic HF?"*, and

RQ4: *"Is a telemedicine intervention in the form of teleconsultations for chronic HF in Slovenia economically viable?"*

The chapter proceeds as follows. First, I describe the study design, data collection, and methodology applied to construct the IIM and CCA. Next, I present the results: a populated IIM that maps outcomes across the predefined IIM domains by stakeholder group, and a CCA that reports both payer and societal perspectives, with measured or literature-informed

effects and, where available, Slovenia-specific estimates. Finally, I synthesise the results, discuss their implications, and conclude.

7.1 Study design

This subchapter outlines the overall design of the study and explains how I integrate the findings of the earlier chapters into the EE of teleconsultations for HF in Slovenia.

Conventional approaches such as CEA and CUA, while valuable in many contexts, primarily focus on aggregated health outcomes and the payer perspective, and may therefore be insufficient for assessing complex interventions such as DHI (e.g., Gomes et al., 2022). This focus may omit indirect costs, spillover effects, caregiver burden, equity implications, organisational change, and environmental impacts relevant for DHI. Accordingly, I base this study on the conceptual framework developed in Chapter 3.

I apply the conceptual framework developed in Chapter 3, which begins with a clear description of the context and complexity of the DHI, followed by the transparent specification of key EE characteristics and the systematic structuring of outcomes within the IIM and CCA. The analysis integrates findings from the systematic review, qualitative interviews, and quantitative observational study, supplemented with unit cost data from the Slovenian health system and relevant literature.

I adopt the healthcare system (payer) perspective as the primary analytical perspective and operationalise it through administrative data. The IIM extends the assessment structurally to broader societal domains, including patients, caregivers, and cross-sectoral impacts. I define the comparator as usual care, operationalised as in-person consultations. I define the time horizon as one year following teleconsultation assignment, reflecting the available follow-up in the administrative data. As the analysis does not extend beyond one year, I do not apply discounting.

I apply the IIM to map impacts across stakeholders and the CCA to present disaggregated costs and consequences side-by-side. In the next subchapter, I describe the data collection process and methodology in greater detail.

7.2 Data collection

This subchapter describes the data sources that I use to populate the IIM and CCA. Data are drawn from primary and secondary sources.

The primary data sources comprise qualitative interviews with patients, cardiologists, digital health experts, and health economists (Chapter 5), and a quantitative analysis of Slovenian administrative data (Chapter 6). The secondary sources include a systematic review of EE of teleconsultations for HF (Chapter 4), Slovenia-specific unit cost and reimbursement data,

and contextual evidence from international and national literature to fill gaps (e.g., caregiver burden, travel costs, environmental impacts).

The systematic literature review conducted in Chapter 4 provides international evidence on the EE of teleconsultations for HF and highlights methodological limitations, including short follow-up, payer-only perspectives, and heterogeneity. These findings provide contextual benchmarks for the Slovenian evaluation.

The qualitative analysis in Chapter 5 identifies stakeholder-relevant costs, consequences, outcomes, and evaluation and implementation barriers, which are often omitted in conventional EE, including caregiver burden, equity, digital literacy, reimbursement constraints, and environmental considerations. These findings inform my inclusion of further impacts within the IIM and of additional costs and consequences in the CCA, so that the EE reflects real-world implementation conditions.

The administrative data analysis in Chapter 6 provides real-world evidence on healthcare utilisation, expenditure, and mortality associated with teleconsultations for patients with HF in Slovenia. It demonstrates that teleconsultation assignment is selective and structured by baseline healthcare utilisation and indicators of clinical severity, particularly during the COVID-19 period. To address confounding, I apply PSM and outcome-specific regression models appropriate for skewed and zero-inflated distributions. The findings indicate reduced outpatient follow-up intensity, increased inpatient intensity, heterogeneous medication effects, and no short-term mortality association. These findings provide the core quantitative inputs for the CCA.

The empirical and qualitative findings are supplemented by Slovenia-specific unit cost and tariff data (e.g., tariffs, travel reimbursement, parking fees) and contextual literature-based estimates. Where direct local data are unavailable, I apply literature-based proxies, including estimates of caregiver time, travel costs, productivity losses, and environmental effects.

Administrative data form the backbone of the healthcare system perspective, qualitative interviews inform the user experience and cross-sectoral impacts, and literature-based proxies address remaining data gaps. This triangulated data structure enables systematic population of the IIM and CCA across domains.

7.3 Methodology

As I discuss in Chapter 3, the EE of DHI first requires a clear description of the context and complexity of the intervention, as well as a transparent definition of key EE aspects. I then systematically map outcomes within an IIM and translate them into a CCA (e.g., Wilkinson et al., 2023).

Accordingly, this study follows the conceptual framework developed in Chapter 3 and incorporates the following structured steps:

1. Define the context and complexity of teleconsultations for HF in Slovenia,
2. Specify the EE characteristics (such as perspective, comparator, and time horizon),
3. Populate the IIM across domains (health, healthcare system, user experience, value of data, and cross-sectoral impact),
4. Translate findings into the CCA with disaggregated costs and consequences, and
5. Integrate and interpret the results, and address the limitations.

I use the IIM to systematically categorise outcomes across five domains: health, healthcare system, user experience, value of data, and cross-sectoral impact (Wilkinson et al., 2023). This structure makes both conventional outcomes (e.g., hospitalisations, healthcare expenditure) and less conventional impacts (e.g., caregiver time, digital equity, environmental effects) explicit within a single framework.

After presenting the IIM, I populate the CCA using the data collected throughout the dissertation. The CCA primarily uses administrative cost and utilisation estimates, supplemented where necessary with literature-based proxies. Where quantification is not feasible, I report the outcomes descriptively. Rather than relying solely on aggregated cost-effectiveness ratios (e.g., ICER), I use the IIM to map multidomain consequences and the CCA to present disaggregated costs and consequences by domain, including direction of effect, units of measurement, and data source. This preserves transparency and makes trade-offs explicit within the Slovenian context. It allows decision-makers to assess outcomes expressed in different units without forcing aggregation.

Finally, I address sensitivity and uncertainty through the use of triangulation. I tested the estimates in Chapter 6, based on administrative data, with alternative model specifications, while qualitative and literature-based inputs provide robustness checks for less quantifiable outcomes. Throughout, I report explicitly and clearly specify outcomes, data sources, and units of measurement.

7.4 Results

In this subchapter, I present the results of the EE of teleconsultations for HF in Slovenia. In line with the methodological framework outlined earlier in this chapter, the results are reported in two complementary parts. First, the IIM provides a structured overview of identified impacts across domains and stakeholders, including both healthcare outcomes and broader societal effects. Second, the CCA translates these impacts into disaggregated estimates of costs and consequences, presented in their original units to enable a transparent assessment of trade-offs.

In the analysis, I integrate administrative utilisation and cost estimates, stakeholder-identified impacts from qualitative interviews, and literature-based proxies where direct Slovenian measurement is unavailable. I first report the multidomain mapping of impacts (Subchapter 7.4.1) and then present the perspective-specific quantitative disaggregation (Subchapter 7.4.2).

7.4.1 Impact inventory matrix

To assess the multidimensional consequences of teleconsultations for HF, I begin the evaluation by presenting an IIM. As discussed in Chapter 3, this tool provides a structured and transparent way of mapping relevant outcomes across domains and stakeholder groups. The IIM (see Table 31) integrates findings from the systematic review (Chapter 4), stakeholder interviews (Chapter 5), and the administrative data analysis (Chapter 6). The IIM shows a multidimensional pattern of benefits and trade-offs distributed unevenly across stakeholders and domains. I summarise the results according to the five IIM domains: health, healthcare system, user experience, value of data, and cross-sectoral impact.

In the health domain, teleconsultations are not associated with a statistically significant difference in 1-year mortality, indicating no observable short-term survival disadvantage within the matched cohort. Interviews and international literature suggest potential improvements in QOL, particularly for stable patients benefiting from reduced travel burden and enhanced self-management. However, I do not directly measure QOL and long-term morbidity outcomes within the Slovenian administrative dataset, and they therefore remain partly inferential. Caregivers report reduced stress where visit frequency declines, contributing indirectly to wellbeing. Long-term morbidity and mortality effects beyond one year remain outside the observed time horizon.

In the healthcare system domain, the most consistent empirical finding is reduced overall cardiology outpatient follow-up intensity, rather than simple substitution between teleconsultations and in-person visits. Administrative data also indicate higher inpatient procedural intensity among patients assigned to teleconsultations during the COVID-19 period, reflecting selective allocation to more clinically complex patients rather than a causal inpatient effect of teleconsultation itself. Stakeholders report potential efficiency gains, including reduced waiting times, fewer no-shows, and improved continuity of care for stable patients. Teleconsultations may involve lower direct consultation costs relative to in-person visits, although this depends on reimbursement structures. At the organisational level, stakeholders highlight fragmented ICT systems, reimbursement constraints, and training needs as implementation challenges. Stakeholders identify system-level resilience, particularly during crisis conditions, as a potential benefit.

In the user experience domain, patients value convenience, reduced travel time, and lower out-of-pocket costs. Improved flexibility and perceived empowerment are reported, particularly among stable patients. However, patients with new or severe symptoms

sometimes report reduced perceived security in remote settings. Digital exclusion remains a recurrent concern, particularly among elderly or low-literacy groups. Caregivers report reduced accompaniment requirements and improved work–life balance when visit frequency declines. Providers report mixed experiences: teleconsultations are viewed as appropriate for selected patient groups but are limited by diagnostic constraints and workflow disruptions where ICT systems are not fully integrated.

Teleconsultations generate additional clinical and behavioural data, including information on adherence, disease progression, and service use. These data may support personalised care and workload planning. For payers and decision-makers, richer datasets can support forecasting, HTA, and healthcare system monitoring. At the societal level, aggregated data could inform public healthcare planning and equity monitoring. However, stakeholders emphasise that data value depends on interoperability, governance, and infrastructure.

Cross-sectoral impacts include time savings for patients and caregivers, which may reduce productivity losses and increase wellbeing. Reduced travel may lower CO_2 emissions, waste, and associated environmental costs. At the same time, digital exclusion risks may exacerbate inequities if technical and educational support are insufficient, particularly for rural or socioeconomically disadvantaged groups.

These multidomain patterns provide the conceptual basis for the quantitative disaggregation that I present in the subsequent CCA.

7.4.2 Cost-consequence analysis

Building on the populated IIM in the previous subchapter, I translate outcomes into measurable units where possible and clearly distinguish between the healthcare system and broader societal perspectives. I draw on five sources: the observational study using HIIS administrative data (Chapter 6), the systematic review of EE of teleconsultations for HF (Chapter 4), qualitative stakeholder interviews (Chapter 5), additional research reporting measurable cost and utilisation outcomes (e.g., travel costs), and Slovenian tariff data (e.g., travel cost reimbursement).

In Table 32, I present each outcome together with its unit of measurement, direction and magnitude of effect, and data source. Whereas the IIM organises impacts across five conceptual domains (health, healthcare system, user experience, value of data, and cross-sectoral impact), the CCA restructures these impacts into cost-relevant clusters to support economic interpretation and decision-making. I report the disaggregated estimates below by perspective and cluster. The disaggregated estimates indicate reduced cardiology outpatient follow-up intensity, heterogeneous pharmaceutical effects, and higher inpatient procedural intensity among more complex patients during the pandemic period, without a statistically significant association with 1-year mortality. In addition, the analysis identifies measurable societal and environmental consequences.

Table 31: Impact inventory matrix for teleconsultations for heart failure patients in Slovenia

Stakeholder	Health outcomes	Healthcare system	User experience	Value of data	Cross-sectoral impact
Patients	Neutral mortality at 1 year (Ch. 6); potential QOL gains from reduced burden; fewer exacerbations (Ch. 5); better self-management for stable HF (Ch. 5, 6); gains in QOL/QALY (Ch. 4)	Fewer outpatient cardiologist visits; reduced need for in-person follow-up in primary care and cardiologist; higher hospital intensity among sicker patients (pandemic allocation effect, not intervention effect per se, Ch. 5, 6)	Convenience; reduced travel costs, including parking and allowance for meals and beverages; improved satisfaction; empowerment; risk of digital exclusion for elderly/low-literacy groups; experience depends on disease severity, new symptoms and patient preferences (Ch. 5)	Clinical and behavioural data on HF care pathways, adherence to therapy and pharmaceuticals, disease progression monitoring (Ch. 5)	Reduced travel costs; time savings usable for work/leisure, reduced productivity loss due to taking time off work or vacation days; potential of digital divide (Ch. 5)
Providers (clinicians, cardiologists, physicians)	Neutral health-related outcomes (Ch. 5, 6); improved follow-up for stable patients. Therapy adherence assessment; avoidable admissions due to earlier interventions; reduced risk of disease transmissions; diagnostic limitations; risk in sicker or newly symptomatic patients (Ch. 5)	Improved ability to follow stable patients closely; more efficient scheduling; reduced outpatient congestion; reduced no-shows and cancellations; workflow issues if ICT not integrated properly (Ch. 5); reduced cost of consultations and time spent per consultation (Ch. 4, 5, 6)	Greater flexibility, risk of if under-resourced; not allocated time for telemedicine and unrecognised value; need for training in utilisation, need for ICT support; teleconsultations more appropriate for certain patient groups (Ch. 5)	Data for workload planning, risk avoidance, quality monitoring, adherence to therapy, continuous disease monitoring (Ch. 5)	Education; organisational adaptation; workload redistribution (Ch. 5)
Payer / healthcare system (hospital, clinic, insurance companies)	Neutral health outcomes at 1 year follow-up (Ch. 6); limitations in diagnostics; risk in clinically more complex patients or patients with new symptoms Ch. 5)	Lower teleconsultations costs (Ch. 4, 5, 6), lower outpatient visitations, higher inpatient intensity (Ch. 6); clinically more complex patients used teleconsultations in the COVID-19 pandemic (Ch. 5, 6); appropriate for continuous monitoring of stable patients with chronic conditions potential cost-efficiency in stable patients (Ch. 5)	Reimbursement challenges; need to adapt financing models; need for recognition by decision-makers, challenges to implementation and standardisation, improved continuity of care and workflow; teleconsultations more appropriate for certain patient groups (Ch. 5)	Richer datasets for planning, forecasting, and HTA, including administrative and clinical data (Ch. 5)	Training needs for all users; ICT support; environmental savings at institutional level; capital costs and recurring programme costs (Ch. 4, 5); workload redistribution; efficiency gains in crisis resilience (Ch. 5)

To be continued

Table 31: Impact inventory matrix for teleconsultations for heart failure patients in Slovenia (cont.)

Stakeholder	Health outcomes	Healthcare system	User experience	Value of data	Cross-sectoral impact
Society (excluding caregivers)	Potential health gains if equitably adopted (Ch. 5, 6); reduced risk of infections (Ch. 5); morbidity/mortality improvements over time for stable, continuously monitored patients with chronic diseases (Ch. 4, 5, 6)	More resilient healthcare system, improved access in underserved areas (if equity addressed properly) (Ch. 5), system capacity reallocation (Ch. 4, 5)	Improved access to care in rural areas and patients with mobility issues, equity risks due to digital divide, concerns around privacy (Ch. 5)	Data for public health planning, population-level insights into digital equity and HF burden (Ch. 5)	Reduced CO_2 emissions, paper and other waste; improved workforce productivity; improved sustainability effects (Ch. 5)
Caregivers	Lower stress if fewer visits needed, potential improved wellbeing due to less stress, improved disease monitoring (Ch. 5)	Less accompaniment required (Ch. 5); reduced transport effort (Ch. 4, 5)	More flexible caregiving (Ch. 5); fewer visitations to coordinate with work, leisure and personal life (Ch. 4, 5)	Shared information supports coordination of disease management, data on caregiver involvement poorly captured (Ch. 5)	Lower travel-related costs; reduced care time, reduced absenteeism and presenteeism (Ch. 4, 5)

Source: Author's work

From the payer perspective, the clearest quantitative finding concerns reduced total cardiology outpatient follow-up intensity rather than simple substitution between consultation modalities. In-person cardiology consultations (€59.08 average per visit) have higher tariff than teleconsultations (€12.68 average per consultation; €12.30 for code 11604, €7.47 for code 91103, and €18.28 for code 91104). This tariff differential translates into lower outpatient expenditure per patient-year, while survival remains statistically indistinguishable between groups. Patients in the teleconsultation group have 61–67% fewer cardiology visits (IRR ≈ 0.33), corresponding to cost reductions of –€45.93 to –€51.64 per patient during the follow-up year. Teleconsultation assignment shows no statistically significant association with emergency visits (IRR = 1.37; p = 0.568), and only one specification indicates a marginal cost decrease (–€0.041 per patient-year; p = 0.071). One-year mortality shows no statistically significant association with teleconsultations (HR = 1.59; p = 0.191), indicating no detectable short-term survival difference within the matched cohort.

HF-related hospitalisations show a different pattern. I observe no statistically significant difference in the number of hospitalisations across specifications (IRR 0.97–1.19; all p > 0.10). However, hospitalisation expenditure in the follow-up year is higher among patients in the treatment group (teleconsultation) (€1,131–€1,287; p = 0.034–0.061). Teleconsultation assignment is also associated with a higher number of procedures during hospitalisations in the adjusted models (IRR 1.39–1.57; p = 0.020–0.076), corresponding to approximately 39–57% greater procedural intensity relative to the control group. As discussed in Chapter 6, this pattern likely reflects pandemic-era selective allocation of more clinically complex patients rather than a direct causal effect of teleconsultations. For contextual comparison, the OECD estimates the average cost of HF readmissions at €3,500–€4,500 (OECD, 2022); these differences reflect country-specific tariffs and costing definitions.

Pharmaceutical cost effects are heterogeneous and specification-sensitive. Beta-blocker prescription counts do not differ significantly across models, although a small but statistically significant cost reduction (–€2.5; p < 0.001) appears in the fully adjusted specification. For ACEI/ARNI therapy, prescription counts increase only in the covariate-adjusted model (IRR = 1.428; p = 0.032), accompanied by a €26.06 cost increase (p = 0.002); other specifications are non-significant and with no stable directional pattern. MRA prescription counts are not statistically significant, with only a trivial cost decrease (–€0.32; p < 0.001) observed in one model. Diuretic prescription counts show no significant differences, although one specification indicates a cost reduction (–€10.73; p < 0.001), not replicated elsewhere. For all categorised HF pharmaceuticals combined, counts decline marginally and borderline significantly only in the fully adjusted model (IRR = 0.905; p = 0.091), with a corresponding cost decrease of –€20.33 (p = 0.029); other specifications show no significant effects.

From the provider perspective, stakeholders report that teleconsultations reduce outpatient congestion and no-shows, allow closer monitoring of stable patients, and facilitate continuity of care and earlier identification of adherence issues. Stakeholder testimony in Chapter 5 indicates that approximately 30% of scheduled appointments are missed under usual conditions, while international evidence reports lower no-show rates for teleconsultations (e.g., 12%) than for in-person visits (25%) (Ojinnaka et al., 2024). Teleconsultations require less time (5–10 minutes) than in-person visits (15–20 minutes) or home visits (approximately 45 minutes) (e.g., McCarthy, 2016; Rasoul et al., 2025), potentially increasing scheduling flexibility and system throughput. However, stakeholders also report implementation challenges: ICT systems lack interoperability, telemedicine time is not formally recognised in workload accounting, and additional training is required. Diagnostic limitations restrict use for unstable or newly symptomatic patients, reinforcing the need for structured triage.

From the patient perspective, teleconsultation assignment is associated with convenience, reduced travel, and continuity of care. Each avoided in-person consultation is estimated to save €30–€52 per visit, combining direct travel costs (parking approximately €2 per hour; incidental expenses of €10–15) and productivity gains (€10–15 per hour), assuming time savings of 1.5–2 hours per visit (including approximately 30 minutes of driving for a 20 km round trip). Productivity losses are valued at approximately €93 per day based on Slovenian estimates (Lotrič Dolinar et al., 2020). These benefits are only partially offset by Slovenia's reimbursement system, which covers travel to the nearest provider but excludes most out-of-pocket costs.

Travel reimbursement is calculated at 10% of the premium petrol price per kilometre, reduced by a deductible, and capped per trip (HIIS, n.d.). A 300 km round trip (€45.69 actual cost) yields €7.36 reimbursement. Public transport reimbursement is subject to similar deductibles, and no refund is issued below the deductible threshold (€37.62 in 2024). Parking and incidental expenses are not reimbursed. Contextual evidence from oncology care illustrates the magnitude of travel-related financial burden in chronic disease management. Došenović Bonča et al. (2023) report average annual travel expenses of €334 per patient. Similar studies show that 42.8% of patients identify transport as their most frequent out-of-pocket cost, and transport-related expenditure contributes to financial toxicity (Skubic et al., 2025; Vörös et al., 2025). These findings support the plausibility of travel-related savings identified in the present CCA, even though disease contexts differ.

From the caregiver perspective, travel and accompaniment burdens are substantial. Nearly one-third of patients in Skubic et al. (2025) report that a family member takes at least one day off work to accompany them; 14% report formal sick leave, and 2% report reduced working hours. Average hourly labour costs in Slovenia are €20 (2020) and €22 (2022) (EUROSTAT, 2025; SURS, 2021). Teleconsultations reduce accompaniment time and associated productivity losses. Unpaid caregivers also incur opportunity costs in terms of lost leisure time.

Table 32: Cost-consequence analysis of teleconsultations for heart failure patients in Slovenia

Perspective	Domain	Item	Unit	Direction of effect and / or estimate	Source / Notes
Payer / Health system	Outpatient utilisation & costs	Cardiology visits	IRR	↓ (IRR ≈ 0.33)	Ch. 6; Ch. 5 decrease
		Cardiology cost	€/patient-year	−€45.59 to −€51.64	Ch. 6; Ch. 5 decrease
		ED visits	IRR	IRR ED = 1.37; not significant, neutral	Ch. 6 neutral; Ch. 4 slight decrease; Ch. 5 potential decrease
		ED costs	€/patient-year	↓ (–€0.041, $p = 0.071$)	Ch. 6; Ch. 5 potential decrease
	Inpatient utilisation & costs	Procedures	IRR	↑ (IRR = 1.39–1.57, $p = 0.020$–0.076)	Ch. 6; higher intensity in pandemic
		HF hospitalisations	IRR	↑↓ (IRR 0.97–1.19, not significant)	Ch. 6
		HF hospitalisation cost	€/patient-year	+€1,131–€1,287 ($p = 0.034$–0.061)	Ch. 6
		Beta-blockers group costs	€/patient-year	−€2.5 ($p < 0.001$)	Ch. 6
		MRA group costs	€/patient-year	−€0.32 ($p < 0.001$)	Ch. 6
		ACEI/ARNI group costs	€/patient-year	+€26.06 ($p = 0.002$, mixed)	Ch. 6
		Diuretics group costs	€/patient-year	−€10.73 ($p < 0.001$)	Ch. 6
		All HF pharmaceuticals costs	€/patient-year	−€20.33 ($p = 0.029$)	Ch. 6
	Clinical outcomes	Mortality	% / HR	HR ≈ 1.59, not significant; neutral at 1 year	Ch. 6
		QOL / QALY	units	↑ small–moderate gains	Ch. 4
	Programme costs	Platform / licences	€/year	↑ recurring costs	Ch. 4; Ch. 5
		Training & setup	€ (initial year)	↑ one-off cost	Ch. 4; Ch. 5
		Staff time per consult	minutes	↓ 5–10 min (tele), 15-20 min (in-person)	Additional literature; Ch 4; Ch. 5
	Workflow or system	No-show rate	%	↓ baseline ≈30%; teleconsultation ≈12%	Ch. 4; Ch. 5
		Continuity of care	qualitative	↑	Ch. 5
		Earlier intervention / avoidable admissions	qualitative	↑ potential	Ch. 5
		Diagnostic limits	qualitative	↓ for complex patients / new symptoms	Ch. 5
	Capacity & resilience	System capacity	qualitative	↑ (potential efficiency if fewer admissions)	Ch. 4; Ch. 5
	Financing	Reimbursement	qualitative	Challenges; need recognition / adaptation	Ch. 5
Societal (patients, caregivers, broader)	Direct patient and caregiver costs	Travel-related costs	€/visit	↓ €30–52 per visit per avoided trip, including fuel, parking and productivity loss of €10-15 per hour	Additional data on Slovenia; Ch. 5
	Time burden	Patient time	h/visit	↓ ~0.7 h	Additional literature; Ch 4
		Caregiver time	h/visit	↓ ~€20-22 per h lost productivity, if working	Ch. 5; Additional data on Slovenia
	Productivity	Work loss	€/day	↓ (sick leave proxy €93/day)	Additional data on Slovenia

To be continued

Table 32: Cost-consequence analysis of teleconsultation for heart failure patients in Slovenia (cont.)

Perspective	Domain	Item	Unit	Direction of effect and / or estimate	Source / Notes
Societal (patients, caregivers, broader)	User experience	Convenience	qualitative	↑ convenience; less travel stress	Ch. 5
		Preference heterogeneity	qualitative	Some still prefer in-person	Ch. 5
		Empowerment & self-management	qualitative	↑ for stable patients	Ch. 5
		Digital exclusion risk	%, qualitative	↑ risk in elderly or lower-literacy patients	Additional data on Slovenia; Ch. 5
	Access or equity	Rural & mobility-impaired access	qualitative	↑ access if supported	Ch. 5
		Fairness/privacy	qualitative	Concerns raised	Ch. 5
	Environment	CO_2 from travel	kg/visit	↓ 3.66 kg per avoided visit	Additional data on Slovenia
		Paper/PPE/waste	units	↓ (1–3 sheets/visit; less waste	Additional literature
	Caregiver wellbeing	Stress & flexibility	qualitative	↑ reduced stress, ↑ flexibility	Ch. 5
	Data value	Additional data generated	qualitative	↑ therapy adherence, monitoring, population-level planning)	Ch. 5

Source: Author's work

Distributional effects are mixed. Teleconsultations improve access for rural and mobility-impaired patients, but digital exclusion risks persist for older or less digitally literate patients without targeted support. Patients with mobility-related comorbidities are more likely to be assigned to teleconsultations (Chapter 5 and 6).

From an environmental perspective, each avoided consultation saves approximately 3.66 kg CO_2 (based on a 20 km round trip and 183 g CO_2/km; ARSO, 2023). International evidence also reports reductions in paper and consumable waste (Morcillo Serra et al., 2022; Purohit et al., 2021).

Taken together, the CCA indicates that reduced follow-up intensity constitutes the largest quantitatively robust cost effect, while inpatient intensity reflects pandemic-era case selection.

7.5 Discussion and conclusions

In this subchapter, I interpret the measurable redistribution of costs and consequences presented in Subchapter 7.4 in light of their economic and policy relevance. Consistent with the methodological framework of this chapter, I use the IIM to reflect on how benefits and trade-offs are distributed across domains and stakeholder groups, and I use the CCA to interpret the implications of disaggregated costs and consequences for decision-making under both the healthcare system and societal perspectives.

