Evaluating the Economic Factors influencing the Implementation of TeleNeonatology in the Netherlands: A Multi-Perspective Analysis

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Evaluating the Economic Factors influencing the Implementation of TeleNeonatology in the Netherlands: A Multi-Perspective Analysis

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Preface

This thesis marks the conclusion of my Master's programme in Complex Systems Engineering and Management at Delft University of Technology. It represents both an academic exploration of the economic considerations surrounding the implementation of TeleNeonatology in the Netherlands and a personal journey of intellectual and professional growth.

The process of writing this thesis has been both challenging and rewarding. I had the privilege of working closely with Erasmus MC, where I was able to combine theoretical analysis with practical insights into neonatal care. Developing the cost-minimization model, conducting interviews with key stakeholders, and applying the NASSS framework taught me not only the complexities of telemedicine adoption but also the importance of balancing academic complexity with real-world applicability.

At the same time, this project offered me the opportunity to immerse myself in a subject I had not previously encountered. Exploring telemedicine and neonatal care was both exciting and eye-opening, and it pushed me beyond my comfort zone in the best possible way. It taught me not only about the economic and organizational complexities of healthcare innovation, but also about the value of approaching new domains with curiosity and openness. This experience has enriched my academic journey and will continue to shape the way I approach challenges in the future.

I am deeply grateful to Dr. Jan Anne Annema, Dr. Naomi van der Linden, and Josephine Wagenaar for their invaluable guidance, critical feedback, and clinical insights, which were essential in shaping this project and bridging the gap between economic analysis and neonatal practice. Furthermore, I owe sincere thanks to all stakeholders who generously shared their time and expertise during the interviews. Your perspectives significantly enriched this research.

Finally, I would like to thank my family and friends for their patience, motivation, and unwavering support during this intensive period. Your encouragement has been a constant source of strength, whether through thoughtful conversations, words of reassurance, or simply by providing moments of distraction and balance when they were most needed. This thesis demanded many hours of focus and dedication, and I am grateful to those closest to me for understanding the challenges that came with it. Without your belief in me and your continuous support, this journey would not have been possible.

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Executive Summary

TeleNeonatology is an emerging digital health innovation that connects hospitals with limited neonatal expertise to specialized Neonatal Intensive Care Units (NICU) via real-time video communication. It holds significant potential to improve neonatal outcomes, reduce unnecessary patient transfers, and alleviate pressure on NICU resources. Despite these advantages, the implementation of TeleNeonatology in the Netherlands remains limited. This thesis investigates the economic considerations that shape such implementation efforts, with a specific focus on how they influence adoption decisions across the different involved stakeholders.
As an empirical entry point, this thesis draws on the 2024 TeleNeonatology pilot between Erasmus MC and Amphia Hospital. The pilot provided operational and economic data. However, the pilot did not demonstrate measurable clinical improvements, underscoring the need to assess implementation primarily through an economic lens.

The research is structured using the NASSS framework (Non-adoption, Abandonment, Scale-up, Spread, and Sustainability). The NASSS framework provides a structured lens to analyze why health technologies are adopted, abandoned, or fail to scale sustainably. In this thesis, the framework is not only applied to assess TeleNeonatology but is extended with explicit economic dimensions across all seven domains. This adaptation allows economic considerations, such as investment costs, reimbursement models, distribution of benefits, and long-term sustainability, to be systematically examined. By operationalizing economic questions within each domain, the framework becomes a tool to reveal where misalignments occur between cost savings at the system level and financial incentives at the institutional level. This integrative approach enables the study to move beyond traditional cost-effectiveness analysis and to uncover how economic logics interact with institutional structures in shaping adoption decisions.

This thesis employs a mixed-methods explanatory design to investigate the economic dimensions of TeleNeonatology. Three complementary methods were combined: a systematic literature review to synthesize existing knowledge, a cost minimization model to analyze economic dynamics in a structured way from different perspectives, and semi-structured stakeholder interviews to explore institutional perspectives and decision-making rationales. The unifying element is the NASSS framework. This ensured that each phase of the research addressed not only its own objectives, but also contributed to a coherent overall analysis of how economic factors interact with the organizational, and systemic conditions of implementation. By structuring the study in this way, the thesis provides both breadth and depth: breadth through systematic coverage of economic considerations across the seven NASSS domains, and depth by combining quantitative modeling with qualitative insights.

The **systematic literature** review reveals that while high initial investment costs, reimbursement uncertainty, and unclear long-term funding models are frequently cited as barriers, they are rarely analyzed in direct relation to actual implementation outcomes. Economic considerations are often treated as abstract constraints rather than operationalized decision criteria, creating a disconnect between economic evaluations and real-world adoption processes. Furthermore, most studies address only isolated aspects within a single NASSS domain rather than examining the interdependencies across domains. Notably, the Organization and Adopter System dimensions receive the least systematic attention, indicating that research to date has insufficiently explored how institutional arrangements and stakeholder dynamics shape the economic feasibility of telemedicine implementation.

The **cost minimization model** indicates that TeleNeonatology reduces average costs per patient across all perspectives considered, with substantial savings for both the healthcare (€3,940) and societal (€4,081) perspective. These gains derive primarily from avoided NICU admissions, fewer inter-hospital transfers, and mitigation of indirect family burdens. While such results highlight the efficiency of TeleNeonatology in reducing resource utilization, their interpretation differs when viewed from a hospital perspective. In the Dutch system of specialist medical care, hospital services are reimbursed through a case-based payment model, where each treatment trajectory is declared as a billable product at regulated or negotiated tariffs. For insurers, these payments constitute expenditures, whereas for hospitals they represent revenues. Accordingly, modeled cost differences that appear as savings at the payer or system level should be reinterpreted as revenue changes resulting from shifts in the volume of billable products at the hospital level. In other words, the same model outcome that evidences cost savings simultaneously signals income reductions for individual providers, underscoring how interpretation shapes the economic meaning of results across perspectives. This reflects the so-called wrong pocket problem, whereby the actor that bears the costs of implementation is not the one that accrues the financial benefits. Therefore, interpretation strongly shapes the economic meaning of results across perspectives.

The **stakeholder interviews** corroborate this misalignment. Most institutions operate with only partial visibility over the broader cost-benefit dynamics, and no single actor possesses a full, system-wide economic overview. Decision-making remains fragmented, with hospitals, insurers, and policymakers each prioritizing their own budgetary constraints. This siloed perspective leads to structural misalignments between where costs are incurred and where benefits accrue.

Overall, this thesis concludes that economic considerations are necessary aspects for sustainable telemedicine implementation, but are often misunderstood or overlooked in practice.

The intervention demonstrates efficiency at the system level, yet its benefits are unevenly distributed and often translate into financial drawbacks for the very providers expected to adopt it. By applying an economics-extended NASSS framework, the study shows that the critical barriers lie in organizational and system-level arrangements, where existing funding structures fail to align incentives across actors. The resulting paradox is that a demonstrably cost-reducing innovation risks stagnation unless governance and financing models evolve to match system-wide value with institutional sustainability.

Based on the generated insights the following recommendations from an economic standpoint should be taken into consideration when implementing TeleNeonatology:

1. **Establish structured stakeholder alignment from the start**
   Misaligned incentives and fragmented perspectives are key barriers. Implementation should begin with a formal steering group including hospitals, insurers, parent organizations, and policymakers. This group should define shared objectives (e.g., reducing transfers, improving parental experience, cost containment), meet regularly, and maintain transparent communication (e.g. with dashboards) economic and financial outcomes.
2. **Embed economic evaluation directly into pilot design**
   Pilots should systematically track economic outcomes across key stakeholder perspectives (hospital, insurer, parental, system). When implementing models, not every perspective must be explicitly included, rather, it is the interpretation of results that determines their relevance. A model showing societal savings, for instance, may simultaneously imply revenue losses at the hospital level. To avoid siloed evaluations particularly those limited to the societal perspective, pilots should explicitly incorporate mechanisms for cross-perspective interpretation, ensuring that economic evidence is actionable and supports informed implementation and scaling decisions.
3. **Develop sustainable financial mechanisms to resolve the “wrong pocket problem”**
   Under current reimbursement structures, avoided transfers reduce hospital revenues even when the system saves costs. To prevent this misalignment, mechanisms should be tested that redistribute savings fairly, such as shared-savings contracts or per-consultation reimbursements. One concrete option is an insurer-funded pool: hospitals would annually report avoided transfers and, if TeleNeonatology led to a net revenue loss, receive compensation up to the breakeven point. This ensures hospitals are not penalized for enabling system-wide efficiency and creates a sustainable basis for broader adoption.

Future research based on this thesis could focus on scaling TeleNeonatology beyond pilot settings including the defined recommendations, and enabling longitudinal evaluation of financial outcomes across diverse hospital networks. In addition, applying the adapted NASSS-economic framework to other telemedicine domains can validate its broader relevance and support comparative insights across digital health innovations.

While grounded in the Dutch healthcare system, these insights are relevant for other telemedicine applications and countries, provided that local financial and institutional conditions are carefully taken into account.

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1 Introduction

Telemedicine, the use of digital communication technologies, is often promoted as a cost-saving and efficiency-enhancing innovation. However, many interventions fail to achieve long-term or system-wide adoption (Granja et al., 2018). Financial barriers are frequently identified as critical obstacles during implementation. At the same time, existing economic evaluations in the field tend to report favorable findings, particularly when assessed from healthcare or societal perspectives. This apparent disconnect suggests that broader economic dimensions, including the distribution of costs and benefits, initial investment, and the structure of reimbursement systems, might play a more decisive role in implementation success rather than cost evaluations alone.

Within this broader context, TeleNeonatology represents a promising yet underutilized application of telemedicine. It facilitates real-time collaboration between Neonatal Intensive Care Units (NICUs) and hospitals with lower levels of neonatal expertise (Jagarapu & Savani, 2021b). This technology enhances care for neonates particularly in high-risk scenarios such as resuscitation or premature birth, where rapid access to specialized expertise can be life-saving (Jagarapu & Savani, 2021b). Each year approximately 15 million children are born prematurely worldwide (born before 37 weeks of pregnancy). In the Netherlands, this number exceeds 11,000 annually (Oudijk, 2022). Infants born at hospitals with limited neonatal care face poorer outcomes due to the lack of experienced personnel and fewer opportunities for procedural practice (Fang et al., 2018). By enabling remote collaboration, TeleNeonatology aims to reduce mortality in very low birth weight infants, avoids unnecessary transfers, and promotes better outcomes (Fang et al., 2018a; Jagarapu & Savani, 2021a). Despite its promise, TeleNeonatology remains underutilized in Europe, also in countries such as the Netherlands (Wagenaar et al., 2025).

To explore the implementation of TeleNeonatology in practice, a pilot project was conducted in 2024 by Erasmus MC and Amphia Hospital, replacing traditional phone-based consultations with a secure telemedicine connection for neonatal case management and transfer decisions. This initiative provides a real-world case to examine the economic conditions and institutional dynamics that shape TeleNeonatology implementation (Wagenaar et al., 2025).

While TeleNeonatology has demonstrated economic benefits by reducing costly patient transfers and enabling more efficient clinical decision-making, its financial and structural feasibility remains unclear. While reducing transfers is economically beneficial from a societal perspective, the business cases for individual hospital might not be. This places greater importance on understanding the financial structures, reimbursement mechanisms, and cost distributions that influence implementation decisions.

Importantly, the Dutch pilot did not yield significantly improved clinical outcomes over usual care, shifting attention toward the economic case as the central justification for implementation. Without

a clear clinical advantage, the sustainability and scalability of TeleNeonatology depends largely on whether it can offer economic value to stakeholders across the healthcare system.
Studies examining the economic impact of TeleNeonatology in the world, as well as in the Netherlands, are scarce, leaving a gap in understanding how healthcare funding models, regulatory requirements, and hospital financial structures influence its implementation. Addressing these challenges requires a comprehensive analysis of the economic considerations that shape the implementation of TeleNeonatology.

1.1 Research Question

This thesis introduces a novel perspective by examining the economic feasibility of TeleNeonatology not only through quantitative cost modeling, but also by exploring the financial and structural realities that influence its implementation. Rather than focusing solely on cost savings, it investigates how economic considerations shape real-world implementation decisions. By combining data from the recently conducted Dutch pilot study with a broader analysis of stakeholder perspectives, this study provides new insights into the systemic conditions necessary for the sustainable integration of telemedicine in neonatal care and beyond.
This leads to the following main research question:

How do economic considerations impact the implementation of TeleNeonatology?

This main research question will be addressed based on a mixed-methods research approach that follows an explanatory sequential design. This is further explained in Chapter 2.

1.2 Core Concepts

In the following paragraph the main four core concepts for this thesis are defined, to create a common understanding:
Neonatology - Neonatology is a specialized branch of medicine focused on the care, development, and diseases of newborn infants, particularly those who are premature or critically ill. It involves highly specialized treatments and expertise for conditions affecting newborns, typically within Neonatal Intensive Care Units (NICUs). Neonatologists provide care for infants born before full-term gestation (before 37 weeks) or with severe health issues requiring immediate and specialized medical attention (Maddox et al., 2021). In the Netherlands, neonatal care is organized into three progressively specialized categories: neonatal medium care wards, neonatal high care wards, and Neonatal Intensive Care Units (Planning Decision on Special Perinatological Care, 2018). NICUs provide the highest level of care, catering to critically ill or extremely premature newborns who require constant monitoring and advanced life support, including respiratory and cardiovascular assistance. High care wards serve infants who are medically stable but still require

significant support, such as incubation or intravenous therapy. Medium care wards focus on neonates with milder health concerns, such as feeding difficulties or the need for medication, without the requirement for intensive monitoring.

Telemedicine - Telemedicine is the use of digital communication technologies, such as video conferencing, remote monitoring, and mobile applications, to provide healthcare services across distances. It allows healthcare providers to diagnose, treat, and monitor patients without requiring in-person visits. Telemedicine encompasses a wide range of applications, from routine check-ups to emergency care, and has become an increasingly valuable tool, particularly in underserved or remote areas. Its use grew significantly during the COVID-19 pandemic, demonstrating its capacity to deliver care efficiently and effectively (Azzuqa et al., 2021; Jagarapu & Savani, 2021a).

TeleNeonatology - TeleNeonatology is a subset of telemedicine that specifically applies to neonatal care. It enables real-time remote consultation and support for healthcare providers in settings with limited neonatal expertise by connecting them with specialists in NICUs. This allows for critical interventions, such as remote guidance during resuscitation or stabilization of premature infants and ensures specialized care in facilities that may lack on-site neonatologists. TeleNeonatology has shown promise in improving neonatal outcomes by reducing infant mortality, preventing unnecessary transfers, and providing timely access to specialized care (Jagarapu & Savani, 2021b).

Economic considerations - Economic considerations for this thesis refer to the financial and resource-based considerations that influence the implementation, sustainability, and scalability of healthcare interventions such as TeleNeonatology. These include initial capital investments for equipment and infrastructure, recurring operational and maintenance costs, and the availability of funding or reimbursement mechanisms. Health institutions must evaluate cost-effectiveness, potential return on investment, and opportunity costs when deciding to adopt new technologies. Economic considerations also involve the distribution of financial responsibilities among stakeholders and the presence (or lack) of financial incentives aligned with improved health outcomes.

1.3 Alignment with CoSEM

This research aligns closely with the CoSEM (Complex Systems Engineering and Management) program by addressing a multi-faceted socio-technical challenge within the healthcare domain. TeleNeonatology represents a complex intervention that extends beyond mere technological implementation. It involves integrating telemedicine solutions into a highly regulated, resource-constrained healthcare environment, requiring consideration of economic feasibility, technical reliability, and institutional structures. This study reflects CoSEM's emphasis on holistic system analysis and strategic decision-making, particularly in managing trade-offs between cost, accessibility, and quality of care.

From a broader systems engineering and policy perspective, this research exemplifies the integration of innovation management, healthcare technology assessment, and policy formulation. The implementation of telemedicine in neonatology is not just a technological upgrade but a system transformation, requiring structured coordination between hospitals, policymakers, technology providers, and financial stakeholders. The study draws on engineering systems principles, as outlined by de Weck et al. (2011), to analyze how interconnected components, such as technical infrastructure, institutional policies, and economic constraints, shape the feasibility and scalability of telehealth interventions. Furthermore, by evaluating TeleNeonatology through the lens of value-driven healthcare and policy-driven technology adoption, the research provides actionable insights for decision-makers seeking to optimize neonatal care delivery. This systemic approach underscores the importance of adaptive policy frameworks and evidence-based innovation strategies in ensuring the long-term success of healthcare transformations.

1.4 Thesis Outline

The thesis is structured into seven main chapters. After the initial problem introduction and defined research question TeleNeonatology is contextualized in Chapter 2. On one side this provides background information to the reader about TeleNeonatology, the healthcare system it is placed in and the involved stakeholders and on the other side this chapter provides guidance for later on decision making such as the selection of interview partners for the qualitative analysis.

Chapter 3 introduces the methodology. This guides through the formulation of the sub-questions and details the research approach, the methods, the data collection techniques, and the analytical tools used.

The main body of this thesis is structured into three core chapters: a systematic literature review, a quantitative economic evaluation, and a qualitative stakeholder analysis. The first analytical step, presented in Chapter 4, is a systematic literature review that identifies key factors influencing the implementation of telemedicine more broadly. It provides a foundational context for understanding more specific applications such as TeleNeonatology. Chapter 5 presents a quantitative economic evaluation based on a decision tree model, comparing cost implications across different stakeholder perspectives. Chapter 6 complements this by adopting a qualitative approach, drawing on stakeholder interviews to explore the economic considerations affecting the implementation of TeleNeonatology and to contextualize the findings of the economic model. Each chapter is designed to stand alone and therefore includes its own introduction, specific methodology, results, and discussion.

Lastly, Chapter 7 discusses the findings, addressing limitations and broader implications, and concludes the study by answering the research questions and identifying avenues for future research. The bibliography and appendices provide additional references and supporting information.

1.5 Ethics and Data Protection

While conducting this research, ethical considerations and data protection play a crucial role, particularly given the sensitive nature of neonatal healthcare data. The data utilized in this study, sourced from the Erasmus MC hospital pilot, is governed by a formal agreement ensuring compliance with relevant ethical and legal standards. The Human Research Ethics Committee (HREC) approved the data handling process. This approval can be found in Appendix 1: HREC Approval (Page 130). Given the increasing reliance on digital health solutions, safeguarding information and ensuring compliance with General Data Protection Regulation (GDPR) and hospital-specific policies remain essential aspects of this research. Addressing these ethical and privacy concerns is critical for ensuring the responsible economic analysis of TeleNeonatology while maintaining trust among healthcare providers, patients, and regulatory bodies.

2 Contextualizing TeleNeonatology

To evaluate the economic implementation of TeleNeonatology, this chapter provides the necessary contextual foundation. It begins by outlining the broader challenges facing healthcare systems, which create the conditions for digital interventions like telemedicine. It then introduces the NASSS framework as a tool to analyze the complexity of implementing health technologies, and explains how this framework is extended to include economic factors. The chapter proceeds by situating TeleNeonatology within the specific clinical and logistical demands of neonatal care. Finally, it introduces the relevant stakeholders, whose roles and financial interests are key to understanding adoption dynamics. Together, these sections support a comprehensive and structured analysis, while guiding the methodological approach taken in the following chapters.

2.1 Challenges of the Healthcare System

Healthcare systems worldwide operate within an increasingly intricate framework. These systems must continuously evolve in response to epidemiological shifts, demographic changes, and broader societal transformations. Additionally, technological advancements, economic conditions, and political and environmental factors all contribute to the growing complexity of global healthcare management (Figueroa et al., 2019).

Among the most pressing challenges is population aging, which drives rising demand for medical services, long-term care, and public health infrastructure. In the Netherlands, the share of people aged 65 and older with complex health conditions is projected to increase from 10% in 2020 to up to 22% by 2040 (Baâdoudi et al., 2023). Additionally, healthcare expenditures are expected to continue rising at least until 2060 (van Ede et al., 2023). These trends intensify the challenge of maintaining accessible, high-quality care while ensuring financial sustainability (Jones & Dolsten, 2024).

Simultaneously, healthcare systems face growing shortages of medical professionals. Globally, the WHO projects a deficit of 18 million healthcare workers by 2030 (Jones & Dolsten, 2024), with the Netherlands also reporting a significant shorfall. These shortages strain exisiting staff, increase burnout and risk degrading care quality (The Netherlands Scientific Council for Government Policy (WRR), 2021). As a result, healthcare systems face a growing imbalance.

In the Netherlands, there is a recognized need for more strategic resource allocation to ensure equitable and efficient healthcare delivery (Ministry of Health, 2022). However, structural inefficiencies and fragmented decision-making processes frequently contribute to delays, excessive costs, and suboptimal care outcomes (Figueroa et al., 2019). Bureaucratic challenges further complicate healthcare administration, increasing the burden on both medical professionals and patients seeking timely care (Figueroa et al., 2019).

2.2 Implementation of Telemedicine

In response to the increasing complexity of healthcare systems and the numerous challenges they face, various interventions are being developed to improve service delivery, optimize resource use, and enhance patient outcomes. Economic, regulatory, political, technical, cultural, and social factors have led healthcare planners to reconsider traditional approaches to care provision (Lockamy & Smith, 2009). As a result, many organizations have turned to telemedicine as a solution to overcome the current challenges.