From the healthcare system (payer) perspective, the clearest and most robust pattern is the reduction in cardiology outpatient follow-up intensity, which translates into lower outpatient expenditure under the prevailing tariff structure. Importantly, I observe no statistically significant association with 1-year mortality, indicating no detectable short-term survival disadvantage within the matched cohort. There is no significant effect on HF hospitalisation or ED visits. Taken together, these results position teleconsultations primarily as an efficiency instrument for routine specialist follow-up when used under appropriate clinical conditions. At the same time, I observe higher inpatient procedural intensity and higher HF-related hospitalisation expenditure in some specifications for patients assigned to teleconsultations during the COVID-19 period. I interpret this pattern as reflecting selective deployment to more clinically complex patients under pandemic conditions, rather than as an intrinsic effect of teleconsultations on inpatient care. This interpretation is consistent with the selection patterns documented in Chapter 6 and with stakeholder accounts in Chapter 5 describing contextual allocation and pathway disruption during the pandemic. Within this study's 1-year horizon, the main system-level trade-off therefore concerns the redistribution of care intensity across care settings under selective assignment, even when outpatient activity declines.

From the societal perspective, the strongest gains relate to reduced patient and caregiver burden. Teleconsultations reduce travel time and associated out-of-pocket costs, and they

mitigate productivity impacts when consultations otherwise require time off work or coordination with caregiving responsibilities. Stakeholder evidence further indicates that lower visit frequency can reduce stress and improve perceived wellbeing among both patients and caregivers. Environmental effects also contribute to societal value, as avoided travel implies reduced emissions and potentially less waste.

Provider experiences are more heterogeneous. Stakeholders describe operational advantages, such as shorter consultations for appropriate patient groups and fewer missed appointments, which can support capacity and continuity of care. However, they also emphasise implementation frictions, including fragmented ICT infrastructure, limited interoperability, misaligned reimbursement and workload recognition, and diagnostic constraints for unstable or newly symptomatic patients. These factors shape the real-world value of teleconsultations and show that their effectiveness depends on how they are integrated into care pathways, not on the digital format alone. Teleconsultations create value primarily when they are embedded within well-defined workflows that include clear pathways for escalation to in-person care. At the same time, equity risks emerge, as digital exclusion disproportionately affects older and less digitally literate patients. Without targeted support, these disparities may undermine potential societal benefits.

Beyond measurable utilisation and costs, the evaluation highlights “data value” as a consequential but conditional domain. Teleconsultations generate digital traces relevant to adherence, engagement, and service use, which can support clinical decision-making, workload planning, and population-level monitoring. Stakeholders emphasise that the value of data generated through teleconsultations depends on effective governance, interoperability, and standardisation; without these foundations, digital data risk increasing administrative burden rather than informing decision-making. In Slovenia, as in many health systems, structural gaps in these areas remain.

Methodologically, I show in this chapter why combining the IIM and CCA strengthens decision relevance in the evaluation of DHI. I use the IIM to ensure structured mapping of impacts across health, healthcare system, user experience, value of data, and cross-sectoral impacts, making inclusion, exclusion, and uncertainty explicit. I then use the CCA to reorganise these impacts into cost-relevant clusters and to present them in their original units, thereby preserving transparency and avoiding premature aggregation under contested valuation assumptions. In this setting, where effects are distributed across stakeholders and implementation conditions shape observed patterns, this paired approach provides a more policy-usable representation of value than a single summary metric.

Taken together, the evidence indicates that the most reliable value of teleconsultations in HF care lies in lower outpatient follow-up intensity and broader societal gains arising from reduced travel and time-related burdens. The main trade-off observed in this study, higher inpatient intensity, appears linked to selective assignment under pandemic conditions rather than to teleconsultations per se. This reinforces the central conclusion of the dissertation:

teleconsultations are most likely to deliver net value when they are selectively deployed for clinically stable patients within structured, hybrid care pathways and when implementation prerequisites (equity safeguards, interoperability, and clear escalation protocols) are in place.

Despite the structured integration of evidence, several limitations of this chapter should be noted. The quantitative estimates inherit the methodological constraints discussed in Chapter 6, including reliance on observational administrative data and the COVID-19 implementation context. In addition, several societal and cross-sectoral outcomes rely on literature-based proxies or qualitative evidence rather than direct measurement within Slovenian patients with HF. Although I report these inputs transparently within the CCA, they introduce uncertainty regarding the magnitude of certain effects. Finally, because the observed consequences are multidimensional and partly redistributional across stakeholders, I do not aggregate them into a single cost-effectiveness ratio. Such aggregation would require stronger assumptions regarding valuation and long-term trajectories than the available data support.

7.6 Summary and implications

In this chapter, I conduct a CCA of teleconsultations for HF in Slovenia by integrating administrative data, stakeholder perspectives, systematic review evidence, and Slovenia-specific cost inputs within the structured framework of the IIM and CCA.

The findings indicate reduced total cardiology outpatient follow-up intensity without a statistically significant association with 1-year mortality, alongside heterogeneous pharmaceutical effects and increased inpatient procedural intensity during the pandemic period, which I interpret as selective allocation rather than as an intrinsic intervention effect. Beyond the healthcare system, teleconsultations generate measurable societal benefits through reduced travel, lower productivity losses, decreased caregiver burden, and environmental benefits. Taken together, the results show that economic value arises primarily from reduced outpatient intensity and the redistribution of care across settings, rather than from universal cost reduction. The observed patterns are sensitive to patient selection, pathway design, and implementation context, consistent with transferability challenges documented for real-world evidence in lower-income European HTA settings (e.g., Kaló et al., 2026). These findings carry implications for healthcare payers, providers, and policymakers responsible for financing and evaluating teleconsultations in HF care.

Based on this EE, five core implications arise:

1. Targeted deployment within structured hybrid care pathways:

   – Economic value derives primarily from reduced outpatient follow-up intensity under appropriate clinical conditions. Teleconsultations can support efficiency objectives in

specialist care and increase operational flexibility through shorter consultations for appropriate patients and fewer missed appointments.

- Because inpatient expenditure is sensitive to patient selection and pathway context, teleconsultations should not be treated as universal cost-saving substitutes. Instead, decision-makers should govern them as part of a targeted service redesign embedded within formal hybrid care pathways. Related nationwide Slovenian registry evidence shows that structured expansion of comprehensive outpatient cardiac rehabilitation increased participation and improved long-term cardiovascular outcomes compared with residential models, highlighting how care modality and organisational embedding can materially influence downstream utilisation and cost-effectiveness in chronic cardiovascular disease (Jug et al., 2025).
- Teleconsultations should be understood as components of structured specialist pathways rather than standalone digital substitutions. Evidence from large-scale HF audits demonstrates that specialist involvement during acute admissions is associated with improved implementation of guideline-directed therapy and lower long-term mortality, underscoring the importance of organisational structure and multidisciplinary care in shaping outcomes (Cannata et al., 2025). Although the mechanisms differ from outpatient teleconsultation, this evidence reinforces the broader principle that outcomes in HF are highly sensitive to pathway configuration and specialist integration. Teleconsultations must therefore be evaluated within the overall configuration of HF care rather than in isolation.
- This requires explicit eligibility criteria, structured triage protocols, and clear escalation mechanisms for clinical deterioration or diagnostic uncertainty. Emphasis should be placed on clinically stable patients with HF requiring routine follow-up. Slovenian experience with establishing dedicated outpatient cardiac rehabilitation centres demonstrates that formalised referral pathways, accreditation, and reimbursement alignment can significantly increase national uptake, underscoring the importance of institutional embedding for successful implementation (Jug, Furlan, et al., 2024).
- Sustainable integration further depends on interoperability, workflow redesign, and formal recognition of teleconsultation time in workload accounting and reimbursement structures. Without these organisational conditions, apparent outpatient efficiency gains may not translate into system-level economic benefits.

2. Interpret cost effects as redistribution:

- Observed outpatient savings must be assessed alongside inpatient intensity and patient selection effects. Economic conclusions should reflect redistribution of care across settings and stakeholder groups rather than assume automatic net cost reduction.
- Outpatient expenditure reductions may coexist with higher inpatient intensity when teleconsultations are selectively allocated to more clinically complex patients.

Economic interpretation should therefore distinguish between true efficiency gains and shifts in cost burden across modalities, providers, and payers.
- Decision-makers should explicitly examine whether observed savings represent structural efficiency improvements or context-specific reallocations driven by differences in patient complexity and implementation conditions.

3. Adopt broader evaluative perspectives:

- Travel costs, productivity losses, caregiver burden, environmental impacts, and equity effects materially influence economic interpretation. Restricting evaluation to payer expenditure risks undervaluation.
- The distribution of costs and benefits is not uniform across patient groups. While teleconsultations can improve access for mobility-impaired and rural populations, risks of digital exclusion persist for older or less digitally literate patients without targeted support.
- Teleconsultations reduce out-of-pocket spending, travel burden, productivity losses, and caregiver burden, while avoided travel generates additional environmental benefits. These cross-sectoral effects support evaluation frameworks that incorporate distributional and environmental consequences rather than restricting assessment to healthcare expenditure alone.
- Policy design should therefore integrate practical equity safeguards, including assisted pathways, digital literacy support, and appropriate in-person alternatives, to ensure that improved access does not translate into widened disparities in access and outcomes.

4. Structure evaluation before aggregation:

- Multidomain mapping (IIM) and disaggregated reporting (CCA) should precede aggregation into single cost-effectiveness metrics, particularly in implementation-dependent digital interventions.
- For decision-makers, this implies that they should undertake structured identification of impacts across domains before synthesising results into summary economic indicators. In complex and context-sensitive interventions, such as teleconsultations, disaggregated presentation of costs and consequences improves transparency and supports informed deliberation.
- Conventional CEA or CUA remain relevant, but premature aggregation risks obscuring redistributional trade-offs under data constraints and contested valuation assumptions. This risk is particularly salient where data limitations and heterogeneous effects make single-metric conclusions unstable or misleading.

5. Strengthen evidence for chronic disease EE:

- Longer analytic horizons are required to capture downstream morbidity trajectories, adherence dynamics, and potential delayed effects on hospitalisation. Administrative data should be linked with richer clinical indicators of disease severity to reduce residual confounding and improve internal validity. This is consistent with Slovenian registry evidence in other chronic cardiovascular disease populations demonstrating graded, time-varying associations between long-term adherence and major outcomes, underscoring the importance of modelling long-term treatment exposure in chronic disease evaluation (Furlan et al., 2026).
- Because economic effects are sensitive to institutional, tariff, and organisational context, transferability requires explicit adaptation rather than direct extrapolation across health systems.

Taken together, the findings illustrate that the economic value of teleconsultations does not arise from universal cost reduction, but from redistribution of care intensity across modalities and stakeholders. This redistribution is economically favourable when it is aligned with an appropriate pathway design, patient selection, and organisational readiness. The intervention's value therefore depends less on the technology itself and more on care pathway design and implementation governance.

Because I conduct this evaluation within the Slovenian healthcare financing and organisational context, including specific tariff structures and pandemic-era implementation conditions, I interpret the results as context-specific rather than universally generalisable. Future research should prioritise evaluation in stable post-pandemic settings, linkage of administrative and clinical datasets, and systematic incorporation of patient-reported, equity, and environmental outcomes to strengthen both internal validity and transferability.

8 CONCLUSIONS

The purpose of this doctoral dissertation is twofold: first, to refine methodological approaches for conducting EE of DHI, with a specific focus on telemedicine; and second, to apply these approaches in a comprehensive EE of teleconsultations for patients with HF in Slovenia. This objective is pursued through bibliometric mapping, a systematic review, stakeholder framework analysis, and advanced statistical models applied to administrative claims data within a structured EE framework. I provide a comprehensive account of how EE of DHI, particularly telemedicine can be structured to achieve both methodological rigour and policy relevance, while also capturing clinical effectiveness, behavioural change, and broader societal impacts.

I intend these findings to support evidence-based decision-making in Slovenia's public healthcare system and to contribute to the wider international debate on the value of DHI. This research advances methodological approaches to EE while generating context-specific evidence grounded in the Slovenian healthcare system. This dissertation therefore makes

both a theoretical contribution, by refining frameworks for EE, and a practical contribution, by informing health policy and resource allocation. Importantly, I both conceptualise and operationalise a multidomain evaluation logic, demonstrating how structured transparency can be implemented in applied EE or HTA practice. I operationalise this logic through the following sequence:

1. transparently structuring impacts across stakeholders and domains and
2. presenting disaggregated consequences in a decision-facing format prior to any aggregation.

This work is guided by four research questions:

RQ1: *"What is the current state of research related to EE of DHI and more specifically telemedicine, globally and in Slovenia?",*

RQ2: *"What are the key challenges in conducting EE of telemedicine interventions? Are they adequately addressed by existing, albeit scarce, guidelines for their EE?",*

RQ3: *"How should the EE of telemedicine interventions be approached in the case of chronic HF?",* and

RQ4: *"Is a telemedicine intervention in the form of teleconsultations for chronic HF in Slovenia economically viable?"*

To address RQ1, I map the current state of research on EE of DHI in Chapters 2 and 3, and I conduct a systematic review in Chapter 4. The findings show that although the use of DHI has expanded rapidly, further accelerated by the COVID-19 pandemic, EE still accounts for less than 5% of the overall literature. The bibliometric analysis reveals a fragmented and heterogeneous field, with inconsistent terminology and limited methodological consensus. Telemedicine and telehealth dominate the field, yet broader perspectives that capture societal costs and consequences, long-term outcomes, and system-level impacts remain uncommon.

In Slovenia, healthcare digitalisation is advancing, but the use of EE to guide these efforts remains underdeveloped, leaving a gap between adoption and structured assessment. In the absence of structured local EE, digital health adoption may precede systematic assessment. These results underline the need for harmonised approaches, the integration of HTA into digital health decision-making, and greater national capacity to conduct high-quality EE. They also indicate that transferability of international telemedicine EE evidence to Slovenia requires explicit contextual adaptation rather than mechanical adoption of published cost-effectiveness conclusions.

To address RQ2, I synthesise methodological challenges through a narrative literature review in Chapter 3. The review shows that while some guidance exists, it remains

fragmented and often fails to capture the full complexity of DHI. Key challenges include methodological heterogeneity, limited inclusion of indirect and societal costs, narrow perspectives (usually healthcare system only), short time horizons, unclear definitions of comparators, and inconsistent outcome measures with a narrow focus on clinical endpoints at the expense of societal and equity considerations.

To address these challenges, I propose structured improvements based on the reviewed literature: the use of structuring tools such as the IIM to capture a broader set of costs and benefits, applying CCA or CBA, adopting longer time horizons, and incorporating equity and distributional impacts into EE. Rather than replacing conventional CEA, these tools function as structuring and transparency devices that precede aggregation and reduce the risk of silent omission of relevant impacts. In this framing, IIM functions as a completeness and perspective check, while CCA functions as a deliberative presentation format that preserves multidomain consequences for decision-makers.

In Chapter 4, the systematic review of EE of teleconsultations for HF confirms that the limited number of existing studies often report favourable findings but are characterised by heterogeneity, short follow-up periods, and incomplete cost categories, which limit comparability and transferability. Accordingly, I use the HF teleconsultation evidence base to inform assumptions and plausible mechanisms, but I do not treat it as directly generalisable to Slovenia without explicit structural adaptation.

To complement the literature and provide a broader, practice-based perspective, I analyse stakeholder insights into EE of telemedicine in Chapter 5. Patients, cardiologists, digital health experts, and health economists confirm that many methodological challenges highlighted earlier, such as narrow cost categories, short time horizons, and limited perspectives, also arise in practice. They stress that conventional EE often overlooks broader impacts, including caregiver burden, equity concerns, and environmental sustainability. Beyond methodological issues, stakeholders point to barriers such as fragmented infrastructure, weak reimbursement models, organisational resistance, and gaps in digital literacy and access. These challenges shape not only how teleconsultations are implemented but also how they should be evaluated. Stakeholders also emphasise that economic value depends on organisational readiness, workflow integration, and reimbursement alignment, which condition whether efficiency gains can be realised in routine delivery.

Across Chapters 3, 4, and 5, the findings show that improving EE of DHI requires moving beyond narrow, healthcare-centric models. Chapter 3 highlights the need for transparent, detailed, and standardised guidelines that combine rigour with flexibility to capture the unique features of telemedicine. To be decision-relevant, EE must prioritise transparent structuring of impacts across stakeholders and perspectives, and then present disaggregated consequences before attempting aggregation. Stakeholder perspectives in Chapter 5 confirm these gaps and stress the importance of also considering equity, caregiver burden, environmental impacts, and organisational readiness. Practical steps include developing

guidelines for EE, adopting structured frameworks such as IIM, combining quantitative and qualitative approaches to address broader effects, and explicitly addressing long-term and distributional effects.

Strengthening EE in this way not only improves comparability across studies but also ensures that evaluations provide decision-makers with credible evidence on cost-effectiveness and wider system impacts. For teleconsultations in HF and DHI more broadly, robust EE therefore requires explicit attention to context, implementation, and redistribution of effects across sectors and stakeholders. Taken together, these chapters support a transparency-first evaluation logic in which completeness and decision-relevance are prioritised before aggregation.

To address RQ3, I examine how EE of telemedicine should be approached in the case of HF. The systematic review reveals that although only a small number of studies exist, several report favourable clinical and economic findings, mainly through reduced readmissions, shorter hospital stays, and improved QOL. However, these studies are constrained by methodological heterogeneity, short follow-up periods, and narrow perspectives, reflecting issues already raised in Chapter 3 under RQ2. These findings suggest potential value, provided that implementation is adapted to local system capacities and patient needs.

Based on this evidence, I argue that EE in HF should adopt broader approaches that integrate patient-centred outcomes, indirect costs such as caregiver time and burden, and longer-term system impacts. Economic value in HF teleconsultations is therefore conditional on pathway design, patient selection, and organisational readiness rather than inherent to the digital modality itself. These broader approaches would enable decision-makers to understand not only whether interventions save money, but also how they affect equity, QOL, and the resilience of healthcare systems.

I extend this analysis in Chapter 5 by drawing on stakeholder perspectives through interviews with patients, cardiologists, digital health experts, and health economists. Stakeholders confirm many methodological challenges highlighted in the literature but also add practice-based concerns. Furthermore, they emphasise that teleconsultations should function as a complementary modality within hybrid HF care pathways, not as a universal substitute for usual care in the form of in-person consultations. They also highlight that equity safeguards, reimbursement alignment, and workflow integration are decisive moderators of economic realisation. These insights demonstrate that evaluation and implementation are structurally linked: the design of the care pathway conditions the economic conclusions that I draw. Patients and caregivers stress the burden of travel, time, and stress that teleconsultations could help reduce. Cardiologists point to organisational barriers such as fragmented infrastructure and uncertain workflows, while experts and economists raise issues of reimbursement, legal uncertainty, and the digital divide. They also identify under-recognised benefits that are rarely captured in EE, including improved

patient empowerment, reduced caregiver strain, and environmental sustainability. In addition, stakeholders emphasise that teleconsultation value emerges primarily through hybrid care pathway redesign and organisational integration rather than through the digital modality alone. Taken together, these insights show that the EE of DHI should not be restricted to narrow, healthcare-centric models. Instead, evaluations should systematically include broader dimensions such as equity, organisational readiness, and sustainability, supported by transparent, standardised frameworks that combine quantitative outcomes with qualitative insights and consider long-term system resilience. Equity emerges not as an ancillary consideration but as a structurally embedded dimension of teleconsultation evaluation. Distributional effects shape both the ethical and economic interpretation of value and therefore require explicit incorporation into EE frameworks. Such an approach allows policymakers to make better-informed decisions, weighing not only cost-effectiveness but also impacts on fairness, patient experience, and the future sustainability of HF care delivery.

To address RQ4, I conduct an observational matched cohort study of teleconsultation assignment among patients with HF in Slovenia during the COVID-19 pandemic, presented in Chapter 6. Using administrative claims data from the health insurance system, I compare patients with HF assigned to teleconsultations with a matched control group of patients with HF assigned to in-person consultation (usual care). I perform matching using PSM to reduce baseline differences, and I apply a range of advanced statistical modelling approaches that are appropriate for count, cost, and time-to-event outcomes, enabling assessment of both clinical and economic outcomes.

The findings show that teleconsultation assignment is associated with a reduction in total cardiology outpatient follow-up intensity (including both teleconsultation and in-person visits combined) and lower related outpatient expenditure. This reflects redistribution of follow-up intensity rather than simple substitution of in-person visits. At the same time, patients assigned to teleconsultations exhibit higher baseline utilisation and severity indicators and are associated with higher inpatient procedural intensity and hospital expenditure in fully adjusted models. Prescription effects are heterogeneous and specification-sensitive, and no statistically significant association is observed for 1-year mortality. Taken together, these results indicate that teleconsultations are not a uniformly cost-saving intervention but are associated with redistribution of care intensity under selective pandemic-era allocation. The observed effects represent context-specific associations rather than causal estimates.

However, interpretation requires caution in light of the broader methodological challenges discussed earlier. The quantitative analysis is limited to a 1-year follow-up period and relies on administrative claims data without granular clinical severity indicators such as NYHA class, LVEF, or laboratory markers. Although matching and covariate adjustment reduce observable imbalance, residual confounding remains plausible, particularly given selective teleconsultation assignment during pandemic implementation. Moreover, the matched

teleconsultation group is relatively small, limiting statistical power, especially for rare outcomes such as 1-year mortality. Teleconsultations were introduced in a rapidly evolving pandemic context, with coding stabilisation and uptake increasing over time; although year indicators and pandemic controls are incorporated, unmeasured time-varying effects cannot be fully excluded. Finally, teleconsultations are embedded within evolving HF care pathways rather than constituting an isolated intervention, which inherently constrains causal attribution.

From an EE perspective, this case study illustrates both the possibilities and constraints of real-world administrative claims data. It identifies observable utilisation shifts and expenditure redistribution but cannot capture indirect costs and consequences, caregiver impacts, equity gradients, or long-term resilience effects within the available data horizon. A more comprehensive EE would require longer follow-up, broader cost categories, and integration of patient-centred and societal outcomes, as suggested in Chapters 3 and 5. In this sense, Chapter 6 not only answers RQ4 but also shows how the methodological challenges identified earlier play out in practice, thereby underscoring the need for transparent, standardised, and context-sensitive approaches to evaluating DHI. The Slovenian case study therefore demonstrates that teleconsultations function as a complementary modality within HF management and that their economic value is implementation- and context-dependent. They should not be expected to universally reduce costs but rather to improve efficiency and resilience in specific care pathways. For decision-makers, this implies that outpatient savings should be evaluated alongside potential inpatient intensity shifts to avoid incomplete economic conclusions. For policymakers, this highlights the importance of tailoring EE to reflect patient risk profiles, system capacities, and the wider role of digital health in supporting sustainable healthcare delivery.

In Chapter 7, I synthesise findings from the systematic review, stakeholder analysis, and observational study within a structured EE framework. I apply the IIM across five domains (health, healthcare system, user experience, value of data, and cross-sectoral impact) and present disaggregated costs and consequences side-by-side using CCA. Rather than producing a single aggregated ICER, I deliberately preserve multidomain transparency. This approach reflects the redistributional and context-dependent nature of teleconsultation effects and recognises that aggregation under substantial structural uncertainty could obscure relevant stakeholder impacts. I show that the sequence of structuring impacts (IIM), followed by disaggregated presentation (CCA), constitutes a practical adoption pathway for complexity-aware EE in resource-constrained settings. In this way, Chapter 7 operationalises the transparency-first logic developed in Chapters 3–5 and demonstrates how mixed-method evidence can be translated into a decision-facing EE structure.

In this dissertation, I provide a foundation for policymakers, care providers, and researchers seeking to implement and evaluate DHI. Specifically, the findings offer valuable guidance for the wider introduction of teleconsultations in Slovenia's healthcare system and for their potential reimbursement within the public insurance framework, with implications for

improving efficiency, effectiveness, and sustainability. By taking a broad approach to the EE of DHI, this dissertation makes important contributions at the empirical, methodological, theoretical, and practical levels. The integration of bibliometric mapping, systematic review, qualitative stakeholder analysis, and administrative claims modelling constitutes a triangulated evaluation strategy. By combining complementary evidence streams, I strengthen contextual validity and reduce reliance on any single data source.

Empirically, I provide the first real-world evidence on teleconsultation assignment for patients with HF in Slovenia, using statistical models suited to skewed, zero-inflated, and semi-continuous healthcare data. Combined with systematic and qualitative evidence, this analysis generates a comprehensive and multidimensional understanding of utilisation, expenditure patterns, and stakeholder-relevant impacts.

Methodologically, I operationalise a transparency-first evaluation logic: IIM functions as a structured completeness check, while CCA enables deliberative presentation of multidomain consequences prior to aggregation. I demonstrate how structured approaches, such as IIM, CCA, and stakeholder-informed frameworks, can be used to capture indirect costs, caregiver burden, digital equity, and sustainability, dimensions that are frequently overlooked in conventional EE. I further demonstrate how qualitative evidence informs impact identification and prevents omission of stakeholder-relevant domains, and how administrative data can be analysed using methods appropriate for excess zeros, skewed distributions, and time-to-event outcomes. The empirical analysis also provides practical modelling guidance for handling semi-continuous, zero-inflated, and overdispersed administrative healthcare data in EE, as well as for survival analysis. Aligning statistical models with the underlying data-generating process is essential to avoid biased inference in real-world evaluation contexts. By integrating bibliometric mapping, systematic review, qualitative framework analysis, and advanced statistical modelling, the dissertation illustrates the value of combining qualitative and quantitative approaches for evaluating complex interventions. Importantly, I use the qualitative research to identify under-recognised dimensions while also highlighting persistent challenges, including fragmented infrastructure, limited reimbursement, legal uncertainty, and unequal access due to digital literacy and connectivity gaps.

Theoretically, I contribute to the wider debate on how to evaluate DHI by arguing for a shift beyond narrow, health-outcomes-centred EE models. Evaluation of DHI requires explicit structuring of context, stakeholders, and pathways before economic aggregation. I argue that DHI value is multidomain and redistributional rather than reducible to a single health outcome metric. I strengthen rigour and comparability by adopting broader frameworks that are flexible enough to capture the unique features of DHI and by structuring impacts explicitly before aggregation. In doing so, I bridge the gap between academic research and practical policy needs, providing conceptual advances that have relevance well beyond the Slovenian healthcare setting.

Practically, the findings provide evidence-based guidance for decision-makers. The findings support the selective use of teleconsultations within hybrid HF pathways, with explicit eligibility criteria, escalation mechanisms, reimbursement alignment, and equity safeguards. Economic value depends on pathway design and organisational readiness rather than on the digital format alone. Reimbursement alignment and formal workload recognition emerge as structural moderators of economic realisation. Without institutional alignment, potential efficiency gains identified in the CCA may not translate into sustainable system-level value. In this way, I offer actionable insights for policymakers, insurers, and providers aiming to integrate teleconsultations into HF care in a sustainable and equitable manner.

The limitations of this dissertation fall into three main categories. First, data-related limitations: reliance on administrative claims data without granular clinical severity measures and restriction to a 1-year follow-up during pandemic implementation. Second, methodological limitations: although matching and multivariable adjustment reduce observable differences, I cannot fully exclude residual confounding excluded; the matched teleconsultation sample limits power; the systematic review is constrained by heterogeneity and small study numbers; qualitative findings are context-specific. Third, contextual and generalisability limitations: the Slovenian tariff structure, institutional setting, and pandemic-era implementation shape observed associations, limiting direct transferability. The pandemic functions simultaneously as an accelerator of teleconsultation adoption and as a structural shock introducing time-varying confounding and coding instability. This dual role reinforces the need for cautious interpretation and context-sensitive evaluation. I present these limitations transparently to clarify the scope of the dissertation rather than to signal design weakness, and to identify areas for refinement. In addition, several cross-sectoral impacts presented in Chapter 7 rely on literature-based parameters and qualitative evidence rather than direct Slovenian HF measurement, which reinforces the need for improved data infrastructure in future evaluations.

Future research should evaluate teleconsultations under stable post-pandemic delivery conditions, link administrative data with richer clinical registries, extend follow-up horizons to capture chronic HF trajectories, and explore quasi-experimental designs where feasible. I argue that stable post-pandemic implementation conditions offer a methodological opportunity to disentangle selection effects from intervention effects more clearly. Future evaluation under routine delivery may therefore allow stronger identification of structural teleconsultation impacts. Further empirical evaluation of EE approaches informed by the IIM and CCA across diverse DHI contexts would strengthen methodological standardisation and transferability. In Slovenia, strengthening health economic capacity and embedding EE into HTA, planning, and reimbursement processes will be central to sustainable digital health integration.

REFERENCE LIST

1. Adeagbo, C. U., Rattanavipapong, W., Guinness, L., & Teerawattananon, Y. (2018). The Development of the Guide to Economic Analysis and Research (GEAR) Online Resource for Low- and Middle-Income Countries' Health Economics Practitioners: A Commentary. *Value in Health: The Journal of the International Society for Pharmacoeconomics and Outcomes Research*, *21*(5), 569–572. https://doi.org/10.1016/J.JVAL.2017.10.003
2. Agresti, A. (2003). Categorical Data Analysis. In *Categorical Data Analysis* (2nd ed.). John Wiley & Sons, Inc. https://doi.org/10.1002/0471249688
3. Ahmadi, M., Sarabi, R. E., Orak, R. J., & Bahaadinbeigy, K. (2015). Information Retrieval in Telemedicine: a Comparative Study on Bibliographic Databases. *Acta Informatica Medica: Journal of the Society for Medical Informatics of Bosnia & Herzegovina*, *23*(3), 172–176. https://doi.org/10.5455/aim.2015.23.172-176
4. Akiyama, M., & Yoo, B. K. (2016). A Systematic Review of the Economic Evaluation of Telemedicine in Japan. *Journal of Preventive Medicine and Public Health*, *49*(4), 183–196. https://doi.org/10.3961/JPMPH.16.043
5. Almazrou, S. H., Alaujan, S. S., & Al-Aqeel, S. A. (2021). Barriers and facilitators to conducting economic evaluation studies of Gulf Cooperation Council (GCC) countries: a survey of researchers. *Health Research Policy and Systems*, *19*(71). https://doi.org/10.1186/S12961-021-00721-1
6. Alzarea, A. I., Khan, Y. H., Alanazi, A. S., Butt, M. H., Almalki, Z. S., AlAhmari, A. K., Alsahali, S., & Mallhi, T. H. (2022). Barriers and Facilitators of Pharmacoeconomic Studies: A Review of Evidence from the Middle Eastern Countries. *International Journal of Environmental Research and Public Health*, *19*(13). https://doi.org/10.3390/IJERPH19137862
7. Aranda-Jan, C. B., Mohutsiwa-Dibe, N., & Loukanova, S. (2014). Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa. *BMC Public Health*, *14*(188), 1–15. https://doi.org/10.1186/1471-2458-14-188
8. Archibald, M. M., Ambagtsheer, R. C., Casey, M. G., & Lawless, M. (2019). Using Zoom Videoconferencing for Qualitative Data Collection: Perceptions and Experiences of Researchers and Participants. *International Journal of Qualitative Methods*, *18*. https://doi.org/10.1177/1609406919874596
9. Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/J.JOI.2017.08.007
10. *ASSESS DHT*. (n.d.). Retrieved January 10, 2026, from https://assess-dht.eu/
11. Auener, S. L., Remers, T. E. P. P., van Dulmen, S. A., Westert, G. P., Kool, R. B., & Jeurissen, P. P. T. T. (2021). The effect of noninvasive telemonitoring for chronic heart failure on health care utilization: Systematic review. *Journal of Medical Internet Research*, *23*(9). https://doi.org/10.2196/26744

12. Austin, P. C. (2011). An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. *Multivariate Behavioral Research*, *46*(3), 399–424. https://doi.org/10.1080/00273171.2011.568786
13. Austin, P. C. (2014). The use of propensity score methods with survival or time-to-event outcomes: reporting measures of effect similar to those used in randomized experiments. *Statistics in Medicine*, *33*(7), 1242. https://doi.org/10.1002/SIM.5984
14. Barnett, M. L., Dopp, A. R., Klein, C., Ettner, S. L., Powell, B. J., & Saldana, L. (2020). Collaborating with health economists to advance implementation science: a qualitative study. *Implementation Science Communications*, *1*(82). https://doi.org/10.1186/S43058-020-00074-W
15. Bashshur, R. L., Shannon, G., Krupinski, E., & Grigsby, J. (2011). Policy The Taxonomy of Telemedicine. *Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association*, *17*(6), 484–494. https://doi.org/10.1089/tmj.2011.0103
16. Bashshur, R. L., & Shannon, G. W. (2009). *History of Telemedicine: Evolution, Context, and Transformation*. Mary Ann Liebert.
17. Basu, A., & Manning, W. G. (2009). Issues for the Next Generation of Health Care Cost Analyses. *Medical Care*, *47*(7 Suppl 1), S1009-14. https://doi.org/10.1097/MLR.0b013e31819c94a1
18. Ben-Assuli, O. (2022). Measuring the cost-effectiveness of using telehealth for diabetes management: A narrative review of methods and findings. *International Journal of Medical Informatics*, *163*. https://doi.org/10.1016/j.ijmedinf.2022.104764
19. Benedetto, V., Filipe, L., Harris, C., Spencer, J., Hickson, C., & Clegg, A. (2023). Analytical Frameworks and Outcome Measures in Economic Evaluations of Digital Health Interventions: A Methodological Systematic Review. *Medical Decision Making*, *43*(1), 125–138. https://doi.org/10.1177/0272989X221132741
20. Bergmo, T. S. (2009). Can economic evaluation in telemedicine be trusted? A systematic review of the literature. *Cost Effectiveness and Resource Allocation*, *7*(1), 1–10. https://doi.org/10.1186/1478-7547-7-18
21. Bergmo, T. S. (2015). How to measure costs and benefits of ehealth interventions: An overview of methods and frameworks. *Journal of Medical Internet Research*, *17*(11), 1–11. https://doi.org/10.2196/JMIR.4521
22. Bijec, J. (2024). *Statistični kazalniki kakovosti in učinkovitosti oskrbe pacientov s koronarno boleznijo*. University of Ljubljana, Faculty of Electrical Engineering.
23. Bird, K. T., Murphy, R. L. H., & Cohen, G. L. (1969). Telemedicine and future of pulmonary disease. *Diseases of the chest*, *56*(3).
24. Black, A. D., Car, J., Pagliari, C., Anandan, C., Cresswell, K., Bokun, T., McKinstry, B., Procter, R., Majeed, A., & Sheikh, A. (2011). The Impact of eHealth on the Quality and Safety of Health Care: A Systematic Overview. *PLOS Medicine*, *8*(1), e1000387. https://doi.org/10.1371/JOURNAL.PMED.1000387

25. Boateng, E., & Abaye, D. (2019). A Review of the Logistic Regression Model with Emphasis on Medical Research. *Journal of Data Analysis and Information Processing*, *7*, 190–207. https://doi.org/10.4236/jdaip.2019.74012
26. Boetje, J., & van de Schoot, R. (2024). The SAFE procedure: a practical stopping heuristic for active learning-based screening in systematic reviews and meta-analyses. *Systematic Reviews*, *13*(1), 81. https://doi.org/10.1186/s13643-024-02502-7
27. Bonat, Wagner H, Jørgensen, Bent, Kokonendji, Célestin C, Hinde, John, & Demétrio, Clarice G B. (2017). Extended Poisson–Tweedie: Properties and regression models for count data. *Statistical Modelling*, *18*(1), 24–49. https://doi.org/10.1177/1471082X17715718
28. Bongiovanni-Delarozière, I., & Le Goff-Pronost, M. (2017). Economic evaluation methods applied to telemedicine: From a literature review to a standardized framework. *European Research in Telemedicine*, *6*(3–4), 117–135. https://doi.org/10.1016/J.EURTEL.2017.08.002
29. Boodoo, C., Zhang, Q., Ross, H. J., Alba, A. C., Laporte, A., & Seto, E. (2020). Evaluation of a Heart Failure Telemonitoring Program Through a Microsimulation Model: Cost-Utility Analysis. *Journal of Medical Internet Research*, *22*(10), e18917. https://doi.org/10.2196/18917
30. Burrell, A., Zrubka, Z., Champion, A., Zah, V., Vinuesa, L., Holtorf, A.-P. P., Bidino, R., Earla, J. R., Entwistle, J., Boltyenkov, A. T., Braileanu, G., Kolasa, K., Roydhouse, J., Asche, C., Redekop, K., Pfeiffer, C., Le, L., Janodia, M., Sharkawy, M., … Paul, S. (2022). How Useful Are Digital Health Terms for Outcomes Research? An ISPOR Special Interest Group Report. *Value in Health*, *25*(9), 1469–1479. https://doi.org/10.1016/j.jval.2022.04.1730
31. Busso, M., Gonzalez, M. P., & Scartascini, C. (2022). On the demand for telemedicine: Evidence from the COVID-19 pandemic. *Health Economics*, *31*(7), 1491–1505. https://doi.org/10.1002/HEC.4523
32. Caffery, L. J., Martin-Khan, M., & Wade, V. (2017). Mixed methods for telehealth research. *Journal of Telemedicine and Telecare*, *23*(9), 764–769. https://doi.org/10.1177/1357633X16665684
33. Caillon, M., Sabatier, R., Legallois, D., Courouve, L., Donio, V., Boudevin, F., de Chalus, T., Hauchard, K., Belin, A., & Milliez, P. (2022). A telemonitoring programme in patients with heart failure in France: a cost-utility analysis. *BMC Cardiovascular Disorders*, *22*(441), 1–14. https://doi.org/10.1186/s12872-022-02878-1
34. Campos, D. G., Fütterer, T., Gfrörer, T., Lavelle-Hill, R., Murayama, K., König, L., Hecht, M., Zitzmann, S., & Scherer, R. (2024). Screening Smarter, Not Harder: A Comparative Analysis of Machine Learning Screening Algorithms and Heuristic Stopping Criteria for Systematic Reviews in Educational Research. *Educational Psychology Review*, *36*(1), 19. https://doi.org/10.1007/s10648-024-09862-5
35. Cannata, A., Bromage, D., Piper, S., Hardman, S., Cleland, J. G. F., & Mcdonagh, T. (2023). Quality of care and long-term outcomes for patients admitted with heart failure

across the pandemic. A nationwide study. *European Heart Journal*, *44*(Supplement_2), ehad655.846. https://doi.org/10.1093/eurheartj/ehad655.846

36. Cannata, A., Mizani, M. A., Bromage, D. I., Piper, S. E., Hardman, S. M. C., Sudlow, C., de Belder, M., Scott, P. A., Deanfield, J., Gardner, R. S., Clark, A. L., Cleland, J. G. F., McDonagh, T. A., & null null. (2025). Heart Failure Specialist Care and Long-Term Outcomes for Patients Admitted With Acute Heart Failure. *JACC: Heart Failure*, *13*(3), 402–413. https://doi.org/10.1016/j.jchf.2024.06.013
37. Caro, J. J., Briggs, A. H., Siebert, U., & Kuntz, K. M. (2012). Modeling Good Research Practices—Overview: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-1. *Value in Health*, *15*(6), 796–803. https://doi.org/10.1016/j.jval.2012.06.012
38. Cheng, H.-M., Chiou, L.-J., Chen, T.-C., Sung, S.-H., Chen, C.-H., & Lang, H.-C. (2019). Real-world cost-effectiveness of drug-eluting stents vs. bare-metal stents for coronary heart disease-A five-year follow-up study. *Health Policy*, *123*, 229–234. https://doi.org/10.1016/j.healthpol.2018.11.010
39. Cheng, J., Sun, J., Yao, K., Xu, M., & Cao, Y. (2022). A variable selection method based on mutual information and variance inflation factor. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *268*, 120652. https://doi.org/10.1016/j.saa.2021.120652
40. Chu, C., Stamenova, V., Fang, J., Shakeri, A., Tadrous, M., & Bhatia, R. S. (2022). The Association Between Telemedicine Use and Changes in Health Care Usage and Outcomes in Patients With Congestive Heart Failure: Retrospective Cohort Study. *JMIR Cardio*, *6*(2). https://doi.org/10.2196/36442
41. Coast, J., & De Allegri, M. (2018). Qualitative Methods in Health Economics. *Oxford Research Encyclopedia, Economics and Finance*. https://doi.org/10.1093/acrefore/9780190625979.013.93
42. Cockatoo Inc. (2025). Phoenix, Arizona, USA. Available at: https://cockatoo.com/
43. Craig, J., & Patterson, V. (2005). Introduction to the practice of telemedicine. *Journal of Telemedicine and Telecare*, *11*(1), 3–9. https://doi.org/10.1177/1357633X0501100102
44. D'Alessandro, M. P., D'Alessandro, D. M., Galvin, J. R., & Erkonen, W. E. (1998). Evaluating overall usage of a digital health sciences library. *Bulletin of the Medical Library Association*, *86*(4), 602–609.
45. Dakin, H., & Wordsworth, S. (2013). Cost-Minimisation Analysis Versus Cost-ffectiveness Analysis, Revisited. *Health Economics*, *22*(1), 22–34. https://doi.org/10.1002/hec.1812
46. Darvish, M., Shakoor, A., Feyz, L., Schaap, J., van Mieghem, N. M., de Boer, R. A., Brugts, J. J., & van der Boon, R. M. A. (2025). Heart failure: assessment of the global economic burden. *European Heart Journal*, ehaf323. https://doi.org/10.1093/eurheartj/ehaf323
47. Dávalos, M. E., French, M. T., Burdick, A. E., & Simmons, S. C. (2009). Economic Evaluation of Telemedicine : Review of the Literature and Research. *Telemedicine*

Journal and E-Health : The Official Journal of the American Telemedicine Association, *15*(10), 933–948. https://doi.org/10.1089/TMJ.2009.0067

48. de Graaf, G., Timmermans, I., Meine, M., Alings, M., Pedersen, S. S., Mabo, P., Zitron, E., Redekop, K., & Versteeg, H. (2024). Economic evaluation of remote monitoring of patients with an implantable cardiac defibrillator (REMOTE-CIED study). *Journal of Telemedicine and Telecare*, *30*(7), 1173–1185. https://doi.org/10.1177/1357633X221129176
49. De Guzman, K. R., Snoswell, C. L., Taylor, M. L., Gray, L. C., & Caffery, L. J. (2022). Economic Evaluations of Remote Patient Monitoring for Chronic Disease: A Systematic Review. *Value in Health*, *25*(1), 897–913. https://doi.org/10.1016/j.jval.2021.12.001
50. de las Heras-Pedrosa, C., Jambrino-Maldonado, C., Rando-Cueto, D., & Iglesias-Sánchez, P. P. (2022). COVID-19 Study on Scientific Articles in Health Communication: A Science Mapping Analysis in Web of Science. *International Journal of Environmental Research and Public Health*, *19*(3). https://doi.org/10.3390/IJERPH19031705
51. DeJonckheere, M., & Vaughn, L. M. (2019). Semistructured interviewing in primary care research: a balance of relationship and rigour. *Family Medicine and Community Health*, *7*(2), e000057. https://doi.org/10.1136/fmch-2018-000057
52. Díez-Villanueva, P., Jiménez-Méndez, C., & Alfonso, F. (2021). Heart failure in the elderly. *Journal of Geriatric Cardiology*, *18*(3), 219–232. https://doi.org/10.11909/j.issn.1671-5411.2021.03.009
53. Dobrev, A., Jones, T., Kersting, A., Artmann, J., Streotmann, K. A., & Stroetmann, V. N. (2008). *Methodology for evaluating the socio-economic impact of interoperable EHR and ePrescribing systems*. EHR Impact. www.ehr-impact.eu
54. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/J.JBUSRES.2021.04.070
55. Dopp, A. R., Mundey, P., Beasley, L. O., Silovsky, J. F., & Eisenberg, D. (2019). Mixed-method approaches to strengthen economic evaluations in implementation research. *Implementation Science*, *14*(1), 1–9. https://doi.org/10.1186/s13012-018-0850-6
56. dos Santos Silva, E. K., Cruz, J. A. W., da Cunha, M. A. V. C., de Moraes, T. P., Marques, S., & da Silva, E. D. (2021). Cost-effectiveness in health: consolidated research and contemporary challenges. *Humanities and Social Sciences Communications*, *8*(254), 1–10. https://doi.org/10.1057/S41599-021-00940-5
57. Drummond, M. F., Schwartz, J. S., Jönsson, B., Luce, B. R., Neumann, P. J., Siebert, U., & Sullivan, S. D. (2008). Key principles for the improved conduct of health technology assessments for resource allocation decisions. *International Journal of Technology Assessment in Health Care*, *24*(3), 244–258. https://doi.org/10.1017/S0266462308080343

58. Drummond, M. F., Sculpher, M. J., Claxton, K., Stoddart, G. L., & Torrance, G. W. (2015). *Methods for the Economic Evaluation of Health Care Programmes*. Oxford University Press.
59. Drummond, M. F., Sculpher, M. J., Torrance, G. W., O'Brien, B. J., & Stoddart, G. L. (2005). *Methods for the economic evaluation of health care programmes* (3rd ed.). Oxford University Press. https://doi.org/10.1093/oso/9780198529446.001.0001
60. Dunn, P. K., & Smyth, G. K. (2005). Series evaluation of Tweedie exponential dispersion model densities. *Statistics and Computing*, *15*(4), 267–280. https://doi.org/10.1007/s11222-005-4070-y
61. Dyer, B. P. (2025). Variable selection for causal inference, prediction, and descriptive research: a narrative review of recommendations. *European Heart Journal Open*, *5*(3), oeaf070. https://doi.org/10.1093/ehjopen/oeaf070
62. Eckard, N., Janzon, M., & Levin, L. Å. (2014). Use of cost-effectiveness data in priority setting decisions: Experiences from the national guidelines for heart diseases in Sweden. *International Journal of Health Policy and Management*, *3*(6), 323–332. https://doi.org/10.15171/IJHPM.2014.105
63. Ekeland, A. G., Bowes, A., & Flottorp, S. (2010). Effectiveness of telemedicine: a systematic review of reviews. *International Journal of Medical Informatics*, *79*(11), 736–771. https://doi.org/10.1016/J.IJMEDINF.2010.08.006
64. European Commission. (2019). *Digital Economy and Society Index Report 2019*. https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2019
65. European Commission. (2022). *Commission Staff Working Document Impact Assessment Report Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on the European Health Data Space*.
66. European Commission. (2023). *Developing eHealth for a healthier society in Slovenia*. https://reform-support.ec.europa.eu/what-we-do/health-and-long-term-care/developing-ehealth-healthier-society-slovenia_en
67. European Commission. (2025). *Member State Coordination Group on HTA (HTACG)*. European Commission. https://health.ec.europa.eu/health-technology-assessment/implementation-regulation-health-technology-assessment/member-state-coordination-group-hta-htacg_en?prefLang=sl
68. European Parliament. (2021a). *Regulation (EU) 2021/2282 of the European Parliament and of the Council of 15 December 2021 on health technology assessment and amending Directive 2011/24/EU*.
69. European Parliament. (2023). *Implementation of the EU regulation on health technology assessment*. https://doi.org/10.2875/606011
70. European Parliament, C. of the E. U. (2021b). Regulation (EU) 2021/2282 of the European Parliament and of the Council of 15 December 2021 on health technology assessment and amending Directive 2011/24/EU (Text with EEA relevance). In *Official Journal of the European Union*.

71. Eze, N. D., Mateus, C., & Hashiguchi, T. C. O. (2020). Telemedicine in the OECD: An umbrella review of clinical and cost-effectiveness, patient experience and implementation. *PLOS ONE*, *15*(8). https://doi.org/10.1371/journal.pone.0237585
72. Faraway, J. J., Tanner, M., Zidek, J., Abramovich, F., Ritov, Y., Afifi, A., May, S., Clark, V., Altman, D., Anderson, A., Banerjee, S., Roy, A., Bilder, C. R., Loughin, T. M., Bissell, D., Blitzstein, J. K., & Hwang, J. (2015). *Modelling Survival Data in Medical Research*. Chapman and Hall/CRC. https://doi.org/10.1201/B18041
73. Fatehi, F., Samadbeik, M., & Kazemi, A. (2020). What is Digital Health? Review of Definitions. *Studies in Health Technology and Informatics*, *275*, 67–71. https://doi.org/10.3233/SHTI200696
74. Fawcett, T. (2006). An introduction to ROC analysis. *Pattern Recognition Letters*, *27*(8), 861–874. https://doi.org/10.1016/j.patrec.2005.10.010
75. Fernández Coves, A., Yeung, K. H. T., van der Putten, I. M., & Nelson, E. A. S. (2022). Teleconsultation adoption since COVID-19: Comparison of barriers and facilitators in primary care settings in Hong Kong and the Netherlands. *Health Policy*, *126*(10), 933–944. https://doi.org/10.1016/J.HEALTHPOL.2022.07.012
76. Fletcher, A. (2016). Applying critical realism in qualitative research: Methodology meets method. *International Journal of Social Research Methodology*, *19*, 1–14. https://doi.org/10.1080/13645579.2016.1144401
77. Flight, L., Julious, S., Brennan, A., Todd, S., & Hind, D. (2020). How can health economics be used in the design and analysis of adaptive clinical trials? A qualitative analysis. *Trials*, *21*(1). https://doi.org/10.1186/S13063-020-4137-2
78. Forouzanfar, M. H., Afshin, A., Alexander, L. T., Biryukov, S., Brauer, M., Cercy, K., Charlson, F. J., Cohen, A. J., Dandona, L., Estep, K., Ferrari, A. J., Frostad, J. J., Fullman, N., Godwin, W. W., Griswold, M., Hay, S. I., Kyu, H. H., Larson, H. J., Lim, S. S., … Zhu, J. (2016). Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*, *388*(10053), 1659–1724. https://doi.org/10.1016/S0140-6736(16)31679-8
79. Frederix, I., Vanderlinden, L., Verboven, A. S., Welten, M., Wouters, D., De Keulenaer, G., Ector, B., Elegeert, I., Troisfontaines, P., Weytjens, C., Mullens, W., & Dendale, P. (2019). Long-term impact of a six-month telemedical care programme on mortality, heart failure readmissions and healthcare costs in patients with chronic heart failure. *Journal of Telemedicine and Telecare*, *25*(5), 286–293. https://doi.org/10.1177/1357633X18774632
80. Furlan, T., Bijec, J., Bonča, P. D., Ograjenšek, I., & Jug, B. (2023). Impact of the COVID-19 pandemic on acute coronary syndrome hospital admission and management in Slovenia. *Open Heart*, *10*(2), e002440. https://doi.org/10.1136/openhrt-2023-002440
81. Furlan, T., Bijec, J., Došenović Bonča, P., Ograjenšek, I., & Jug, B. (2026). The impact of long-term adherence to guideline-directed medical therapy on outcomes in peripheral

artery disease. *Vascular Medicine*, 1358863X251410939. https://doi.org/10.1177/1358863X251410939

82. Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, *13*(117). https://doi.org/10.1186/1471-2288-13-117
83. Gansen, F. M. (2018). Health economic evaluations based on routine data in Germany: A systematic review. *BMC Health Services Research*, *18*, 1–11. https://doi.org/10.1186/S12913-018-3080-3
84. Garrison, L. P., Neumann, P. J., Willke, R. J., Basu, A., Danzon, P. M., Doshi, J. A., Drummond, M. F., Lakdawalla, D. N., Pauly, M. V, Phelps, C. E., Ramsey, S. D., Towse, A., & Weinstein, M. C. (2018). A Health Economics Approach to US Value Assessment Frameworks—Summary and Recommendations of the ISPOR Special Task Force Report [7]. *Value in Health*, *21*(2), 161–165. https://doi.org/10.1016/j.jval.2017.12.009
85. Gatchel, R. J., McGeary, D. D., McGeary, C. A., & Lippe, B. (2014). Interdisciplinary chronic pain management: past, present, and future. *The American Psychologist*, *69*(2), 119–130. https://doi.org/10.1037/a0035514
86. Gega, L., Jankovic, D., Saramago, P., Marshall, D., Dawson, S., Brabyn, S., Nikolaidis, G. F., Melton, H., Churchill, R., & Bojke, L. (2022). Digital interventions in mental health: evidence syntheses and economic modelling. *Health Technology Assessment*, *26*(1), 1–181. https://doi.org/10.3310/RCTI6942
87. Goldberg, S. B., Lam, S. U., Simonsson, O., Torous, J., & Sun, S. (2022). Mobile phone-based interventions for mental health: A systematic meta-review of 14 meta-analyses of randomized controlled trials. *PLOS Digital Health*, *1*(1), 1–21. https://doi.org/10.1371/JOURNAL.PDIG.0000002
88. Gomes, M., Murray, E., & Raftery, J. (2022). Economic Evaluation of Digital Health Interventions: Methodological Issues and Recommendations for Practice. *PharmacoEconomics*, *40*, 367–378. https://doi.org/10.1007/S40273-022-01130-0
89. Greiwe, J. (2022). Telemedicine Lessons Learned During the COVID-19 Pandemic. *Current Allergy and Asthma Reports*, *22*, 1–5. https://doi.org/10.1007/S11882-022-01026-1
90. Grove, A., Sanders, T., Salway, S., Goyder, E., & Hampshaw, S. (2019). A qualitative exploration of evidence-based decision making in public health practice and policy: the perceived usefulness of a diabetes economic model for decision makers. *Evidence & Policy A Journal of Research Debate and Practice*, *15*(4), 461–487. https://doi.org/10.1332/174426418X15245020185055
91. Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., Webster, S., Cameron-Blake, E., Hallas, L., Majumdar, S., & Tatlow, H. (2021). A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nature Human Behaviour*, *5*(4), 529–538. https://doi.org/10.1038/s41562-021-01079-8