Digital health solutions and telehealth innovations are now recognized as critical tools in supporting healthcare systems worldwide. The World Health Organization's global strategy emphasizes the role of digital and information technologies as key enablers in addressing health system challenges, ensuring more equitable access to care, and working towards universal health coverage (Digital Health and Innovation (DHI), 2021). These technologies have been positioned as digital public goods, adaptable across different countries and healthcare settings to support equitable access and avoid disparities in digital healthcare adoption (Digital Health and Innovation (DHI), 2021).

2.2.1 Introduction of the NASSS framework

Therefore, most research on technological innovations in healthcare has concentrated on the development of new technologies and identifying patterns of their adoption. However, considerably less attention has been given to understanding why certain technologies, despite showing promise, fail to be adopted, are later abandoned, or struggle to scale and sustain within health and care systems. To address this gap, the NASSS framework was created as a practical, evidence-based tool for analyzing the barriers to long-term and widespread implementation of health technologies (Greenhalgh Trisha & Abimbola Seye, 2019). The NASSS framework stands "for non-adoption and abandonment of technologies by individuals and the challenges to scale-up, spread and sustainability of such technologies in health and care organizations" (Greenhalgh Trisha & Abimbola Seye, 2019). The framework discuss the broader factors of implementation, or non-implementation for healthcare technologies.

At its core, NASSS outlines seven key domains that can influence a technology's trajectory in healthcare systems. Each domain present different levels of complexity. The higher the complexity across these domains, the greater the likelihood that the technology will face implementation challenges or be abandoned altogether.

As such, NASSS supports researchers, policymakers, and practitioners in developing a deeper, more nuanced understanding of why some technologies succeed while others fail to integrate sustainably into health and care systems (Greenhalgh Trisha & Abimbola Seye, 2019).

This framework is particularly relevant for this study because it enables a comprehensive and systemic analysis of the factors influencing TeleNeonatology implementation. Rather than focusing solely on cost or clinical outcomes, NASSS facilitates exploration of the broader socio-technical and organizational context. Moreover, it aligns well with the multi-stakeholder nature of TeleNeonatology, which spans multiple institutions, professional roles, and levels of healthcare infrastructure. Its emphasis on scale, sustainability, and system readiness makes it a suitable lens through which to assess the economic feasibility of telemedicine in a real-world context.

2.2.2 Extension of the Framework to Economic Factors

Since this is a framework for the general reasons why technology fails to get implemented in healthcare it will be translated to economic factors that influence each of the domains. This will be done understanding these economic factors per domain.

This study uses each domain as a lens through which to ask key guiding questions. These questions aim to uncover where economic barriers may arise, or facilitators support the implementation of telemedicine, which stakeholders are financially affected, and what structural conditions determine financial feasibility. The questions are not exhaustive but are designed to prompt reflection on how economic considerations shape adoption, integration, and sustainability of telemedicine interventions.

Table 1 below summarizes the NASSS domains, describes what each domain is intended to examine, and outlines the key economic questions that guide their application in this study.

Table 1: NASSS domain and corresponding economic and financial guiding questions

NASSS Domain	**NASSS description** (Greenhalgh Trisha & Abimbola Seye, 2019)	**Key Economic and Financial Questions for Implementers**
1. The Condition	The illness or condition being addressed.	- What is the current cost burden of this condition on the healthcare system? - Does the condition require frequent or long-term care that could benefit economically from remote care? - Are there measurable cost savings or efficiency gains by shifting to telemedicine?
2. The Technology	The technology itself: features, maturity, knowledge required, etc.	- What are the total costs of purchasing, implementing, and maintaining the telemedicine technology (hardware, software, infrastructure)? - Are there hidden costs (e.g., training, productivity loss during roll-out)? - How well does the technology integrate with existing IT systems, and what is the cost of ensuring interoperability? - Is the technology scalable and economically sustainable over time?
3. The Value Proposition	The benefits perceived by developers, providers, and users (supply and demand sides).	- Who benefits financially from the implementation (e.g., providers, payers, patients)? - What is the expected return on investment (ROI) or cost-benefit ratio? - Can value be demonstrated through measurable improvements in outcomes or efficiency? - Is the business model sustainable and acceptable to stakeholders?
4. The Adopter System	The individuals expected to use the technology (clinicians, patients, carers).	- Are there financial incentives or reimbursement mechanisms in place to encourage use by clinicians and patients? - What are the potential costs to users (e.g., time, learning curve, additional unpaid tasks)? - How are the perceived economic benefits communicated to end-users?
5. The Organisation	The organization(s) responsible for adoption and implementation	- Does the organisation have the budget or resources to invest in and support implementation? - What internal restructuring or workflow changes are required, and what are their costs? - Is the telemedicine model aligned with the organisation's financial strategy and long-term goals?
6. The Wider System	External influences: policy, regulation, legal and professional norms.	- What reimbursement policies apply to the telemedicine service? - Are there national or regional funding programs that can offset costs? - Are there regulatory or legal requirements that may impose financial burdens or risks?

		- How predictable and stable are the external funding structures?
7. Embedding and Adaptation Over Time	Long-term evolution and adaptation between technology and the system.	- What is the long-term financial plan for maintaining and upgrading the technology? - How can the financial model adapt to changing regulations or market conditions? - What mechanisms ensure ongoing value demonstration to secure continued support and integration into routine care?

This framework is essential for this research since it provides a structured approach to identifying the systemic, organizational, and contextual factors that influence the implementation of health technologies, enabling a comprehensive analysis of how economic considerations interact with broader adoption dynamics. The operationalizing of it within this thesis is further explained in the method section in chapter 3.5.

2.3 TeleNeonatology

With this conceptual structure in place, the next section turns to the specific context in which the framework will be applied: neonatal care. TeleNeonatology represents a concrete use case of telemedicine that exemplifies many of the economic and organizational dynamics outlined in the NASSS framework.

Same as the general healthcare system, Neonatology also deals with short- and long-term challenges. The Netherlands provides a high standard of neonatal care, yet there remain opportunities for improvement. Given the distribution of the specialized care units across various hospitals, patient transfers are sometimes necessary to ensure that each newborn receives the most appropriate level of care. However, these transfers can introduce additional logistical challenges and stress for both the infant and their family (Stark et al., 2023). Capacity strain is a pressing issue, often necessitating the transfer of pregnant women or critically ill neonates to other facilities due to bed shortages. These transfers, can disrupt continuity of care and place additional stress on both medical teams and families (Wagenaar et al., 2025). In addition, neonatal outcomes, despite the country's strong healthcare infrastructure and commitment to quality care, still shows room for improvement when compared to other high-income nations (perined.nl, 2025). Addressing these capacity constraints and reducing avoidable transfers are critical steps toward enhancing both patient and parental outcomes. In this context, TeleNeonatology presents a promising solution.

TeleNeonatology is the application of Telemedicine in Neonatology. Telemedicine enables collaboration between NICUs and hospitals with limited neonatal expertise, improving care in critical situations like resuscitation or preterm births, where swift access to specialized knowledge can be crucial for survival (Jagarapu & Savani, 2021b). Besides that, TeleNeonatology significantly enhances NICU resource allocation by reducing unnecessary patient transfers and enabling a more efficient use of NICU beds and staff resources (Makkar et al., 2020, 2021).

Research shows that with telemedicine, rural hospitals can receive expert consultations and management support for neonatal care without sending infants to specialized centers (Azzuqa et al., 2021; Makkar et al., 2021; Yoo et al., 2022). This practice helps reserve high-level NICU beds for the most critical cases, relieving pressure on NICU facilities and optimizing overall resource distribution (Okada et al., 2020; Thao et al., 2022). By minimizing transfers, telemedicine also reduces the risks associated with neonatal transportation itself and alleviates logistical strains on regional healthcare systems. Additionally, TeleNeonatology has been shown to provide greater comfort for caregivers and improve staff satisfaction (Asiedu et al., 2019). Telemedicine supports remote neonatal assessments, which streamline patient care and help NICUs manage their workload more effectively (Haynes et al., 2021).

One of the most profound impacts of TeleNeonatology is on parents, who face considerable emotional and logistical challenges when an infant requires NICU care. Parental stress is a significant concern, as parents of critically ill neonates experience heightened anxiety, particularly when their infants require NICU admissions and multiple transfers (Ballantyne et al., 2017). Telemedicine enables care to be delivered closer to home, which not only reduces healthcare costs but also minimizes the emotional and financial burden associated with long-distance NICU care (Asiedu et al., 2019; Makkar et al., 2020). The ability to connect with neonatologists virtually means that families can receive detailed updates, be involved in decision-making, and even participate in care discussions without the challenges of travel (Azzuqa et al., 2021; Makkar et al., 2021). This approach aligns with family-centered care principles, which have been shown to positively affect parental well-being (Albritton et al., 2018; Makkar et al., 2021).

Additionally, Telemedicine in neonatal care offers substantial long-term economic benefits by reducing costs associated with transport, extended hospital stays, and transfers to higher-level care centers (Asiedu et al., 2019; Makkar et al., 2021; Nesmith et al., 2020; Rasmussen et al., 2020).

2.4 Stakeholder Analysis

Telehealth initiatives involve a diverse range of stakeholders, each with unique perspectives and priorities.

The following section introduces the stakeholders that are connected to TeleNeonatology. Stakeholders are individuals or groups with a stake in the actions, resources, and outcomes of an organization or system, including those affected by or influencing its activities. In healthcare, this includes providers, patients, families, managers, regulators, NGOs, and other relevant bodies. To structure and cluster the identified stakeholders into meaningful categories, the framework by (Schiller et al., 2013) is applied, which distinguishes stakeholders across different layers of involvement. For this layered approach four layers reflect the structure of TeleNeonatology: the core layer, the operational layer, the institutional layer, the strategic & regulatory layer.

In Figure 1, the different stakeholder layers of TeleNeonatology are illustrated and in the following introduced.

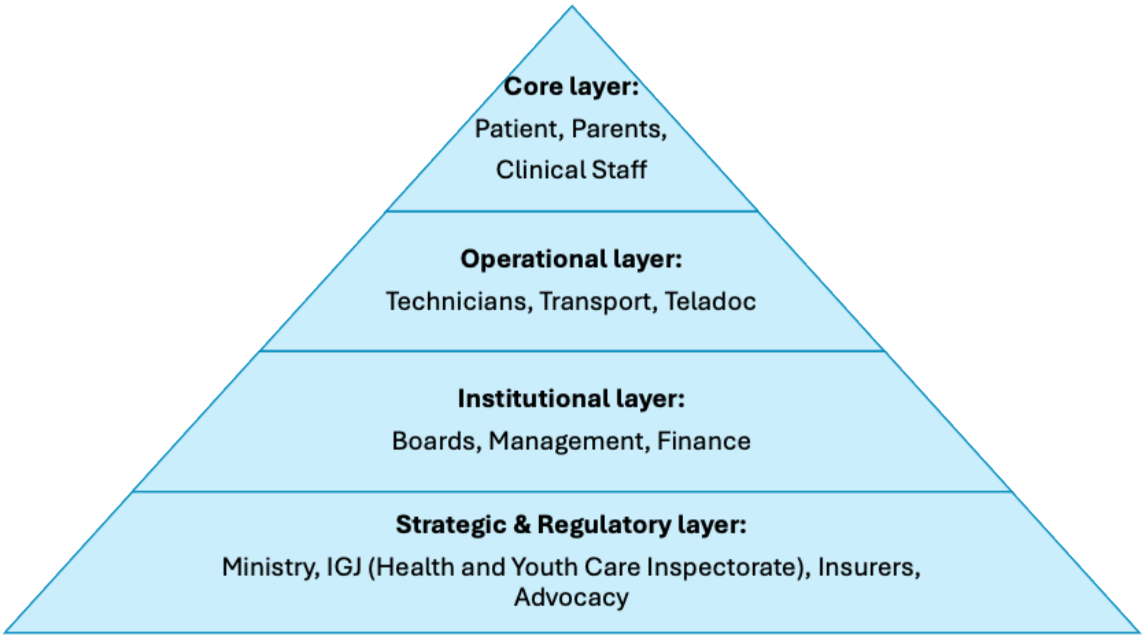


Figure 1: Stakeholder Layers of TeleNeonatology

Core layer:

The patients, the neonates, are at the heart of the intervention, as all clinical and operational efforts are directed toward improving their health outcomes and overall quality of care. Although they do not participate in decision-making, their condition directly determines the priorities and actions of other stakeholders.

The parents play a central role as primary caregivers who are deeply involved in the daily care and emotional wellbeing of the patient. Their active engagement in communication and decision-making makes them key participants in the care process, especially when it comes to accepting the use of telemedicine (Garne Holm et al., 2019).

The nurses in the neonatologies are closely involved in the day-to-day delivery of care, operating at the frontline of the intervention. They are responsible for monitoring the patient, managing treatment protocols, and interacting with both technology and families. Their involvement provides crucial insights into feasibility and clinical impact.

Neonatologists within the NICU hold significant responsibilities in directing medical treatment and clinical decisions. They are highly involved in both the strategic and operational implementation of the intervention and are likely to influence its acceptance among other clinical staff. Their role also includes evaluating the clinical appropriateness of telemedicine use and integrating it into standard care procedures.

Operational layer:

Stakeholders in the operational layer support the technical and logistical implementation of the intervention.

Technicians from Erasmus and Amphia are responsible for maintaining the medical devices and telemedicine infrastructure, ensuring that systems are functional, secure, and integrated into the hospital’s workflows. Their role, while behind the scenes, is vital for maintaining continuity and usability of the technology.

Transportation teams handle the physical movement of patients and equipment between departments or facilities, facilitating care delivery across sites. This is a particularly important function in regional collaborations.

Technology suppliers for telemedicine, provides the digital platform and services that enable remote care. Their involvement includes implementation support, customization to clinical needs, and ongoing service provision, aligning with both operational and strategic interests.

Admission coordinators support patient intake and scheduling, interacting with clinical staff to ensure a smooth flow of care. Although their engagement in strategic planning is limited, they contribute to workflow efficiency and patient access, both of which affect intervention uptake. Collaborating research groups bring external expertise and help ensure scientific rigor through data collection, analysis, and dissemination. Their involvement is collaborative and shaped by mutual interest in evaluating the intervention’s outcomes.

Insitutional layer:

The institutional layer consists of hospital-level stakeholders with decision-making authority and oversight functions.

The management teams of neonatologies are responsible for overseeing clinical operations and staff performance. Their engagement spans both the planning and implementation phases of the intervention. They are essential for integrating the project into the hospital’s existing structure, resolving organizational barriers, and aligning teams across departments.

The boards of Erasmus and Amphia, along with their respective business controllers, operate at a more strategic level and are primarily concerned with long-term impact, budgeting, and resource allocation. Financial sustainability is a key concern at this level. These actors evaluate the potential return on investment of telemedicine tools, taking into account direct costs, efficiency gains, and implications for staffing and infrastructure. Their approval and support are often prerequisites for scaling the intervention beyond a pilot phase.

Strategic & regulatory layer:

The strategic and regulatory layer includes stakeholders responsible for setting policies, standards, and funding conditions.

The Ministry of Healthcare establishes national health priorities and provides funding streams that shape hospitals’ operational capacity. Their policies influence whether telemedicine is eligible for reimbursement, how it is evaluated, and how it fits into broader healthcare strategies such as digitalization or decentralization of care.

In the Dutch healthcare system, health insurers act as key intermediaries responsible for purchasing and financing care under the Health Insurance Act (Zorgverzekeringswet). Insurers negotiate contracts with providers and determine whether TeleNeonatology is covered under existing reimbursement frameworks. They collect premiums, receive risk equalization payments, and manage reimbursement to providers for a wide range of services, including general practitioners, hospitals, and prescribed medications (Netherlands Scientific Council for Government Policy (WRR), 2021).

The IGJ (Inspection for Health and Youth Care) functions as a regulatory authority, overseeing quality standards, safety compliance, and ethical conduct. They monitor whether telemedicine interventions align with care guidelines and uphold patient rights. Their approval or scrutiny can accelerate or delay implementation timelines, particularly when interventions involve high-risk scenarios like neonatal resuscitation.

Lastly, patient and parent advocacy, such as Care4Neo, help to shape the public narrative and policy attention surrounding neonatal care. Though not a formal regulator, their influence can guide national or hospital-level priorities through lobbying, public awareness campaigns, or direct collaboration with health institutions.

2.5 Takeaways

This chapter has established the contextual and conceptual foundations for assessing the economic considerations of TeleNeonatology. Three key insights emerge:

Healthcare system pressures create a clear rationale for digital interventions:

Ageing populations, rising healthcare costs, and workforce shortages are straining the sustainability of care systems. These challenges underscore the urgency of solutions like telemedicine that can optimize resources, improve access, and maintain quality.

The NASSS framework offers a structured lens for the analysis of the implementation of Telemedicine:

By adapting the NASSS domains to include financial and economic questions, this study ensures that the evaluation of TeleNeonatology considers not only clinical feasibility but also the conditions for long-term economic sustainability. This approach addresses barriers and facilitators at multiple levels technical, organizational, and systemic. Ensuring to connect the thesis on a methodological level.

TeleNeonatology is embedded in a multi-stakeholder environment:

Successful implementation depends on aligning the clinical, logistical, and financial priorities of a diverse stakeholder network, from frontline NICU staff and parents to hospital boards, insurers, and regulators. Understanding these interdependencies is essential for assessing both adoption potential and scalability.

Together, these insights create the basis in first line to understand the extend of this research topic. Secondly, this information was used to choose the methodological approach, which will be introduced in the following, where the NASSS framework that initially was used to understand the implementation of Telemedicine, is now extended to be used as a guiding framework. This ensures that the gathered insights are being linked with broader system challenges, an adapted theoretical framework, and stakeholder perspectives.

3 Research Methodology

This chapter lays out the chosen research approach and methods, and places the research within the guiding NASSS framework. The NASSS framework is used as a tool to sstructure the research methods, and specifically the conduction of

3.1 Overview

Table 2 shows the overall research approach with the defined sub-question and each research method, including the data collection and data tools can be seen. This is also connected to the roles of the guiding NASSS framework.

Table 2: Overview of the Research Approach

Sub-Question		Research Method	Data Collection	Data Tools	Role of the NASSS framework
Literature Analysis					
SQ1	What economic factors influence the success of the implementation of Telemedicine?	Systematic literature review.	Peer-reviewed articles, government/industry reports.	Academic databases (PubMed, Scopus), Asreview, Excel	Used to categorize economic factors and identify gaps across seven implementation domains.
Quantitative Analysis					
SQ2	What are the outcomes from an economic evaluation of TN from different perspectives?	Quantitative analysis, cost minimization analysis based on a decision tree modelling.	Pilot data from Erasmus and Amphia hospital with extended data whenever needed.	Statistical software Python and decision modeling tools (TreeAge Pro, Excel, Python)	Guides model structure and stakeholder validation, linking cost results to real-world adoption and system fit.
Qualitative Analysis					
SQ3	What economic factors influence the implementation TeleNeonatology from various Stakeholder perspectives?	Qualitative interviews to explore in-depth considerations.	Qualitative data from interviews regarding decision-making processes.	Qualitative coding tools (Excel, MAXQDA)	Frames interview analysis by mapping economic and systemic barriers across NASSS domains.

The research flow diagram (Figure 2) shows how the research was executed.

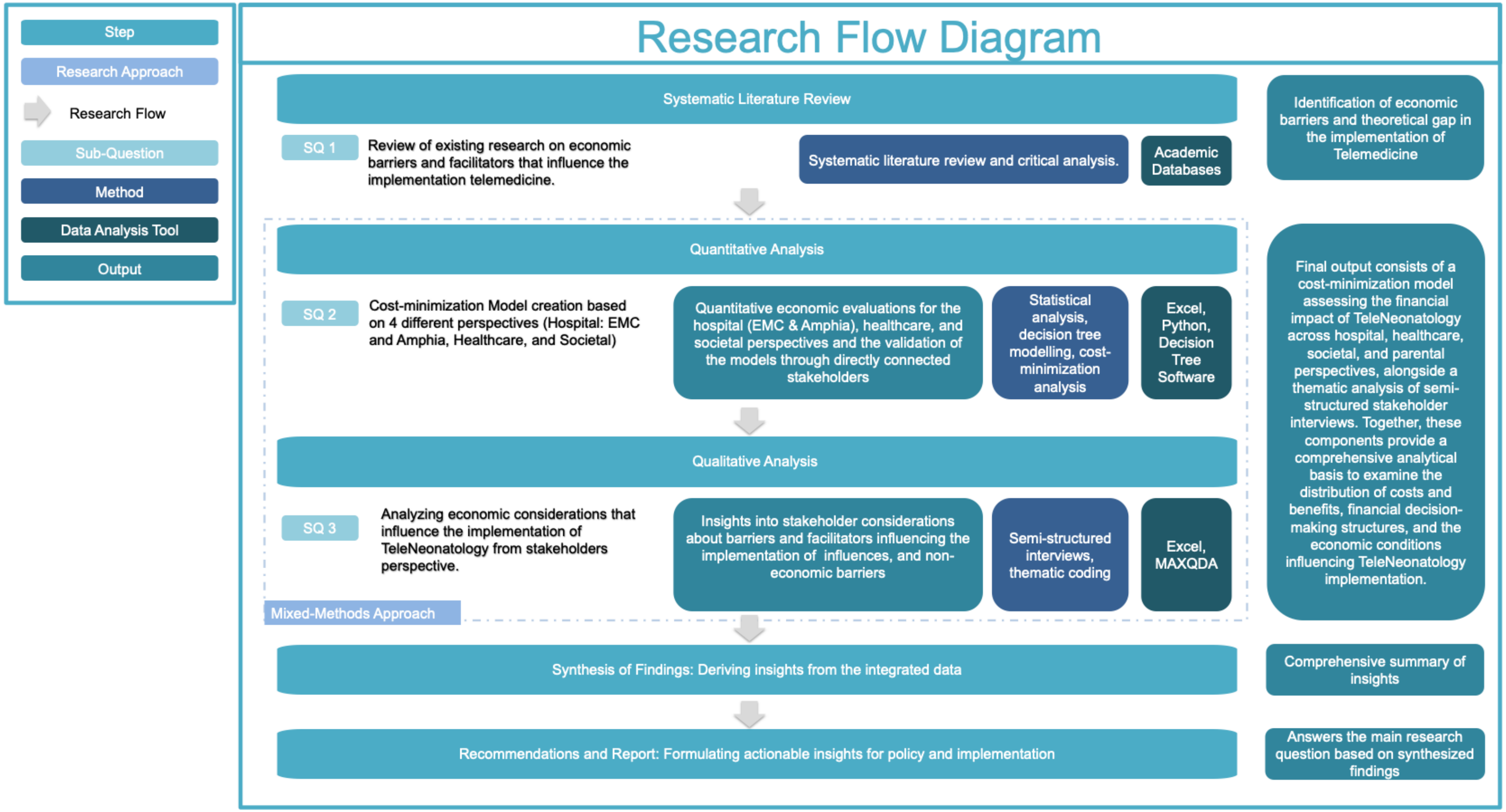


Figure 2: Research Flow Diagram

3.2 Sub-Questions

In the first Chapter the main research question was introduced:

How do economic considerations impact the implementation of TeleNeonatology?

In order to explore this question in depth, the following sub-questions were developed and analyzed. This progression started with a broad exploration of economic factors in the wider field of telemedicine, then narrowed the focus to the specific economic evaluation of TeleNeonatology, and finally considered stakeholder perspectives and implementation implications. This layered structure enabled a comprehensive understanding of the economic considerations influencing the implementation of TeleNeonatology.

SQ 1: What economic factors influence to the success of the implementation of telemedicine?

This question did set the foundation by identifying general economic factors that are known to facilitate or hinder the implementation of telemedicine more broadly. It helped contextualize TeleNeonatology within the wider field and drew connections to the implementation of it specifically. Without this initial step, subsequent analyses would have lacked a comparative basis and might have overlooked common economic barriers or enablers that influence telemedicine adoption across contexts. It thus ensured that the case-specific findings are interpreted within the broader systemic and economic realities of telehealth implementation.

SQ 2: What are the outcomes from an economic evaluation of TeleNeonatology from different perspectives?

This question focused on the quantitative results of the economic evaluation and explored the cost implications of TeleNeonatology from various perspectives (e.g., hospitals, healthcare, societal).

SQ 3: What economic factors influence the implementation of TeleNeonatology from various stakeholder perspectives?

This question connected general economic considerations to the specific case of TeleNeonatology from various stakeholder perspectives. It identified which financial barriers, incentives, or structural features play a decisive role in implementation, particularly in the Dutch healthcare context.

3.3 Research Approach and Methods

This study employed a mixed-methods approach using an explanatory sequential design. An explanatory sequential design is a type of mixed-methods approach where quantitative data is collected and analyzed first, and the results from this phase inform the subsequent qualitative phase, which delves deeper into understanding the 'why' and 'how' behind the numerical outcomes (Creswell & Clark, 2017). For this research project a quantitative analysis was conducted to model the economic evaluations of TeleNeonatology, and then a qualitative phase followed to explain and contextualize those quantitative findings.

Traditionally, economic evaluations in healthcare have relied heavily on quantitative methods that emphasize statistical rigor and financial metrics. However, in the past there have been more advocates for a more overall approach that incorporates qualitative insights into economic analyses. Qualitative research offers valuable depth in understanding stakeholder perspectives, organizational dynamics, and contextual factors that shape implementation. These methods allow researchers to capture nuanced experiences and decision-making rationales that would otherwise be missed in purely numerical evaluations (Dopp et al., 2019).

Rather than replacing quantitative methods, qualitative approaches can complement them through mixed-method designs. Mixed-method economic evaluations aim to integrate the strengths of both traditions to provide richer, more actionable insights. Such approaches are particularly valuable in implementation science, where financial decisions are often influenced by contextual factors, stakeholder priorities, and organizational readiness. These are areas where qualitative methods provide the right insights. Despite their potential, mixed-method economic evaluations remain underutilized in health services research, presenting a clear opportunity for advancement in this area (Dopp et al., 2019).

This approach is particularly suited, as TeleNeonatology is a complex socio-technical intervention operating at the intersection of economic, technical, and human factors. A purely quantitative analysis would overlook the nuances of implementation and user experience, while a qualitative-only approach would lack the rigor needed for economic decision-making (Creswell & Clark, 2017). The quantitative phase ensures initial rigor by enabling the development of a detailed economic model that captures cost evaluations from hospital, societal, and healthcare perspectives, while the subsequent qualitative phase offers contextual elaboration by exploring barriers and implementation challenges of TeleNeonatology. By sequencing the phases, the study conducts a focused investigation that first establishes measurable economic impacts before delving into the underlying reasons for any discrepancies or unexpected outcomes.

By combining both methods, this approach ensures a comprehensive evaluation that is both evidence-based and contextually informed (Creswell & Clark, 2017).

Limitations: While the explanatory sequential design offers a rigorous framework for addressing complex research questions, it also presents several limitations. First, the sequential nature of the design results in an extended timeline and greater resource demands. This requires precise planning and phased scheduling to ensure that both the quantitative and qualitative phases are conducted efficiently. Second, the reliance on a structured sequence can introduce rigidity, potentially limiting the ability to adapt to unexpected findings. If new insights emerge during the qualitative phase that suggest the need for additional quantitative analysis, revisiting the initial phase may be impractical due to time and resource constraints. Finally, the qualitative phase is highly dependent on the findings of the quantitative phase; if the initial quantitative results are inconclusive or limited, the subsequent qualitative analysis may lack sufficient depth. To mitigate this dependency, it is critical to ensure robust quantitative data collection and to allow for methodological flexibility during the qualitative phase to adjust based on preliminary findings.

Despite its limitations, the explanatory sequential design is well-suited to the study of TeleNeonatology. By addressing the complexity of this interdisciplinary field through an explanatory sequential design, the research is positioned to produce actionable, evidence-based, and stakeholder-informed outcomes.

3.4 Research Data and Analysis Tools

To address the sub-questions, the research relied on different data sources. This included financial, clinical and literature data:

Empirical Evidence and Data:

- Pilot Program Financials**:** Operational and economic data from the TeleNeonatology pilot at Erasmus MC and Amphia Hospital provided real-world context for the analysis. For further detailed information, the protocol for this pilot can be found here: https://pubmed.ncbi.nlm.nih.gov/40044493/. However, pilot programs may not fully represent long-term trends or broader applicability (Leon et al., 2010). Therefore, additional sources, such as telemedicine pilots in other hospitals or regions, served as benchmarks and were taken into consideration.
- Pilot Program Outcomes: Clinical insights from the TeleNeonatology pilots at Erasmus MC and Amphia helped to define relevant care pathways, model assumptions (e.g., length of stay, likelihood of transfer), and outcomes that were used in the economic model.
- Stakeholder Interviews: Semi-structured interviews with clinicians, medical managers, and technical staff provided insight into clinical workflows, care coordination practices, and how telemedicine affects clinical routines. These perspectives helped to interpret clinical-economic trade-offs that may not be captured in quantitative datasets. The selection of the interviews was based on the stakeholder analysis, to ensure that from each level one representative was included.

Theoretical/ Conceptual Evidence and Data:

- Literature Review: Academic literature served multiple purposes within this research. It helped to define key topics, guided methodological choices, supported decision-making during model development, and provided context for interpreting both quantitative and qualitative findings. The sources include studies on neonatal care, healthcare financing, telehealth reimbursement, and implementation frameworks such as NASSS.
- Benchmarking and Validation: Theoretical literature was also used to compare and validate findings. For instance, studies on cost-effectiveness of telemedicine and adoption trends in similar healthcare systems provide external validity and support triangulation of results.

These data sources ensured that the research is grounded in empirical evidence while also drawing from broader industry knowledge. The variance of data sources provided the best base ensuring the inclusion of different perspectives towards TeleNeonatology in this socio-technical system.

The following tools were used to analyze the collected data:

Literature Review

- AsReview and Excel: For the literature review, ASReview was used for screening, while Excel was used to extract and organize the data.

Quantitative Tools

- Python and Excel: These tools were used to develop the decision tree model, to conduct the sensitivity analyses, and to evaluate cost minimization relationships.

Qualitative Tools

- MAXQDA and Excel: These tools supported the coding and thematic analysis of interview and survey data, identifying recurring themes and insights.

This combination of tools ensured that the data was analyzed rigorously, allowing for both detailed quantitative evaluation and rich qualitative interpretation.

3.5 Operationalizing the NASSS Framework Across Research Phases

The previously introduced NASSS framework (chapter 2.2.1) not only provided theoretical grounding but also served as a guiding structure across all research components. The following section outlines how the framework informed the literature review, quantitative modeling, and qualitative analysis, ensuring a consistent and holistic approach to understand the economic considerations for the implementation of TeleNeonatology. The framework helped to systematically explore and reveal underlying mechanisms and contextual factors that may otherwise have been overlooked. It also guided the interpretation of results. It supported identifying both explicit and latent drivers and barriers of TeleNeonatology adoption, scale-up, and sustainability, thereby strengthening the comprehensiveness and relevance of this research.

Literature Review (SQ 1)

Using the NASSS framework provided a structured way to understand the complex interplay of factors that influence the implementation of telemedicine interventions. By organizing insights into the structured domains, the framework allowed for an exploration of both economic and system-level considerations. This is particularly valuable in telemedicine research, where interventions that appear cost-effective in controlled evaluations often fail to scale or sustain in real-world settings.

In addition, applying the NASSS framework helped to discuss and support critical reflection about the insights found. It not only deepened the analysis but also improved the relevance of findings. It shifted the focus from isolated outcomes towards a holistic understanding of what drives or hinders the successful implementation of telemedicine in complex healthcare environments.

Quantitative Analysis – Model Creation & Validation (SQ2)

The NASSS framework informed the structure and interpretation of the quantitative cost model by providing a systems lens through which to understand the financial implications of TeleNeonatology. Domains such as “The Technology”, and “The Value Proposition” are central to identifying cost drivers and assessing economic feasibility from different stakeholder perspectives (hospital, healthcare system, and society). By aligning the model with these domains, the analysis went beyond static cost comparison and considered contextual elements.

Quantitative Analysis – Stakeholder Perspectives (SQ3)

For this stage, the NASSS framework provided a valuable lens to understand how economic and non-economic factors influence stakeholder decision-making. By mapping implementation factors onto the NASSS domains, the analysis captured the multifaceted nature of adoption decisions. This ranged from perceived value and risk to organizational readiness and alignment with policy frameworks. This structured approach enabled a more nuanced interpretation of stakeholder motivations and resistance, revealing where implementation efforts may fail despite favorable economic evaluations. The NASSS framework thus supported the integration of economic modeling with real-world decision-making dynamics and highlighted leverage points for policy and operational interventions.

3.6 Takeaways

This chapter outlined the methodological foundation for examining the economic considerations of the TeleNeonatology implementation, combining quantitative rigor with qualitative depth through an explanatory sequential mixed-methods design. By sequencing an economic evaluation with stakeholder-focused interviews, the approach ensures that cost findings are not only robust, but also interpreted within the realities of organizational readiness, policy frameworks, and user experience. The inclusion of diverse data sources, from pilot program financials and clinical pathways to literature benchmarks, supports both triangulation and external validity.

The NASSS framework provided a consistent analytical lens across all research phases, guiding the structuring of sub-questions, informing model development, and framing the interpretation of stakeholder perspectives. This integration allows for the identification of both explicit and latent economic factors that shape adoption, scale-up, and sustainability. In doing so, the methodology creates a coherent bridge between system-level theory and context-specific economic analysis.

With this foundation in place, the research is positioned to generate findings that are not only empirically sound but also practically relevant for decision-makers, revealing how economic considerations intersect with the systemic dimensions of implementing TeleNeonatology.

4 Economic Factors influencing the Implementation of Telemedicine

4.1 Introduction

Health interventions are typically defined as actions, programs, or technologies designed to reduce or prevent health problems. Their overarching aim is to improve patient outcomes and enhance quality of life. However, the healthcare environment in which these interventions are introduced is often complex, rapidly evolving, and influenced by numerous interdependent factors (Mosadeghrad et al., 2022). In the context of telemedicine, evaluations often focus on the interventions themselves rather than on the broader health systems into which they are introduced, which may consist of multiple interacting components (Lau & Kuziemsky, 2017).
Given the inherently multifaceted nature of telehealth, traditional economic evaluation methods may be insufficient to capture its full complexity (Lau & Kuziemsky, 2017). Numerous documented cases show that health interventions, regardless of their clinical potential, often encounter economic implementation challenges in real-world settings. Increasing recognition is being given to the role of implementation processes themselves, with the success of an intervention depending not only on its design but also on how it is introduced and integrated into practice. Implementation strategies, which are the deliberate methods or techniques used to support adoption and long-term use, are considered essential for realizing the intended impact of an intervention (Ross et al., 2018).
This leads to the research question of the systematic literature review:

- What economic factors influence the success of the implementation of Telemedicine?

4.2 Methods

In the following the search terms, the used databases as well as the including and excluding criteria are introduced.

4.2.1 Databases

To ensure a comprehensive and systematic identification of relevant literature, four major bibliographic databases were searched: Medline ALL (via Ovid), Embase (via Embase.com), Web of Science Core Collection (via Web of Knowledge), and the Cochrane Central Register of Controlled Trials (via Wiley). These databases were selected to capture a broad and interdisciplinary range of studies. The range includes clinical, technological, policy, and economic dimensions of papers. Medline and Embase were included for their extensive coverage of biomedical and health sciences literature, while Web of Science provides access to a wide array of interdisciplinary research, including implementation and health services studies. The Cochrane Central Register was included to ensure that relevant controlled trials and evaluation studies are captured. Using multiple databases reduces the risk of publication bias and enhances the breadth of retrieved studies. The initial search was conducted with the support of the Medical Library at Erasmus MC. They supported translating the search terms into search strings and adapting this to the different searches on each database. They also combined the results into a RIS file.

4.2.2 Search Terms

To answer the research question effectively, a comprehensive search string was developed. The construction of the search string was guided by four key conceptual categories derived from the sub-research question:

1. *Telemedicine and Digital Health Technologies:* The first component includes terms related to telemedicine. This extends to telehealth, remote consultation, telemonitoring, videoconferencing, and other digital health applications. The terms ensure that the search captures a wide range of telemedicine interventions.
2. *Barriers, Facilitators, and Evaluation Constructs:* The second component targets studies that discuss enablers and challenges related to the implementation or effectiveness of telemedicine. This includes terms such as “barrier,” “facilitator,” “evaluation,” “acceptance,” and “perception.” Including this category allows for the identification of research that addresses why interventions succeed or fail beyond clinical outcomes.
3. *Economic Aspects:* The third component narrows the scope to literature that includes economic evaluations or considerations. Terms such as “cost,” “economic,” “investment,” “reimbursement,” and “financial” are included to ensure that the search retrieves studies that incorporate economic data or reflect financial perspectives relevant to implementation.
4. *Implementation and Adoption:* The final component focuses on the implementation process itself, including the adoption and implementation of telemedicine technologies. This captures studies that address real-world application, uptake, and sustainability.

4.2.3 Search String

Since each database uses different search structures and boolean operators (e.g. ADJ in Medline, NEAR in Embase and Web of Science, and NEXT in Cochrane) the search strings needed to be adjusted to match the syntax requirements and indexing logic of each platform. The time horizon was 2020-present. The overview of each search string and the adaption to each database can be seen in the following Table 3. For the search string no specific MESH terms were used.

Table 3: Overview of search string for each database

Medline	(exp *Telemedicine/ OR exp *Remote Consultation/ OR *Telecommunications/ OR Videoconferencing/ OR (telehospital* OR tele-hospital* OR telehealth* OR tele-health* OR telemedic* OR tele-medic* OR telemonitor* OR tele-monitor* OR telecare OR tele-care OR tele-icu* OR tele-intensive-car* OR telepresence* OR tele-presence* OR tele-referral* OR telereferral* OR teleconsultat* OR teleradiol* OR tele-radiol* OR ((remot* OR virtual*) ADJ3 (health* OR intervention* OR consult* OR diagno* OR medicine*)) OR electronic*-consult* OR ((remot*) ADJ3 (monitor*)) OR videoconferenc* OR video-conferenc* OR videocall* OR video-call*).ab,ti,kf. OR (((digital*) ADJ3 (health* OR intervention* OR consult* OR diagno* OR medicine*))).ti.) **AND** ("Evaluation Study".pt. OR (barrier* OR facilitator* OR enabl* OR challeng* OR influenc* OR restrict* OR percept* OR ((evaluat*) ADJ3 (stud*))).ab,ti,kf. OR (evaluat* OR factor* OR motivat* OR acceptabil* OR acceptance*).ti.) **AND** (exp Costs and Cost Analysis/ OR Economic Factors/ OR (cost* OR economic* OR financ* OR reimburs* OR invest OR investment* OR invested OR incentive* OR parameter*).ab,ti,kf.) **AND** ((implement*).ab,ti,kf. OR (adoption*).ti.) **NOT** ("Editorial".pt. OR "Comment".pt. OR "Letter".pt. OR "News".pt. OR "Congress".pt. OR "Meeting Abstract".pt. OR "Abstracts".pt. OR "Academic Dissertation".pt. OR "Published Erratum".pt. OR "Monograph".pt. OR "Textbook".pt. OR "Academic Dissertation".pt.) **AND** 2020:2030.(sa_year).
Embase	('telemedicine'/de/mj OR 'telediagnosis'/de/mj OR 'teleconsultation'/de/mj OR 'telesurgery'/de/mj OR 'telecare'/exp/mj OR 'telehealth'/exp/mj OR 'telemonitoring'/exp/mj OR 'telecommunication'/de/mj OR 'electronic consultation'/exp/mj OR 'videoconferencing'/de/mj OR (telehospital* OR tele-hospital* OR telehealth* OR tele-health* OR telemedic* OR tele-medic* OR telemonitor* OR tele-monitor* OR telecare OR tele-care OR tele-icu* OR tele-intensive-car* OR telepresence* OR tele-presence* OR tele-referral* OR telereferral* OR teleconsultat* OR teleradiol* OR tele-radiol* OR ((remot* OR virtual*) NEAR/3 (health* OR intervention* OR consult* OR diagno* OR medicine*)) OR electronic*-consult* OR ((remot*) NEAR/3 (monitor*)) OR videoconferenc* OR video-conferenc* OR videocall* OR video-call*):ab,ti,kw OR (((digital*) NEAR/3 (health* OR intervention* OR consult* OR diagno* OR medicine*))):ti) **AND** ('barriers'/exp OR 'facilitator'/exp OR 'influencing factor'/exp OR 'evaluation study'/exp OR (barrier* OR facilitator* OR enabl* OR challeng* OR influenc* OR restrict* OR percept* OR ((evaluat*) NEAR/3 (stud*))):ab,ti,kw OR (evaluat* OR factor* OR motivat* OR acceptabil* OR acceptance*):ti) AND ('cost'/exp OR 'economic parameters'/de OR 'economic aspect'/exp OR (cost* OR economic* OR financ* OR reimburs* OR invest OR investment* OR invested OR incentive* OR parameter*):ab,ti,kw) **AND** ('implementation'/exp OR (implement*):ab,ti,kw OR (adoption*):ti) **NOT** ([Conference Abstract]/lim OR 'editorial'/it OR 'letter'/it OR 'note'/it OR 'chapter'/it OR 'conference abstract'/it OR 'conference paper'/it OR 'conference review'/it OR 'erratum'/it OR [preprint]/lim) **AND** [2020-2030]/py
Web of Science	(TS=(telehospital* OR tele-hospital* OR telehealth* OR tele-health* OR telemedic* OR tele-medic* OR telemonitor* OR tele-monitor* OR telecare OR tele-care OR tele-icu* OR tele-intensive-car* OR telepresence* OR tele-presence* OR tele-referral* OR telereferral* OR teleconsultat* OR teleradiol* OR tele-radiol* OR ((remot* OR virtual*) NEAR/3 (health* OR intervention* OR consult* OR diagno* OR medicine*)) OR electronic*-consult* OR ((remot*) NEAR/3 (monitor*)) OR videoconferenc* OR video-conferenc* OR videocall* OR video-call*) OR TI=(((digital*) NEAR/3 (health* OR intervention* OR consult* OR diagno* OR medicine*)))) **AND** (TS=(barrier* OR facilitator* OR enabl* OR challeng* OR influenc* OR restrict* OR percept* OR ((evaluat*) NEAR/2 (stud*))) OR TI=(evaluat* OR factor* OR motivat* OR acceptabil* OR acceptance*)) **AND** TS=(cost* OR economic* OR financ* OR reimburs* OR invest OR investment* OR invested OR incentive* OR parameter*) **AND** (TS=(implement*) OR TI=(adoption*)) **AND** PY=(2020-2030) **NOT** (DT=("BOOK CHAPTER" OR "MEETING ABSTRACT" OR "LETTER" OR "EDITORIAL MATERIAL" OR "CORRECTION" OR "NOTE" OR "BOOK REVIEW" OR "CORRECTION ADDITION" OR "DISCUSSION"))
Cochrane CENTRAL	Filtered: publication date from Jan 2020 to Apr 2025 ((telehospital* OR tele NEXT/1 hospital* OR telehealth* OR tele NEXT/1 health* OR telemedic* OR tele NEXT/1 medic* OR telemonitor* OR tele NEXT/1 monitor* OR telecare OR tele NEXT/1 care OR tele NEXT/1 icu* OR tele NEXT/1 intensive NEXT/1 car* OR telepresence* OR tele NEXT/1 presence* OR tele NEXT/1 referral* OR telereferral* OR teleconsultat* OR teleradiol* OR tele NEXT/1 radiol* OR ((remot* OR virtual*) NEAR/3 (health* OR intervention* OR consult* OR diagno* OR medicine*)) OR electronic* NEXT/1 consult* OR ((remot*) NEAR/3 (monitor*)) OR videoconferenc* OR video NEXT/1 conferenc* OR videocall* OR video NEXT/1 call*):ab,ti,kw OR (((digital*) NEAR/3 (health* OR intervention* OR consult* OR diagno* OR medicine*))):ti) **AND** ((barrier* OR facilitator* OR enabl* OR challeng* OR influenc* OR restrict* OR percept* OR ((evaluat*) NEAR/3 (stud*))):ab,ti,kw OR (evaluat* OR factor* OR motivat* OR acceptabil* OR acceptance*):ti) **AND** ((cost* OR economic* OR financ* OR reimburs* OR invest OR investment* OR invested OR incentive* OR parameter*):ab,ti,kw) **AND** ((implement*):ab,ti,kw OR (adoption*):ti)

4.2.4 Inclusion and Exclusion Criteria

The primary objective of this review was to identify and analyze economic barriers/ facilitators to the implementation or expansion of telemedicine interventions. Therefore, studies must explicitly address economic considerations. This must be either the central focus of the paper or addressed as a clearly defined challenge within the broader implementation context.