92. Hall, A. K., Cole-Lewis, H., & Bernhardt, J. M. (2015). Mobile text messaging for health: a systematic review of reviews. *Annual Review of Public Health*, *36*, 393–415. https://doi.org/10.1146/annurev-publhealth-031914-122855
93. Hanna, T. P., Nguyen, P., Pater, J., O'Callaghan, C. J., Mittmann, N., Earle, C. C., Tu, D., Jonker, D., & Hay, A. E. (2019). Can administrative data improve the performance of cancer clinical trial economic analyses? *Journal of Oncology Practice*, *15*(9), e807–e824. https://doi.org/10.1200/JOP.18.00691
94. Harst, L., Timpel, P., Otto, L., Richter, P., Wollschlaeger, B., Winkler, K., & Schlieter, H. (2020). Identifying barriers in telemedicine-supported integrated care research: scoping reviews and qualitative content analysis. *Journal of Public Health*, *28*(5), 583–594. https://doi.org/10.1007/s10389-019-01065-5
95. Hartfiel, N., & Edwards, R. T. (2019). Cost–consequence analysis of public health interventions. *Applied Health Economics for Public Health Practice and Research*, 233–247. https://doi.org/10.1093/med/9780198737483.003.0010
96. Hazra, N. C., Rudisill, C., & Gulliford, M. C. (2019). Developing the role of electronic health records in economic evaluation. *European Journal of Health Economics*, *20*, 1117–1121. https://doi.org/10.1007/S10198-019-01042-5
97. Heinze, G., Wallisch, C., & Dunkler, D. (2018). Variable selection – A review and recommendations for the practicing statistician. *Biometrical Journal*, *60*(3), 431–449. https://doi.org/10.1002/bimj.201700067
98. Heinzelmann, P. J., Lugn, N. E., & Kvedar, J. C. (2005). Telemedicine in the future. *Journal of Telemedicine and Telecare*, *11*(8), 384–390. https://doi.org/10.1177/1357633X0501100802
99. Hessel, F. P. (2021). Overview of the socio-economic consequences of heart failure. *Cardiovascular Diagnosis and Therapy*, *11*(1), 254–262. https://doi.org/10.21037/cdt-20-291
100. Hilbe, J. M. (2011). Negative Binomial Regression. In *Negative Binomial Regression, Second Edition*. Cambridge University Press. https://doi.org/10.1017/CBO9780511973420
101. Hilbe, J. M. (2014). *Modeling Count Data*. Cambridge University Press. https://doi.org/10.1017/CBO9781139236065
102. Hilty, D. M., Ferrer, D. C., Parish, M. B., Johnston, B., Callahan, E. J., & Yellowlees, P. M. (2013). The Effectiveness of Telemental Health: A 2013 Review. *Telemedicine and E-Health*, *19*(6), 444–454. https://doi.org/10.1089/TMJ.2013.0075
103. Hollis, C., Falconer, C. J., Martin, J. L., Whittington, C., Stockton, S., Glazebrook, C., & Davies, E. B. (2017). Annual Research Review: Digital health interventions for children and young people with mental health problems – a systematic and meta-review. *Journal of Child Psychology and Psychiatry*, *58*(4), 474–503. https://doi.org/10.1111/jcpp.12663
104. Hong, S. J., & Cho, H. (2023). The role of uncertainty and affect in decision-making on the adoption of AI-based contact-tracing technology during the COVID-19 pandemic. *Digital Health*, *9*, 1–15. https://doi.org/10.1177/20552076231169836

105. Hosmer, D. W., Lemeshow, S., & May, S. (2008). Applied Survival Analysis. In *Applied Survival Analysis: Regression Modeling of Time to Event Data* (2nd ed.). Wiley. https://doi.org/10.1002/9780470258019
106. Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied Logistic Regression. In *Applied Logistic Regression* (3rd ed.). Wiley. https://doi.org/10.1002/9781118548387
107. Howe, S. J., Ladipus, D., Hull, M., Yeaw, J., Stevenson, T., & Sampson, J. B. (2022). Healthcare resource utilization, total costs, and comorbidities among patients with myotonic dystrophy using U.S. insurance claims data from 2012 to 2019. *Orphanet Journal of Rare Diseases*, *17*(1), 1–13. https://doi.org/10.1186/S13023-022-02241-9
108. Husereau, D., Jacobs, P., Manns, B., Hoomans, T., Marshall, D., & Tamblyn, R. (2014). *Economic evaluation of complex health system interventions: a discussion paper*. 1–38.
109. Huter, K., Krick, T., & Rothgang, H. (2022). Health economic evaluation of digital nursing technologies: a review of methodological recommendations. *Health Economics Review*, *12*(35), 1–13. https://doi.org/10.1186/S13561-022-00378-8
110. Hwang, R., Morris, Hwang, R., Morris, N. R., Mandrusiak, A., Bruning, J., Peters, R., Korczyk, D., Russell, T. R., Mandrusiak, A., Bruning, J., Peters, R., Korczyk, D., & Russell, T. (2019). Cost-Utility Analysis of Home-Based Telerehabilitation Compared With Centre-Based Rehabilitation in Patients With Heart Failure. *Heart Lung and Circulation*, *28*(12). https://doi.org/10.1016/J.HLC.2018.11.010
111. Imlach, F., McKinlay, E., Middleton, L., Kennedy, J., Pledger, M., Russell, L., Churchward, M., Cumming, J., & McBride-Henry, K. (2020). Telehealth consultations in general practice during a pandemic lockdown: survey and interviews on patient experiences and preferences. *BMC Family Practice*, *21*(1). https://doi.org/10.1186/S12875-020-01336-1
112. Institute for Clinical and Economic Review. (2025). *ICER's Reference Case for Economic Evaluations: Elements and Rationale*. ICER.
113. Iribarren, S. J., Cato, K., Falzon, L., & Stone, P. W. (2017). What is the economic evidence for mHealth? A systematic review of economic evaluations of mHealth solutions. *PLoS ONE*, *12*(2). https://doi.org/10.1371/JOURNAL.PONE.0170581
114. ISPOR. (n.d.). *Pharmacoeconomic Guidelines Around the World*. Retrieved August 22, 2022, from https://www.ispor.org/heor-resources/more-heor-resources/pharmacoeconomic-guidelines
115. Jahan, N., Naveed, S., Zeshan, M., & Tahir, M. A. (2016). How to Conduct a Systematic Review: A Narrative Literature Review. *Cureus*, *8*(11). https://doi.org/10.7759/CUREUS.864
116. Jankovic, D., Bojke, L., Marshall, D., Saramago Goncalves, P., Churchill, R., Melton, H., Brabyn, S., & Gega, L. (2021). Systematic Review and Critique of Methods for Economic Evaluation of Digital Mental Health Interventions. *Applied Health Economics and Health Policy*, *19*, 17–27. https://doi.org/10.1007/S40258-020-00607-3

117. Jit, M., & Cook, A. R. (2024). Informing Public Health Policies with Models for Disease Burden, Impact Evaluation, and Economic Evaluation. *Annual Review of Public Health*, *45*(Volume 45, 2024), 133–150. https://doi.org/10.1146/annurev-publhealth-060222-025149
118. Jug, B., Fras, Z., Furlan, T., Novaković, M., Tasič, J., Lainščak, M., Farkaš, J., Gavrić, D., Ograjenšek, I., & Bonča, P. D. (2025). Uptake and Effectiveness of Outpatient vs. Residential Cardiac Rehabilitation After Myocardial Infarction: A Nationwide Analysis. *Global Heart*, *20*(1), 80. https://doi.org/10.5334/gh.1470
119. Jug, B., Furlan, T., Ravnikar, T., Farkas Lainscak, J., Lainscak, M., Novakovic, M., Dosenovic Bonca, P., & Fras, Z. (2024). Increased nation-wide uptake after establishment of comprehensive outpatient cardiac centres in Slovenia: an interrupted time-series. *European Journal of Preventive Cardiology*, *31*(Supplement_1), zwae175.220. https://doi.org/10.1093/eurjpc/zwae175.220
120. Jug, B., Sedlar Kobe, N., Stojinic, D., Lainscak, M., & Farkas, J. (2024). Cardiac rehabilitation patient perspectives during COVID-19 pandemic: quantitative and qualitative study. *Frontiers in Cardiovascular Medicine*, *Volume 11*. https://doi.org/10.3389/fcvm.2024.1373684
121. Kaba, E., Stavropoulou, A., Kelesi, M., Triantafyllou, A., Goula, A., & Fasoi, G. (2021). Ten Key Steps to Writing a Protocol for a Qualitative Research Study: A Guide for Nurses and Health Professionals. *Global Journal of Health Science*, *13*(6), 58. https://doi.org/10.5539/GJHS.V13N6P58
122. Kaló, Z., Petrova, G., Németh, B., Bonča, P. D., Delnoij, D., Bennett, A., Tachkov, K., Zhang, Y., Kreif, N., Knies, S., Lipska, I., Tesar, T., Mitkova, Z., Ponten, J., Viberg, A., Paveliu, M.-S., Piniazkho, O., Turcu-Stiolica, A., Doležal, T., … Manca, A. (2026). Transferability of Real World Evidence to Support HTA Recommendations in Lower Income European Countries. *Health Science Reports*, *9*(2), e71534. https://doi.org/10.1002/hsr2.71534
123. Kidholm, K., & Kristensen, M. B. D. (2018). A Scoping Review of Economic Evaluations Alongside Randomised Controlled Trials of Home Monitoring in Chronic Disease Management. *Applied Health Economics and Health Policy*, *16*(2), 167–176. https://doi.org/10.1007/S40258-017-0351-9
124. Kim, David Daeho, & Neumann, Peter J. (2020). Analyzing the Cost Effectiveness of Policy Responses for COVID-19: The Importance of Capturing Social Consequences. *Medical Decision Making*, *40*(3), 251–253. https://doi.org/10.1177/0272989X20922987
125. Klersy, C., De Silvestri, A., Gabutti, G., Raisaro, A., Curti, M., Regoli, F., & Auricchio, A. (2011). Economic impact of remote patient monitoring: An integrated economic model derived from a meta-analysis of randomized controlled trials in heart failure. *European Journal of Heart Failure*, *13*(4), 450–459. https://doi.org/10.1093/eurjhf/hfq232

126. Kolasa, K., & Kozinski, G. (2020). How to Value Digital Health Interventions? A Systematic Literature Review. *International Journal of Environmental Research and Public Health*, *17*(6), 1–22. https://doi.org/10.3390/IJERPH17062119
127. Kosednar, H. (2023). *Digitalizacija zdravstva in storitve eZdravja v Slovenij*. https://nijz.si/wp-content/uploads/2023/01/Digitalizacija-zdravstva-in-storitve-eZdravja-v-Sloveniji-Hajdi-Kosednar-2.pdf
128. Kovačić, M., Mutavdžija, M., & Buntak, K. (2022). e-Health Application, Implementation and Challenges: A Literature Review. *Business Systems Research Journal*, *13*(1), 1–18. https://doi.org/doi:10.2478/bsrj-2022-0001
129. Kristensen, F. B., Lampe, K., Wild, C., Cerbo, M., Goettsch, W., & Becla, L. (2017). The HTA Core Model(®)-10 Years of Developing an International Framework to Share Multidimensional Value Assessment. *Value in Health : The Journal of the International Society for Pharmacoeconomics and Outcomes Research*, *20*(2), 244–250. https://doi.org/10.1016/j.jval.2016.12.010
130. Kursīte, M., Stars, I., Strēle, I., Gobiņa, I., Ķīvīte-Urtāne, A., Behmane, D., Dūdele, A., & Villeruša, A. (2022). A mixed-method study on the provision of remote consultations for non-communicable disease patients during the first wave of the COVID-19 pandemic in Latvia: lessons for the future. *BMC Health Services Research*, *22*(1), 263. https://doi.org/10.1186/s12913-022-07634-x
131. Kurz, C. F. (2017). Tweedie distributions for fitting semicontinuous health care utilization cost data. *BMC Medical Research Methodology*, *17*(1), 171. https://doi.org/10.1186/s12874-017-0445-y
132. Kwon, J., Lee, Y., Young, T., Squires, H., & Harris, J. (2021). Qualitative research to inform economic modelling: a case study in older people's views on implementing the NICE falls prevention guideline. *BMC Health Services Research*, *21*(1), 1020. https://doi.org/10.1186/s12913-021-07056-1
133. Lakdawalla, D. N., Doshi, J. A., Garrison Jr, L. P., Phelps, C. E., Basu, A., & Danzon, P. M. (2018). Defining Elements of Value in Health Care—A Health Economics Approach: An ISPOR Special Task Force Report [3]. *Value in Health*, *21*(2), 131–139. https://doi.org/10.1016/j.jval.2017.12.007
134. Le Goff-Pronost, M., & Sicotte, C. (2010). The added value of thorough economic evaluation of telemedicine networks. *The European Journal of Health Economics*, *11*(1), 45–55. https://doi.org/10.1007/s10198-009-0162-5
135. Lee, K. H., Pedroza, C., Avritscher, E. B. C., Mosquera, R. A., & Tyson, J. E. (2023). Evaluation of negative binomial and zero-inflated negative binomial models for the analysis of zero-inflated count data: application to the telemedicine for children with medical complexity trial. *Trials*, *24*(1), 613. https://doi.org/10.1186/s13063-023-07648-8
136. Leite, W. (2019). Practical Propensity Score Methods Using R. In *Practical Propensity Score Methods Using R*. SAGE Publications, Inc. https://doi.org/10.4135/9781071802854

137. Lemmon, E., Hanna, C. R., Hall, P., & Morris, E. J. A. (2021). Health economic studies of colorectal cancer and the contribution of administrative data: A systematic review. *European Journal of Cancer Care*, *30*(5), e13477. https://doi.org/10.1111/ECC.13477
138. Liu, H., Muhunthan, J., Ananthapavan, J., Hawe, P., Shiell, A., & Jan, S. (2018). Exploring the use of economic evidence to inform investment in disease prevention – a qualitative study. *Australian and New Zealand Journal of Public Health*, *42*(2), 200–206. https://doi.org/10.1111/1753-6405.12748
139. Lotrič Dolinar, A., Došenović Bonča, P., & Sambt, J. (2017). Longevity in Slovenia: Past and potential gains in life expectancy by age and causes of death. *Zdravstveno Varstvo*, *56*(2), 124–130. https://doi.org/10.1515/SJPH-2017-0016
140. Lotrič Dolinar, A., Zvan, B., & Dosenovic Bonca, P. (2020). Productivity Losses Due to Migraine in Slovenia: An Analysis of Absenteeism and Presenteeism Costs Based on Administrative and Self-Reported Data. *Slovenian Journal of Public Health*, *59*, 75–82. https://doi.org/10.2478/sjph-2020-0010
141. Mandrik, O. (Lena), Severens, J. L. (Hans., Bardach, A., Ghabri, S., Hamel, C., Mathes, T., Vale, L., Wisløff, T., & Goldhaber-Fiebert, J. D. (2021). Critical Appraisal of Systematic Reviews With Costs and Cost-Effectiveness Outcomes: An ISPOR Good Practices Task Force Report. *Value in Health*, *24*(4), 463–472. https://doi.org/10.1016/j.jval.2021.01.002
142. Manteghinejad, A., & Javanmard, S. H. (2021). Challenges and opportunities of digital health in a post-COVID19 world. *Journal of Research in Medical Sciences*, *26*(11). https://doi.org/10.4103/jrms.JRMS_1255_20
143. Maria, A. R. J., Serra, H., & Heleno, B. (2022). Teleconsultations and their implications for health care: A qualitative study on patients' and physicians' perceptions. *International Journal of Medical Informatics*, *162*, 104751. https://doi.org/10.1016/J.IJMEDINF.2022.104751
144. McCarthy, M. (2016). Sustainable general practice: looking across Europe. *The British Journal of General Practice*, *66*(642), 36. https://doi.org/10.3399/BJGP16X683233
145. McCullagh, P., & Nelder, J. A. (1989). *Generalized Linear Models* (2nd ed.). Chapman & Hall.
146. McDonagh, T. A., Metra, M., Adamo, M., Gardner, R. S., Baumbach, A., Böhm, M., Burri, H., Butler, J., Celutkiene, J., Chioncel, O., Cleland, J. G. F., Coats, A. J. S., Crespo-Leiro, M. G., Farmakis, D., Gilard, M., & Heymans, S. (2021). 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. *European Heart Journal*, *42*(36), 3599–3726. https://doi.org/10.1093/eurheartj/ehab368
147. McGill, E., Er, V., Penney, T., Egan, M., White, M., Meier, P., Whitehead, M., Lock, K., Anderson de Cuevas, R., Smith, R., Savona, N., Rutter, H., Marks, D., de Vocht, F., Cummins, S., Popay, J., & Petticrew, M. (2021). Evaluation of public health interventions from a complex systems perspective: A research methods review. *Social Science & Medicine (1982)*, *272*. https://doi.org/10.1016/J.SOCSCIMED.2021.113697
148. McNamee, P., Murray, E., Kelly, M. P., Bojke, L., Chilcott, J., Fischer, A., West, R., & Yardley, L. (2016). Designing and Undertaking a Health Economics Study of Digital

Health Interventions. *American Journal of Preventive Medicine*, *51*(5), 852–860. https://doi.org/10.1016/j.amepre.2016.05.007

149. McQueen, R. B., & Slejko, J. F. (2021). Toward Modified Impact Inventory Tables to Facilitate Patient-Centered Value Assessment. In *PharmacoEconomics* (Vol. 39, Issue 4, pp. 379–382). https://doi.org/10.1007/s40273-021-01017-6
150. Menard, S. (2000). Coefficients of Determination for Multiple Logistic Regression Analysis. *The American Statistician*, *54*(1), 17–24. https://doi.org/10.2307/2685605
151. Mendeley. (n.d.). *Mendeley Reference Manager*. Elsevier.
152. Merlo, G., Page, K., Zardo, P., & Graves, N. (2019). Applying an Implementation Framework to the Use of Evidence from Economic Evaluations in Making Healthcare Decisions. *Applied Health Economics and Health Policy*, *17*(4), 533–543. https://doi.org/10.1007/s40258-019-00477-4
153. Michaud, T. L., Zhou, J., McCarthy, M. A., Siahpush, M., & Su, D. (2018). Costs of Home-Based Telemedicine Programs: A Systematic Review. *International Journal of Technology Assessment in Health Care*, *34*(4), 410–418. https://doi.org/10.1017/S0266462318000454
154. Michie, S., Yardley, L., West, R., Patrick, K., & Greaves, F. (2017). Developing and evaluating digital interventions to promote behavior change in health and health care: Recommendations resulting from an international workshop. *Journal of Medical Internet Research*, *19*(6), 1–13. https://doi.org/10.2196/jmir.7126
155. Mihaylova, B., Briggs, A., O'Hagan, A., & Thompson, S. G. (2011). Review of statistical methods for analysing healthcare resources and costs. *Health Economics*, *20*(8), 897–916. https://doi.org/10.1002/hec.1653
156. Ministry of Health. (2022). *Slovenija – e-zdravje za bolj zdravo družbo*. https://www.gov.si/assets/ministrstva/MZ/DOKUMENTI/staro/Slovenija-E-zdravje-za-bolj-zdravo-druzbo-v2.pdf
157. Ministry of Health. (2024). *Proposal for a regulation - Health Care Quality Act*. https://e-uprava.gov.si/si/drzava-in-druzba/e-demokracija/predlogi-predpisov/predlog-predpisa.html?id=16750&lang=si
158. Ministry of Health. (2025). *Digitalization of healthcare* . https://www.gov.si/zbirke/projekti-in-programi/prenova-zdravstvenega-sistema/digitalizacija-zdravstva/
159. Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive Statistics and Normality Tests for Statistical Data. *Annals of Cardiac Anaesthesia*, *22*(1).
160. Mistry, H. (2012). Systematic review of studies of the cost-effectiveness of telemedicine and telecare. Changes in the economic evidence over twenty years. *Journal of Telemedicine and Telecare*, *18*(1), 1–6. https://doi.org/10.1258/JTT.2011.110505
161. Monaghesh, E., & Hajizadeh, A. (2020). The role of telehealth during COVID-19 outbreak: A systematic review based on current evidence. *BMC Public Health*, *20*(1193), 1–9. https://doi.org/10.1186/s12889-020-09301-4

162. Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x
163. Murray, E., Daff, K., Lavida, A., Henley, W., Irwin, J., & Valabhji, J. (2019). Evaluation of the digital diabetes prevention programme pilot: uncontrolled mixed-methods study protocol. *BMJ Open*, *9*(5), e025903. https://doi.org/10.1136/BMJOPEN-2018-025903
164. Murray, E., Hekler, E. B., Andersson, G., Collins, L. M., Doherty, A., Hollis, C., Rivera, D. E., West, R., & Wyatt, J. C. (2016). Evaluating Digital Health Interventions: Key Questions and Approaches. *American Journal of Preventive Medicine*, *51*(5), 843–851. https://doi.org/10.1016/j.amepre.2016.06.008
165. Naoum, P., Pavi, E., & Athanasakis, K. (2021). Economic Evaluation of Digital Health Interventions in Palliative Care: A Systematic Review of the Literature. *Frontiers in Digital Health*, *3*, 1–7. https://doi.org/10.3389/FDGTH.2021.730755
166. National Institute of Public Health. (2020). *Koeficient razvitosti občin | Zdravje v občini | NIJZ*. Zdrava Občina Za Zdravo Slovenijo. https://obcine.nijz.si/kazalniki/K1.1
167. National Institute of Public Health. (2021a). *ICD-10-AM, version 6*. https://nijz.si/podatki/klasifikacije-in-sifranti/mkb-10-am-verzija-6/
168. National Institute of Public Health. (2021b). *Public Health Achievements in Slovenia*.
169. National Institute of Public Health. (2022). *Classification of Types of Health Activities (Šifrant vrst zdravstvene dejavnosti (VZD)*. https://nijz.si/podatki/klasifikacije-in-sifranti/sifrant-vrst-zdravstvene-dejavnosti-vzd/
170. NICE. (2018). *Evidence standards framework for digital health technologies* (pp. 1–47). National Institute for Health and Care Excellence.
171. NICE. (2022). *NICE health technology evaluations: the manual*. National Institute for Health and Care Excellence.
172. Noyes, J., Booth, A., Moore, G., Flemming, K., Tunçalp, Ö., & Shakibazadeh, E. (2019). Synthesising quantitative and qualitative evidence to inform guidelines on complex interventions: clarifying the purposes, designs and outlining some methods. *BMJ Global Health*, *4*(Suppl 1), e000893. https://doi.org/10.1136/bmjgh-2018-000893
173. OECD. (2021). *Health at a Glance 2021: OECD Indicators*. OECD. https://doi.org/10.1787/ae3016b9-en
174. OECD. (2022). *OECD Health Statistics 2022*. https://www.oecd.org/health/health-data.htm
175. OECD. (2024). *Latest health spending trends: Navigating beyond the recent crises*. https://doi.org/10.1787/df0bb1ba-en
176. Oh, H., Rizo, C., Enkin, M., & Jadad, A. (2005). What Is eHealth (3): A Systematic Review of Published Definitions. *Journal of Medical Internet Research*, *7*(1). https://doi.org/10.2196/JMIR.7.1.E1
177. Ojinnaka, C. O., Johnstun, L., Dunnigan, A., Nordstrom, L., & Yuh, S. (2024). Telemedicine Reduces Missed Appointments but Disparities Persist. *American Journal*

of Preventive Medicine, *67*(1), 90–96. https://doi.org/10.1016/J.AMEPRE.2024.02.012,

178. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, *372*. https://doi.org/10.1136/BMJ.N71
179. Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health*, *42*(5), 533. https://doi.org/10.1007/S10488-013-0528-Y
180. Paré, G., Jaana, M., & Sicotte, C. (2007). Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base. *Journal of the American Medical Informatics Association*, *14*(3), 269–277. https://doi.org/10.1197/JAMIA.M2270
181. Peretz, D., Arnaert, A., & 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), 13–21. https://doi.org/10.1177/1357633X16669239
182. Petticrew, M., Anderson, L., Elder, R., Grimshaw, J., Hopkins, D., Hahn, R., Krause, L., Kristjansson, E., Mercer, S., Sipe, T., Tugwell, P., Ueffing, E., Waters, E., & Welch, V. (2013). Complex interventions and their implications for systematic reviews: a pragmatic approach. *Journal of Clinical Epidemiology*, *66*(11), 1209–1214. https://doi.org/10.1016/J.JCLINEPI.2013.06.004
183. Pirhonen, L., Gyllensten, H., Olofsson, E. H., Fors, A., Ali, L., Ekman, I., & Bolin, K. (2020). The cost-effectiveness of person-centred care provided to patients with chronic heart failure and/or chronic obstructive pulmonary disease. *Health Policy OPEN*, *1*, 100005. https://doi.org/10.1016/j.hpopen.2020.100005
184. Podolsky, M. I., Present, I., Neumann, P. J., & Kim, D. D. (2022). A Systematic Review of Economic Evaluations of COVID-19 Interventions: Considerations of Non-Health Impacts and Distributional Issues. *Value in Health*, *25*(8), 1298–1306. https://doi.org/10.1016/j.jval.2022.02.003
185. Polisena, J., Coyle, D., Coyle, K., & McGill, S. (2009). Home telehealth for chronic disease management: A systematic review and an analysis of economic evaluations. *International Journal of Technology Assessment in Health Care*, *25*(3), 339–349. https://doi.org/10.1017/S0266462309990201
186. Pongiglione, B., & Torbica, A. (2022). How real can we get in generating real world evidence? Exploring the opportunities of routinely collected administrative data for evaluation of medical devices. *Health Economics*, *31*(S1), 25–43. https://doi.org/10.1002/HEC.4562

187. Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World. *Publications*, *9(1)*(12). https://doi.org/10.3390/PUBLICATIONS9010012
188. Prelog, I., Pilej, A., & Turk, E. (2025). The role of health technology assessment in health system globally, in the European Union and in Slovenia. *Slovenian Medical Journal*, *94*(5–6), 132–141. https://doi.org/10.6016/ZdravVestn.3571
189. Prevolnik Rupel, V. (2017). Current implementation of health technology assessment in healthcare system in Slovenia. *International Journal of Technology Assessment in Health Care*, *33*(3), 360–364. https://doi.org/10.1017/S0266462317000083
190. Pritchard, A. (1969). Statistical Bibliography or Bibliometrics. *Journal of Documentation*, *25*, 348–349.
191. Rant, Ž. (2021). Telemedicine in Slovenia. *BLED 2021 Proceedings*, 87–96.
192. Rant, Ž., & Rudel, D. (2021). Telemedicinske storitve v Sloveniji. *40th International Conference on Organizational Science Development Values Competencies and Changes in Organizations*, 849–863. https://doi.org/10.18690/978-961-286-442-2.57
193. Rasoul, D., Chattopadhyay, I., Mayer, T., West, J., Stollar, H., Black, C., Oguguo, E., Kaur, R., MacDonald, R., Pocock, J., Uzdzinska, B., Umpleby, B., Hex, N., Lip, G. Y. H., & Sankaranarayanan, R. (2025). Economic evaluation of the Liverpool heart failure virtual ward model. *European Heart Journal - Quality of Care and Clinical Outcomes*, *11*(2), 197–205. https://doi.org/10.1093/ehjqcco/qcae095
194. Ritchie, H., & Roser, M. (2019). *Our World in Data - Age Structure*. https://ourworldindata.org/age-structure
195. Ritchie, J., & Spencer, L. (1994). Qualitative Data Analysis for Applied Policy Research. In *Analyzing qualitative data*. Routledge. https://doi.org/10.4324/9780203413081_chapter_9
196. Roseboom, K. J., Van Dongen, J. M., Tompa, E., Van Tulder, M. W., & Bosmans, J. E. (2017). Economic evaluations of health technologies in Dutch healthcare decision-making: A qualitative study of the current and potential use, barriers, and facilitators. *BMC Health Services Research*, *17*(1), 1–11. https://doi.org/10.1186/S12913-017-1986-9
197. Rosenbaum, P. R., & Rubin, D. B. (1985). Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score. *The American Statistician*, *39*(1), 33–38. https://doi.org/10.1080/00031305.1985.10479383
198. Rudel, D., Slemenik-Pušnik, C., Epšek-Lenart, M., Pušnik, S., Balorda, Z., & Lavre, J. (2017). Telemedicine support to patients with chronic diseases for better long-term control at home. *Slovenian Medical Journal*, *85*(11–12). https://doi.org/10.6016/zdravvestn.1553
199. Sanders, G. D., Neumann, P. J., Basu, A., Brock, D. W., Feeny, D., Krahn, M., Kuntz, K. M., Meltzer, D. O., Owens, D. K., Prosser, L. A., Salomon, J. A., Sculpher, M. J., Trikalinos, T. A., Russell, L. B., Siegel, J. E., & Ganiats, T. G. (2016). Recommendations for Conduct, Methodological Practices, and Reporting of Cost-

effectiveness Analyses: Second Panel on Cost-Effectiveness in Health and Medicine. *JAMA*, *316*(10), 1093–1103. https://doi.org/10.1001/jama.2016.12195