During the abstract screening phase, the following inclusion criteria were applied:

- The paper must address telemedicine or broader digital health interventions (e.g., e-health).

- The paper must mention implementation barriers or challenges, regardless of whether these are specified as economic in nature.
- Studies were included if the abstract indicated that implementation barriers or facilitators would be discussed in the full text, even if the specific types of barriers were not listed.
- Abstracts referencing cost analyses or economic evaluations were also included, provided they were linked to telemedicine implementation.

Papers were excluded during the abstract screening, if:

- They focused exclusively on the technical (e.g., system architecture) or clinical (e.g., treatment outcomes) aspects of telemedicine, without any reference to implementation challenges or economic factors.
- They discussed telemedicine in general terms without any mention of barriers, costs, or system-level implementation considerations.
- The mentioned intervention did not connect to Telemedicine, also not in any broader context.

For the full-text review phase, the inclusion criteria were refined to ensure a more targeted analysis. Only papers that analyze telemedicine or digital health intervention implementation from an economic perspective were included:

- Studies explicitly examining economic barriers (e.g., financial constraints, reimbursement issues, return on investment).
- Studies assessing cost-effectiveness, cost-benefit, or budget impact as part of implementation feasibility.
- Studies identifying financial enablers or disincentives that affect the scaling, adoption, or sustainability of telemedicine interventions.

Studies were excluded at this stage, if:

- They did not provide a substantive discussion or analysis of economic factors related to telemedicine implementation.
- They focused solely on clinical efficacy, user satisfaction, or technical functionality, without linking these to financial or systemic considerations.
- The economic analysis was limited to broader healthcare system costs without specific application to the implementation process of telemedicine.

These criteria ensured that the final selection of studies directly informs the economic feasibility of telemedicine interventions, with a particular focus on identifying real-world implementation barriers and facilitators.

4.3 Results

4.3.1 Data Extraction

Extracting the data from all the Databases based on the search string and the defined time horizon, the following results were achieved (Table 4), performed on 01.04.2025.

Table 4: Results Database Search[1]

Database searched	Platform	Years of coverage	Records
Medline ALL	Ovid	1946 - Present	2142
Embase	Embase.com	1971 - Present	2829
Web of Science Core Collection*	Web of Knowledge	1975 - Present	2595
Cochrane Central Register of Controlled Trials**	Wiley	1992 - Present	868
Total			**8434**

A total of 8,434 records were retrieved, and after removal of duplicates, 4,845 unique records remained for screening.

4.3.2 PRISMA Diagram

The PRISMA chart (Figure 3) provides a structured overview of the literature selection process for the systematic review, including the following stages: Identification, Screening, Eligibility, and Inclusion.

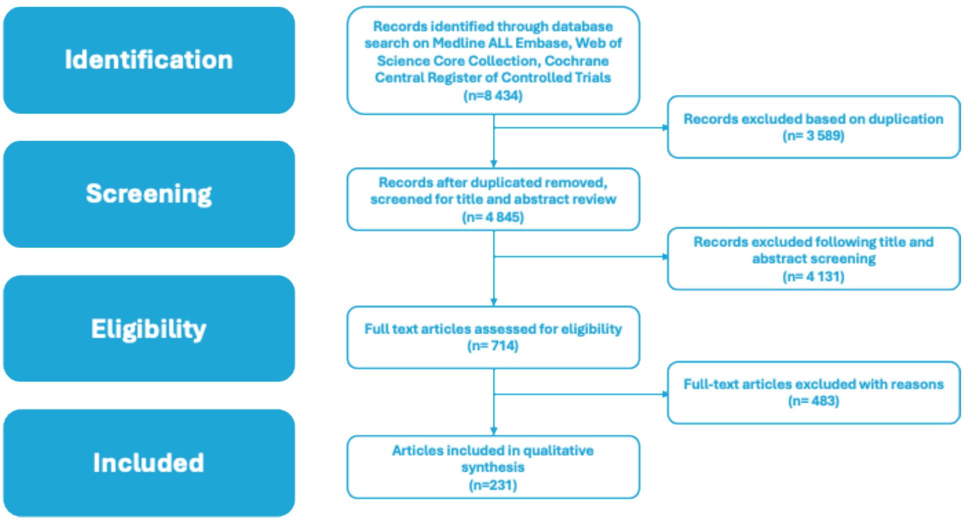


Figure 3: PRISMA chart

[1] *Science Citation Index Expanded (1975-present) ; Social Sciences Citation Index (1975-present) ; Arts & Humanities Citation Index (1975-present) ; Conference Proceedings Citation Index- Science (1990-present) ; Conference Proceedings Citation Index- Social Science & Humanities (1990-present) ; Emerging Sources Citation Index (2005-present)

*Exact search turned on in Web of Science Core Collection

** Manually deleted abstracts from trial registries

No other database limits were used than those specified in the search strategies

The number of studies included in the qualitative synthesis equals 231. These studies form the basis of the systematic analysis and will be further examined.

4.3.3 Analyzing the Influencing Economic Factors for the Implementation of Telemedicine

In the following the papers will be analyzed based on the adapted NASSS framework. Table 5 provides an overview of the included articles from the literature analysis, listing the authors, article titles, and the NASSS domains (1–7) identified in each publication. It illustrates the distribution of domain-level implementation factors across the reviewed studies, serving as the basis for the cross-domain analysis presented in the figures afterwards.

Table 5: Selected papers of the systematic literature review and the featured domains

Title	Authors	Domains						
		1	2	3	4	5	6	7
"A decade's worth of work in a matter of days": The journey to telehealth for the whole population in Australia	(Hall Dykgraaf et al., 2021)						x	
A Blueprint for the Conduct of Large, Multisite Trials in Telemedicine	(Commiskey et al., 2021)						x	
A double-edged sword-telemedicine for maternal care during COVID-19: findings from a global mixed-methods study of healthcare providers	(Galle et al., 2021)		x		x		x	
A Framework-Driven Systematic Review of the Barriers and Facilitators to Teledermatology Implementation	(Dovigi et al., 2020)						x	
A Narrative Review of Factors Historically Influencing Telehealth Use across Six Medical Specialties in the United States	(Rangachari et al., 2021)				x		x	x
A National Evaluation of Surgeon Experiences in Telemedicine for the Care of Hernia and Abdominal Core Health Patients	(Nikolian et al., 2022)						x	
A Scalable Framework for Telehealth: The Mayo Clinic Center for Connected Care Response to the COVID-19 Pandemic	(Haddad et al., 2021)						x	
A Survey of Tele-Critical Care State and Needs in 2019 and 2020 Conducted among the Members of the Society of Critical Care Medicine	(Laudanski et al., 2022)						x	
Acceptance factors of telemedicine technology during Covid-19 pandemic among health professionals: A qualitative study	(Mohammed et al., 2023)				x		x	
Achieving Equity in Telehealth: "Centering at the Margins" in Access, Provision, and Reimbursement	(Westby et al., 2021)		x				x	
Advancing Access to Healthcare through Telehealth: A Brownsville Community Assessment	(Ely-Ledesma & Champagne-Langabeer, 2022)				x		x	
Advancing telemedicine in cardiology: A comprehensive review of evolving practices and outcomes in a postpandemic context	(Huerne & Eisenberg, 2024)						x	
Advantages and Challenges of Telecardiology and Providing Solutions for Its Successful Implementation: A Scoping Review	(Nasim Aslani et al., n.d.)		x				x	
An evaluation of the provision of oncology rehabilitation services via telemedicine using a participatory design approach	(Brady et al., 2022)			x				
An insight into the implementation, utilization, and evaluation of telemedicine e-consultation services in Egypt	(Kamal et al., 2024)		x	x			x	
Analysis of the virtual healthcare model in Latin America: a systematic review of current challenges and barriers	(De La Torre et al., 2024)		x				x	
Analyzing the Effect of Telemedicine on Domains of Quality Through Facilitators and Barriers to Adoption: Systematic Review	(C. S. Kruse et al., 2023)		x				x	
Applications of Telemedicine in the Middle East and North Africa Region: Benefits Gained and Challenges Faced	(Abouzid et al., 2022)		x					
Are we ready for telemonitoring inflammatory bowel disease? A review of advances, enablers, and barriers	(Del Hoyo et al., 2023)						x	
Are we there yet? Unbundling the potential adoption and integration of telemedicine to improve virtual healthcare services in African health systems	(Mbunge et al., 2022)		x				x	
Assessing Telehealth in Palliative Care: A Systematic Review of the Effectiveness and Challenges in Rural and Underserved Areas	(Ghazal et al., 2024)		x	x				
Assessment of physician's knowledge, perception and willingness of telemedicine in Riyadh region, Saudi Arabia	(Albarrak et al., 2021)		x					
Assessment of the Barriers and Enablers of the Use of mHealth Systems in Sub-Saharan Africa According to the Perceptions of Patients, Physicians, and Health Care Executives in Ethiopia: Qualitative Study	(Aboye et al., 2024a)		x			x		x
Barriers and Facilitators for Implementing Paediatric Telemedicine: Rapid Review of User Perspectives	(Tully et al., 2021)			x	x		x	
Barriers and facilitators for the sustainability of digital health interventions in low and middle-income countries: A systematic review	(Kaboré et al., 2022)		x			x	x	
Barriers and facilitators to implementing telehealth services during the COVID-19 pandemic: A qualitative analysis of interviews with cystic fibrosis care team members	(Van Citters et al., 2021)						x	
Barriers and facilitators to the adoption of digital health interventions for COPD management: A scoping review	(Ramachandran et al., 2023)		x		x			
Barriers to Sustainable Telemedicine Implementation in Ethiopia: A Systematic Review	(Sagaro et al., 2020)		x					
Barriers to telemedicine adoption among rural communities in developing countries: A systematic review and proposed framework	(Lestari et al., 2024)			x			x	
Barriers to Telemedicine Adoption during the COVID-19 Pandemic in Taiwan: Comparison of Perceived Risks by Socioeconomic Status Correlates	(Wu & Ho, 2023)				x		x	
Benefits and drawbacks of videoconferencing for collaborating multidisciplinary teams in regional oncology networks: a scoping review	(Van Huizen et al., 2021)		x				x	
Breaking Sound Barriers: Exploring Tele-Audiology's Impact on Hearing Healthcare	(M. J. Lin & Chen, 2024)						x	x
Cardiac telerehabilitation: current status and future perspectives	(Brouwers et al., 2024)						x	
Care provider views on app-based treatment for female urinary incontinence: A mixed-methods study	(Wessels et al., 2023)						x	
Challenges and benefits of telepathology in education: lessons learned from COVID-19-a systematic review	(Borazjani et al., 2024)		x					
Challenges and solutions for implementing telemedicine in Iran from health policymakers' perspective	(Hosseini et al., 2024)		x				x	x
Challenges of Telemedicine during the COVID-19 pandemic: a systematic review	(Ftouni et al., 2022)						x	
Challenges of Using Telemedicine in Hospital Specialty Consultations during the COVID-19 Pandemic in Portugal According to a Panel of Experts	(Cunha et al., 2024)				x		x	
Challenges, Barriers, and Facilitators in Telemedicine Implementation in India: A Scoping Review	(Arora et al., 2024)						x	
Changes in Clinical Management of Patients with Schizophrenia Treated with Long-Acting Injectable Antipsychotics (LAIs), Including Telepsychiatry Use, During the COVID-19 Pandemic	(Haider et al., 2023)						x	
Changes in telepsychiatry regulations during the COVID-19 pandemic: 17 countries and regions' approaches to an evolving healthcare landscape	(Kinoshita et al., 2022)						x	
Clinical effectiveness and cost-effectiveness of teledermatology: Where are we now, and what are the barriers to adoption?	(R. H. Wang et al., 2020)			x			x	x
Clinician Perceptions of Barriers and Facilitators for Delivering Early Integrated Palliative Care via Telehealth	(Sadang et al., 2023)						x	
Cloud Horizons: Strengthening Rural Healthcare Through Telemedicine's Digital Canopy	(Kitole & Shukla, 2024)				x		x	

Considerations for the Implementation of a Telestroke Network: A Systematic Review	(Tumma et al., 2022)						x	x
Contraceptive care service provision via telehealth early in the COVID-19 pandemic at rural and urban federally qualified health centers in 2 southeastern states	(K. Beatty et al., 2023)				x		x	
Cost-Effectiveness of Telemedicine in Asia: A Scoping Review	(Salsabilla et al., 2021)		x					
Current and future use of telemedicine in surgical clinics during and beyond COVID-19: A narrative review	(McMaster et al., 2021)			x			x	
Current status of reimbursement practices for remote monitoring of cardiac implantable electrical devices across Europe	(Boriani et al., 2022)						x	
Current use of telehealth in urology: a review	(Castaneda & Ellimoottil, 2020)						x	
Current Use, Challenges, Barriers, and Chances of Telemedicine in the Ambulatory Sector in Germany-A Survey Study Among Practicing Cardiologists, Internists, and General Practitioners	(Gehrmann et al., 2025)						x	
Design, Adoption, Implementation, Scalability, and Sustainability of Telehealth Programs	(C. J. Wang et al., 2020)						x	x
Determinants of Telehealth Adoption Among Older Adults: Cross-Sectional Survey Study	(Tan et al., 2025)		x					
Disparities from bedside to "webside": barriers to achieving equity in telemedicine in obstetrics	(Udegbe et al., 2023)						x	
Early Patient-Centered Outcomes Research Experience With the Use of Telehealth to Address Disparities: Scoping Review	(Bailey et al., 2021)					x	x	
Effectiveness and barriers of telehealth services during COVID-19 pandemic: A narrative review	(Kalal et al., 2022)		x				x	
Effectiveness of Telepharmacy in Rural Communities in Africa: A Scoping Review	(Nwachuya et al., 2023)		x	x				
eHealth implementation in Europe: a scoping review on legal, ethical, financial, and technological aspects	(Bente et al., 2024)		x	x	x	x	x	x
Enablers and barriers in upscaling telemonitoring across geographic boundaries: a scoping review	(Gijsbers et al., 2022)						x	
Enablers and obstacles to implementing remote monitoring technology in cardiac care: A report from an interactive workshop	(Diaz-Skeete et al., 2020)				x		x	
Enabling Telemedicine From the System-Level Perspective: Scoping Review	(X. Li et al., 2025)			x	x	x	x	
Enterprise Adoption of Telehealth: An Academic Medical Center's Experience Utilizing the Telehealth Service Implementation Model	(Valenta et al., 2021)					x		
Evaluation of challenges for adoption of smart healthcare strategies	(Renukappa et al., 2022)		x				x	
Evaluation of Telehealth Services that are Clinically Appropriate for Reimbursement in the US Medicaid Population: Mixed Methods Study	(Saravanakumar & Ostrovsky, 2024)						x	x
Evaluation of Telemedicine Use for Anesthesiology Pain Division: Retrospective, Observational Case Series Study	(Jalilian et al., 2022)				x		x	
Examining the Role of Telemedicine in Diabetic Retinopathy	(Land et al., 2023)		x				x	
Expanding Technology-Enabled Nurse Delivered Chronic Disease Care	(German et al., 2024)						x	
Experiences of Medicaid Programs and Health Centers in Implementing Telehealth	(Uscher-Pines et al., 2019)				x		x	
Exploration of implementation, financial and technical considerations within allied health professional (AHP) telehealth consultation guidance: a scoping review including UK AHP professional bodies' guidance	(Leone et al., 2021)						x	
Exploring Barriers to Implementing Telerehabilitation from experiences of managers, policymakers, and providers of rehabilitation services in Iran: A Qualitative Study	(Rabanifar et al., 2022)						x	
Exploring factors of uneven use of telehealth among outpatient pharmacy clinics during COVID-19: A multi-method study	(Thomas et al., 2022)				x			
Exploring the adoption of telemedicine and virtual software for care of outpatients during and after COVID-19 pandemic	(Bokolo, 2021)				x		x	
Exploring the impact and challenges of tele-ICU: A qualitative study on nursing perspectives	(Saifan et al., 2025)		x	x			x	
Facilitators and Barriers for Telemedicine Systems in India from Multiple Stakeholder Perspectives and Settings: A Systematic Review	(Venkataraman et al., 2023)		x	x				
Facilitators and Barriers to the Adoption of Telemedicine During the First Year of COVID-19: Systematic Review	(C. Kruse & Heinemann, 2022)		x				x	
Factors influencing decision making for implementing e-health in light of the COVID-19 outbreak in Gulf Cooperation Council countries	(Al-Anezi, 2022)				x			
Factors Influencing Telehealth Adoption in Managing Healthcare in Saudi Arabia: A Systematic Review	(H. M. Alamri & Alshagrawi, 2024)		x		x		x	
Factors Influencing Telehealth Implementation and Use in Frontier Critical Access Hospitals: Qualitative Study	(Haque et al., 2021)		x				x	
Factors Influencing Telemedicine Adoption Among Health Care Professionals: Qualitative Interview Study	(Schürmann et al., 2025)					x	x	
Factors influencing telemedicine adoption among physicians in the Malaysian healthcare system: A revisit	(Tan et al., 2024)						x	
Financial Health Management of Otolaryngology by Telemedicine: Opportunities and Challenges	(M. I. Khan et al., 2024)		x	x	x	x	x	
Financial impact of telehealth: rural chief financial officer perspectives	(Uscher-Pines et al., 2022)				x	x	x	
Global Perspective on Telemedicine for Parkinson's Disease	(Shalash et al., 2021)						x	
Health policy experts' perspectives on implementing mental health specialist video consultations in routine primary care - a qualitative interview study	(Tönnies et al., 2021)						x	
Health professionals? Perspective towards challenges and opportunities of telehealth service provision: A scoping review	(Jonasdottir et al., 2022)			x			x	
Healthcare professional and manager perceptions on drivers, benefits, and challenges of telemedicine: results from a cross-sectional survey in the Italian NHS	(Antonacci et al., 2023)		x				x	
Healthcare Workers' Perspectives of mHealth Adoption Factors in the Developing World: Scoping Review	(Addotey-Delove et al., 2023)				x	x		
How can regulation and reimbursement better accommodate flexible suites of digital health technologies?	(Mathias et al., 2024)						x	
How to Pay for Telemedicine: A Comparison of Ten Health Systems	(Raes et al., 2022)						x	
How to promote telemedicine patient adoption behavior for greener healthcare?	(Lu et al., 2024)		x	x				
Identifying barriers in telemedicine-supported integrated care research: scoping reviews and qualitative content analysis	(Harst et al., 2020)		x	x	x		x	

Impact on healthcare costs of adding telemedicine to a multidisciplinary disease management program for heart failure: a sub-analysis of the iCOR trial	(Morillas Climent et al., 2024)			x				
Implementation factors influencing the sustained provision of tele-audiology services: insights from a combined methodology of scoping review and qualitative semistructured interviews	(Ramkumar et al., 2023)		x					
Implementation Guide for Rapid Integration of an Outpatient Telemedicine Program During the COVID-19 Pandemic	(Smith et al., 2020)						x	
Implementation of a full-scale prehospital telemedicine system: evaluation of the process and systemic effects in a pre-post intervention study	(Bergrath et al., 2021)			x				
Implementation of e-health innovative technologies in North Lebanon hospitals	(Halwani & Mouawad, 2021)		x					
Implementation of eMental health technologies for informal caregivers: A multiple case study	(Bastoni et al., 2023)						x	
Implementation of tele visit healthcare services triggered by the COVID-19 emergency: the Trentino Province experience	(Testa et al., 2022)						x	
Implementation of Telemedicine in a Laryngology Practice During the COVID-19 Pandemic: Lessons Learned, Experiences Shared	(Strohl et al., 2022)						x	
Implementation of telemedicine in the care of patients with aortic dissection	(Nishath et al., 2022)						x	
Implementation Science Perspectives on Implementing Telemedicine Interventions for Hypertension or Diabetes Management: Scoping Review	(Khalid et al., 2023)		x				x	
Implementation, Adoption, and Perceptions of Telemental Health during the COVID-19 Pandemic: Systematic Review	(Appleton et al., 2021)		x	x			x	
Implementing Technologies: Assessment of Telemedicine Experiments in the Paris Region: Reasons for Success or Failure of the Evaluations and of the Deployment of the Projects	(Le Bras et al., 2023)			x	x			
Implications for implementation and adoption of telehealth in developing countries: a systematic review of China's practices and experiences	(Ye et al., 2023)						x	
Integrating Telemedicine in Botulinum Toxin Type-A Treatment for Spasticity Management: Perspectives and Challenges from Italian Healthcare Professionals	(Spina et al., 2024)						x	x
Integrating the Consolidated Framework for Implementation Research (CFIR) and Tensions into a Novel Conceptual Model for Telehealth Advancement in Healthcare Organizations	(Schweidenback et al., 2024)		x				x	x
Interest in Improving Access to Pediatric Trauma Care Through Telemedicine	(Taylor et al., 2021)						x	
Investigating eHealth Lifestyle Interventions for Vulnerable Pregnant Women: Scoping Review of Facilitators and Barriers	(Smit et al., 2024)		x	x	x			
Investigating Pharmacists' Views on Telepharmacy: Prioritizing Key Relationships, Barriers, and Benefits	(Ameri et al., 2020)						x	
IoB-TMAF: Internet of Body-based Telemedicine Adoption Framework	(Ghiwaa et al., 2024)		x	x	x			
Knowledge, Attitude, and Barriers to Telerehabilitation-Based Physical Therapy Practice in Saudi Arabia	(Aloyuni et al., 2020)		x					
Leveraging health system telehealth and informatics infrastructure to create a continuum of services for COVID-19 screening, testing, and treatment	(D. Ford et al., 2020)						x	
Managing innovation: a qualitative study on the implementation of telehealth services in rural emergency departments	(Nataliansyah et al., 2022)		x		x		x	
Mobile Health Technology and Healthcare Providers: Systemic Barriers to Adoption	(Zakerabasali et al., 2021)				x		x	
Multidisciplinary telehealth interventions for autistic children in sub-Saharan Africa: challenges and recommendations	(Agbamu et al., 2025)		x			x	x	
National Emergency Tele-Critical Care in a Pandemic: Barriers and Solutions	(Pamplin et al., 2024)						x	x
Objectives, Outcomes, Facilitators, and Barriers of Telemedicine Systems for Patients with Alzheimer's Disease and their Caregivers and Care Providers: A Systematic Review	(Amiri et al., 2022)			x				
Optimising implementation of telehealth in oncology: A systematic review examining barriers and enablers using the RE-AIM planning and evaluation framework	(Bu et al., 2022)				x			
Optimizing the Potential for Telehealth in Cardiovascular Care (in the Era of COVID-19): Time Will Tell	(Patel et al., 2021)			x			x	
Outpatient Telehealth Implementation in the United States during the COVID-19 Global Pandemic: A Systematic Review	(Lieneck et al., 2021)						x	
Overcoming barriers of retinal care delivery during a pandemic-attitudes and drivers for the implementation of digital health: a global expert survey	(Faes et al., 2021)							
Overcoming Diffusion Barriers of Digital Health Innovations: Conception of an Assessment Method	(Hobeck et al., 2021)		x				x	
Overcoming Pilotitis in Digital Medicine at the Intersection of Data, Clinical Evidence, and Adoption	(Egermark et al., 2022)		x				x	
Patient and Clinician Satisfaction in Teledermatology: Key Factors for Successful Implementation	(Y. Li et al., 2023)			x		x	x	
Patient and provider perspectives of the implementation of remote consultations for community-dwelling people with mental health conditions: A systematic mixed studies review	(Galvin et al., 2022)		x	x			x	
Patient satisfaction with telemedicine in the Philippines during the COVID-19 pandemic: a mixed methods study	(Noceda et al., 2023)		x					
Patient's Perspectives of Telepsychiatry: The Past, Present and Future	(Naik et al., 2020)						x	
Pediatric Telehealth in the COVID-19 Pandemic Era and Beyond	(Curfman et al., 2021)						x	
Perception of telemedicine among medical practitioners in Malaysia during COVID-19	(Thong et al., 2021)						x	
Perceptions and barriers of telehealth services among trauma and acute care surgery patients	(Emily et al., 2022)						x	
Perspectives on telehealth implementation in Australia: An exploratory qualitative study with practice managers and general practitioners	(Savira et al., 2024)						x	
Protocol for an economic evaluation of scalable strategies to improve mental health among perinatal women: non-specialist care delivered via telemedicine vs. specialist care delivered in-person	(Singla et al., 2023)			x				
Provider perspectives on telemental health implementation: Lessons learned during the COVID-19 pandemic and paths forward	(Lipschitz et al., 2022)						x	
Radiologists' experiences and perceptions regarding the use of teleradiology in South Africa	(Schoeman & Haines, 2023)						x	
Recommendation to implementation of remote patient monitoring in rheumatology: lessons learned and barriers to take	(Hamann et al., 2023)						x	
Recommendations for Developing a Telemedicine Strategy for Botswana: A Meta-Synthesis	(Ncube et al., 2023)						x	

Recommendations for the Development of Telemedicine in Poland Based on the Analysis of Barriers and Selected Telemedicine Solutions	(Furlepa et al., 2022)						x	
Sauerbruch, STARPAHC, and SARS: Historical Perspectives on Readiness and Barriers in Telemedicine	(Reifegerste et al., 2021)						x	
Shared Decision-Making During Virtual Care Regarding Rheumatologic and Chronic Conditions: Qualitative Study of Benefits, Pitfalls, and Optimization	(Zickuhr et al., 2024)						x	
Shared features of successful tele-ICU models–A narrative review of successful implementation with a focus on LMIC models	(Hilker et al., 2023)		x					
Sociotechnical Factors Affecting Patients' Adoption of Mobile Health Tools: Systematic Literature Review and Narrative Synthesis	(Jacob et al., 2022)		x				x	
Spine surgeon perceptions of the challenges and benefits of telemedicine: an international study	(Riew et al., 2021)		x	x			x	
Spread, Scale-up, and Sustainability of Video Consulting in Health Care: Systematic Review and Synthesis Guided by the NASSS Framework	(James et al., 2021)				x			
Stakeholder perceptions of factors contributing to effective implementation of exercise cardiac telerehabilitation in clinical practice	(Rawstorn et al., 2025)						x	
Strategies to Make Telemedicine a Friend, Not a Foe, in the Provision of Accessible and Equitable Cancer Care	(Calton et al., 2023)						x	
Surgical decision-making in the digital age: the role of telemedicine - a narrative review	(Parveen et al., 2025)		x			x	x	x
Synchronous Home-Based Telemedicine for Primary Care: A Review	(Lindenfeld et al., 2023)						x	
System-Level Factors Associated With Telephone and Video Visit Use: Survey of Safety-Net Clinicians During the Early Phase of the COVID-19 Pandemic	(A. E. Sharma et al., 2022)						x	
Teleconsultation adoption since COVID-19: Comparison of barriers and facilitators in primary care settings in Hong Kong and the Netherlands	(Fernández Coves et al., 2022)						x	x
Teleconsultation as a strategy to support primary health care professionals: A scoping review: Teleconsultation to support primary health care	(Almeida et al., 2025)			x				
Teledermatology in remote Indigenous populations: Lessons learned and paths to explore, an experience from Canada (Quebec) and Australia	(Nguyen et al., 2023)		x	x				
Telehealth Benefits and Barriers	(Gajarawala & Pelkowski, 2020)						x	
Telehealth Beyond COVID-19	(Haque, 2021)						x	
Telehealth consultations in general practice during a pandemic lockdown: survey and interviews on patient experiences and preferences	(Imlach et al., 2020)						x	
Telehealth development in the WHO European region: Results from a quantitative survey and insights from Norway	(Gullslett et al., 2024)				x			
Telehealth during COVID-19: why Sub-Saharan Africa is yet to log-in to virtual healthcare?	(Babalola et al., 2021)		x				x	x
Telehealth for Contraceptive Care During the Initial Months of the COVID-19 Pandemic at Local Health Departments in 2 US States: A Mixed-Methods Approach	(K. E. Beatty et al., 2022)						x	
Telehealth for HIV Care Services in South Carolina: Utilization, Barriers, and Promotion Strategies During the COVID-19 Pandemic	(Yelverton et al., 2021)				x		x	
Telehealth for rural diverse populations: telebehavioral and cultural competencies, clinical outcomes and administrative approaches	(Hilty et al., 2020)						x	
Telehealth implementation for children with attention deficit hyperactivity disorder: a scoping review	(Susmarini et al., 2024)			x	x			
Telehealth Implementation Response to COVID-19 in the OneFlorida+ Clinical Research Network: Perspectives of Clinicians and Health Systems Leaders	(Theis et al., 2024)						x	x
Telehealth in chronic obstructive pulmonary disease: before, during, and after the coronavirus disease 2019 pandemic	(Sculley et al., 2022)		x				x	
Telehealth in pediatric emergency medicine	(Schinasi et al., 2021)			x			x	x
Telehealth in US hospitals: State-level reimbursement policies no longer influence adoption rates	(Gaziel-Yablowitz et al., 2021)						x	
Telehealth use in emergency care during coronavirus disease 2019: a systematic review	(Jaffe et al., 2021)		x				x	
Telehealth-Based Services During the COVID-19 Pandemic: A Systematic Review of Features and Challenges	(Khoshrounejad et al., 2021)						x	
Telehealth-guided provider-to-provider communication to improve rural health: A systematic review	(Totten et al., 2024)						x	
Telehealth, Ultrasound, and the Physician of the Future	(De la Mora, 2021)		x				x	
Telehealth: A new paradigm? Paediatric surgical subspecialty telemedicine survey in the COVID-19 Pandemic at a tertiary care centre	(Shin et al., 2024)						x	
Telemedicine along the cascade of care for substance use disorders during the COVID-19 pandemic in the United States	(C. Lin et al., 2023)						x	
Telemedicine and Cancer Care Barriers and Strategies to Optimize Delivery	(Doshi et al., 2024)		x			x	x	x
Telemedicine and COVID-19 pandemic: The perfect storm to mark a change in diabetes care. Results from a world-wide cross-sectional web-based survey	(Giani et al., 2021)						x	
Telemedicine and Deep brain stimulation - Current practices and recommendations	(V. D. Sharma et al., 2021)						x	
Telemedicine and Inequities in Health Care Access: The Example of Transgender Health	(Hamnvik et al., 2022)						x	
Telemedicine and information technology in health care management: Perspectives and barriers among the nursing students	(White et al., 2024)		x		x			
Telemedicine and Pediatric Care in Rural and Remote Areas of Middle-and-Low-Income Countries: Narrative Review	(Alnasser et al., 2024)						x	
Telemedicine for Kidney Transplant Recipients: Current State, Advantages, and Barriers	(Hezer et al., 2024)			x	x		x	
Telemedicine for Managing Type 1 Diabetes in Children and Adolescents Before and After the COVID-19 Pandemic	(Fogliazza et al., 2024)			x			x	
Telemedicine for neuro-ophthalmology: challenges and opportunities	(Liu et al., 2021)						x	
Telemedicine implementation and use in community health centers during COVID-19: Clinic personnel and patient perspectives	(Payán et al., 2022)						x	
Telemedicine Implementation in Pain Medicine: A Survey Evaluation of Pain Medicine Practices in Spring 2020	(Brian Brenner, 2022)						x	
Telemedicine in cancer care: lessons from COVID-19 and solutions for Europe	(Gottlob et al., 2025)						x	x
Telemedicine in Low- and Middle-Income Countries During the COVID-19 Pandemic: A Scoping Review	(Mahmoud et al., 2022)		x				x	
Telemedicine in Middle Eastern countries: Progress, barriers, and policy recommendations	(Al-Samarraie et al., 2020)		x			x	x	
Telemedicine in Orthopaedic Surgery: Challenges and Opportunities	(Makhni et al., 2020)				x		x	

Telemedicine in Overactive Bladder Syndrome	(Jericevic & Brucker, 2023)						x	
Telemedicine in Sleep-Disordered Breathing: Expanding the Horizons	(Verbraecken, 2021)			x			x	
Telemedicine in the driver's seat: new role for primary care access in Brazil and Canada: The Besrour Papers: a series on the state of family medicine in Canada and Brazil	(Agarwal et al., 2020)			x				
Telemedicine in the emergency department: an overview of systematic reviews	(Sharifi Kia et al., 2022)		x	x				
Telemedicine in the era of COVID-19: The East and the West	(Pardal et al., 2020)						x	
Telemedicine in the OECD: An umbrella review of clinical and cost-effectiveness, patient experience and implementation	(Eze et al., 2020)		x		x	x		
Telemedicine Pays: Billing and Coding Update	(Bajowala et al., 2020)		x				x	x
Telemedicine technology and implications for reproductive office operations	(Uustal & Blackmon, 2020)				x		x	
Telemedicine Use by Oculoplastic Surgeons During the COVID-19 Pandemic	(Lelli et al., 2022)						x	
Telemedicine Use in Disasters: A Scoping Review	(Litvak et al., 2022)						x	
Telemedicine use in Sub-Saharan Africa: Barriers and policy recommendations for Covid-19 and beyond	(Dodoo et al., 2021)		x	x			x	
Telemedicine: Current Status & Future Prospects	(Khade, 2023)		x		x			
Telemonitoring in Portugal: where do we stand and which way forward?	(Miranda et al., 2023)				x		x	
Telepharmacy and pharmaceutical care: A narrative review by International Pharmaceutical Federation	(Viegas et al., 2022)		x	x		x	x	
Telepharmacy for outpatients with cancer: An implementation evaluation of videoconsults compared to telephone consults using the CFIR 2.0	(Ryan et al., 2024)			x			x	
Teleradiology in India during the COVID-19 pandemic: merits, pitfalls and future perspectives	(Rackimuthu et al., 2022)						x	
The 'wrong pocket' problem as a barrier to the integration of telehealth in health organisations and systems	(Alami et al., 2023)		x	x	x	x	x	
The Benefits and Challenges of Implementing Teleophthalmology in Low-Resource Settings: A Systematic Review	(I. A. Khan et al., 2024)		x				x	
The Challenges of Telemedicine in Rheumatology	(Song et al., 2021)						x	
The Cost-Effectiveness of a Telemedicine Screening Program for Diabetic Retinopathy in New York City	(Muqri et al., 2022)		x					x
The Current Status of Telemedicine Technology Use Across the World Health Organization European Region: An Overview of Systematic Reviews	(Saigí-Rubió et al., 2022)		x		x			
The current use of telehealth in ALS care and the barriers to and facilitators of implementation: a systematic review	(Helleman et al., 2020)		x				x	
The efficacy, challenges, and facilitators of telemedicine in post-treatment cancer survivorship care: an overview of systematic reviews	(Chan et al., 2021)			x				
The emergence of telemedicine in a low-middle-income country: challenges and opportunities	(Kyei et al., 2024)		x					
The evolution of health system planning and implementation of maternal telehealth services during the COVID-19 Pandemic	(Aijaz et al., 2024)			x				
The Growing Role of Digital Health Tools in the Care of Patients with Cancer: Current Use, Future Opportunities, and Barriers to Effective Implementation	(Haemmerle et al., 2024)						x	
The impact of COVID-19 on urology office visits and adoption of telemedicine services	(Butaney & Rambhatla, 2021)		x	x				
The policy dimensions, regulatory landscape, and market characteristics of teledermatology in the United States	(Puri et al., 2020)						x	
The potential of telemental health in improving access to mental health services in Lebanon: Analysis of barriers, opportunities, and recommendations	(Naal et al., 2021)		x				x	
The promise of telemedicine in Pakistan: A systematic review	(Mahdi et al., 2022)		x	x				
The use of telemedicine in family medicine: a scoping review	(Mahdavi et al., 2025)			x	x		x	x
The utilisation of teledentistry in Australia: A systematic review and meta-analysis	(Lee et al., 2024)						x	
The utilization of telehealth during the COVID-19 pandemic: An American Pediatric Surgical Association survey	(Shah et al., 2022)						x	
The worldwide impact of telemedicine during COVID-19: current evidence and recommendations for the future	(Omboni et al., 2022)						x	
There and back again: the shape of telemedicine in U.S. nursing homes following COVID-19	(J. H. Ford et al., 2022)					x		
Towards virtual doctor consultations: A call for the scale-up of telemedicine in sub-Saharan Africa during COVID-19 lockdowns and beyond	(Chitungo et al., 2021)						x	
Turning digital in times of crisis: A values-based theory of telehealth adoption during the Covid-19 pandemic	(Bernardi, 2023)				x		x	x
Understanding barriers of telemedicine adoption: A study in North India	(Bakshi & Tandon, 2022)		x		x	x	x	
Understanding Barriers to Telemedicine Implementation in Rural Emergency Departments	(Zachrison et al., 2020)				x		x	
Understanding the implementation of telepractice in speech and language services for children and adults using a mixed-methods approach	(Ramkumar et al., 2022)						x	
United States Medicolegal Progress and Innovation in Telemedicine in the Age of COVID-19: A Primer for Neurosurgeons	(Cruz et al., 2021)						x	
Uptake and implementation of cardiac telerehabilitation: A systematic review of provider and system barriers and enablers	(Ferrel-Yui et al., 2024)			x			x	
Use of Telemedicine in Pediatric Services for 4 Representative Clinical Conditions: Scoping Review	(Southgate et al., 2022)						x	
Utility of Telehealth Platforms Applied to Burns Management: A Systematic Review	(García-Díaz et al., 2023)			x				
Videoconferencing psychotherapy in the public sector: Synthesis and model for implementation	(Muir et al., 2020)						x	
Virtual Primary Care Implementation During COVID-19 in High-Income Countries: A Scoping Review	(De Vera et al., 2022)						x	

Figure 4 provides an overview of how often each of the seven NASSS domains was mentioned across all reviewed articles.

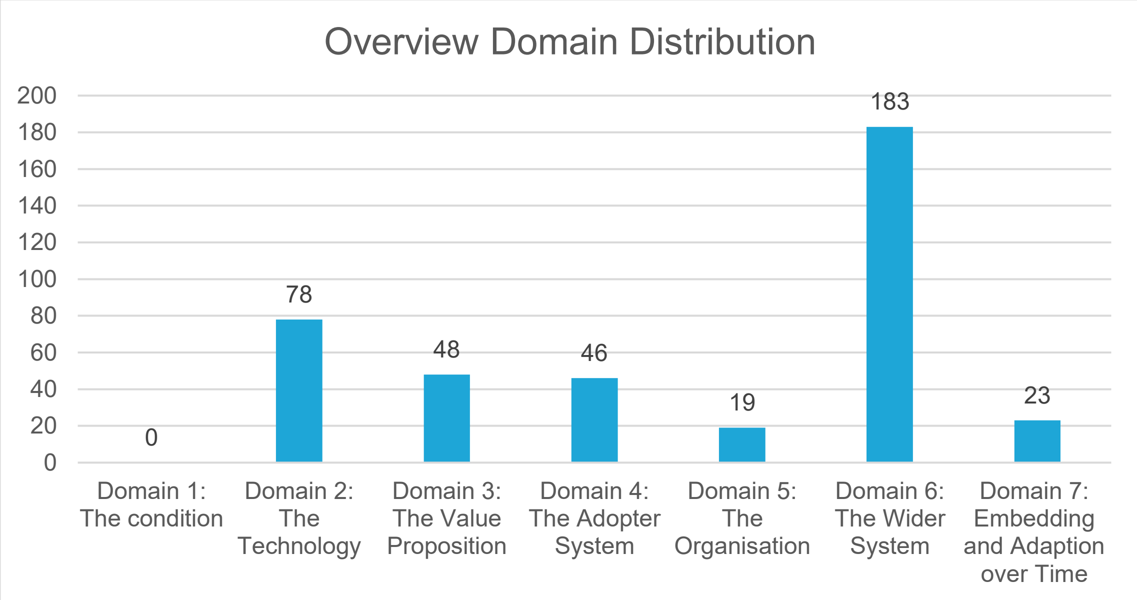


Figure 4: Overview of the NASSS Domain Distribution from the included Ltierature

Domain 6 (The wider system) was referenced most frequently, with 183 mentions (in around 80% of the included papers), highlighting the central role of policy, regulatory frameworks, and external system-level factors in influencing telemedicine implementation.