200. Santos, A. R., von Hafe, F., Sampaio, F., Londral, A. R., & Perelman, J. (2026). Mapping Methodologies for Economic Evaluation of Digital Health Technologies: A Scoping Review. *Value in Health*, *29*(2), 311–323. https://doi.org/10.1016/j.jval.2025.09.012
201. Sanyal, C., Stolee, P., Juzwishin, D., & Husereau, D. (2018). Economic evaluations of eHealth technologies: A systematic review. *PLOS ONE*, *13*(6), e0198112. https://doi.org/10.1371/JOURNAL.PONE.0198112
202. Sauerbrei, W., Perperoglou, A., Schmid, M., Abrahamowicz, M., Becher, H., Binder, H., Dunkler, D., Harrell, F. E., Royston, P., Heinze, G., Abrahamowicz, M., Becher, H., Binder, H., Dunkler, D., Harrell, F., Heinze, G., Perperoglou, A., Rauch, G., Royston, P., … initiative, for T. of the S. (2020). State of the art in selection of variables and functional forms in multivariable analysis—outstanding issues. *Diagnostic and Prognostic Research*, *4*(1), 3. https://doi.org/10.1186/s41512-020-00074-3
203. Schuster, V. (2024). EU HTA Regulation and Joint Clinical Assessment-Threat or Opportunity? *Journal of Market Access & Health Policy*, *12*(2), 100–104. https://doi.org/10.3390/jmahp12020008
204. Seixas, A. A., Olaye, I. M., Wall, S. P., & Dunn, P. (2021). Optimizing Healthcare Through Digital Health and Wellness Solutions to Meet the Needs of Patients With Chronic Disease During the COVID-19 Era. *Frontiers in Public Health*, *9*(667654), 1–7. https://doi.org/10.3389/fpubh.2021.667654
205. Seto, E. (2008). Cost Comparison Between Telemonitoring and Usual Care of Heart Failure: A Systematic Review. *Telemedicine and E-Health*, *14*(7), 679–687. https://doi.org/10.1089/tmj.2007.0114
206. Severino, P., D'amato, A., Prosperi, S., Magnocavallo, M., Maraone, A., Notari, C., Papisca, I., Mancone, M., & Fedele, F. (2022). Clinical Support through Telemedicine in Heart Failure Outpatients during the COVID-19 Pandemic Period: Results of a 12-Months Follow Up. *Journal of Clinical Medicine*, *11*(10). https://doi.org/10.3390/JCM11102790
207. Shahim, B., Kapelios, C. J., Savarese, G., & Lund, L. H. (2023). Global Public Health Burden of Heart Failure: An Updated Review. *Cardiac Failure Review*, *9*, e11. https://doi.org/10.15420/cfr.2023.05
208. Sharma, D., Aggarwal, A. K., Downey, L. E., & Prinja, S. (2021). National Healthcare Economic Evaluation Guidelines: A Cross-Country Comparison. *PharmacoEconomics - Open*, *5*, 349–364. https://doi.org/10.1007/S41669-020-00250-7
209. Shoaib, A., Van Spall, H. G. C., Wu, J., Cleland, J. G. F., McDonagh, T. A., Rashid, M., Mohamed, M. O., Ahmed, F. Z., Deanfield, J., de Belder, M., Gale, C. P., & Mamas, M. A. (2021). Substantial decline in hospital admissions for heart failure accompanied by increased community mortality during COVID-19 pandemic. *European Heart Journal - Quality of Care and Clinical Outcomes*, *7*(4), 378–387. https://doi.org/10.1093/ehjqcco/qcab040

210. Sikandar, H., Vaicondam, Y., Parveen, S., Khan, N., & Qureshi, M. I. (2021). Bibliometric Analysis of Telemedicine and E-Health Literature. *International Journal of Online and Biomedical Engineering (IJOE)*, *17*(12), 52–69. https://doi.org/10.3991/ijoe.v17i12.25483
211. Silverman, D. (2017). *Doing Qualitative Research. A Handbook* (5th ed.). SAGE Publications.
212. Singhal, A., & Cowie, M. R. (2021). Digital Health: Implications for Heart Failure Management. *Cardiac Failure Review 2021;7:E08.* https://doi.org/10.15420/cfr.2020.28
213. Sittimart, M., Rattanavipapong, W., Mirelman, A. J., Hung, T. M., Dabak, S., Downey, L. E., Jit, M., Teerawattananon, Y., & Turner, H. C. (2024). An overview of the perspectives used in health economic evaluations. *Cost Effectiveness and Resource Allocation*, *22*(1), 41. https://doi.org/10.1186/s12962-024-00552-1
214. Skivington, K., Matthews, L., Simpson, S. A., Craig, P., Baird, J., Blazeby, J. M., Boyd, K. A., Craig, N., French, D. P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M., & Moore, L. (2021). A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ*, *374*, n2061. https://doi.org/10.1136/bmj.n2061
215. Snoswell, C. L., North, J. B., & Caffery, L. J. (2020). Economic Advantages of Telehealth and Virtual Health Practitioners: Return on Investment Analysis. *JMIR Perioperative Medicine*, *3*(1), e15688. https://doi.org/10.2196/15688
216. Snoswell, C. L., Smith, A. C., Scuffham, P. A., & Whitty, J. A. (2017). Economic evaluation strategies in telehealth: Obtaining a more holistic valuation of telehealth interventions. *Journal of Telemedicine and Telecare*, *23*(9), 792–796. https://doi.org/10.1177/1357633X16671407
217. Snoswell, C. L., Taylor, M. L., Comans, T. A., Smith, A. C., Gray, L. C., & Caffery, L. J. (2020). Determining if Telehealth Can Reduce Health System Costs: Scoping Review. *Journal of Medical Internet Research*, *22*(10). https://doi.org/10.2196/17298
218. Sood, S., Mbarika, V., Jugoo, S., Dookhy, R., Doarn, C. R., Prakash, N., & Merrell, R. C. (2007). What is telemedicine? A collection of 104 peer-reviewed perspectives and theoretical underpinnings. *Telemedicine Journal and E-Health : The Official Journal of the American Telemedicine Association*, *13*(5), 573–590. https://doi.org/10.1089/TMJ.2006.0073
219. Srivastava, A., & Thomson, S. B. (2009). Framework Analysis: A Qualitative Methodology for Applied Policy Research. *Journal of Administration and Governance*, *72*.
220. Srok, A., & Došenović Bonča, P. (2024). ICT-enabled healthcare and economic evaluations: a bibliometric analysis. In *Dealing with Uncertainty* (pp. 197–218). University of Rijeka, Faculty of Economics and Business.
221. Srok, A., & Došenović Bonča, P. (2025). Economic Evaluations of Digital Health Interventions: A Bibliometric Analysis and a Review of Methodological Challenges. *Business Systems Research : International Journal of the Society for Advancing*

Innovation and Research in Economy, *16*(1), 285–304. https://doi.org/10.2478/BSRJ-2025-0014

222. Srok, A., & Došenović Bonča, P. (2022). ICT-enabled healthcare and economic evaluations: a bibliometric analysis. *International Scientific Conference Economics of Digital Transformation (EDT) - "Dealing with Uncertainty,"* 29.
223. Stanimirovic, D. (2015). A framework for information and communication technology induced transformation of the healthcare business model in Slovenia. *Journal of Global Information Technology Management*, *18*(1), 29–47. https://doi.org/10.1080/1097198X.2015.1015826
224. Stanimirovic, D. (2021). eHealth patient portal - becoming an indispensable public health tool in the time of Covid-19. *Public Health and Informatics: Proceedings of MIE 2021*, 880–884. https://doi.org/10.3233/SHTI210305
225. Stanimirović, D., & Matetić, V. (2020). Can the COVID-19 pandemic boost the global adoption and usage of eHealth solutions? *Journal of Global Health*, *10*(2). https://doi.org/10.7189/JOGH.10.0203101
226. Stanisavljevic, V., & Tekić Sauerborn, B. (2024). On Privacy Protection of Consumer Data Collected by e-Health Devices. *ENTRENOVA - ENTerprise REsearch InNOVAtion*, *9*, 121–131. https://doi.org/10.54820/entrenova-2023-0013
227. StataCorp. (2015). *Stata Statistical Software: Release 15*. College Station.
228. StataCorp. (2021). *Stata Statistical Software: Relase 17*. College Station.
229. Statistical Office of the Republic of Slovenia. (n.d.). *Health expenditure and sources of funding, 2020*. 2024. Retrieved April 5, 2025, from https://www.stat.si/StatWeb/en/News/Index/10394
230. Statistical Office of the Republic of Slovenia. (2008). *Standard Classification of Activities 2008 (SKD 2008), harmonised with NACE Rev.2*. https://www.stat.si/StatWeb/Methods/Classifications
231. Statistical Office of the Republic of Slovenia. (2022). *Income of the population, 2020*. Income of the Population, 2020. https://www.stat.si/StatWeb/en/News/Index/10346
232. Stevens, W. J. M., van der Sande, R., Beijer, L. J., Gerritsen, M. G. M., & Assendelft, W. J. J. (2019). eHealth Apps Replacing or Complementing Health Care Contacts: Scoping Review on Adverse Effects. *Journal of Medical Internet Research*, *21*(3). https://doi.org/10.2196/10736
233. Strehle, E. M., & Shabde, N. (2006). One hundred years of telemedicine: does this new technology have a place in paediatrics? *Archives of Disease in Childhood*, *91*(12), 956–959. https://doi.org/10.1136/ADC.2006.099622
234. Stroetmann, K. A., Jones, T., Dobrev, A., & Stroetmann, V. N. (2006). *eHealth is Worth it The economic benefits of implemented eHealth solutions at ten European sites*. Office for Official Publications of the EuropeanCommunities. https://doi.org/10.13140/2.1.1551.9367
235. Stuart, E. A. (2010). Matching methods for causal inference: A review and a look forward. *Statistical Science : A Review Journal of the Institute of Mathematical Statistics*, *25*(1), 1–21. https://doi.org/10.1214/09-STS313

236. Sturgiss, E., & Clark, A. (2020). Using critical realism in primary care research: an overview of methods. *Family Practice*, *37*, 143–145. https://doi.org/10.1093/fampra/cmz084
237. Sülz, S., van Elten, H. J., Askari, M., Weggelaar-Jansen, A. M., & Huijsman, R. (2021). eHealth Applications to Support Independent Living of Older Persons: Scoping Review of Costs and Benefits Identified in Economic Evaluations. *Journal of Medical Internet Research*, *23*(3). https://doi.org/10.2196/24363
238. Tan, H., Gu, T., Chen, E., Punekar, R., & Shieh, P. B. (2019). Healthcare Utilization, Costs of Care, and Mortality Among Patients With Spinal Muscular Atrophy. *Journal of Health Economics and Outcomes Research*, *6*(3), 185–195. https://doi.org/10.36469/63185
239. Taylor, M. L., Thomas, E. E., Snoswell, C. L., Smith, A. C., & Caffery, L. J. (2021). Does remote patient monitoring reduce acute care use? A systematic review. *BMJ Open*, *11*(3), e040232. https://doi.org/10.1136/BMJOPEN-2020-040232
240. Thomas, E. E., Taylor, M. L., Ward, E. C., Hwang, R., Cook, R., Ross, J.-A., Webb, C., Harris, M., Hartley, C., Carswell, P., Burns, C. L., & Caffery, L. J. (2024). Beyond forced telehealth adoption: A framework to sustain telehealth among allied health services. *Journal of Telemedicine and Telecare*, *30*(3), 559–569. https://doi.org/10.1177/1357633X221074499
241. Tsang, W., Silversides, C. K., Rashid, M., Roche, S. L., Alonso-Gonzalez, R., Austin, P. C., & Lee, D. S. (2021). Outcomes and healthcare resource utilization in adult congenital heart disease patients with heart failure. *ESC Heart Failure*, *8*(5), 4139. https://doi.org/10.1002/EHF2.13529
242. Tsiasiotis, E., Mezei, F., Di Bidino, R., Basile, M., Battaglia, L., Strammiello, V., Kidholm, K., Oortwijn, W., Cicchetti, A., & Sacchini, D. (2025). Toward a Harmonized Health Technology Assessment Framework for Digital Health Technologies in Europe. *Value in Health : The Journal of the International Society for Pharmacoeconomics and Outcomes Research*. https://doi.org/10.1016/j.jval.2025.12.004
243. Turner, H. C., Archer, R. A., Downey, L. E., Isaranuwatchai, W., Chalkidou, K., Jit, M., & Teerawattananon, Y. (2021). An Introduction to the Main Types of Economic Evaluations Used for Informing Priority Setting and Resource Allocation in Healthcare: Key Features, Uses, and Limitations. *Frontiers in Public Health*, *9*. https://doi.org/10.3389/FPUBH.2021.722927
244. Udeh, B. L. (2020). Economic Evaluation Studies. *Chest*, *158*(1), S88–S96. https://doi.org/10.1016/j.chest.2020.03.008
245. Uribe-Toril, J., Ruiz-Real, J. L., & Nievas-Soriano, B. J. (2021). A study of ehealth from the perspective of social sciences. *Healthcare*, *9*(2), 1–18. https://doi.org/10.3390/HEALTHCARE9020108
246. Valenzuela Espinoza, A., Steurbaut, S., Dupont, A., Cornu, P., Van Hooff, R. J., Brouns, R., & Putman, K. (2019). Health Economic Evaluations of Digital Health Interventions for Secondary Prevention in Stroke Patients: A Systematic Review. *Cerebrovascular Diseases Extra*, *9*, 1–8. https://doi.org/10.1159/000496107

247. van de Schoot, R., de Bruin, J., Schram, R., Zahedi, P., de Boer, J., Weijdema, F., Kramer, B., Huijts, M., Hoogerwerf, M., Ferdinands, G., Harkema, A., Willemsen, J., Ma, Y., Fang, Q., Hindriks, S., Tummers, L., & Oberski, D. (2020). Open Source Software for Efficient and Transparent Reviews. *Nature Machine Intelligence*, *3*(2), 125–133. https://doi.org/10.1038/s42256-020-00287-7
248. van de Schoot, R., de Bruin, J., Schram, R., Zahedi, P., de Boer, J., Weijdema, F., Kramer, B., Huijts, M., Hoogerwerf, M., Ferdinands, G., Harkema, A., Willemsen, J., Ma, Y., Fang, Q., Hindriks, S., Tummers, L., & Oberski, D. L. (2021). An open source machine learning framework for efficient and transparent systematic reviews. *Nature Machine Intelligence*, *3*, 125–133. https://doi.org/10.1038/s42256-020-00287-7
249. van Dongen, J. M., Tompa, E., Clune, L., Sarnocinska-Hart, A., Bongers, P. M., van Tulder, M. W., van der Beek, A. J., & van Wier, M. F. (2013). Bridging the gap between the economic evaluation literature and daily practice in occupational health: A qualitative study among decision-makers in the healthcare sector. *Implementation Science*, *8*(1). https://doi.org/10.1186/1748-5908-8-57
250. van Eck, N. J., & Waltman, L. (2010). VOSviewer: A Computer Program for Bibliometric Mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3
251. van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. *Measuring Scholarly Impact*, 285–320. https://doi.org/10.1007/978-3-319-10377-8_13
252. Varnai, P., Nausedaite, R., Beckers, D., Madubuko, T., Terrier, A., Zoboli, E., Eljas, K., & ESPON. (2019). *eHealth - Future Digital Health in the EU*. ESPON 2020 Cooperation Programm.
253. Veijer, C., van Hulst, M. H., Friedrichson, B., Postma, M. J., & van Asselt, A. D. I. (2024). Lessons Learned from Model-based Economic Evaluations of COVID-19 Drug Treatments Under Pandemic Circumstances: Results from a Systematic Review. *PharmacoEconomics*, *42*(6), 633–647. https://doi.org/10.1007/s40273-024-01375-x
254. Velayati, F., Ayatollahi, H., Hemmat, M., & Dehghan, R. (2021). Key components and critical factors for developing a telehealth business framework: a qualitative study. *BMC Medical Informatics and Decision Making*, *21*(1), 1–9. https://doi.org/10.1186/S12911-021-01707-3
255. VERBI Software. (2011). *VERBI Software. (2011). MAXQDA 11 [computer software]. Berlin, Germany: VERBI Software. Available from maxqda.com.*
256. VERBI Software. (2024). *VERBI Software. (2024). MAXQDA 2024 [computer software]. Berlin, Germany: VERBI Software. Available from maxqda.com.*
257. Visser, M., van Eck, N. J., & Waltman, L. (2021). Large-scale comparison of bibliographic data sources: Scopus, Web of Science, Dimensions, Crossref, and Microsoft Academic. *Quantitative Science Studies*, *2*(1), 20–41. https://doi.org/10.1162/qss_a_00112
258. Von Huben, A., Howell, M., Howard, K., Carrello, J., & Norris, S. (2021). Health technology assessment for digital technologies that manage chronic disease: A

systematic review. *International Journal of Technology Assessment in Health Care*, *37*(1). https://doi.org/10.1017/S0266462321000362

259. Walker, S., Griffin, S., Asaria, M., Tsuchiya, A., & Sculpher, M. (2019). Striving for a Societal Perspective: A Framework for Economic Evaluations When Costs and Effects Fall on Multiple Sectors and Decision Makers. *Applied Health Economics and Health Policy*, *17*, 577–590. https://doi.org/10.1007/S40258-019-00481-8
260. Waqas, A., Teoh, S. H., Lapão, L. V., Messina, L. A., & Correia, J. C. (2020). Harnessing telemedicine for the provision of health care: Bibliometric and scientometric analysis. *Journal of Medical Internet Research*, *22*(10), 1–16. https://doi.org/10.2196/18835
261. Wells, I., & Giacco, D. (2024). Theoretical frameworks used to inform qualitative mental health research: a focus on positivism, interpretivism and critical realism. *BJPsych Advances*, 1–9. https://doi.org/DOI: 10.1192/bja.2024.66
262. Whitten, P. S., Mair, F. S., Haycox, A., May, C. R., Williams, T. L., & Hellmich, S. (2002). Systematic review of cost effectiveness studies of telemedicine interventions. *British Medical Journal*, *324*(7351), 1434–1437. https://doi.org/10.1136/BMJ.324.7351.1434
263. WHO. (1998). *A health telematics policy in support of WHO's Health-for-All Strategy for Global Health Development*.
264. WHO. (2003). *Making choices in health: WHO guide to cost-effectiveness analysis*. World Health Organization. https://apps.who.int/iris/handle/10665/42699
265. WHO. (2010). *Telemedicine: Opportunities and Developments in Member States: Report on the Second Global Survey on eHealth*. https://apps.who.int/iris/handle/10665/44497
266. WHO. (2011). *mHealth: new horizons for health through mobile technologies: second global survey on eHealth*. https://apps.who.int/iris/handle/10665/44607
267. WHO. (2016). *Monitoring and evaluating digital health interventions: a practical guide to conducting research and assessment*. https://apps.who.int/iris/handle/10665/252183
268. WHO. (2019). *WHO guideline Recommendations on Digital Interventions for Health System Strengthening*. https://www.who.int/publications/i/item/9789241550505
269. WHO. (2021a). *Essential public health operations in Slovenia: Key findings and recommendations on strengthening public health capacities and services*. https://apps.who.int/iris/handle/10665/345236
270. WHO. (2021b). *Global strategy on digital health 2020-2025*. https://apps.who.int/iris/handle/10665/344249
271. WHO. (2025). *Anatomical Therapeutic Chemical (ATC) Classification*. https://www.who.int/tools/atc-ddd-toolkit/atc-classification
272. Wildman, J., & Wildman, J. M. (2019). Combining Health and Outcomes Beyond Health in Complex Evaluations of Complex Interventions: Suggestions for Economic Evaluation. *Value in Health*, *22*(5), 511–517. https://doi.org/10.1016/J.JVAL.2019.01.002

273. Wilkinson, T., Wang, M., Friedman, J., Gaye, Y.-E., & Görgens, M. (2024). Knowing when digital adds value to health: a framework for the economic evaluation of digital health interventions. *Open Digital Health*, *2*(S2). https://doi.org/10.1093/oodh/oqae028
274. Wilkinson, T., Wang, M., Friedman, J., & Prestidge, M. (2023). A Framework for the Economic Evaluation of Digital Health Interventions. In *Policy Research Working Paper* (Vol. 10407). The World Bank. https://doi.org/10.1596/1813-9450-10407
275. Wooldridge, J. M. (2019). *Introductory Econometrics: A Modern Approach* (7th ed.). Cengage Learning.
276. Wootton, R. (2012). Twenty years of telemedicine in chronic disease management-an evidence synthesis. *Journal of Telemedicine and Telecare*, *18*(4), 211–220. https://doi.org/10.1258/jtt.2012.120219
277. World Health Assembly. (2005). *Fifty-eighth World Health Assembly*. https://apps.who.int/iris/handle/10665/20398
278. Ziegler, A., Oner, A., Quadflieg, G., Betschart, R. O., Thiery, A., Babel, H., Mwambi, H. G., Neumeyer, H., Mackschin, S., Hintz, S., Mann, M., Dittrich, H., & Schmidt, C. (2023). Cost-effectiveness of a telemonitoring programme in patients with cardiovascular diseases compared with standard of care. *HEART*, *109*(21), 1617–1623. https://doi.org/10.1136/heartjnl-2023-322518
279. Zuur, A. F., Ieno, E. N., & Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution*, *1*(1), 3–14. https://doi.org/10.1111/j.2041-210X.2009.00001.x
280. Zwack, C. C., Haghani, M., & de Bekker-Grob, E. W. (2024). Research trends in contemporary health economics: a scientometric analysis on collective content of specialty journals. *Health Economics Review*, *14*(1), 6. https://doi.org/10.1186/s13561-023-00471-6

APPENDICES

Appendix 1: Daljši povzetek (Extended summary in Slovene language)

Naslov: Pospeševanje napredka ekonomskih vrednotenj telemedicine za okrepitev na dokazih temelječega razporejanja virov pri obravnavi srčnega popuščanja v Sloveniji

1 Uvod

V tej disertaciji se osredotočam na ekonomska vrednotenja (v nadaljevanju EV) digitalnih zdravstvenih intervencij (v nadaljevanju DHI). EV so ključno analitično orodje za primerjavo DHI s standardno ambulantno obravnavo ter nudijo nujno podporo odločanju v zdravstvu, razporejanju virov ter sprejemanju odločitev o uvajanju in povračilu stroškov. Vendar uporaba EV pri DHI ostaja metodološko zahtevna zaradi kompleksnosti digitalnih zdravstvenih intervencij, njihove kontekstualne odvisnosti in hitrega tehnološkega razvoja. Za obravnavo teh izzivov uporabljam raziskovalno zasnovo mešanih metod, ki združuje dokaze iz literature, perspektive deležnikov in administrativne podatke o zdravstvenih obravnavah. Empirični del disertacije je usmerjen v specifično DHI, in sicer telekonzultacije za bolnike s srčnim popuščanjem (v nadaljevanju HF), analiza pa se zaključi z EV telekonzultacij za bolnike s HF.

Ob tem disertacija priznava, da vrednotenje DHI, zlasti tistih, uvedenih med pandemijo covida-19, vključuje neizogibne metodološke in kontekstualne omejitve. Telekonzultacije so vpete v spreminjajoče se poti oskrbe in organizacijske prakse, zaradi česar je njihov vpliv težko povsem ločiti od širših sistemskih sprememb. Skladno s tem analiza zavzema pragmatično, v javno politiko usmerjeno perspektivo, z namenom oblikovanja kontekstualno ustreznih dokazov za podporo odločanju v realnem zdravstvenem okolju. Zagovarjam temo, da osrednji izziv EE DHI ni pomanjkanje metod, temveč neskladje med tradicionalnimi okviri vrednotenja ter kontekstualno, organizacijsko in večdeležniško naravo DHI. Namesto da bi predlagala enotno metodološko rešitev, disertacija proučuje, kako obstoječe pristope prilagoditi, kombinirati in interpretirati za boljši prispevek k odločanju v praksi.

V podpoglavju 1.1 podam pregled raziskovalnega področja. V podpoglavju 1.2 predstavim namen raziskave, raziskovalna vprašanja, metodologijo in podatke. V podpoglavju 1.3 obravnavam prispevek disertacije. V podpoglavju 1.4 predstavim njeno strukturo.

1.1 Pregled raziskovalnega področja

V obdobju pred digitalizacijo in sodobnim napredkom je bila pričakovana življenjska doba bistveno nižja od 40 let. K njenemu podaljšanju so bistveno prispevali izboljšani življenjski pogoji, boljša stanovanjska oskrba in sanitarni standardi, višja raven izobrazbe in kakovostnejša prehrana ter medicinski napredek z uvedbo cepiv in antibiotikov. Leta 2021 je bila povprečna pričakovana življenjska doba ob rojstvu 80,3 leta (OECD, 2022), leta 2018 pa je prvič v zgodovini število oseb, starejših od 64 let, preseglo število otrok, mlajših od pet let (H. Ritchie & Roser, 2019). Zaradi rasti svetovnega prebivalstva in daljše

pričakovane življenjske dobe, tehnološkega napredka ter spremenjenih navad in pričakovanj prebivalstva izdatki za zdravstvo po svetu vztrajno naraščajo, trend povečanja pa se napoveduje tudi za prihodnost (OECD, 2021, 2022). V obdobju 2013–2019 so v OECD državah izdatki za zdravstvo znašali približno 8,8 % bruto domačega proizvoda (v nadaljevanju BDP). Leta 2021 je svetovna zdravstvena kriza zaradi pandemije covida-19 povzročila skokovit porast izdatkov za zdravstvo na približno 9,7 % BDP (OECD, 2022). Leta 2022 se je ta delež znižal na 9,2 %, za leto 2023 pa se predvideva, da bo delež BDP znašal med 9 % in 10 %, kar še vedno presega ravni pred pandemijo (OECD, 2024).

Kljub povečanju izdatkov za zdravstvo se zdravstveni sistemi po svetu soočajo s številnimi izzivi, kar narekuje nenehno iskanje rešitev za preoblikovanje preobremenjenih zdravstvenih sistemov in zmanjševanje resnih zdravstvenih tveganj. Med globalno zdravstveno krizo, ki jo je sprožila pandemija covida-19, so postale posebej očitne različne strukturne slabosti zdravstvenih sistemov. Stroge omejitve neposrednih stikov med pandemijo covida-19 so poudarile ključno vlogo informacijskih in komunikacijskih tehnologij (v nadaljevanju IKT) ter pospešile njihovo uvajanje kot nujno sredstvo za zagotavljanje zdravstvenih storitev na daljavo (Busso et al., 2022; Greiwe, 2022; Monaghesh & Hajizadeh, 2020). Pandemija je omogočila hitro in ponekod obvezno uvedbo določenih oblik IKT, s čimer so se delno zmanjšale ovire, povezane s stroški implementacije in potrebami po usposabljanju, ki so pred tem predstavljale znatne prepreke. Razširjena uporaba IKT je hkrati odprla priložnosti za izvajanje dodatnih raziskav in obsežnejše proučevanje njihovega dejanskega vpliva na zdravje. Hitro širjenje IKT in delna nadomestitev tradicionalnih modelov izvajanja zdravstvenih storitev sta tako delovala kot katalizator širše transformacije zdravstvenih sistemov.