This is followed by Domain 2 (The technology) and Domain 3 (The value proposition), indicating the relevance of economic feasibility at the beginning of the implementation and perceived benefits in the literature. In contrast, Domains 1 (The condition), 5 (The organisation), and 7 (Embedding and adaptation over time) were discussed less frequently, suggesting that these aspects receive comparatively less attention in economic or implementation-focused studies.

Overall, the findings highlight a strong focus on external system-level factors and technological aspects within the current body of literature, while issues related to long-term adoption and organizational processes appear to be underrepresented.

Figure 5 presents the number of NASSS domains identified per article in the literature analysis.

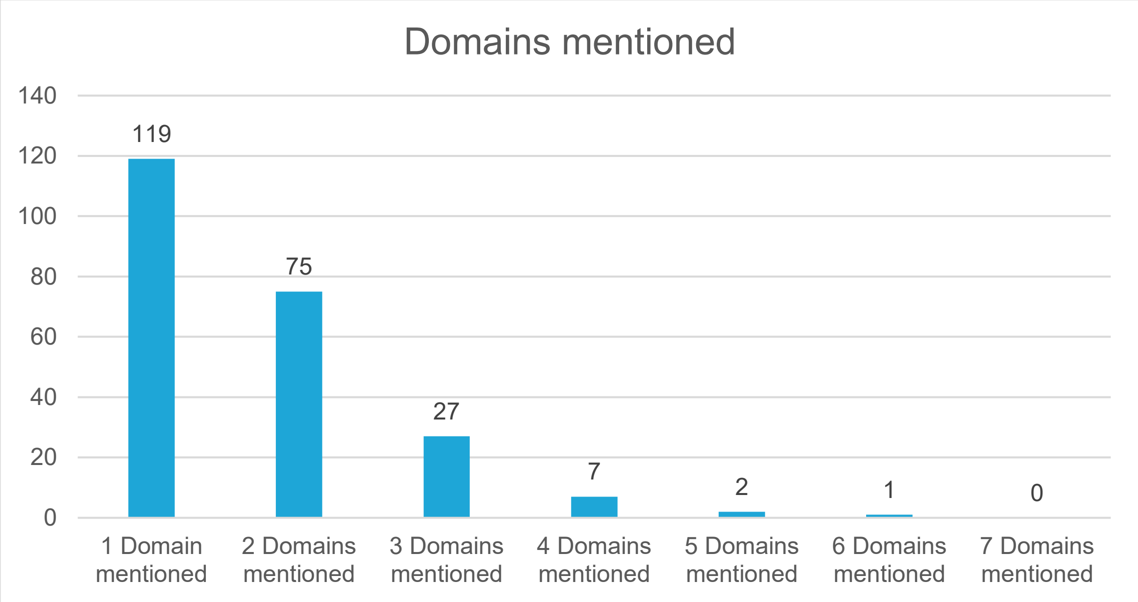


Figure 5: Distribution of the amount of mentioned domains

The results show that most articles referred to only one domain (175 articles) or two domains (75 articles). A smaller subset of articles addressed three (27 articles) or four domains (7 articles), while only two articles mentioned five, one mentioning six domains. Notably, no article covered all seven domains.

This distribution indicates that the majority of the literature focuses on a limited set of implementation aspects, often emphasizing specific areas of concern rather than providing a comprehensive, cross-domain perspective. This could reflect the fragmented nature of research on telemedicine implementation or the discipline-specific focus of individual studies.

In the following now each of the domains is discussed by providing the perspectives and insights the papers mention, understanding barriers and facilitators.

Domain 1: The condition

For Domain 1 (The Condition), no meaningful economic considerations were identified in the reviewed literature. This absence can be attributed to the nature of this domain, which focuses on the clinical characteristics of the health condition being addressed, such as disease burden, complexity, or acuity. In many telemedicine studies, these aspects are treated as fixed contextual variables rather than economic decision points.

Domain 2: The Technology

The economic implications tied to the technological dimension of telemedicine constitute a critical factor influencing adoption. Across the literature, three interrelated categories of financial burden are frequently identified: initial investment, ongoing operational costs, and training-related expenditures.

A recurring theme is the high upfront cost associated with implementation. These costs include the purchase of specialized hardware and software but also the necessary upgrades to existing infrastructure to support integration. Studies consistently cite these initial expenses as a principal barrier to adoption, especially in resource-constrained settings or systems with limited risk tolerance for unproven returns (Harst et al., 2020; Hilker et al., 2023; Renukappa et al., 2022). While developed healthcare systems may absorb such investments more readily, providers in low- and middle-income contexts often perceive the financial outlay as disprop(Babalola et al., 2021; Bakshi & Tandon, 2022)l., 2021; Bakshi & Tandon, 2022).

Beyond start-up costs, ongoing expenses related to system maintenance, software updates, and technical support further complicate the financial case for telemedicine. These recurring costs not only require sustained budget allocations but are also amplified by the often-custom nature of telemedicine platforms, which reduces opportunities for economies of scale (De La Torre et al., 2024; Ghazal et al., 2024). Downtime due to system failures or the need for technical intervention can further reduce the operational efficiency and erode the return on investment (Renukappa et al., 2022).

Training health professionals to use telemedicine technologies represents another critical financial consideration. The opportunity costs associated with training periods, during which staff are unavailable for clinical duties, are particularly significant in systems already operating under capacity constraints (De La Torre et al., 2024; Naal et al., 2021). Furthermore, inadequate training may result in reduced quality of care during early implementation phases, leading to reputational and clinical risks (Ghazal et al., 2024).

Importantly, technological standardization and broader market penetration are expected to drive down unit costs over time, making telemedicine more accessible and financially sustainable in the long term (Muqri et al., 2022).

Domain 3: The value proposition

The economic value proposition of telemedicine is inherently tied to how costs and benefits are distributed across stakeholders (patients, providers, and payers). While the clinical promise of telemedicine is widely acknowledged, its perceived financial value varies significantly, depending on perspective and context. This uneven distribution shapes both the willingness to adopt and the sustainability of implementation efforts.

From the healthcare provider’s perspective, concerns about financial burden and lack of return on investment (ROI) persist. Studies consistently report that providers face high implementation and operational costs, including those for equipment, training, and infrastructure (Venkataraman et al., 2023). Without clear financial integration into healthcare systems, many institutions lack incentives to commit long-term resources to telemedicine.

By contrast, several studies highlight the significant cost-saving potential of telemedicine, especially from the patient and system perspectives. Patients benefit from reduced travel costs, lower out-of-pocket expenses, and less time off work (Ghazal et al., 2024; M. I. Khan et al., 2024;

Susmarini et al., 2024). For example, M. I. Khan et al. (2024) demonstrated that telemedicine consultations were substantially cheaper than in-person visits, and providers also reported reduced operational costs, such as decreased demand for physical space and administrative resources. These savings are not only valued by individuals but also accumulate to broader system-level efficiencies, particularly in reducing hospital admissions and improving care continuity (Almeida et al., 2025; Morillas Climent et al., 2024).

Importantly, the literature shows that value creation is context-dependent. While some stakeholders realize direct savings, others may bear disproportionate costs. This misalignment complicates implementation. For instance, hospitals may invest in telemedicine systems but not be reimbursed at rates that reflect the value they generate, especially when societal or payer-level benefits are not internalized by the provider (Venkataraman et al., 2023).

To address these challenges, value-based financing approaches and validated economic models have been identified as critical enablers. Where robust cost-effectiveness analyses or ROI projections are available, they strengthen the rationale for reimbursement and long-term investment (Bente et al., 2024).

In summary, while telemedicine can generate substantial value, the distribution of that value, and the absence of mechanisms to equitably balance costs and gains remains a central implementation challenge. Effective economic evaluations must therefore account for who pays, who benefits, and under what conditions, in order to design financing strategies that are fair, sustainable, and scalable.

Domain 4: The adopter system

Adoption of telemedicine depends heavily on how clinicians and patients (the adopters of telemedicine) perceive its economic value and associated burdens. For clinicians, implementation often brings uncompensated tasks such as training, workflow changes, and system troubleshooting. These indirect costs, combined with a lack of financial incentives, can create resistance, especially in resource-constrained environments (Alamri & Alshagrawi, 2024; Bernardi, 2023). Concerns are heightened in private or rural hospitals, where high implementation costs and low return on investment (ROI) have led some to avoid adoption altogether, citing financial risk or even bankruptcy (Bakshi & Tandon, 2022).

Patients generally view telemedicine more favorably, especially when it reduces travel, wait times, and out-of-pocket expenses (Bernardi, 2023; White et al., 2024).

A major issue is that economic benefits are often poorly communicated to users. Clinicians are more likely to adopt when they understand time-saving potential and improved patient prioritization, while patients respond positively when direct cost savings are clearly outlined (Ghazal et al., 2024).

Facilitators include early stakeholder engagement, pilot programs demonstrating efficiency gains, and investments in professional training and dedicated implementation teams (Bente et al., 2024;

Cunha et al., 2024). These measures help reduce adoption friction and align perceived costs with actual benefits.

In summary, user-level adoption hinges on minimizing hidden burdens and making the economic value clear. Without addressing these practical concerns, even cost-effective systems may fail to gain traction among those expected to use them.

Domain 5: The organisation

At the organizational level, financial planning and leadership capacity play a decisive role in determining whether telemedicine systems are successfully adopted and maintained. One of the key challenges identified across the literature is the lack of a viable, long-term business model tailored to preventive or digital care interventions (Bente et al., 2024). Many healthcare institutions continue to view telemedicine as a cost-intensive solution, resulting in reluctance to pursue implementation, especially in settings where stable reimbursement mechanisms are absent (Bakshi & Tandon, 2022).

Poor integration of digital health into broader hospital strategies is a recurring issue. Strategic misalignment between digital development and existing business operations often limits funding allocation for telemedicine, particularly for recurrent costs such as maintenance and system updates (Aboye et al., 2024b). These issues are further amplified by weak cross-sector collaboration, where the lack of coordinated engagement among healthcare departments, governmental agencies, and technical partners undermines organizational capacity to scale and sustain telemedicine programs (Addotey-Delove et al., 2023).

Leadership also emerges as a critical factor. Studies emphasize that insufficient support from hospital management and the absence of clear mandates or incentives can significantly impede adoption. Even when systems are technically in place, uptake by staff remains low in environments where leadership fails to promote the active use of digital health tools for planning or care delivery (Addotey-Delove et al., 2023).

However, several organizational facilitators are also identified. Establishing a sustainable financial framework—such as through budget impact assessments or public-private partnerships—can enhance the feasibility of telemedicine implementation (Al-Samarraie et al., 2020; Bente et al., 2024; Eze, Mateus, & Cravo Oliveira Hashiguchi, 2020). Effective early-stage collaboration with third-party stakeholders has been linked to improved planning, reduced uncertainty, and clearer pathways for long-term funding (Bente et al., 2024). Furthermore, explicitly linking telemedicine initiatives to clinical performance or efficiency gains can strengthen the organizational case for investment (Valenta et al., 2021).

In summary, the organizational context significantly shapes the financial sustainability of telemedicine interventions. Leadership commitment, strategic alignment, and budgetary planning are essential to ensure the integration of telemedicine into core institutional functions.

Domain 6: The wider system

At the system level, the adoption of telemedicine is shaped by broader institutional, regulatory, and financial structures. Many of the structural barriers relate to the absence of stable funding mechanisms, regulatory clarity, and long-term reimbursement policies. These limitations are particularly pronounced in systems where funding is fragmented or heavily reliant on pilot-specific or short-term financial aid.

Historically, limited governmental funding and the absence of robust reimbursement frameworks have hindered the scale-up of telemedicine interventions (Babalola et al., 2021; Harst et al., 2020). While temporary regulatory flexibility during the COVID-19 pandemic facilitated initial uptake, many of these measures were not institutionalized to their full potential (Bernardi, 2023; De la Mora, 2021).

The lack of insurance reimbursement remains a dominant barrier across health systems. Many providers report that low or absent compensation for virtual care disincentivizes continued investment in telemedicine services (Mahdavi et al., 2025; Venkataraman et al., 2023). Moreover, variations in regional and national policies create uncertainty for multinational or cross-border telehealth services, particularly concerning liability and patient data governance (Bente et al., 2024; Shin et al., 2024).

Efforts to resolve these barriers emphasize the need for coherent national strategies. Investment in digital infrastructure, standardization of reimbursement schemes, and the establishment of clear regulatory pathways are critical enablers (Arora et al., 2024). Countries that have embedded telemedicine into public healthcare frameworks, backed by dedicated funding and aligned policy instruments, demonstrate greater sustainability and integration (Gottlob et al., 2025).

Overall, the wider system reveals that the implementation of telemedicine is constrained by by the surrounding financial and regulatory environment. Addressing these systemic constraints is central to creating a stable foundation for long-term adoption and institutionalization.

Domain 7: Embedding and Adaptation Over Time

Long-term sustainability of telemedicine initiatives depends on their ability to be embedded within institutional routines and adapted in response to evolving economic and organizational conditions. A key challenge in this domain lies in the uncertainty surrounding continued financial support, particularly with respect to reimbursement mechanisms.

Following the surge in telemedicine use during the COVID-19 pandemic, many temporary funding structures and regulatory waivers were withdrawn or left undefined, leading to hesitation among healthcare providers to commit to permanent integration (Bernardi, 2023). This underscores a broader concern around the instability of financing, which undermines the long-term planning and scalability of telemedicine programs.

The lack of established business models and long-term reimbursement policies further exacerbates this issue, particularly in underserved regions where telemedicine could offer the greatest benefit but faces the greatest funding volatility (Muqri et al., 2022). Without reliable financial models, implementation efforts risk reverting to short-lived pilot projects rather than evolving into systemic solutions.

Nonetheless, several strategies have been identified to facilitate sustained adoption. Expanding the patient base can improve financial viability by distributing fixed costs across a broader population (Bente et al., 2024). Additionally, successful programs tend to combine cost-effectiveness with operational simplicity and resource efficiency (Parveen et al., 2025). These features not only support economic sustainability but also foster clinical and administrative acceptance.

On a structural level, integrating telemedicine into national health budgets and aligning funding with strategic healthcare priorities are seen as essential measures to ensure long-term support (Babalola et al., 2021). Complementary investment from public-private partnerships and the inclusion of telemedicine in insurance reimbursement schedules can diversify funding sources and mitigate risks associated with dependence on singular funding streams (Gottlob et al., 2025; Mahdavi et al., 2025).

In summary, sustained adoption of telemedicine requires stable, long-term financial frameworks and strategic alignment with health system priorities. Embedding such innovations involves both institutional commitment and systemic policy adaptations that extend beyond temporary crisis responses.

4.3.4 Summary of the Influencing Economic Factors

Table 6 provides an overview of how each NASSS domain can be adapted to reflect key economic and financial considerations relevant to the implementation of telemedicine, summarizing associated barriers and facilitators identified across the literature. Rather than providing an exhaustive list, the table offers an overview that can support decision-makers, researchers, and practitioners in diagnosing implementation challenges.

Table 6: NASSS domain and corresponding adaption to economic and financial aspects

NASSS Domain	Aspects to be Considered	Barriers	Facilitators
1. The Condition	- Economic implications tied to disease burden and care complexity - Feasibility and scalability based on frequency/intensity of care - Cost-effectiveness in relation to population risk levels	- Not explicitly addressed in most studies	- Not explicitly addressed in most studies
2. The Technology	- Initial investment costs (hardware/software) - Maintenance and upgrade costs - Training costs / productivity losses during adoption - Cost of interoperability with existing systems	- High start-up and maintenance costs - Ongoing operational costs - Financial risk and infrastructure expense	- Hardware cost reduction - Patient-perceived affordability - Long-term cost savings
3. The Value Proposition	- Distribution of costs and benefits across stakeholders - Business models and financial returns - Economic justification of implementation (e.g., ROI)	- Low ROI - Financial burden for providers and patients - Lack of validated financial models	- ROI analysis - Value-based financing models - Savings in travel and admissions

4. The Adopter System	- Economic incentives for clinicians and patients - Financial consequences of workload or workflow changes - Perceived cost-benefit alignment	- Equipment and adoption costs - Misaligned financial incentives - Higher workload	- Early stakeholder engagement - Demonstrated cost-effectiveness/ minimization - Institutional readiness
5. The Organisation	- Budget availability and internal funding prioritization - Costs of workflow redesign and system integration - Strategic alignment with financial goals	- Weak leadership - Lack of strategic financial planning - Poor integration into business models	- Public-private partnerships - Strategic alignment - Clear financial frameworks
6. The Wider System	- Reimbursement models - Clarity of financial pathways - Regulatory requirements - National or regional funding policies	- Lack of reimbursement schemes - Fragmented legislation - Limited or temporary funding	- Updated reimbursement mechanisms - Investment in infrastructure - Investment possibilities
7. Embedding and Adaptation Over Time	- Long-term sustainability of financial models - Flexibility to adapt to funding structures - Integration into routine care	- Short-term funding focus - Risk of reimbursement withdrawal - Lack of sustainable financial models	- Expansion to broader populations - National budget allocations - Sustainable funding mechanisms

4.4 Discussion and Conclusion

The review of current literature reveals a predominant focus on financial costs, rather than broader economic dynamics, when evaluating the barriers to telemedicine adoption (Harst et al., 2020). Most studies highlight high implementation, maintenance, and training costs, as well as reimbursement uncertainty, as central economic challenges. These issues are consistently referenced regardless of the specific type of telemedicine being discussed, suggesting a shared understanding of the main financial barriers across different settings and technologies.

A noticeable limitation is that many studies only address one or two NASSS domains, leading to a fragmented analysis, with limited connection to concrete implementation strategies. The majority focusses on Domain 2 (Technology), Domain 3 (Value Proposition), Domain 4 (Adopter System), and Domain 6 (Wider System), while Domain 1 (Condition), Domain 5 (Organisation), and Domain 7 (Embedding over time) remain underexplored. This underrepresentation restricts the ability to fully capture the broader systemic and contextual factors that influence financial sustainability and long-term integration.

However, differences emerged in how frequently these aspects were discussed and how they were framed within the NASSS domains. Domains addressing system-level or technical concerns were more often associated with economic barriers, while domains like Organisation or Condition were frequently overlooked. This reinforces the relevance of the initial domain distribution overview, which provides a necessary contextual foundation to interpret how economic factors are represented in the literature and to assess how comprehensively the broader implementation landscape is considered.

While the NASSS framework helps structure the findings, its domains should not be viewed in isolation. Economic aspects often span multiple domains simultaneously. For instance, implementation costs may be reduced when sustainable practices (Domain 7) are planned from the outset, and understanding future reimbursement structures requires integrating both wider system (Domain 6) and sustainability considerations (Domain 7). Recognizing these interdependencies is crucial for interpreting economic barriers and developing coordinated implementation strategies.

To translate these general findings into actionable guidance for TeleNeonatology, it is necessary to better understand the specific economic conditions under which such interventions are implemented. The identified barriers, particularly around upfront investment, reimbursement uncertainty, and operational sustainability, apply directly to neonatalcare settings. Therefore, adapting these insights to TeleNeonatology requires closer alignment between economic evaluations and the organizational and system-level factors identified in this review.

5 Economic Evaluation of TeleNeonatology

In the paragraphs below, sentences and numbers have been blacked out because they contain confidential hospital data. This information, or aggregated information, is potentially available upon reasonable request at Naomi van der Linden.

5.1 Introduction

In the systematic literature review, structured by the seven NASSS domains, the economic considerations for the implementation of Telemedicine were introduced and analyzed.
The next step is to assess the financial and economic implications of implementing TeleNeonatology. Therefore, this chapter presents an economic evaluation based on a decision tree model to estimate total cost outcomes under varying scenarios. The purpose of this evaluation is to systematically compare the costs associated with TeleNeonatology against the standard care pathway and to determine the potential economic value from multiple perspectives, including the hospital perspectives, the healthcare system perspective, and the societal perspective.
While the previous chapters explored the broader systemic, economic implementation factors of telemedicine, this chapter takes a more quantitative approach by focusing on the concrete costs linked to the introduction and operation of TeleNeonatology. However, rather than viewing economic evaluation in isolation, it is important to place this analysis within the overarching framework used throughout this research, the NASSS framework.
Within this framework, the economic evaluation primarily intersects with two domains:
First, the *technology* domain is directly addressed through the modelling of resource use and associated costs linked to telemedicine. This includes upfront and ongoing costs such as investments in telemedicine technology, maintenance.
Second, is the connection to the *value proposition* domain. The decision model does more than calculating the total costs. It distinguishes between different stakeholder perspectives and identifies how the costs and potential benefits (such as reduced transfers and shortened hospital stays) are distributed across actors in the healthcare system. The model explicitly includes cost perspectives, thus contributing to an understanding of the broader economic justification for TeleNeonatology. By examining whether the intervention creates value for each stakeholder group, the model supports decision-making processes.
While the model includes perspectives from key actors, such as hospitals, payers, and society, it does not yet reflect the full complexity captured in the NASSS domains of Organisation and Wider System. The Organisation domain refers to internal structures and processes within hospitals,

while the Wider System domain encompasses health system dynamics, regulatory structures, and societal-level considerations. Although these actors (hospital, healthcare system, society) are included from a cost perspective, the broader institutional, policy, and systemic complexities they are embedded in are not modelled. Instead, these aspects are examined through the qualitative component of this research, where such interdependencies can be explored in more depth.