Naraščajoče število raziskav o dopolnjevanju tradicionalne zdravstvene oskrbe z IKT kaže, da je tak pristop obetaven ter ima potencial za preoblikovanje modelov izvajanja zdravstvenih storitev z namenom doseganja večjih zdravstvenih koristi ob omejenih virih. Svetovna zdravstvena organizacija (v nadaljevanju WHO) uporabo IKT v zdravstvu obravnava kot ključno za napredek zdravstvenih sistemov, saj omogoča izboljšave na kliničnem, vedenjskem, tehničnem in organizacijskem področju (Kolasa & Kozinski, 2020; WHO, 2021b). IKT lahko prispevajo tudi k reševanju izzivov, povezanih s finančno vzdržnostjo zdravstvenih sistemov. Izboljšano obvladovanje bolezni in spremljanje zdravljenja lahko vodita do boljših kliničnih izidov, vključno z natančnejšo diagnostiko in učinkovitejšim zdravljenjem. Izboljšani zdravstveni izidi in višja kakovost oskrbe lahko zmanjšajo število hospitalizacij ter skrajšajo njihovo trajanje. Oskrba na daljavo lahko zniža stroške pacientov zaradi manjših potnih stroškov, boljše spremljanje poteka bolezni in večjo dostopnost v ruralnih območjih ali pri bolnikih z omejeno mobilnostjo ter izboljša dostop do zdravstvenih storitev in prispeva k zmanjševanju neenakosti v zdravju med pacienti. IKT se lahko uporabljajo tudi za spodbujanje zdravja in dobrega počutja, ozaveščanje o zdravstvenih vprašanjih ter podporo zdravstvenemu izobraževanju. Večjo učinkovitost in vzdržnost zdravstvenega sistema je mogoče doseči z uporabo IKT za integracijo sistemov,

izboljšano komunikacijo med zdravstvenimi organizacijami ter lažjim dostopom do zdravstvenih podatkov. IKT lahko pomagajo blažiti vse večje pomanjkanje zdravstvenega kadra z boljšim obvladovanjem časa, na primer z zmanjševanjem števila neopravičenih izostankov pri pregledih in boljšim načrtovanja dela, s čimer se zmanjšujejo izgube produktivnosti. IKT omogočajo tudi izobraževanje na daljavo, strokovna srečanja, supervizijo ter upravljanje zdravstvenih podatkov (Busso et al., 2022; Greiwe, 2022; Huter et al., 2022; Kovačić et al., 2022; Monaghesh & Hajizadeh, 2020). Vpliv IKT se zato razteza tudi na različne potrebe izvajalcev zdravstvenih storitev in uporabnikov, različna zdravstvena stanja, različna okolja ter specifične skupine bolnikov.

Vendar pa se vključevanje IKT v zdravstveni sistem sooča tudi š številnimi izzivi, kot so kompleksnost implementacije, potrebe po usposabljanju, digitalni razkorak, ki lahko izključuje digitalno manj vešče bolnike, ter ovire pri vključevanju v obstoječe zdravstvene sisteme. Drugi pomisleki vključujejo prikrite operativne stroške, tveganja z vidika zagotavljanja pravičnosti in varovanja zasebnosti ter težave pri celovitem zajemanju njihove klinične in družbene vrednosti v okviru vrednotenj.

Zaradi raznolike uporabe IKT v zdravstvu se v literaturi pojavlja širok nabor terminologije, povezane z integracijo IKT v zdravstvo. Izraza telemedicina in telezdravje se nanašata na izvajanje zdravstvenih storitev na daljavo, pri čemer telemedicina običajno vključuje klinične storitve (npr. telekonzultacije, telemonitoring, telerehabilitacijo), telezdravje pa vključuje neklinične storitve (npr. sestanke, izobraževanje). Pojem eHealth (eZdravje) se nanaša na uporabo IKT na lokaciji izvajanja storitev in na daljavo, mHealth (mZdravje) pa na uporabo mobilnih tehnologij v zdravstvu. V zadnjem času se uveljavlja izraz digitalno zdravje kot širok krovni pojem za različne oblike uporabe IKT v zdravstvu (WHO, 2021b) ter vključuje tudi druge uporabe IKT in intervencije v zdravstvu, ki jih povzemajo izrazi telemedicina, telezdravje, eHealth in mHealth. V pričujoči disertaciji se zato za označevanje različnih aplikacij IKT v zdravstvu uporablja izraz DHI.

DHI se lahko obravnavajo kot dopolnilo tradicionalni obravnavi v ambulanti ali pa jo v ustreznih primerih nadomestijo. Zaradi tega imajo digitalne zdravstvene storitve potencial za povračilo stroškov in javno financiranje iz zdravstvenih proračunov. Zmanjševanje in obvladovanje izdatkov za zdravstvo tako predstavlja pomemben motiv za njihovo uvajanje in financiranje. Za zagotavljanje dokazov, potrebnih za odločanje o javnem financiranju in povračilu stroškov, je treba oceniti ekonomsko upravičenost alternativnih postopkov v primerjavi s tradicionalnimi postopki, pri čemer se uporabljajo EV. EV imajo osrednjo vlogo pri dokazovanju ekonomske upravičenosti digitalnega zdravja ter se uporabljajo za ocenjevanje stroškov in pozitivnih učinkov z namenom maksimiranja učinkov uvedbe digitalnih rešitev v zdravstveni sistem (Benedetto et al., 2023; Gomes et al., 2022; Wilkinson et al., 2023). EV predstavljajo nabor analitičnih orodij za primerjavo DHI s standardnimi zdravstvenimi intervencijami ter so podpora pri odločanju, na primer pri dodeljevanju virov (npr. Walker et al., 2019) ter spodbujanju nadaljnjega uvajanja in povračila stroškov DHI. Kljub temu število publikacij o EV DHI ostaja zelo nizko, čeprav

sta razvoj in uporaba teh intervencij v veliki meri odvisna prav od javnega financiranja, ki temelji na dokazih o ekonomski upravičenosti.

Nadaljnji razvoj EV DHI je zato ključen za krepitev na dokazih temelječega razporejanja virov v javnih zdravstvenih sistemih. Obstoječe raziskave o ekonomski upravičenosti DHI so pogosto tarča kritik zaradi neprepričljivih ekonomskih dokazov, nizke kakovosti EV, izrazite heterogenosti in omejene posplošljivosti (npr. Eze et al., 2020; Hwang et al., 2019; Snoswell, Taylor, et al., 2020). Številne sinteze dokazov o EV DHI za različne bolezni in intervencije izpostavljajo pomanjkanje robustnih ekonomskih dokazov (Huter et al., 2022; Jankovic et al., 2021; Naoum et al., 2021; Valenzuela Espinoza et al., 2019). DHI so običajno kompleksne intervencije, ki se sčasoma razvijajo, vključujejo številne deležnike, kot so bolniki, negovalci in zdravstveni delavci, so tehnološko raznolike, se uporabljajo v različnih kontekstih in pri različnih zdravstvenih stanjih ter lahko ustvarjajo vrsto izidov ter učinke prelivanja, ki niso nujno neposredno povezani z zdravjem in niso odvisni le od same intervencije, temveč tudi od uporabnikov (Husereau et al., 2014; Petticrew et al., 2013). Kot take predstavljajo poseben izziv za EV, zato je pri vrednotenju DHI potrebna posebna pozornost, na primer pri izbiri primerjalne skupine, izbiri perspektive, izbiri in ocenjevanju stroškov ter učinkov, izbiri ustreznih podatkovnih virov (npr. podatki kliničnih preskušanj, administrativni podatki) in izbiri metodologije (Benedetto et al., 2023; Bergmo, 2015; Gomes et al., 2022; Husereau et al., 2014; Jankovic et al., 2021; McNamee et al., 2016; Snoswell et al., 2017; Walker et al., 2019; Wilkinson et al., 2023). Splošno uporabljene metode za EV zdravstvenih programov obravnavajo stroške z vidika plačnika, z zdravjem povezane izide, kot je kakovost življenja (v nadaljevanju QOL), v analizi stroškov in koristi (CUA) ali klinične izide v analizi stroškovne učinkovitosti (CEA; Drummond et al., 2005). Vendar pa upoštevanje zgolj z zdravjem povezanih izidov in sprejetje perspektive plačnika ne moreta ustrezno zajeti širokega nabora učinkov DHI ter ne zagotavljata dovolj trdnih ekonomskih dokazov za odločitve o financiranju (Benedetto et al., 2023; Bergmo, 2015; Gomes et al., 2022; Kolasa & Kozinski, 2020; Snoswell et al., 2017).

Glede na to, da številni identificirani izzivi pri EV še niso bili razrešeni, še vedno primanjkuje jasnih in celovitih smernic za EV DHI (Gomes et al., 2022; Wilkinson et al., 2024). Redke obstoječe smernice za vrednotenje DHI so večinoma splošne in ne zagotavljajo podrobnega analitičnega okvira za ocenjevanje ekonomskih izidov (Kolasa & Kozinski, 2020; Wilkinson et al., 2024). Za vrednotenje DHI se predlagata analiza stroškov in dobrobiti (v nadaljevanju CBA) ter analiza stroškov in posledic (v nadaljevanju CCA), saj omogočata lažje vključevanje raznolikih stroškov in učinkov z družbenega vidika, poleg tega pa ju odločevalci lažje razumejo (Benedetto et al., 2023; Dobrev et al., 2008; Gomes et al., 2022; Snoswell et al., 2017). CCA se pogosto izvaja tudi pri uporabi administrativnih podatkov v zdravstvenih EV (npr. Gansen, 2018; Lemmon et al., 2021), kar je relevantno za DHI, pri katerih se vsi pomembni ekonomski izidi pogosto ne zbirajo sistematično vnaprej. Glede na nedavno razširitev DHI, zlasti telemedicine, zaradi pandemije covida-19 ter naraščajočih pritiskov na finančno vzdržnost javnih zdravstvenih sistemov, bodo

izboljšane EV telemedicine in drugih DHI igrale ključno vlogo pri dokazovanju njihove ekonomske upravičenosti ter spodbujanju njihove širše uporabe (Gomes et al., 2022). Le trdni klinični in ekonomski dokazi lahko ustrezno podprejo odločitve o dodeljevanju virov in s tem spodbujajo uvajanje digitalnega zdravja. Zato se EV telemedicine in drugih DHI obravnavajo kot hitro razvijajoče se področje zdravstvene ekonomike.

1.2 Namen raziskave, raziskovalna vprašanja, metodologija in podatki

Namen doktorske disertacije je pregledati in kritično oceniti obstoječa ekonomska vrednotenja DHI s poudarkom na telemedicini, sistematizirati izzive in priporočila, povezana z izvajanjem ekonomskih vrednotenj v teoriji in praksi, ter ugotovitve uporabiti za nadaljnje pospeševanje napredka ekonomskih evalvacij telemedicine in jih aplicirati na konkreten primer v Sloveniji, in sicer na telemedicinski poseg pri bolnikih s srčnim popuščanjem. Doktorska naloga ima tri ključne cilje. Prvič, na podlagi kritične presoje obstoječih študij in literature razvijem metodološko utemeljena priporočila za EV telemedicinskih intervencij. Drugič, izvedem kvalitativno analizo zaznav deležnikov glede ustreznih stroškov, pozitivnih učinkov in ključnih izzivov, povezanih s telemedicinskimi intervencijami. Tretjič, izvedem statistično analizo in EV specifične telemedicinske intervencije, tj. telekonzultacij za bolnike s srčnim popuščanjem (HF) v Sloveniji. Ti cilji so namenjeni krepitvi na dokazih temelječega dodeljevanja virov v slovenskem javnem zdravstvenem sistemu.

Za operacionalizacijo teh ciljev oblikujem štiri raziskovalna vprašanja, ki strukturirajo disertacijo in usmerjajo izbiro metod ter podatkov. Prvo raziskovalno vprašanje (RV) je:

RV1: Kakšno je trenutno stanje raziskav, povezanih z EV DHI in podrobneje s telemedicino, na svetovni ravni in v Sloveniji?

Pregled obstoječih raziskav o EV telemedicine in drugih DHI predstavlja temelj za nadaljnje analize. Ustrezne publikacije, povezane z EV DHI, kvantitativno proučim z bibliometričnimi metodami, katerih uporabnost so priznali številni avtorji za kartiranje hitro rastočih raziskovalnih področij, kot je digitalno zdravje (de las Heras-Pedrosa et al., 2022; dos Santos Silva et al., 2021; Sikandar et al., 2021; Uribe-Toril et al., 2021; Waqas et al., 2020; Zwack et al., 2024). Dos Santos Silva et al. (2021) so ugotovili omejene dokaze o stroškovni učinkovitosti pri novejših intervencijah, kot je telemedicina, Zwack et al. (2024) pa so opozorili, da EV DHI še niso ustrezno raziskovalno podprte. Na podlagi tega dela izvedem celovito bibliometrično analizo z uporabo več analitičnih orodij za poglobljeno proučevanje publikacij o EV DHI.

Bibliografske podatke o publikacijah pridobim iz zbirke Web of Science Core Collection (v nadaljevanju WoS CC), ki se v bibliometričnih raziskavah pogosto uporablja ter zaradi svoje obsežnosti in kakovosti podatkov velja za referenčno bazo (Pranckutė, 2021; Visser et al., 2021). Bibliometrična analiza preučuje: (1) delež raziskovalnih prispevkov, ki obravnavajo

ekonomsko upravičenost DHI v širši literaturi o digitalnem zdravju, ter njihovo spreminjanje skozi čas; (2) v kolikšni meri je pandemija covida-19 spodbudila raziskovalni interes za EV DHI; (3) vrste vrednotenih DHI s posebnim poudarkom na telemedicinskih intervencijah; (4) glavne bibliometrične značilnosti obstoječih študij; ter (5) ključna ekonomska in metodološka vprašanja, ki jih obravnava literatura. Ta analiza omogoča presojo, ali literatura predvsem izpostavlja pomanjkanje robustnih ekonomskih dokazov ali pa podaja izvedljiva priporočila za premagovanje ključnih izzivov pri EV DHI. Bibliometrično analizo na globalni ravni dopolnim z narativnim pregledom literature o raziskavah, povezanih z DHI v Sloveniji, saj so se telemedicinske in eHealth intervencije razširile zlasti med pandemijo covida 19.

Drugo raziskovalno vprašanje je:

RV2: Kateri so ključni izzivi pri izvajanju EV telemedicinskih intervencij? Ali so ti izzivi ustrezno obravnavani v obstoječih, čeprav redkih, smernicah za njihovo ekonomsko vrednotenje?

Kot je bilo obravnavano v pregledu raziskovalnega področja, obstoječe raziskave identificirajo več vsebinskih in metodoloških izzivov pri izvajanju EV DHI (Bergmo, 2015; Gomes et al., 2022; Husereau et al., 2014; Jankovic et al., 2021; Kolasa & Kozinski, 2020; McNamee et al., 2016; Michie et al., 2017; Snoswell et al., 2017). Nerešena vprašanja glede metodoloških izzivov, vidika analize in merjenja izidov se odraža v odsotnosti celovitih in prilagojenih smernic za EV DHI (npr. Ekeland et al., 2010; Gomes et al., 2022; Hall et al., 2015; Michie et al., 2017). Obstoječe smernice EV so večinoma zasnovane za farmacevtske izdelke in medicinske pripomočke, pri čemer običajno obravnavajo CUA kot referenčni standard ter se izvajajo z vidika plačnika (Sharma et al., 2021). Pregled obstoječih okvirov vrednotenja razkriva enajst smernic, ki so relevantne za DHI, vendar nobena ne zagotavlja podrobnega analitičnega okvira za vrednotenje ekonomskih izidov (Kolasa & Kozinski, 2020). Od teh se tri osredotočajo na telemedicino, štiri na mHealth, štiri pa so splošne. Slednja skupina vključuje smernice, ki jih je izdal britanski Nacionalni inštitut za odličnost v zdravstvu in oskrbi (v nadaljevanju NICE), ki glede na predviden namen intervencije priporočajo analizo vpliva na proračun, CUA in CCA (NICE, 2018).

Za sistematizacijo in kritično presojo teh izzivov izvedem narativni pregled literature. Poleg tega izvedem kvalitativno analizo intervjujev z deležniki, da bi zajela njihove zaznave o ustreznih stroških, koristih in ostalih učinkih ter izzivih. Kvalitativne raziskave so se izkazale za koristne pri prepoznavanju temeljnih metodoloških in praktičnih ovir za uporabo EV pri odločanju v zdravstvu, saj osvetljujejo procese, ki oblikujejo ekonomske dokaze, in pridobivajo poglede deležnikov o ustreznih ekonomskih izidih (Barnett et al., 2020; Dopp et al., 2019; Grove et al., 2019; van Dongen et al., 2013). Uporaba kvalitativnih dokazov je poudarjena tudi v smernicah NICE za vrednotenje DHI (NICE, 2018). Poleg tega se kvalitativni pristopi vse pogosteje priporočajo za zajemanje kompleksnosti telemedicinskih intervencij (Caffery et al., 2017; Skivington et al., 2021), kljub njihovi razmeroma omejeni

uporabi v zdravstveni ekonomiki (Coast & De Allegri, 2018; Dopp et al., 2019; Merlo et al., 2019).

Kvalitativna analiza podaja odgovore tudi na tretje raziskovalno vprašanje:

RV3: Kako je treba pristopiti k ekonomskim vrednotenjem telemedicinskih intervencij v primeru kroničnega srčnega popuščanja (HF)?

Telemedicinske intervencije so posebej relevantne za kronična stanja, pri katerih stalna uporaba zdravstvenih storitev ustvarja znatne neposredne in posredne stroške, vključno z izgubami produktivnosti (npr. Akiyama & Yoo, 2016; Forouzanfar et al., 2016; Von Huben et al., 2021). Kljub temu razpoložljivi dokazi o EV telemedicine pri kroničnih boleznih ostajajo omejeni (Ben-Assuli, 2022; Boodoo et al., 2020; Caillon et al., 2022; De Guzman et al., 2022; Frederix et al., 2019). Obstoječe študije se močno razlikujejo glede na vrsto intervencije, pristop k vrednotenju, časovni horizont, uporabljene podatke in stroškovne komponente. Stroški običajno vključujejo opremo, stroške implementacije in delovanja, usposabljanje ter čas osebja, medtem ko učinki vključujejo izboljšane klinične izide, kakovost življenja, zmanjšano umrljivost ter manjšo porabo zdravstvenih storitev, denimo manj obiskov na urgentnih oddelkih (v nadaljevanju ED) in manjše število hospitalizacij (De Guzman et al., 2022; Eze et al., 2020; Klersy et al., 2011; Snoswell, North, et al., 2020; Taylor et al., 2021).

Čeprav so bile telemedicinske intervencije za kronična stanja, kot je HF, v Sloveniji že uvedene (Rudel et al., 2017), njihovo širše uvajanje ostaja omejeno kljub dokazom o pozitivnih učinkih, ki vključujejo krajše čakalne dobe in manj hospitalizacij (Rant, 2021). Ovire vključujejo finančne omejitve, zastarelo infrastrukturo, institucionalno togost, pomisleke glede pravičnosti in varnosti podatkov ter odsotnost standardiziranih okvirov vrednotenja (Rant, 2021; Stanimirovic, 2015, 2021; Varnai et al., 2019; WHO, 2021a). Pandemija covida-19 je pospešila uvajanje DHI v Sloveniji, zlasti telekonzultacij in telemonitoringa; del teh storitev je v letih 2020 in 2021 financiral Zavod za zdravstveno zavarovanje Slovenije (v nadaljevanju ZZZS; Rant & Rudel, 2021). Nadaljnje financiranje pa ostaja pogojeno z robustno ekonomsko upravičenostjo.

Z uporabo orodja za pregled literature, podprtega s strojnim učenjem (van de Schoot et al., 2021), izvedem sistematičen pregled literature o telekonzultacijah za bolnike s HF, da opredelim metodološke značilnosti obstoječih EV. Priporočila, izpeljana iz literature, združim s spoznanji deležnikov, kar služi kot podlaga za oblikovanje kontekstualno občutljivega okvira vrednotenja. Kvalitativne ugotovitve uporabim tudi za informiranje nadaljnjega EV modela s kontekstualnimi informacijami, relevantnimi za odločanje v zdravstvu (Caffery et al., 2017; Coast & De Allegri, 2018; McGill et al., 2021; Skivington et al., 2021). Kvalitativne podatke pridobim z delno strukturiranimi intervjuji z namensko izbranimi deležniki (Palinkas et al., 2015), vključno z bolniki, kardiologi, predstavniki zdravstvenih organizacij ter strokovnjaki za digitalno zdravje in zdravstveno ekonomiko.

Vodič za intervjuje pripravim vnaprej, vključno s seznamom ključnih vprašanj in spodbud, ki so bile na podlagi literature prepoznane kot pomembne glede ključnih značilnosti in izzivov EV telemedicine. Intervjuje izvedem prek videokonference, kadar osebna srečanja niso izvedljiva; ta pristop se je v zdravstvenih raziskavah izkazal za učinkovitega zaradi delovne obremenjenosti in profesionalnih zavez udeležencev, kar prispeva k boljšemu odzivu (npr. Archibald et al., 2019). Intervjuje posnamem, transkribiram in analiziram z uporabo tematske analize in sistematične matrične analize za strukturiranje stališč deležnikov, ki sta primerni za opisovanje in interpretacijo specifičnih procesov ter za obravnavo vnaprej opredeljenih raziskovalnih vprašanj (Coast & De Allegri, 2018; Gale et al., 2013; Murray et al., 2019; J. Ritchie & Spencer, 1994).

To raziskovalno vprašanje se umešča na presečišče metodoloških smernic, empiričnih dokazov in kontekstualnih omejitev, značilnih za obravnavo kroničnega srčnega popuščanja (HF).

Četrto raziskovalno vprašanje je:

RV4: Ali je telemedicinska intervencija v obliki telekonzultacij za kronično srčno popuščanje (HF) v Sloveniji ekonomsko upravičena?

Za odgovor na to vprašanje izvedem statistično analizo in EE telekonzultacij za HF z uporabo administrativnih podatkov, pridobljenih od ZZZS (pogodba št. 1721-13/2021-DI/1, Priloga 1), ter na podlagi odobritve Komisije Republike Slovenije za medicinsko etiko (št. 0120-223/2021/4, Priloga 1). Analiza podatkov temelji na prispevkih deležnikov iz kvalitativne študije ter na metodoloških priporočilih in dokazih iz primerljivih intervencij v podobnih okoljih, kot so sintetizirani v prejšnjih poglavjih. Administrativni podatki ZZZS so podatki na ravni populacije, ki zajemajo bolnike s srčno-žilnimi boleznimi v obdobju 2015–2022; vključujejo demografske informacije, uporabo zdravstvenih storitev, izdatke ter izbrane kazalnike izidov, kot sta ponovna hospitalizacija in umrljivost. Administrativni podatki, pogosto imenovani »podatki iz resničnega sveta« (real-world data), se v zdravstveni ekonomiki vse pogosteje uporabljajo kot vir sistematično zbranih podatkov o stikih pacientov z zdravstvenimi izvajalci v zdravstvenem sistemu. To omogoča celovitejši zajem stroškov in porabe storitev, kot je običajno na voljo v podatkih iz kliničnih raziskav (Gansen, 2018; Hanna et al., 2019; Hazra et al., 2019; Lemmon et al., 2021; Pongiglione & Torbica, 2022). Vendar pa večina administrativnih zbirk vključuje predvsem neposredne stroške z vidika plačnika in informacije o uporabi zdravstvenih storitev, medtem ko primanjkuje podrobnih kliničnih kazalnikov, ki so običajno del zdravstvene dokumentacije.

Podatki o telekonzultacijah so na voljo za obdobje pandemije covida-19, od leta 2020 do 2022. Za identifikacijo bolnikov, ki so deležni telekonzultacije, in za povezovanje podatkovnih baz uporabim edinstveno identifikacijsko številko pacienta. Za oblikovanje primerljive kontrolne skupine bolnikov, ki prejemajo običajno oskrbo (obravnavo v ambulanti), se na podlagi opazovanih značilnosti bolnikov (npr. Cheng et al., 2019;

Pongiglione & Torbica, 2022) ocenijo mere nagnjenosti (v nadaljevanju PSM), kar se pogosto uporablja v zdravstvenih raziskavah z administrativnimi podatki (npr. Gansen, 2018). Ker administrativni podatki ne vsebujejo podrobnih kazalnikov klinične resnosti bolezni, le-to ocenjujem s približkom na podlagi preteklih vzorcev uporabe zdravstvenih storitev in ponovnih hospitalizacij. Uporabo zdravstvenih storitev in izide med obravnavano skupino (telekonzultacije) in kontrolno skupino (obravnava v ambulanti) primerjam z uporabo ustreznih statističnih testov, regresijskih modelov in analize preživetja, po vzoru primerljivih študij, ki uporabljajo administrativne podatke (npr. Chu et al., 2022; Howe et al., 2022; Jit & Cook, 2024; Severino et al., 2022; Tan et al., 2019; Tsang et al., 2021). V vseh empiričnih delih rezultate interpretiram previdno glede na omejitve podatkov, vključno z razpoložljivimi kontrolnimi spremenljivkami, omejitvami velikosti vzorca in časovnimi učinki, specifičnimi za pandemijo, kar je podrobneje obravnavano v sklopu omejitev disertacije in smernic za nadaljnje raziskave (npr. Jit & Cook, 2024).

Izbira CCA z vidika plačnika glede na razpoložljive podatke odraža tako razpoložljivost podatkov kot potrebo po pragmatičnem okviru vrednotenja, ki omogoča zajem več izidov (npr. Gansen, 2018; Lemmon et al., 2021). V disertaciji obravnavam tudi zahteve po podatkih za razširitev analize v širšo družbeno perspektivo, skupaj z omejitvami, povezanimi s trenutno nedostopnimi podatki. Te metodološke izbire odražajo realne omejitve pri ocenjevanju zdravstvenih tehnologij (v nadaljevanju HTA) in so sestavni del prispevka te disertacije. Na podlagi teh ugotovitev predlagam ustrezne pristope k vrednotenju telekonzultacij, hkrati pa jasno opredelim, katere podatke je treba zbirati ob implementaciji telemedicine. To bi omogočilo izboljšane EV tako v fazi *ex-ante* kot tudi *in medias re*, kar vodi h kontinuiranemu izboljševanju izvajanja zdravstvenih storitev.

Vsako raziskovalno vprašanje obravnavam v samostojnem poglavju, kar zagotavlja koherenten prehod od konceptualne analize (RV1) prek metodološkega razvoja (RV2 in RV3) do empiričnega in ekonomskega vrednotenja (RV4).

1.3 Prispevki disertacije

Ta disertacija prinaša tri medsebojno povezane prispevke na področju zdravstvene ekonomike in digitalnega zdravja. Prvič, s pregledom literature in bibliometrično analizo publikacij, povezanih z EV DHI, prispeva k preučevanju vpliva pandemije covida-19 na rast števila objav ter analizo ključnih bibliometričnih kazalnikov, kot so najvplivnejše revije, publikacije in ključne besede. Ta bibliometrični prispevek zagotavlja strukturiran empirični pregled obsega, razvoja in intelektualne strukture raziskav o EV DHI.

Drugič, disertacija metodološko prispeva s strukturirano sintezo dokazov o izzivih pri izvajanju EV DHI, kot so opredeljeni v literaturi, ter s kritično presojo, kako so ti izzivi obravnavani v obstoječih smernicah vrednotenja. S sintetiziranjem razpršenih dokazov in njihovo primerjavo s trenutnimi smernicami disertacija nadgrajuje razumevanje vztrajnih metodoloških vrzeli pri EV DHI, s posebnim poudarkom na telemedicinskih intervencijah.

Tretjič, disertacija empirično in integrativno prispeva z nadgradnjo EV telemedicinskih intervencij prek kombiniranega kvalitativnega in kvantitativnega pristopa. Natančneje, z uporabo administrativnih podatkov na ravni populacije ocenjuje ekonomsko upravičenost telekonzultacij za bolnike s HF v Sloveniji, s čimer ustvarja dokaze, specifične za lokalni kontekst, ki so neposredno relevantni za odločanje v zdravstvu. Hkrati v okvir EV sistematično vključuje perspektive deležnikov, s čimer prikazuje, kako lahko kvalitativna spoznanja dopolnjujejo kvantitativne analize pri presoji kompleksnih DHI.

Integracija bibliometrične analize, narativnega pregleda metodoloških izzivov pri EV DHI ter sistematičnega, kontekstualno specifičnega pregleda telekonzultacij za bolnike s HF, skupaj s kvalitativno analizo deležnikov in statistično analizo, povezano z EV specifične telemedicinske intervencije, predstavlja celovito in metodološko robustno raziskavo, ki krepi metodološko strogost EV telemedicine in drugih DHI ter relevantnost EV DHI za na dokazih temelječe odločanje o razporejanju virov v javnih zdravstvenih sistemih. S povezovanjem splošnih metodoloških spoznanj z dokazi, specifičnimi za HF in slovenski prostor, disertacija prispeva k bolj poglobljenemu razumevanju tega, kako načrtovati, interpretirati in uporabljati EV kompleksnih DHI v realnih zdravstvenih okoljih.

Poleg tega disertacija s praktičnimi priporočili za prihodnje zbiranje in analizo podatkov podpira razvoj trdnejših dokazov za EV ter prispeva h krepitvi zmogljivosti za na dokazih temelječe razporejanje virov v slovenskem javnem zdravstvenem sistemu. S prikazom uporabe CCA in priprave matrike vplivov (IIM) kot transparentnih in prilagodljivih orodij EV disertacija te pristope umešča kot posebej primerne za realne procese HTA in odločitve o povračilu stroškov, vključno z okolji, ki jih zaznamujejo omejitve podatkov in konkurenčne prednostne naloge politike. Disertacija je umeščena tudi v hitro razvijajoč se evropski javnopolitični kontekst, vključno z aktualnimi pobudami glede HTA na ravni Evropske unije (v nadaljevanju EU) in upravljanja digitalnega zdravja, kar dodatno potrjuje relevantnost transparentnih in prilagodljivih pristopov k EV, čeprav ti ostajajo zunaj empiričnega obsega pričujoče analize. Prispevek disertacije je tako hkrati teoretičen in praktičen, saj prispeva k premoščanju vrzeli med raziskavami na področju EV in dejanskim odločanjem v zdravstvu.

1.4 Struktura disertacije

Disertacija je sestavljena iz osmih poglavij. V 1. poglavju predstavim raziskovalno področje, opredelim namen raziskave, zastavim raziskovalna vprašanja in opišem celotno strukturo disertacije. V 2. poglavju podam pregled širšega raziskovalnega področja DHI, vključno s ključno terminologijo in njeno uporabo na podlagi bibliometrične analize, ter predstavim DHI, ki so na voljo v Sloveniji. V 3. poglavju podam pregled EV v zdravstvu in izvedem bibliometrično analizo obstoječe literature za oceno trenutnega stanja raziskav na področju EV DHI. Poleg tega proučim metodološke izzive, s katerimi se soočajo EV DHI, ter pregledam nedavne metodološke predloge in smernice za reševanje teh izzivov. V 4. poglavju predstavim HF kot obravnavano klinično stanje raziskave zaradi njegove

relevantnosti za telekonzultacije v Sloveniji. Podam narativni pregled raziskav s področja telemedicine in izvedem sistematični pregled literature, posebej osredotočen na telekonzultacije za bolnike s HF. V 5. poglavju predstavim kvalitativno analizo intervjujev z ustreznimi deležniki, vključenimi v DHI, s posebnim poudarkom na telekonzultacijah za bolnike s HF. V 6. poglavju predstavim empirično analizo, v okviru katere izvedem več statističnih analiz z uporabo administrativnih podatkov o telekonzultacijah za bolnike s HF, uvedenih med pandemijo covida-19 v Sloveniji. V 7. poglavju izvedem analizo stroškov in posledic (CCA) telekonzultacij za HF, pri čemer s pomočjo matrike vplivov sintetiziram dokaze iz predhodnih poglavij. V 8. poglavju povzamem glavne ugotovitve, razpravljam o njihovih implikacijah, obravnavam omejitve raziskave in predstavim splošne zaključke disertacije.

Appendix 2: Supplementary overview of digital health projects in Slovenia (2022–2027)

This appendix provides an overview of selected digital health–related projects implemented or planned in Slovenia as part of the national digitalisation strategy for healthcare (2022–2027), including projects funded through the Recovery and Resilience Plan (Ministry of Health, 2022; 2025). The examples listed here complement the condensed overview presented in Subchapter 2.3. These examples do not constitute an exhaustive inventory but rather illustrate the breadth of ongoing investments and reforms. The projects summarised below are grouped according to their primary function:

1. DHI
    a. Remote health and telemedicine (provision of remote services between patients and healthcare professionals, in progress).
2. Digital tools and platforms
    a. Central Picture Archiving and Communication System (a centralised system for storing radiological images, in progress);
    b. eKarton and the unified data model (patient history and data as the basis for the overall digital transformation and provision of the necessary infrastructure for long-term storage of health data, in progress);
    c. Electronic Temperature Therapy Sheet (clinical information system for monitoring a patient's vital signs, which is used to monitor, implement and control the prescription and administration of medication, in preparation).
3. Data infrastructure and interoperability
    a. Healthcare Data Management System (establishing a system for managing strategic data resources in the healthcare system and consolidation of data for efficient decision-making, in progress);
    b. Certification of solutions for the use of eHealth (certification of local ICT measures in the healthcare sector for connection to eHealth and the EHDS, in preparation);

c. Speech recognition for doctors in primary healthcare (enables more efficient recording of medical documentation, in preparation);
d. Robotic preparation, storage and dispensing of pharmaceuticals (pharmacy robot system that transports pharmaceuticals to and from the warehouse, in preparation).

4. Policy and operational transformation
    a. Supporting the digital transformation of healthcare (securing an interdisciplinary team of experts, in progress);
    b. Transition to paperless operations for healthcare providers (simple exchange of data and documents in the healthcare sector, in progress);
    c. Procurement of additional equipment for digital transformation from contractors (upgrade and customisation of existing information systems for standardised data capture and networking, in preparation);
    d. Information system for healthcare dispatchers (new comprehensive information system for the needs of healthcare and emergency medicine, in progress).

Appendix 3: Classification of cardiovascular and non-cardiovascular comorbidities in heart failure

This appendix provides the detailed classification of cardiovascular and non-cardiovascular comorbidities used in the empirical analyses presented in Chapter 6. Comorbidities were identified using ICD-10-AM, version 6, which has been officially adopted in Slovenia. The classifications are standard clinical groupings developed for diagnostic and treatment purposes; in this dissertation, I use them analytically to characterise patient complexity and disease burden observable in routine healthcare data. The categorisation was informed by the 2021 European Society of Cardiology Guidelines for the Diagnosis and Management of Acute and Chronic Heart Failure (McDonagh et al., 2021), which I reviewed with a specialised cardiologist to ensure clinical validity.

The cardiovascular comorbidities are categorised into six groups (with one diagnosis listed separately due to its significance as suggested by a specialised cardiologist):

- Arrhythmias and conduction disturbances: Ventricular arrhythmias, Symptomatic bradycardia, pauses and atrioventricular block (I44–I47, I49),
- Atrial fibrillation & atrial flutter (I48),
- Chronic coronary syndromes (I20–I25),
- Valvular heart disease: Aortic stenosis, Aortic regurgitation, Mitral regurgitation, Tricuspid regurgitation (I05–I08, I34–I39),
- Hypertension (I10–I13, I15), and
- Stroke (I63–I64).

Non-cardiovascular comorbidities were categorised into 14 groups:

- Diabetes (E10–E14),
- Thyroid disorders (E00–E07),
- Obesity (E66),
- Frailty, cachexia, sarcopenia (R54, R64, M62.84),
- Iron deficiency, anaemia (D50–D64, E61.1),
- Kidney dysfunction (N17–N19),
- Electrolyte disorders: hypokalaemia, hyperkalaemia, hyponatraemia, hypochloraemia (E87.1, E87.5, E87.6, E87.8),
- Lung disease, sleep disorders, COPD (J18, J40, J44–J45, J84, G47, G47.1, G47.3),
- Hyperlipidaemia (E78),
- Gout, arthritis (E79.0, M05–M06, M10, M13),
- Erectile dysfunction (N48.4),
- Depression (F32, F33, F41.2, F92.0),
- Cancer (C), and
- Infection: bacterial, viral, parasitic, respiratory, etc. (A00–B99, J10–J18, L00–L08, U07, N39.0).

Appendix 4: Overview of analytical variables

This appendix provides a structured overview of the principal variables extracted and constructed for the empirical analysis presented in Chapter 6. The list focuses on the key demographic, clinical, utilisation, expenditure, pharmaceutical and contextual variables used in the modelling framework. It is not an exhaustive data dictionary but rather documents the main operational definitions and categories underlying the analytical dataset, to enhance transparency and reproducibility.

The analytical dataset includes indicator variables, counts, totals and composite measures, which are organised as follows:

1. Demographic variables
    a. Age at treatment,
    b. Gender,
    c. Municipality of residence,
        i. Municipality-level average monthly income (per 1000 inhabitants), and
        ii. Municipal development index,
2. Health status variables
    a. Primary diagnosis during hospitalisation,
    b. Secondary diagnoses during hospitalisation, including:
        i. Cardiovascular comorbidities, and
        ii. Non-cardiovascular comorbidities,
    c. Total comorbidity count,

    d. Hospitalisation severity score,
3. Hospital utilisation variables
    a. Unique hospitalisation ID,
    b. Admission date,
    c. Discharge date,
    d. Length of stay,
    e. Total number of hospitalisations in the pre-treatment and post-treatment period,
    f. Number of procedures performed during hospitalisation,
    g. Number of secondary diagnoses recorded during hospitalisation, and
    h. Total hospitalisation expenditure,
4. ED variables
    a. Visit date,
    b. Number of procedures performed during visit,
    c. Total ED visits in the pre-treatment and post-treatment period, and
    d. ED expenditure,
5. Outpatient specialist variables
    a. Visit date,
    b. Service type and subtype,
    c. Number of procedures,
    d. Total specialist visits in the pre-treatment and post-treatment period, and
    e. Specialist visit expenditure,
6. Prescription utilisation per patient
    a. Prescription date,
    b. ATC code,
    c. Pharmaceutical group,
    d. Prescription expenditure,
    e. Number of pharmaceutical groups,
7. Contextual variables
    a. Daily COVID-19 Stringency Index (Slovenia).

Appendix 5: Qualitative study materials

This appendix presents the materials used in the qualitative component of the dissertation, including the recruitment email, participant information sheet and consent form, and the semi-structured interview guide. These materials support the stakeholder framework analysis presented in Chapter 5. All interviews were conducted following ethical procedures. Participants were informed about the purpose of the research, data protection measures, voluntary participation, and their right to withdraw at any time. Names were collected for administrative purposes only and were removed during transcription and anonymisation. All reported findings in Chapter 5 are based on coded and anonymised data.

Appendix 5.1: Recruitment Email

Subject: *Invitation to participate in research related to telemedicine for heart failure patients*

I would like to invite you to participate in a research study on telemedicine interventions for patients with heart failure. The study forms part of the doctoral dissertation entitled "Advancing economic evaluation of telemedicine to strengthen evidence-based resource allocation in heart failure care in Slovenia."

The motivation for this research arises from the increased use of telemedicine interventions, particularly teleconsultations, during the COVID-19 pandemic. The aim of the study is to investigate the perceived costs and benefits of such interventions, as well as the challenges and potential associated with their implementation, in order to better understand telemedicine from the perspective of relevant stakeholders. The results may contribute to discussions regarding reimbursement and further adoption of teleconsultation and related telemedicine interventions.

If you agree to participate, you will be invited to take part in an interview conducted via video conference. No preparation is required. The interview questions will be provided in advance, and the interview will last no longer than 45 minutes. After reading and signing the informed consent form, you will be asked to propose a suitable date and time.

This study is supervised by Prof. Dr. Petra Došenović Bonča. If you require further information, please contact me at: antonija.srok@efri.hr. Thank you for considering participation in this research.

Appendix 5.2: Participant information sheet and consent form

PART I: INFORMATION SHEET

Introduction: Thank you for considering participation in this research. It is important that you understand why the study is being conducted and what your participation entails. Please read the following information carefully. If anything is unclear or you require additional information, you are encouraged to ask questions. Please take sufficient time to decide whether you wish to participate.

Purpose of the research: This study aims to examine the methodological challenges of economic evaluation of telemedicine interventions for patients with heart failure and to identify relevant data for such evaluations, including associated costs and perceived benefits. The results will be used to develop recommendations for improving economic evaluation in order to better inform healthcare decision-making, including reimbursement and adoption decisions. The study seeks to explore stakeholders' views regarding what should be included in economic evaluation of telemedicine interventions.

Type of research and expected duration: Participation involves a single interview lasting up to 45 minutes.

Participant selection: You have been invited because you are involved in managing, using, or working with telemedicine interventions for patients with heart failure.

Voluntary participation: Participation is entirely voluntary. You may withdraw at any time without providing a reason.

Procedures: If you agree to participate, you will complete a brief questionnaire and take part in a video interview (e.g., via Zoom or Google Meet) at a time convenient to you. If you prefer not to answer a particular question, you may decline and proceed to the next question. No one will be present during the interview except the researcher, unless you request otherwise.

Risks and benefits: Participation does not involve any anticipated risks. While there is no direct personal benefit, your contribution will support improved understanding of teleconsultation costs, benefits, and implementation challenges. The findings may help inform future economic evaluations and healthcare decision-making.

Reimbursement: No financial incentive is provided for participation.

Confidentiality: All interview data will be treated confidentially. Participants will be assigned identification codes rather than names. Data will be stored in password-protected files. Interviews will be recorded with permission and destroyed after transcription. Transcription will occur within one month of the interview. Transcripts will be deleted after completion of the study. No identifying information will be shared outside the research team. Published results will not include participant names.

Sharing the results: Results may be published in academic journals and presented at scientific conferences. Participants will remain anonymous.

Right to refuse or withdraw: You may withdraw from the study at any time. You may also request deletion of any part of your interview data. You are not required to answer any question you do not wish to answer.

Contact information: For further information, please contact Antonija Srok, PhD candidate, at: antonija.srok@efri.hr.

PART II: CERTIFICATE OF CONSENT

I have read and understood the information provided. I have had the opportunity to ask questions and have received satisfactory answers. I voluntarily agree to participate in this study.

Name of participant: _____ Signature: _____ Date: _____

Statement by the Researcher:

I confirm that I have provided the participant with the information sheet and ensured that they understand the research procedures. I confirm that participation is voluntary and that informed consent has been obtained.

Name of researcher: _____ Signature: _____ Date: _____

Appendix 5.3 Semi-structured interview guide

This interview guide was used to structure stakeholder interviews. The guide includes thematic sections with prompts to ensure consistency across interviews while allowing flexibility for follow-up questions.

All participants were informed about confidentiality and recording procedures prior to commencement.

INTRODUCTION

Aim of the research and the goal of the interview: This research focuses on telemedicine interventions, particularly teleconsultations, for patients with heart failure. Stakeholders are patients and health professionals who use or are familiar with teleconsultations. The aim of the interview is to gain an understanding of the different experiences of stakeholders in relation to teleconsultations. I am interested in the key values associated with teleconsultations, such as costs and benefits to stakeholders. In addition, I am interested in the use in practice and the perceived challenges and potential of teleconsultations. A particular focus of this research is on possible recommendations for the economic evaluation of teleconsultations and how to demonstrate their cost-effectiveness.

Use of data, recordings and confidentiality: The information about each participant is confidential and the participants will be coded according to their function in the organisation, therefore, the data used for research will be anonymous. The videoconference (or face-to-face interview) is recorded. After the transcription of the recordings and the publication of the research results related to the analysis, the recordings will be destroyed.

Ask for permission to record. If the interviewee refuses, take written notes. Before we begin, I want to make sure that you have read and signed the consent form? Do you have any questions?

STRUCTURED TOPICS WITH QUESTIONS AND PROMPTS

Sociodemographic and introductory questions:

We will start with a brief introduction of you as a participant. How old are you? What is your current level of education? What is your profession? How long have you been working in healthcare?

I would like to hear more about your experience with teleconsultations. Teleconsultations are a subset of telemedicine that refers to medical consultations between physicians (clinicians) or physicians (clinicians) and patients using ICT (telephone, video call, etc.) for the purpose of diagnostic or therapeutic consultation. What is your attitude toward telemedicine interventions in general? What is your attitude toward teleconsultations in particular?

Choice of comparator: Which face-to-face health services can be supported by teleconsultations? Which face-to-face health services can be completely replaced by teleconsultations?

Choice of benefits: I would like to discuss in more detail the various benefits of using teleconsultations instead of face-to-face consultations. I am interested in the benefits from the perspective of different stakeholders, such as patients and physicians or clinicians, but also in the benefits that the use of teleconsultations bring to the hospital and the health payer or health insurance.

What are, in your opinion, the main benefits of using teleconsultations for different stakeholders? From a health professional's perspective, can you think of other benefits of teleconsultation? Can you think of other benefits of teleconsultation when you consider the patient's perspective? What are the health benefits of teleconsultation from the patient's perspective? What are the non-health benefits of teleconsultation from the patient's perspective? Do you think teleconsultation may be of greater benefit to a particular patient population? What are the benefits at the organizational (hospital) level of using teleconsultations instead of face-to-face consultations? How does the use of teleconsultations affect the efficiency of a hospital? Can you think of any benefits to the healthcare payer? What data do you think should be collected to demonstrate the benefits of teleconsultation? Are some of the relevant data collected in hospital records or by the health insurance company? What outcomes would you consider when demonstrating the benefits of teleconsultation? How would you collect the data that are not collected in hospital records or by health insurance?

Cost savings are often discussed as one of the main benefits of teleconsultations instead of face-to-face consultations. I would like to focus more on how exactly teleconsultations reduce costs for different stakeholders. What are the main cost savings you would like to point out when using teleconsultations instead of face-to-face consultations? What outcomes would you consider when demonstrating demonstrate the cost savings of teleconsultation? From a health professional's perspective, can you think of other cost savings from using teleconsultations? Can you think of other cost savings from teleconsultations when you

consider the patient's perspective? Could teleconsultations be more cost saving for a particular patient population? Can you think of any cost savings at the organizational (hospital) level that could be achieved by switching some face-to-face consultations to teleconsultations? Can you think of any cost savings for the healthcare payer? What data do you think should be collected to demonstrate the cost savings of teleconsultations? Are some of the relevant data collected in hospital records or by the health insurance company? How would you collect the data that are not collected in hospital records or by health insurance?

Choice of costs: Telemedicine interventions are associated with several benefits and cost savings, but for some, also with high implementation costs. I would like to know more about the cost of implementing and using teleconsultations. What do you think are the most important costs associated with teleconsultations from the perspective of the different stakeholders? From the perspective of health professionals, what are the costs associated with the implementation and use of teleconsultation? From the patients' perspective, what are the costs associated with the implementation and use of teleconsultation? From the perspective of the organization (hospital), what costs are associated with the implementation and use of teleconsultation? Can you think of any costs to the healthcare payer associated with the implementation and use of teleconsultations compared to usual care? What data do you think should be collected to capture the costs of implementing and using teleconsultations? Are some of the relevant data collected in hospital records or by the health insurance? How would you collect the data that are not collected in hospital records or by the health insurance?

Time frame: What do you think would be an appropriate time period for monitoring teleconsultations to capture all relevant effects of the intervention (such as costs and benefits)?

Challenges: Telemedicine research is on the rise, especially since the widespread use of telemedicine interventions during the COVID -19 pandemic. A common theme in research is the challenges of implementing and using telemedicine interventions. What are, in your opinion, the challenges to implementing and using teleconsultation, from the previously considered perspectives (patient, healthcare professional, organization, healthcare payer)? Can you think of any other shortcomings or limitations of teleconsultations? Are there any risks associated with teleconsultations? Are there any uncertainties associated with teleconsultations? What might motivate wider use of teleconsultations?

Economic evaluations: Economic evaluations (such as CBA or CEA compare the costs and benefits of healthcare interventions. They are used to provide evidence for health care decision making and government reimbursement, and to attract investment and funding. However, a particular problem in the telemedicine literature is the small number and low quality of economic evaluation studies.

What do you think are the challenges related to the economic evaluation of telemedicine interventions? Are there other reasons for the small number of research on economic evaluation? Are there other reasons for the low quality of economic evidence? What might motivate economic evidence research related to telemedicine interventions? What resources and which data would you consider necessary to begin research on the economic evaluation of telemedicine interventions? Are there challenges related to telemedicine research in general that you would like to highlight?

Concluding remarks and open dialogue with participant: How do you see the future of telemedicine and teleconsultations? Do you have anything further to add?

Thank you very much for your time and for your participation in the research.

Appendix 6: Supplementary tables

Table A.1: Active Substance Name and Anatomical Therapeutic Chemical level 5

Active Substance Name	LEVEL 5	Active Substance Name	LEVEL 5
LEVEL 2: C07 BETA BLOCKING AGENTS			
bisoprolol	C07AB07	propranolol	C07AA05
nebivolol	C07AB12	atenolol	C07AB03
nebivolol and thiazides	C07BB12	bisoprolol, combination	C07AB57
carvedilol	C07AG02	bisoprolol and acetylsalicylate acid	C07FX04
metoprolol	C07AB02	bisoprolol and perindopril	C09BX02
Bisoprolol and thiazides	C07BB07		
LEVEL 2: C09 AGENTS ACTING ON THE RENIN-ANGIOTENSIN SYSTEM			
perindopril, amlodipine and indapamide	C09BX01	enalapril	C09AA02
perindopril	C09AA04	candesartan	C09CA06
losartan and diuretics	C09DA01	telmisartan and amlodipine	C09DB04
losartan	C09CA01	telmisartan and diuretics	C09DA07
perindopril and diuretics	C09BA04	enalapril and lercanidipine	C09BB02
fosinopril	C09AA09	trandolapril	C09AA10
ramipril	C09AA05	valsartan, amlodipine and hydrochlorothiazide	C09DX01
zofenopril	C09AA15	zofenopril and diuretics	C09BA15
telmisartan	C09CA07	ramipril and diuretics	C09BA05
valsartan and diuretics	C09DA03	candesartan and diuretics	C09DA06
bisoprolol and perindopril	C09BX02	ramipril and amlodipine	C09BB07
lisinopril	C09AA03	captopril	C09AA01
perindopril and amlodipine	C09BB04	trandolapril and verapamil	C09BB10
valsartan and sacubitril	C09DB04	irbesartan	C09CA04
valsartan	C09CA03	irbesartan and diuretics	C09DA04
lisinopril and diuretics	C09BA03	valsartan and amlodipine	C09DB01
enalapril and diuretics	C09BA02	candesartan and amlodipine	C09DB07
		fosinopril and diuretics	C09BA09
LEVEL 4: A10BX		**LEVEL 3: A10B**	
spironolactone	C03DA01	empagliflozin	A10BX12
eplerenone	C03DA04	dapagliflozin	A10BX09

Note: I operationalise pharmaceutical groups in the empirical analysis using ATC codes as follows: beta-blockers (C07); agents acting on the renin–angiotensin system (C09*), including ACE inhibitors (C09AA*), angiotensin II receptor blockers (C09CA*), and relevant combination products (including ARNI); MRA (C03DA*); SGLT2 inhibitors (A10BK*); and diuretics (C03*).*

Source: ATC-DDD Toolkit, WHO (2025)

Table A.2: Themes and subthemes

Theme	Subtheme	Code
Health related clinical outcomes	Clinical events and disease progression	Mortality
		Complications (Morbidity)
		Chronic condition management
	Management effectiveness	Treatment adherence
		Health status control
		Diagnostic accuracy
		Timeliness & continuity of care
	Patient safety and risk reduction	Adverse events avoided
Healthcare utilisation outcomes	Hospital utilisation	Hospital admissions/readmissions
		Length of stay
		In-hospital diagnostics/procedures
		Avoidable hospitalisations
	Emergency department utilisation	ED visits
		Avoidable ED use
	Outpatient and community care	Outpatient visits
		Referrals, diagnostics
	Service continuity in healthcare utilisation	Time to follow-up
		Appointment adherence
	Medication use	Pharmaceutical prescriptions
Patient centred outcomes and behaviours	User experience	Satisfaction
		Convenience & comfort
		Emotional impact (e.g., anxiety reduction)
		Empowerment & self-efficacy
		Acceptance and engagement
	Adherence to care	Medication adherence
		Follow-up and appointment adherence
		Continuation with care plans
	Self-management care continuity and access	Access to timely follow-up
		Understanding and monitoring
		Perceived care continuity
Societal and equity outcomes	Improved spatial equity in care delivery	Improved access for rural/underserved populations
		Support for aging or disabled populations
		Disparity reduction across income, age, or ability
	Population-level benefits	Community-level impact from reduced healthcare utilisation
		Scalability for public health programs
	Environmental impact	Environmental sustainability
Organisational and technical outcomes	Workforce efficiency and workflow improvements	Flexible care delivery and task delegation
		Reduced administrative workload
		Improved provider productivity and scheduling
		Optimised space, time, and budget use
	Adoption and changes in daily practice	Provider adoption and usability
		Supportive organizational environment
	Technical integration and usability	EHR and system interoperability
Economic and financial costs	Direct healthcare costs	Staff time (physician, nurse, specialist)
		Cost of consultation
		Hospitalisation and inpatient care
		Outpatient services and diagnostics
		Medication costs
	Implementation & maintenance costs	ICT infrastructure (hardware, software, system integration)
		IT support and technical staff
		Training (staff/user onboarding)
		Cybersecurity and data protection
		Ongoing tech costs (licenses, updates, storage)
		Evaluation and quality assurance
	Direct non-healthcare costs (patient & caregiver)	Travel and transport
		Meals and incidental costs
		Childcare or eldercare during visits

To be continued

Table A.2: Themes and subthemes (cont.)