In summary, this economic evaluation, situated at the intersection of Technology and Value Proposition within the NASSS framework, plays a central role in translating clinical and operational innovations into actionable financial insights.

It is important to conduct the quantitative analysis first, as its results provide a necessary foundation for the subsequent qualitative phase. This ensures that the qualitative investigation is grounded in specific, real-world findings rather than abstract assumptions and stakeholder discussions can directly engage with the model outcomes

This chapter aims to answer the following sub-research question:

- What are the outcomes from an economic evaluation of TeleNeonatology from different perspectives?

While grounded in this particular context of TeleNeonatology, the model provides a transferable structure that can be adapted and scaled for use in other healthcare settings.

5.2 Methods

5.2.1 Definition of an Economic Evaluation

Every healthcare system is ultimately constrained by limited resources, inlcuding personnel, time, facilities, equipment, and knowledge. Therefore decisions must be made on how to allocate these resources to maximize population health and welfare (Drummond, 2015; Udeh, 2020). Since no society has the capacity to meet the needs of every individual, prioritization is inevitable. Within this context, efficiency refers to the ability to achieve the greatest possible benefit with the resources available (Udeh, 2020).

Health Technology Assessment (HTA) provide a systematic, multidisciplinary process to evaluate both the direct and indirect impacts of healthcare technologies. Its purpose is to assess their overall value and to support decision-making regarding their use within healthcare systems globally (WHO, n.d.). HTA aims to bring together evidence from medical, social, economic, and ethical domains in a structured, impartial, and transparent way (Facey, 2017).

A full economic evaluation systematically compares the resources used and the effects generated by at least two courses of action. These evaluations assess a health intervention against a clearly defined comparator, which may reflect current clinical practice or a standard approach within the specific healthcare context (Shafie et al., 2017). A more detailed overview of economic evaluations can be seen in Appendix 2: Economic Evaluation Overview (Page 131).

As resource allocation decisions become increasingly complex, particularly when comparing interventions across various populations and conditions, economic evaluations fill a critical knowledge gap (Udeh, 2020). This makes them particularly relevant for decision-makers who must determine how to spend for example a fixed public budget on healthcare services. Over time, the role of health economic evaluations in shaping health policy has expanded, reflecting their value in guiding evidence-informed decisions about resource use (Turner et al., 2021). Health economic analysis contribute to this process by assessing whether a health intervention provides value for money and supports optimal allocation of scarce healthcare resources (Shiell, 2002).

In the view of the National Health Care Institute of the Netherlands, economic evaluations help maintain healthcare that is both accessible and affordable by ensuring a balance between clinical benefits and financial investment. This principle is embedded in their guideline for economic evaluations, published in January 2024 (National Health Care Institute, 2024).

5.2.2 Selection of an Economic Evaluation Method

There are four primary forms of full economic evaluations, all of which compare the costs and outcomes of different policy or treatment options. These include cost-effectiveness analysis (CEA), cost-utility analysis (CUA), cost-benefit analysis (CBA), and cost-minimization analysis (CMA) (Briggs & O’Brien, 2001).

In the context of the current implementation pilot, no evidence was found indicating a difference in clinical outcomes between TeleNeonatology and the standard approach involving telephonic consultation. Given this equivalence in effectiveness, a cost-minimization analysis (CMA) is considered the appropriate method for evaluating the economic impact of the intervention. CMA is specifically designed for situations where alternative interventions are assumed to produce identical health outcomes, allowing the analysis to focus solely on the cost differences between them (Drummond, 2015; Sittimart et al., 2024; Tirrell et al., 2024).

CMA is a type of comparative economic evaluation that quantifies and compares the costs of two or more healthcare interventions under the assumption that they yield equivalent effects. It is primarily used in the healthcare sector to support decision-making by identifying the least costly alternative when clinical outcomes do not differ (Higgins & Harris, 2012; Sittimart et al., 2024). The analysis involves identifying the relevant perspective and determining all resource inputs. These resources are then measured in physical units, such as the number of hospital days or clinical visits, and translated into monetary values by applying corresponding unit costs (Duenas, 2013).

5.2.3 Decision Tree

In order to analyze the costs, influenced by the probabilty of events, a model was set up. In health economic evaluation, a model can be used to estimate the expected costs and effects of interventions (National Health Care Institute, 2024). These models rely on input parameters derived from empirical sources, such as clinical trials, and must be supported by statistically sound estimation methods (National Health Care Institute, 2024).

A decision tree is a structured modeling approach widely used in health economic evaluations to represent the possible outcomes and associated costs of different healthcare interventions over a defined period. It visualizes the progression of an individual through a series of events, beginning with a decision point and branching out into multiple clinical pathways (Drummond, 2015). This model is appropriate when patient interactions, such as infection transmission or queuing, are not relevant, and the decision problem does not involve recursive events or long-term transitions between many health states. Decision trees are particularly useful for modeling short- to medium-term interventions where the pathways and outcomes can be clearly defined within a specific time horizon, such as weeks or months (Gray, 2010).

In the case of TeleNeonatology, events like transfer rates, type of transport, and length of NICU or non-NICU stays may be integrated into the tree structure (Thao et al., 2022). The model's structure enables to assign costs to each outcome, adjust for the likelihood of different clinical events, and run sensitivity analyses to test how changes in individual parameters affect overall results (Thao et al., 2022).

At its core, a decision tree has three fundamental components:

- Decision nodes, typically represented as square boxes, mark the initial point where alternative strategies or treatments are compared (Drummond, 2015; Padula, 2023).
- Chance nodes, depicted as circles, represent points of uncertainty where multiple outcomes may occur based on clinical probabilities (Drummond, 2015).
- Terminal nodes denote the endpoints of each possible pathway (triangles). At these points, all relevant costs and effectiveness outcomes are tallied and weighted by the probability of reaching that specific outcome (Padula, 2023).

As Padula (2023) notes, while there is no single way to construct a decision tree, developing a valid and robust model requires careful alignment with the clinical pathway and the outcomes of interest. Decision trees serve as transparent tools for visualizing and comparing healthcare decisions, especially when the timing and nature of outcomes are relatively predictable.

5.2.4 Perspectives

In economic evaluations, the term perspective refers to the viewpoint from which the analysis is conducted. This perspective determines which types of costs and outcomes are considered relevant for inclusion in the study. The choice of perspective is critical, as it shapes the interpretation of value and cost-effectiveness in healthcare interventions. Greenhalgh et al. (2017) emphasizes that the perspective must be clearly stated and well-justified, as it directly affects which data is collected, how resources are valued, and ultimately, the policy conclusions drawn from the evaluation.

The perspective is especially important in telemedicine contexts because the distribution of costs and benefits may extend beyond the healthcare provider to other stakeholders, such as patients or caregivers (Lau & Kuziemsky, 2017). The broader the chosen perspective, the more comprehensive the evaluation (Sittimart et al., 2024).

Common Perspectives in Health Economic Evaluations

Each perspective has different implications for which costs and benefits are considered:

Hospital Perspective: The hospital perspective focuses on costs incurred directly by a specific institution, such as a neonatal intensive care unit (NICU) or a general hospital ward. It includes costs related to personnel, equipment, and infrastructure. Importantly, from the hospital's viewpoint, a reduction in costs, such as through fewer transfers or shorter stays, can also result in missed reimbursements or lost revenue, depending on the prevailing funding structure. As such, cost savings do not necessarily translate into financial benefits and may even pose disincentives to adoption under current reimbursement models.However, it excludes external services or patient-incurred costs, unless these are reimbursed directly by the hospital. In the case of TeleNeonatology it includes the perspective of the Amphia Hospital and Erasmus Hospital.

Healthcare System Perspective: This perspective includes all direct medical costs incurred by the healthcare system, regardless of which institution bears the cost. It encompasses both reimbursed and non-reimbursed healthcare expenses, such as hospital admissions, medical procedures, consultations, medications, diagnostics, and telemedicine infrastructure. It excludes costs borne by patients or society that fall outside the healthcare system but it does include all health-related costs that the system is ultimately responsible for, whether through public funding, insurance payments, or institutional budgets.

Societal Perspective: The societal perspective is the most inclusive and is often regarded as the gold standard in economic evaluations (Kim et al., 2020; Sittimart et al., 2024). It includes all healthcare costs, as well as non-healthcare costs such as caregiver time, patient travel, accommodation, and productivity losses. This approach provides a comprehensive view of welfare impact and helps avoid inefficient resource allocation caused by cost-shifting between sectors. However, implementing a societal perspective often requires more extensive data collection and methodological complexity. A balance must be struck between comprehensiveness and feasibility (Sittimart et al., 2024).

An overview can be seen in Table 7.

All of these above mentioned perspectives are included for this economic evaluation. Each model will follow the same structure but applies different cost components as defined by the respective perspective. This structured comparison helps highlight where cost-shifting occurs.

Table 7: Overview Perspectives

Perspective	Includes	Excludes	Best For	Goal
Hospital	Staff time, equipment, direct operational costs	Patient costs	Internal budgeting, service delivery analysis	Evaluate costs for a specific institution or department
Healthcare	All reimbursed and non-reimbursed	Informal care, patient travel	System-wide cost-effectiveness evaluations	Inform decisions at the health

	medical care (e.g. hospital + transfers)			system or insurer level
Societal	All health + non-health costs (caregivers, travel, productivity)	—	Policy decisions, welfare maximization	Capture the total impact on society, including indirect effects

5.3 Model Overview

The economic evaluation of the TeleNeonatology intervention is guided by PICOTS (patient population, intervention, comparator, outcomes, time horizon, setting) to ensure clarity and consistency (National Health Care Institute, 2024). Using the PICOTS helps to define the relevant context (Matchar, 2012), seen in Table 8.

The objective of this economic evaluation is to assess the cost implications and potential economic benefits of implementing TeleNeonatology as an add-on to existing neonatal care, in comparison

Patient	= the intended patient population the intervention is aimed at	- neonates within a regional perinatal care system in the Netherlands, specifically those receiving care within a collaboration between a level II NICU (Amphia Hospital) and a level IV NICU (Erasmus MC) - neonates >32 weeks born at the level II NICU with an indication or potential indication for transfer to a level IV NICU
Intervention	= the intervention under consideration	- TeleNeonatology, is implemented as an add-on to usual care - operationalized using the Teladoc Lite device, enabling real-time audiovisual consultations between the two hospital sites - supplements existing communication and aims to support clinical decision-making and parental interaction
Comparator	= the comparative intervention(s)	- comparator is usual care, which is currently defined as telephonic consultation between the involved clinicians at the level II and level IV NICUs - represents standard practice in Dutch neonatal care for inter-hospital communication
Outcome	= the relevant outcomes/outcome measures	(1) a reduction in the number of inter-hospital NICU transfers (2) an improvement in parental experience - Clinical outcomes such as mortality or comorbidity were found to be equivalent across groups and are therefore not included as effectiveness measures
Time	= the relevant time span for which effects and costs must be measured	- 10 years (depreciation time of technology investment)
Setting	= the context in which the care is delivered, when it can make a difference to the effect of the intervention, for example primary or secondary healthcare	- Context of a regional neonatal care network in the Netherlands. Care is delivered across two settings—a level IV NICU and a level II NICU—where differences in specialization, resources, and care protocols may influence both costs and outcomes. - The implementation context is representative of secondary and tertiary healthcare collaboration in Dutch clinical practice.

to usual care involving only telephonic consultations. The evaluation focuses on quantifying differences in resource use, particularly regarding inter-hospital NICU transfers, and aims to explore whether the intervention supports more efficient care delivery within a regional neonatal network.

Table 8: PICOTS (Patient, Intervention, Comparator, Outcome, Time, Setting)

5.3.1 Patient Journey Map - Pathways of TeleNeonatology

A patient journey map was created to understand all costs and probabilities included in the economic evaluations of TeleNeonatology (Figure 6). This patient journey map illustrates the clinical care pathway for a neonate requiring specialized consultation for a potential transfer between a NICU level II and IV. It captures the sequence of events, potential outcomes, and decision points that may occur from the moment a newborn is identified as needing advanced neonatal care.

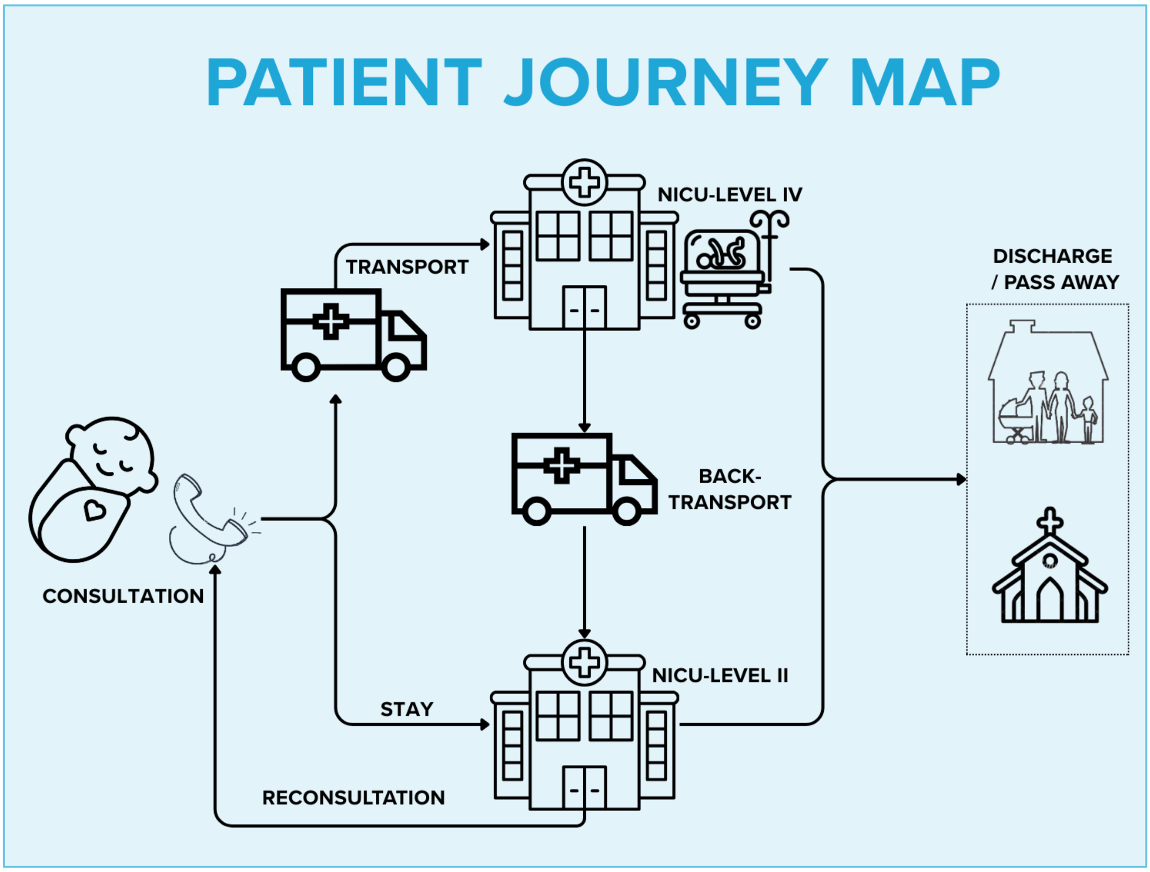


Figure 6: Patient Journey Map (own representation)

This journey map reflects the dynamic and non-linear nature of neonatal care. It also integrates the logistical realities of neonatal transport, back-transfer practices, and the possibility of repeated consultations, providing a comprehensive view of care continuity for vulnerable newborns.

The journey begins with a consultation. In this stage, a neonatologist or pediatric specialist remotely assesses the newborn's condition and advises whether care can continue at the local hospital, the Level II Neonatal Intensive Care Unit (NICU) at Amphia, or whether the newborn requires transfer to the more specialized facility at Erasmus Hospital.

If the newborn's condition is stable and manageable within the local NICU, the patient remains there for treatment. This is referred to as the "stay" pathway. Following this hospital stay, two outcomes are possible: the newborn may either be discharged home after successful treatment or may unfortunately pass away during care. If the patient's condition worsens during the stay or complications arise, a reconsultation may be triggered, restarting the assessment and potentially altering the care plan.

In cases where the initial consultation determines that higher-level care is required, the patient is transported to the Level IV NICU at Erasmus Hospital, where more intensive treatment and specialized resources are available. At this advanced facility, several outcomes are possible. If the newborn recovers, they may either be discharged directly from the Level IV NICU or back-transported to the original hospital (Level II NICU) for continued care closer to home. At the Level II NICU, the patient then follows the usual care trajectory, which may result in either discharge or death.

At any stage of the journey, whether following discharge or after a change in clinical status, a reconsultation may take place. This means the process can recur, as ongoing health concerns might necessitate further specialist input, renewed transfer, or additional intervention.

5.3.2 Model Structure

The creation of a decision tree is the next step for the economic evaluation. This is based on the previously introduced patient journey in 5.3.1. The decision tree, including the usual care and the intervention, as well as the possible pathways are pictured in Figure 7.

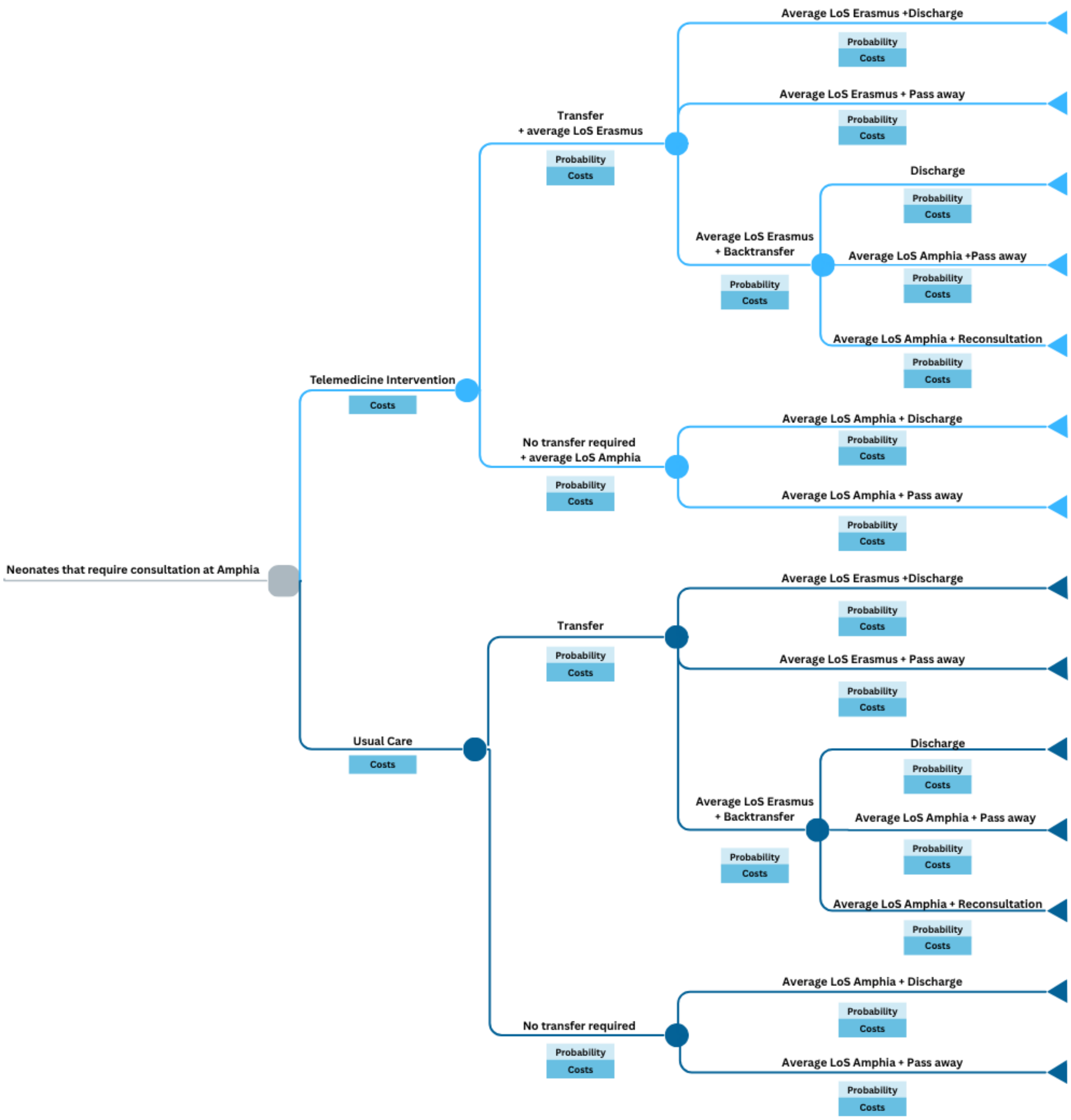


Figure 7: Decision Tree TeleNeonatology (Dark Blue – Usual Care; Light Blue – Telemedicine)

5.3.3 Model Implementation

The decision tree model was developed using a combination of Microsoft Excel and Python. While Excel was used primarily for data organization, cost and probabilistic calculations, and assumptions, Python was employed to build the underlying decision logic, perform sensitivity analyses, and visualize the model structure. The Python code allowed for more flexibility in handling complex branching and facilitated a clearer representation of the decision tree, which aligns with the patient journey introduced in Section 5.3.1. The full Python code used for model construction is included in the Appendix 3: Python Code: Decision Tree Model and Sensitivity Analysis (Page 132) for transparency and reproducibility.