Theme	Subtheme	Code
Economic and financial costs	Direct non-healthcare costs (patient & caregiver)	Lost caregiver time
	Indirect costs	Absenteeism
		Presenteeism
		Lost caregiver productivity
		Long-term disability impact
		Lost future income due to premature death
Methodological aspects in economic evaluation	Perspective	Societal
		Healthcare payer
	Time horizon	Sufficiently long to capture downstream effects
	Comparator	Usual care
		Teleconsultation as hybrid or triage
	Data sources & data quality	Administrative data, EHR, insurance claims
		Standardised, complete, and valid
		Sufficient duration and stability
		Aligned systems and platforms
Challenges and risks	Adoption and uptake risks	Resistance or lack of organisational change
		Digital literacy and digital divide
	Legal and regulatory barriers	Regulatory uncertainty and compliance barriers
	Technical risks	Technology failure, trust and privacy concerns
	Incentive structure and mandates	Lack of reimbursement and economic evaluation mandates

Source: Author's work

Table A.3: Framework analysis matrix

	Health-related clinical outcomes	**Healthcare utilisation outcomes**	**Patient-centred outcomes and behaviours**	**Societal and equity outcomes**	**Organisational and technical outcomes**	**Economic and financial costs**	**Methodological aspects in economic evaluation**	**Challenges and risks**
Patient 1	Teleconsultations are good for routine follow-ups and chronic disease management, but not for new and acute conditions	Shorter waiting time for specialist consultation, good for chronic medication prescription	More comfortable access to health services, good tool to search for a second opinion	Better access to healthcare for the disabled and rural and isolated populations	Doctors can see more patients per day through teleconsultations than with in-person visits	Minimal costs for patients since most have access to Internet. High cost for implementation for hospitals. High level of maintenance needed		Older doctors aren't keen in implementing new methods. Digital literacy of older population is a challenge.
Patient 2	Good for specific situations. Uncertain about diagnostic accuracy	Saves time for patients and doctors for routine pharmaceutical prescription	Would be less anxious if had easier access to doctor or nurse	Better access for the disabled	Easier and faster for both medical professionals and patients	Reduced travel costs for patients. Cost of new devices and education of staff and patients	Data collection from patients through questionnaires	Data security concerns
Patient 3	Would use for regular follow-ups but if new symptoms emerge would go in person	Uses regularly for chronic medication prescription and referrals	Easier access to doctors advice. Feels safer.	Better access for the disabled and elderly	Increased efficiency of hospitals and outpatient clinics	Reduced travel costs, no food and drink costs, telecommunication services costs for patients	Data collection from patients through questionnaires	Data security concerns. Low digital literacy of the elderly.
Patient 4	Doesn't see any positives. General dislike of technology	Can order medication on-line but still needs to collect them in person, so doesn't see the point	Feels safer going in person	Can be useful for the disabled	Don’t need to carry a lot of papers when seeing different doctors since its available through the system	Less work hours lost for the working population. Reduced travel costs.	-	Personal resistance to implementation of digital technologies. High level of cybersecurity needed
Patient 5	Prefers in person consultations. Doesn't see positives of telemedicine	Can see the positives of ordering chronic medications on-line but still prefers going in person	Reduced waiting times, less time lost on consultations	Can be useful for the disabled and geographically isolated populations	Increased workload for health professionals	Need for education and constant IT support for the elderly		Personal resistance to use of teleconsultations. Sees going to the doctor as part of social life. Cybersecurity concerns.

To be continued

Table A.3: Framework analysis matrix (cont.)

	Health-related clinical outcomes	**Healthcare utilisation outcomes**	**Patient-centred outcomes and behaviours**	**Societal and equity outcomes**	**Organisational and technical outcomes**	**Economic and financial costs**	**Methodological aspects in economic evaluation**	**Challenges and risks**
Cardio 1	Teleconsultations can be used for HF patients with stable condition	Can lead to better disease monitoring and fewer hospitalisations. Specialist available through teleconsultations can lead to fewer ED visits. Shorter waiting times	Reduced anxiety in patients with more available doctors. Better disease monitoring. Increased adherence to treatment	Better access to healthcare for isolated populations (islands)	Doctors can see more patients through teleconsultations. Time saved on teleconsultations can be used for other procedures	Cost of devices is lower than hospitalisation costs for complicated patients which was preventable through telemedicine. Reduced travel costs for patients. High level of maintenance needed	Lack of data standardization and absence of large databases	Necessity of proper guidelines. Different levels of equipment in healthcare institutions
Cardio 2	Good for chronic condition monitoring and treatment adherence monitoring	Can be used for consultations prior to ED visits thus reducing the number of patients	Use of remote patient monitoring devices can lead to better disease management	Easier access for rural population	Higher patient turnover. Time for teleconsultations needs to be scheduled	Doesn't care how much money is spent as long as the patient is getting better. Reduced travel costs of patients. Patients don’t need to miss work	Need for financial incentives to take on extra workload with teleconsultations	Need for systemic implementation and guidelines
Cardio 3	Good for follow-ups of chronic conditions. Can react to new symptoms sooner. Some adverse effects can be avoided (infectious disease transmission)	Could lead to better disease control, less hospitalisations and shorter length of stay	Better QOL for both patients and caregivers/family members. Reduced waiting times	Better for the disabled. Transportation services can then be used for others	Teleconsultations would reduce the number of people coming in person	Reduced travel costs, less time lost for caregivers. Cost of implementation and education. Cost of telecommunication services for patients	Evaluation time between 1 and 5 years. Data collection from patients through questionnaires	Good level of digital literacy needed
Cardio 4	Too wide implementation of teleconsultations would lower the quality of care. You can never assess patient status correctly via teleconsultations	Teleconsultations can shorten the reaction time a thus avoid unnecessary ED visits.	Better access to care for patients. Patients would feel safer if they could seek doctors advice more often through teleconsultations	Better and more comfortable access to care for the disabled	Shorter waiting times. Less staff needed for teleconsultations	Reduced travel costs. No need for specialists in every hospital. High cost of initial implementation. Need for good quality software specialized for teleconsultations	Comparing hospitals with and without outsourced specialists. Measuring length of stay in hospitals	Need for legal framework and professional guidelines

To be continued

Table A.3: Framework analysis matrix (cont.)

	Health-related clinical outcomes	**Healthcare utilisation outcomes**	**Patient-centred outcomes and behaviours**	**Societal and equity outcomes**	**Organisational and technical outcomes**	**Economic and financial costs**	**Methodological aspects in economic evaluation**	**Challenges and risks**
Econ 1	Good for chronic conditions and straightforward cases. You can't diagnose everything. Telemedicine is not a substitute for standard care	Doctors in rural areas could consult specialists before using emergency transport	Patients would feel safer if they could call a doctor	Easier access to care for rural, island population and the disabled	Less time spent on consultations for both patients and doctors. Less administration	Less missed work hours for patients. Need for education. Most patients have smartphones through which can perform teleconsultations	Longer the evaluation time the better, at least 1 year. Need to monitor both health outcomes and non-health related outcomes (i.e., financial, QOL, etc)	People are generally resistant to change. Privacy and data security concerns
Econ 2	Good for chronic condition management and administrative work	Less unnecessary visits, for example patients visiting doctors for social reasons	There is an initial fear from teleconsultations in both doctors and patients, but with time it will pass	Good for rural populations	Decreased workload and better organization of working hours. Data standardization between institutions is lacking	Additional technical support and maintenance. Education needed. Reduced travel costs	Minimal evaluation time of 3 years. Data needs to be standardized. EU funds can be used	Cybersecurity concerns. Levels of digital literacy in the elderly
Econ 3	1st appointment should be in person. Reduced risk of spreading infectious diseases	Chronic medication prescription and regular referrals should be done through teleconsultations	Psychological and behavioural benefits for patients	In rural areas there should be telemedicine centres with necessary equipment and IT support staff	Doctors are more efficient with teleconsultations and time saved can be used for other services. Need for more administrative workers in healthcare	15 minutes online compared to a part day lost for a consultation. Implementation, software and education costs	Wider cooperation between healthcare professionals and economists is needed. Low quality of data collected. No standardization of data	Resistance to change. Cybersecurity concerns. Digital literacy concerns.
DHE 1	Uncertainty of diagnosis made through telemedicine	What is the cost compared to one saved life, if care was delivered in time	Shorter wait times for appointments. Better condition monitoring through RPM devices	Better access for isolated populations and for the disabled	Complex system of authentication, requires a single sign-on system	Costs of devices for patients are extremely low compared to infrastructure and software implementation costs. Cybersecurity cost for such high-risk systems are high	Data collected can be used to quantify efficiency. Large amount of data can be collected.	Required investments in cybersecurity. Requires redundant system in case of failure

To be continued

Table A.3: Framework analysis matrix (cont.)

	Health-related clinical outcomes	**Healthcare utilisation outcomes**	**Patient-centred outcomes and behaviours**	**Societal and equity outcomes**	**Organisational and technical outcomes**	**Economic and financial costs**	**Methodological aspects in economic evaluation**	**Challenges and risks**
DHE 2	Reduced diagnostic accuracy. All chronic conditions can be managed with teleconsultations. A „triage“ of non-emergency cases and set up appointments with specialists accordingly can lead to benefits	For more concerned patients teleconsultations would be useful to avoid unnecessary ED visit	Satisfaction of doctors and patients is needed. There are always resistance at the beginning of using a new service	Can increase disparity (digitally literate patients with resources), potentially excluding people of lower socio-economic status	Allows for „digital nomad“ lifestyle for doctors. Easier organization of workday for doctors	Health insurance companies could adjust policies with teleconsultation use. High cost of IT	People's heath movement as potential source of data. Efficiency control with collected data	Security breaches and system failures. Need for legal framework – data governance act
DHE 3	All health services can eventually be replaced by telemedicine. Better diagnostic accuracy since you have access to experts in the field regardless of where you live. Shortens the diagnostic process	Possibility of triage in the field and asses who needs to go to the ED. Monitored patients are more adherent to therapy and doctors don't waste time looking at patients with good health stats since the system alerts them only to the bad ones	Reduced stress in patients. Better adherence of patients. Constant need for travel comes with risks – road accidents	Higher availability leads to more regularity. Reduced pollution in cities – most traffic is around healthcare institutions	Can see more patients per day. Devices can be utilised 24/7 while the doctor reads results at a different location. Soon there will be integration AI and digital health	Potential for reducing healthcare costs without reducing the quality of care. Costs of telemedicine interventions are 30% of standard in person costs. High cost for device and software implementation. Savings in miscellaneous items like paper, ink, waste	Comparing institution with and without telemedicine - measure productivity, costs and health outcomes. In telemedicine systems doctors are paid per consultation made – better motivation. Potential to collect large quantities of high quality data	Systemic resistance to new technologies. Most of the population is sufficiently digitally literate. Need for guidelines and legal framework
DHE 4	Better adherence. Sooner reaction with monitoring devices to avoid serious complications. Good for chronic condition management	Reduced ED use. 65% decrease in time to follow-up. Lower no-show rates.	Access to care from the safety of home. Higher appointment adherence. Patients more engaged in monitoring their health	Better access to care for rural and isolated populations	When a critical mass is reached, doctors can see more patients per day. With RPM devices doctors don't waste time on patients with good lab values	Cost of devices and training. Patients don't need to miss work. With better monitoring avoiding complications and avoidable hospitalisations. Reduced travel costs.	Almost 95% of patients coming to follow-ups are unnecessary with no change in treatment. Need for standardization of data. Need for better pay for IT specialists in hospitals.	Systemic resistance to change

To be continued

Table A.3: Framework analysis matrix (cont.)

	Health-related clinical outcomes	**Healthcare utilisation outcomes**	**Patient-centred outcomes and behaviours**	**Societal and equity outcomes**	**Organisational and technical outcomes**	**Economic and financial costs**	**Methodological aspects in economic evaluation**	**Challenges and risks**
DHE 5	Even one life saved is enough. 30% of patients never show for appointments	Medication prescription and lab values explanation should be done through teleconsultations	Most patients think telemedicine services are something exciting	Better quality of care for rural and isolated populations	No need for (sub)specialists in every hospital	Implementation and education costs. Need for IT support available 24/7. Reduced travel costs	Doctors should be paid by efficiency not on a fixed pay. A lot of data can be collected with telemedicine and used for various evaluations and efficiency measurement	Potential of technical failure of digital systems
DHE 6	Good for repetitive consults in chronic disease management. Reduces risk of infections	Higher availability and shorter waiting times	Patients are more satisfied and can access healthcare from the comfort of home	Availability of specialists to rural populations	Better organization of clinic hours. Higher patient turnover. Reduced administrative burden.	Need for IT support and constant software updates. Education costs. Reduced travel costs	EHDS regulative will create Health record centres with standardized data – source of data. Health Technology Assessment group – potential for cooperation. Constant re-evaluation of healthcare metrics leads to better quality of care	Currently no plan and strategy for telemedicine implementation and evaluation. Need for regulatory framework. Resistance to change.

Note: Statements reflect individual opinions; synthesis in Chapter 5 distinguishes recurring themes.

Source: Author's work

Table A.4: Classification codes for economic and healthcare activities

86	Human health activities		
86.2	Medical and dental practice activities		
86.220	Specialist medical practice activities		
	211	Cardiology and vascular medicine in the outpatient speciality clinic	
		220	Cardiology and vascular medicine
	212	Cardiovascular surgery in the outpatient specialised clinic	
		221	Cardiovascular surgery
	238	Emergency medicine in the specialist outpatient clinic	
		255	Internal medicine

Source: Statistical Office of the Republic of Slovenia, (2008) and National Institute of Public Health, (2022)

Table A.5: Summary statistics for the teleconsultations and in-person consultations groups

Variable	**Teleconsultations (83)**	**In-person (1,792)**	***p*-value**
(Semi)continuous	**Median (IQR)**	**Median (IQR)**	**MW test**
Age at treatment (years)	75 (15)	75 (15)	0.6332
Average monthly net earnings (EUR)	1,158.38 (315.83)	1,126.29 (128.63)	0.0819*
Stringency index (%)	69.44 (36.57)	43.88 (35.19)	0.0000***
Average number of additional diagnoses per hospitalisation (1 year pre-treatment)	4.00 (4.00)	3.00 (3.00)	0.0720*
Average number of additional diagnoses per hospitalisation (2 years pre-treatment)	4.00 (4.00)	3.00 (3.00)	0.0431**
Average number of additional diagnoses per hospitalisation (1-year post-treatment)	3.00 (2.00)	2.00 (3.00)	0.0641*
Average number of procedures per hospitalisation (1 year pre-treatment)	10.75 (8.00)	6.40 (9.00)	0.0002***
Average number of procedures per hospitalisation (2 years pre-treatment)	10.50 (8.00)	6.50 (9.00)	0.0000***
Average number of procedures per hospitalisation (1-year post-treatment)	11.00 (6.33)	6.83 (9.00)	0.0124**
Hospitalisation severity score (2 years pre-treatment)	0.38 (1.08)	0.00 (1.11)	0.0001***
Binary (Yes = 1, No = 0)	**N (%)**	**N (%)**	**χ^2**
Gender (male = 1)	47 (56.6%)	1053 (58.8%)	0.6994
Hospitalisation with HF diagnosis (2-year pre-treatment)	67 (80.7%)	1492 (83.3%)	0.5462
Hospitalisation with main diagnosis HF (2-year pre-treatment)	60 (72.3%)	1297 (72.4%)	0.986
HF diagnosis in outpatient clinic (2-year pre-treatment)	16 (19.3%)	300 (16.7%)	0.5462
Diabetes diagnosis (2-year pre-treatment)	18 (21.7%)	468 (26.1%)	0.368
Thyroid disorder diagnosis (2-year pre-treatment)	5 (6.0%)	126 (7.0%)	0.7249
Obesity diagnosis (2-year pre-treatment)	6 (7.2%)	58 (3.2%)	0.0502*
Frailty or related conditions (2-year pre-treatment)	0	0	
Iron deficiency diagnosis (2 years pre-treatment)	8 (9.6%)	153 (8.5%)	0.7264
Kidney disease diagnosis (2-year pre-treatment)	22 (26.5%)	360 (20.1%)	0.1559
Electrolyte disorder diagnosis (2-year pre-treatment)	6 (7.2%)	116 (6.5%)	0.7849
Lung or sleep disorder diagnosis (2-year pre-treatment)	12 (14.5%)	212 (11.8%)	0.4706
Hyperlipidaemia diagnosis (2-year pre-treatment)	24 (28.9%)	380 (21.2%)	0.0949*
Gout or arthritis diagnosis (2-year pre-treatment)	7 (8.4%)	62 (3.5%)	0.0186**
Depression diagnosis (2-year pre-treatment)	1 (1.2%)	19 (1.1%)	0.9003
Cancer diagnosis (2-year pre-treatment)	2 (2.4%)	44 (2.5%)	0.979
Infection diagnosis (2-year pre-treatment)	10 (12.0%)	255 (14.2%)	0.577
Other arrhythmias diagnosis (2-year pre-treatment)	10 (12.0%)	187 (10.4%)	0.6394
Atrial fibrillation I48 diagnosis (2-year pre-treatment)	37 (44.6%)	825 (46.0%)	0.7942
Chronic coronary syndrome diagnosis (2-year pre-treatment)	36 (43.4%)	709 (39.6%)	0.4882

To be continued

Table A.5: Summary statistics for teleconsultations and in-person consultations group (cont.)

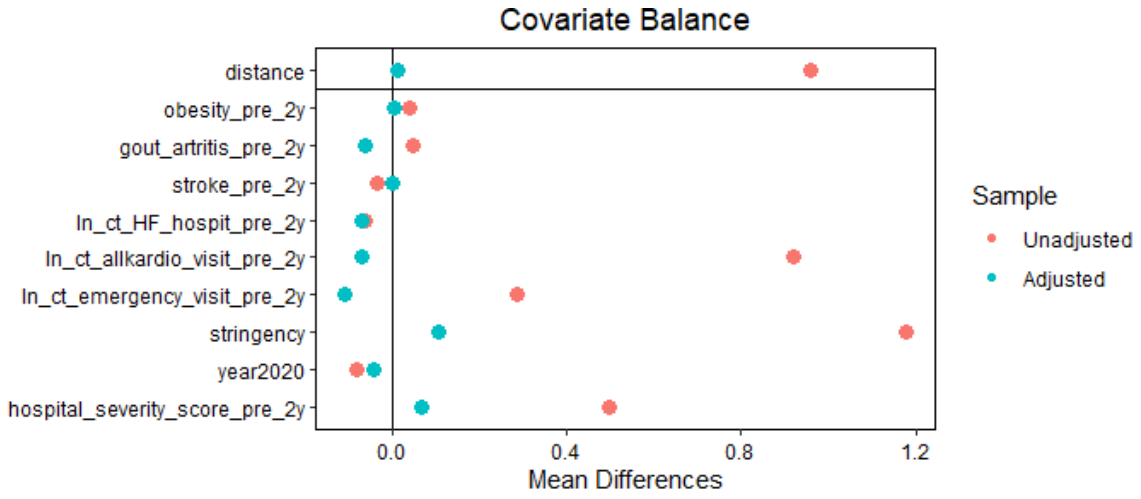
Variable	Teleconsultations (83)	In-person (1,792)	*p*-value
Binary (Yes = 1, No = 0)	**N (%)**	**N (%)**	**χ^2**
Hypertension diagnosis (2-year pre-treatment)	52 (62.7%)	886 (49.4%)	0.0186**
Stroke diagnosis (2-year pre-treatment)	2 (2.4%)	104 (5.8%)	0.1906
Died in hospital within 1-year post-treatment	6 (7.2%)	48 (2.7%)	0.0154**
Died out of hospital within 1-year post-treatment	17 (20.5%)	451 (25.2%)	0.3349
Count	**Median (IQR)**	**Median (IQR)**	**MV U test**
Number of HF hospitalisations (2-year pre-treatment)	1.00 (0.00)	1.00 (0.00)	0.7448
Number of HF hospitalisations (1-year pre-treatment)	1.00 (1.00)	1.00 (1.00)	0.1689
Number of hospital procedures (2-year pre-treatment)	13.00 (14.00)	9.00 (15.00)	0.0023***
Number of hospital procedures (1-year pre-treatment)	6.00 (15.00)	5.00 (13.00)	0.383
Number of additional diagnoses during hospitalisations (2-year pre-treatment)	5.00 (5.00)	4.00 (5.00)	0.1595
Number of additional diagnoses during hospitalisations (1-year pre-treatment)	3.00 (6.00)	3.00 (4.00)	0.8405
Number of comorbidities (2-year pre-treatment)	1.00 (2.00)	1.00 (1.00)	0.3771
Number of important comorbidities (2-year pre-treatment)	0.00 (1.00)	0.00 (1.00)	0.2217
Number of cardiovascular comorbidities (2-year pre-treatment)	2.0 (2.00)	2.00 (1.00)	0.0116**
Number of important cardiovascular comorbidities (2-year pre-treatment)	1.00 (1.00)	1.00 (2.00)	0.0422**
Number of cardiology outpatient visits (2-year pre-treatment)	1.00 (1.00)	0.00 (1.00)	0.000***
Number of cardiology outpatient visits (1-year pre-treatment)	1.00 (2.00)	0.00 (0.00)	0.000***
Number of cardiology outpatient visits (1-year post-treatment)	0.00 (1.00)	1.00 (1.00)	0.000***
Number of ED visits (2-year pre-treatment)	0.00 (1.00)	0.00 (0.00)	0.0002***
Number of ED visits (1-year pre-treatment)	0.00 (0.00)	0.00 (0.00)	0.0106**

*Note: MV – Mann–Whitney; Continuous variables are presented as median (IQR); categorical variables as n (%). p-values from tests are denoted as *p<0.10; **p<0.05; ***p<0.01.*

Source: Author's work

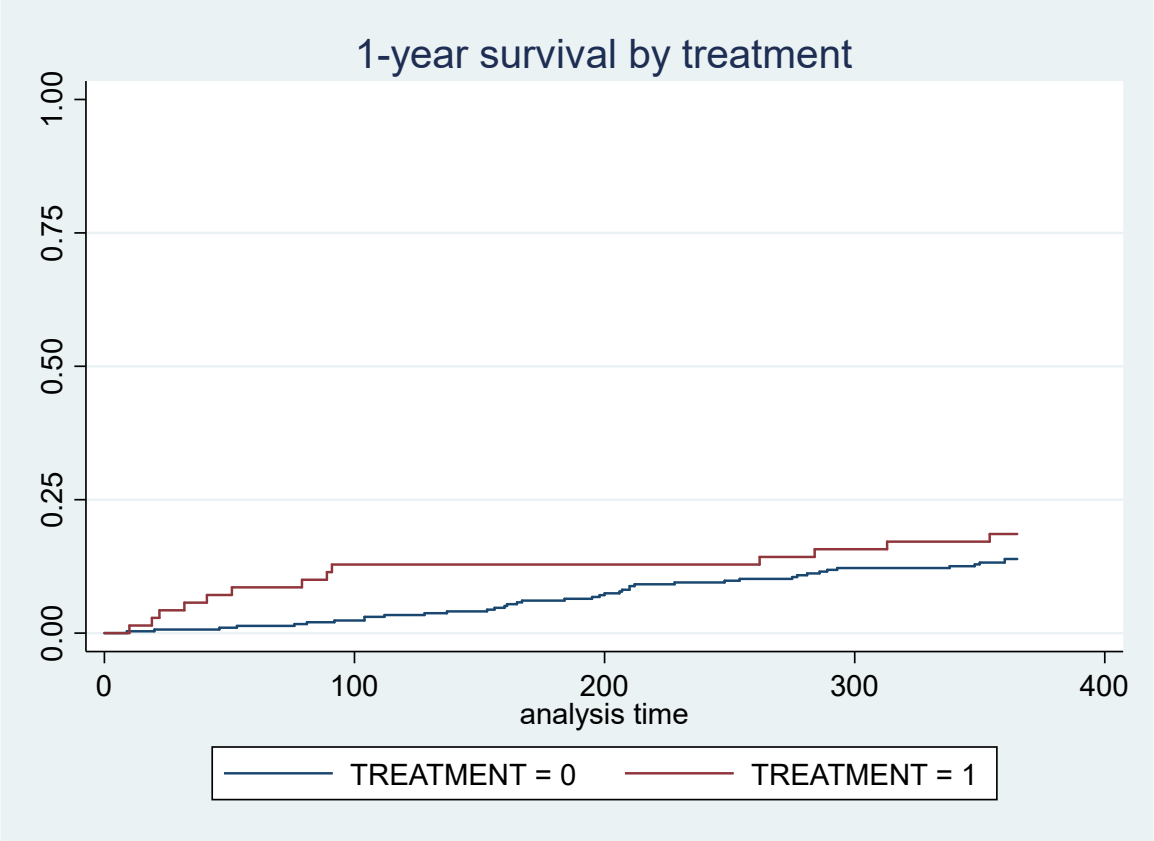
Appendix 7: Supplementary figures

Figure A.1: Love plot for Covariate Balance



Source: Author's work

Figure A.2: Kaplan–Meier failure curves (cumulative probability of death)



Source: Author's work

Appendix 8: Data management plan

Name of the doctoral student:
Antonija Srok, Registration No. 19208441
Doctoral programme and scientific field:
School of Economics and Business, University of Ljubljana, Economics track
Title of the doctoral dissertation:
Advancing economic evaluation of telemedicine to strengthen evidence-based resource allocation in heart failure care in Slovenia
Type of data and methods used if new data were collected or produced
1. What data have you collected and/or produced?
Bibliographic data
- details about publications

Qualitative data
- transcribed interviews with relevant stakeholders

Quantitative data
- administrative data related to heart failure patients in Slovenia

2. How did you collect and/or produce new data and how did you use existing data for your doctoral thesis?
Bibliographic data
- downloaded in .txt format from Web of Science
- used for bibliometric analysis

Qualitative data

- collected using a previously developed interview guide based on related research and relevant research questions
- in-person interviews and videoconference interviews were recorded and transcribed, after which the recordings were deleted
- transcribed interviews are stored in .docx files
- used for framework analysis

Quantitative data

- administrative data related to heart failure patients in Slovenia
- provided by HIIS (contract no. 1721-13/2021-DI/1, annex 1), in spreadsheet .xlsx files
- obtained approval of the National Medical Ethics Committee (no. 0120-223/2021/4, Annex 1)
- used for statistical analysis and economic evaluation

3. Have you been dealing with sensitive data? If yes, how have you ensured compliance with ethical measurements when collecting and/or producing data?

The data collected were coded using anonymised patient identification numbers and an anonymised interviewee number.

Interviewees in the qualitative study were given an Informed consent form containing all information about the research (Part 1: Information sheet), indicating that the data collected will be anonymised and used only for research purposes. Interviewees in the qualitative study had to sign the Informed consent form and state their compliance to participate in the research (Part 2: Certificate of consent).

For quantitative data provided by HIIS the researchers signed a consent form stating that the data will be used for research purposes only. The researchers also obtained consent of the National Medical Ethics Committee (no. 0120-223/2021/4, Annex 1).

How the data were stored and protected during research for a doctoral thesis

1. How did you store the data?

The data were stored on password protected computers at the researchers' facilities, on computers used exclusively by the researcher. The data were also stored on a password protected backup hard drive, with the backup performed when needed. The recorded videoconferences and in-person interviews were transcribed and anonymised, after which the recordings were deleted.

2. If you have worked with sensitive data, how have you ensured that it was kept safe and secure? (Move to the next question if not applicable)

Both the devices and the folders containing the data were password protected.

Long-term data availability and storage

1. In which data repository will you store the data for the long term after the completion of the research work and make it accessible in accordance with the requirement of Article 50 of the Regulations on Doctoral Studies of the UL?

In the Repository of University of Ljubljana for the data collected by the PhD student.

2. Do you plan to restrict access to the data for a certain period? If yes, please explain the reasons for this (e.g. for intellectual property or patent protection, or other reasons).

The data will be restricted for a few years, as the researchers intend to further study the collected data and publish relevant research papers after the completion of the PhD.