5.4 Model Inputs

To enable a comprehensive evaluation of the economic impact of the TeleNeonatology, relevant parameters were systematically identified and categorized. These inputs include both the cost data and probabilties.

Cost parameters are derived by combining resource use estimates with corresponding unit costs. Resource use parameters quantify the volume or frequency of specific healthcare activities, while unit cost parameters assign a monetary value to each unit of resource used. Unit costs are drawn from standardized reference prices, internal hospital records, and expert consultation. Together, these components provide a comprehensive representation of costs incurred along the patient pathway. Each cost is explicitly assigned to one or more perspectives (healthcare provider, societal, and parental).

In parallel, probabilistic inputs reflect clinical pathways and patient outcomes under both the telemedicine and usual care scenarios. These probabilities are based on empirical pilot data and expert-informed assumptions where necessary, guiding the flow of patients through the decision tree model.

Together, these model inputs form the foundation for estimating the expected costs and outcomes under each intervention scenario, enabling a perspective-specific economic comparison of the TeleNeonatology implementation.

First an overview of all the entailed costs is given. Subsequently, the probabilties are listed. This is concluded with the assumptions for this model creation.

5.4.1 Cost Overview

Table 9 provides a consolidated overview of all cost components used in the economic evaluation of TeleNeonatology. Each row in the table refers to a specific cost category within the patient journey, from initial transport and admission to consultations and aftercare. Where applicable, the price year is indicated to ensure temporal consistency of cost data. For all values that are not based on 2024 cost levels, an inflation adjustment is applied according to the relevant consumer price index, with the percentage increase listed under “Inflation (add-on)”.[2] The resulting final cost column reflects the total cost per resource use item in 2024 in euros, which is used in the economic model calculations. All prices are rounded.

[2] For further information see Guideline for economic evaluations in healthcare 2024 version, Chapter 3.2.3

Table 9: Overview Cost Input

Resource		Unit Cost in €	Source	Estimated Use		Source	Price year*	Final cost €
Cate-gorie	**Description**			**Description**	**Units of cost needed per patient**			
Imple men-tation	TeleNeonatology Technology Cost Consultation (Erasmus)	[redacted]	Implementation Cost Pilot	One consultation per patient	1	Pilot Data	2024	[redacted]
	TeleNeonatology Technology Cost Consultation (Amphia)	[redacted]	Implementation Cost Pilot	One consultation per patient	1	Pilot Data	2024	[redacted]
Transport	Preparation for Transport at Amphia	[redacted]	Internal Hospital Information	One-time	1	Internal Hospital Information	2024	[redacted]
	Transport from Amphia to Erasmus	[redacted]	Internal Hospital Information	One transport needed	1	Internal Hospital Information	2024	[redacted]
	Backtransport from Erasmus to Amphia	[redacted]	Internal Hospital Information	One transport needed	1	Internal Hospital Information	2024	[redacted]
	Post Intensiv Care Surcharge at Amphia	[redacted]	Internal Hospital Information	Additional days at Amphia	5	Internal Hospital Information	2024	[redacted]
	Transport of the Mother	[redacted]	Reference Price	One transport needed	1	Internal Hospital Information	2022*	[redacted]
Admissio n Day	Amphia Day Charge	[redacted]	Reference Price	Mean Length of Stay	13.4	Pilot Data	2022*	[redacted]
	Erasmus Day Charge	[redacted]	Reference Price	Mean Length of Stay (Passing Away)	15	Internal Hospital Information	2022*	[redacted]
			Reference Price	Mean Length of Stay (Backtransfer)	5	Internal Hospital Information	2022*	[redacted]
Post-Disch arge	Hearing Test at Erasmus	[redacted]	Internal Hospital Information	One-time visit	1	Internal Hospital Information	2024	[redacted]
Consultation	TeleNeonatology Consultation Costs (Erasmus) per hour (Staff cost Neonatologist)	167	CAO Salary	Minutes	13	Pilot Data	2024	36
	TeleNeonatology Consultation Costs (Amphia) per hour (Staff cost Pediatrician + Nurse)	220	CAO Salary	Minutes	13	Pilot Data	2024	48
	Phone Consultation (Erasmus) per hour (Staff cost Neonatologist)	167	CAO Salary	Minutes	8	Pilot Data	2024	22

	Phone Consultation (Amphia) per hour (Staff cost Pediatrician)	171	CAO Salary	Minutes	8	Pilot Data	2024	23
Parental Costs	Dicsount Parking (14 day pass, at 4 week pass 14 Day Pass	[redacted]	Internal Hospital Information	Mean Length of Stay (Backtransfer)	1	Internal Hospital Information	2024	[redacted]
	4 Week Pass	[redacted]	Internal Hospital Information	Mean Length of Stay (Passing Away)	1	Internal Hospital Information	2024	[redacted]
	Ronald McDonald House Cost per Stay	[redacted]	Ronald McDonald Children's Fund (n.d.)	Mean Length of Stay (Passing Away)	15	Internal Hospital Information	2024	[redacted]
				Mean Length of Stay (Backtransfer)	5	Internal Hospital Information	2024	375
	Car Cost per Kilometer	[redacted]	Reference price / Google Maps	Distance Amphia Erasmus (55km)*Mean Length of Stay(Backtransfer)*2-way	550	Internal Hospital Information, Costing Manual Calculation	2022	[redacted]
				Distance Amphia Erasmus (55km)*Mean Length of Stay(Passing Away)*2-way	1650	Internal Hospital Information, Costing Manual Calculation	2022	460
	Additional Daily Expenses	[redacted]	Expert information	Mean Length of Stay (Passing Away)	15	Internal Hospital Information	2024	[redacted]
				Mean Length of Stay (Backtransfer)	5	Internal Hospital Information	2024	133

*price year outside of 2024, inflation adjustment (2022→ 2024 of 7.31%)

5.4.2 Implementation Costs

Implementation costs refer to the upfront and recurring expenses required to establish and operate the TeleNeonatology infrastructure, including hardware, software, installation, and licensing fees necessary for conducting remote consultations (seen in Table 10). This data was received directly from the implementation costs that Amphia and Erasmus incurred with this purchase.

Amphia requires the full TeleNeonatology setup to conduct video consultations, which includes the necessary hardware and installation. The purchasing cost of the equipment amounts to [redacted] complemented by installation expenses of [redacted] Following the Dutch costing manual, these are capitalized using annuity depreciation over 10 years at an interest rate of 2.5%, resulting in annual depreciation and interest costs [redacted] (Table 11). When combined with a yearly user license [redacted] and device license fees [redacted]), Amphia's total annual implementation costs amount to [redacted], corresponding to a per-consultation cost of [redacted] (n=31). In total 31 TeleNeonatology consultation was conducted during the pilot within 1-year. Therefore this number is used to calculate the per-consultation cost, equaling to [redacted] (Table 12).

In contrast, Erasmus only requires the software to receive video calls and provide remote consultation. Therefore, its costs are limited to a user license fee [redacted] [redacted] per year, which grants access to the TeleNeonatology platform without the need for dedicated hardware. This reflects Erasmus's role as a consultant centre that participates in the telemedicine process solely through video connection initiated by Amphia. Therefore the per-consultation cost equals [redacted] (Table 12).

Table 10: Implementation Cost Overview

Purchasing Costs in €	**Erasmus**	**Amphia**
Purchasing	/	[redacted]
Installation	/	[redacted]
Total	/	[redacted]
License Costs in €	**Erasmus**	**Amphia**
Device License	-	[redacted]
User License	[redacted]	[redacted]
Total	[redacted]	[redacted]

Table 11: Depreciation and interest costs calculation

Input Parameter	**Value**
Capital Investment (Purchase + Installation)	[redacted]
Depreciation Period (n)	10 years
Interest Rate (i)	2.5%
Annuity Factor	8.75
Annual Depreciation and Interest Cost	[redacted]

Table 12: Yearly Consultation Costs based on Purchase and License

Yearly Cost in €	**Erasmus**	**Amphia**
Annual depreciation and interest costs		[redacted]
License Cost Total	[redacted]	[redacted]
Total	[redacted]	[redacted]
Per consultation (n=31)	[redacted]	[redacted]

5.4.3 Transport Costs

Transport-related costs are a significant component of the neonatal care pathway, when infants require inter-hospital transfer for specialized treatment. Table 13 summarizes the transport costs drawing from current reimbursement tariffs directly from Amphia and Erasmus Hospital and Dutch reference prices, depending on the cost type.

The preparation for transport at Amphia costs [redacted], covering the clinical and logistical work involved in stabilizing the infant prior to transfer. The ambulance transport from Amphia to Erasmus MC, where neonatal intensive care is provided, costs at 2 939€ (Reference Price). If the infant is subsequently stabilized and returned to Amphia for step-down care, a backtransport cost of €781 applies. An additional [redacted] surcharge is included for post-intensive care management at Amphia following repatriation, reflecting the elevated clinical demands during this transitional phase. This is a daily charge, that continues to be paid for 5 days after the backtransfer. All these figures are based on current 2024 reimbursement rates and are used without further inflation adjustments.

In addition to infant-related transfers, the model also includes maternal transportation costs where relevant. In the model, mothers are always assumed to be transported one-way alongside their newborn, as transfers often occur shortly after birth, when the mother is still hospitalized and requires medical transport herself. This is costed at 528€, based on 2022 reference prices for inter-hospital transfers. Applying an inflation rate of 7.31%, the final 2024 cost amounts to 567€.

These transport costs reflect essential clinical and logistical activities in neonatal care and vary depending on the patient's pathway.

Table 13: Transport Cost Overview

Transport Component	Final Cost (€)
Preparation for Transport at Amphia	[redacted]
Transport from Amphia to Erasmus MC	2 939
Backtransport from Erasmus to Amphia	781
Post-Intensive Care Surcharge at Amphia	[redacted]
Transport of the Mother	567

5.4.4 Admission Day Costs

Hospitalization during the neonatal care pathway incurs daily admission costs, which vary depending on the hospital setting and are based on established Dutch reference prices. At Amphia Hospital, the daily admission cost is 644€ (Reference Price), covering standard neonatal care, personnel, and infrastructure expenses. Resource use is determined using the mean length of stay (LOS), based on pilot data and illustrated through a boxplot analysis. The mean LOS at Amphia is 13.4 days (Figure 8), resulting in a total admission cost of 8 630€. Since this price is based on 2022 values, it is adjusted using an inflation rate of 7.31%, yielding a final 2024 cost of 9 260€.

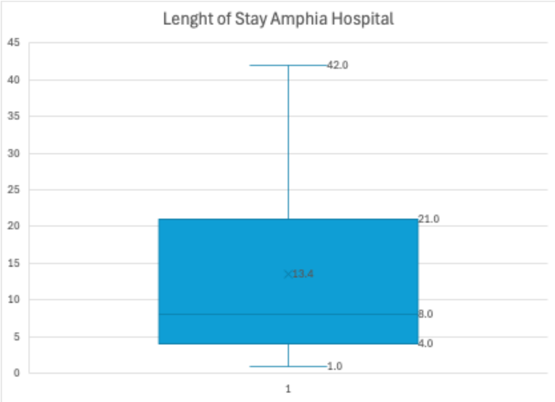
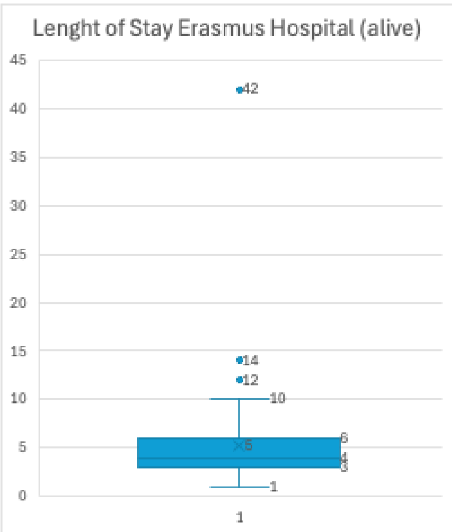


Figure 8: Length of Stay Amphia Hospital

At Erasmus MC the daily admission cost is significantly higher at 2 727€ (reference price). This elevated cost reflects the hospital's status as a level IV NICU, where care is more intensive and resource-demanding. It includes specialized personnel, advanced neonatal equipment, higher staff-to-patient ratios, and the overhead associated with providing highly complex and critical care services typically not available in secondary hospitals. Two care pathways are considered. First, in cases where infants pass away during NICU admission, the mean LOS is 15 days (Figure 10), resulting in an after-inflation total of 43 895€. Second, for infants stabilized at Erasmus and transferred back to Amphia, the average LOS is 5 days (Figure 9), leading to a total cost of 14 632€.

The length of Stay is based on the overall NICU stay data of the infants being transferred between Amphia and Erasmus in the years 2019 - 2024.



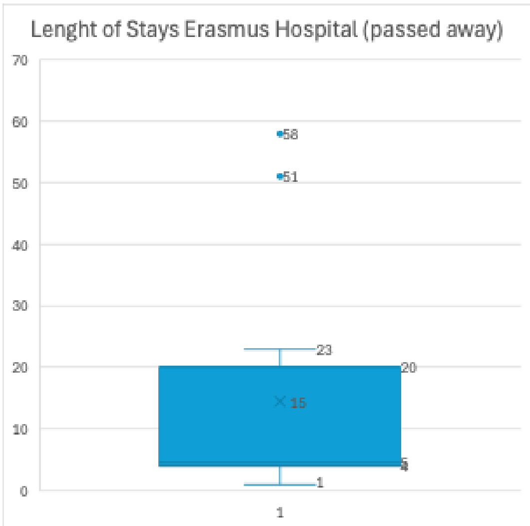


Figure 9: Length of Stay Erasmus Hospital *Figure 10: Length of Stay Erasmus Hospital*

5.4.5 Aftercare Costs

Following discharge, a hearing test at Erasmus MC represents a single follow-up appointment cost. This test occurs once and costs 31€ (Table 14). This appointment is required for all neonates who have stayed at Erasmus MC due to the increased risk of hearing impairments associated with neonatal conditions and treatments.

Table 14 Overview Costs Follow-up appointments

Defintion	Description	Final Cost €
Aftercare/ Follow-up appointments	Hearing test at Erasmus	31

5.4.6 Salary Structure and Consultation Costs

To estimate the personnel-related costs associated with TeleNeonatology and phone consultations, the analysis draws on the hourly staff cost rates. This calculates the consultation costs.

In accordance with the Guideline for Economic Evaluations in Healthcare (2024 version), a standardized costing approach is applied to estimate the personnel-related costs of key clinical roles involved in neonatal care. The Costing Manual specifically, outlines how to determine unit costs for healthcare resources, including staff time

For the purpose of this analysis, staff cost estimates are developed for three clinical positions. These include a neonatologist from Erasmus MC, as well as a pediatrician, and nurse from Amphia. Salary data for Erasmus MC is derived from the CAO UMC[3], while figures for Amphia Hospital are based on the CAO Ziekenhuizen[4]. The estimation process follows consistent assumptions across both hospitals to ensure comparability.

The salary scale defines the base remuneration band for a specific professional role (e.g., UMS for a neonatologistor 55.00 for a general nurse), while the intermediate step indicates the level of seniority or progression within that scale (e.g., step 3.0 for a pediatrician or step 7.0 for a nurse). These two components jointly determine the gross monthly salary applicable to each staff category at different points in the year.

The full calculation, including considerations for e.g. social security costs, can be seen in the Appendix 4: Salary Overview (Page 136).

The calculation reflects the full financial burden of each clinical role from the healthcare provider's perspective, incorporating salary, employer contributions, and overheads (Table 15). This is derived by multiplying the appropriate hourly rate by the average consultation duration, as observed during the pilot phase.

Table 15: Cost per patient-related hour

Position	Institution	Cost per patient-related hour (€)
Neonatologist	Erasmus MC	167
Pediatrician	Amphia	171
Nurse	Amphia	49

TeleNeonatology consultations are typically longer and involve multiple professionals, as they require visual interaction, real-time decision-making, and multidisciplinary discussion. Based on

[3] https://www.nfu.nl/sites/default/files/2024-09/Cao_2025-2025_NFU-24.01131_NL.pdf
[4] https://cao-ziekenhuizen.nl/sites/default/files/2024-02/salaristabel%20AMS%20voor%20publicatie%202023-2025.pdf

data from the pilot, the average duration of a TeleNeonatology consultation is approximately 13 minutes. In the Erasmus setting, this involves the neonatologist alone. At Amphia Hospital, the consultation is jointly attended by the pediatrician and a nurse, both actively participating in the session.

Given an hourly staff cost of 167€ for the Erasmus neonatologist, the cost of a 13-minute TeleNeonatology consultation is 31€. For Amphia, this is calculated for the combined hourly cost of the pediatrician (171€) and the nurse (49€). This results in a total of 220€ per hour, leading to a per-consultation cost of 48€ for 13 minutes.

In contrast, phone consultations are shorter and generally less collaborative. They are estimated at 8 minutes per consultation based on pilot data and typically involve fewer stakeholders. At Erasmus, phone consultations are again conducted by the neonatologist, while at Amphia, they are carried out solely by the pediatrician. The corresponding staff costs per consultation are 22€ for Erasmus and 23€ for Amphia.

Table 16 summarizes the consultation costs by type, institution, duration, and staff involved:

Table 16: Consultation Cost Overview

Consultation Type	Institution	Duration (min)	Involved Staff	Cost per Session (€)
TeleNeonatology	Erasmus	13	Neonatologist	36
	Amphia	13	Pediatrician + Nurse	48
Phone	Erasmus	8	Neonatologist	22
	Amphia	8	Pediatrician	23

5.4.7 Parental Costs

In addition to institutional and healthcare-related costs, the model incorporates parental expenses to capture the broader financial burden on families. These out-of-pocket costs are considered part of the societal perspective and include the parking costs and the travel costs, for the mean length of stay at Erasmus. It also includes the costs for families staying at the Ronald McDonald House, which based on the source directly from Ronald McDonald costs 75€ per night (multiplied with the length of stay). In addition to travel, parking, and accommodation costs, the model also includes additional daily parental expenses. These costs were estimated based on information obtained during the validation interview, in which an amount of €26.50 per day was indicated. The added expenses reflect the reality that parents often incur extra costs for food, drinks, and basic daily needs when they are unable to return home, particularly during prolonged hospitalizations at Erasmus (Table 17). These costs contribute to the overall societal burden and are included to provide a more complete view of the financial impact on families during neonatal treatment.

Table 17: Overview Parental Costs

Defintion	Final Cost in €
Dicsount Parking 14 Days	45
Discount Parking 4-week	60
Ronald McDonald House (pass away)	1 800
Ronald McDonald House (alive)	502
Car Cost for traveling back and forth (pass away)	736
Car Cost for traveling back and forth (alive)	205
Additional Daily Expenses (pass away)	636
Additional Daily Expenses (alive)	177

5.4.8 Model Input Parameters per Perspective

Since not all costs are incurred by each perspective, an overview is given on the different cost parameters and from which perspective they are considered (Table 18). An overview of the overall costs per decision branch in the model can be seen in Appendix 5: Decision Tree Branch Costs per Perspective (Page 137).

Table 18: Overview of Model Input per Perspective

Cost Description		Perspectives			
		Amphia	Erasmus	Healthcare	Societal
Implementation	TeleNeonatology Technology Cost Consultation (Erasmus)		x	x	x
	TeleNeonatology Technology Cost Consultation (Amphia)	x		x	x
Transport	Preparation for Transport at Amphia	x		x	x
	Transport from Amphia to Erasmus		x	x	x
	Backtransport from Erasmus to Amphia		x	x	x
	Post Intensiv Care Surcharge at Amphia	x		x	x
	Transport of the Mother			x	x
Admission Day	Amphia Day Charge	x		x	x
	Erasmus Day Charge		x		x
Post-Discharge	Hearing Test at Erasmus		x	x	x
Consultation	TeleNeonatology Consultation Costs (Erasmus) per hour		x	x	x
	TeleNeonatology Consultation Costs (Amphia) per hour	x		x	x
	Phone Consultation (Erasmus) per hour		x	x	x
	Phone Consultation (Amphia) per hour	x		x	x
Parental Costs	Dicsount Parking				x
	Ronald McDonald House Personal Contribution				x
	Travel Cost				x
	Additional Daily Expenses				x

5.4.9 Pathway Probabilities

To model clinical and logistical pathways in the economic evaluation, specific probabilities were assigned to each possible patient trajectory. These probabilities reflect observed or assumed likelihoods of transfer, survival, discharge, and reconsultation events based on empirical data and expert judgment. The following section describes the assigned probabilities for both the Telemedicine intervention and Usual Care scenarios, with an overview in Table 19.

Table 19: Overview Probabilities

Path	Telemedicine		Usual Care	
	Probability	Source	Probability	Source
Transfer to Erasmus	0.81	Pilot Data	1	General Procedure at Erasmus/ Expert Opinion
Discharge from Erasmus	0.00	General Procedure at Erasmus/ Expert Opinion	0	General Procedure at Erasmus and Amphia/ Expert Opinion
Pass Away from Erasmus	0.03	Pilot Data	0.03	General Procedure at Erasmus/ Expert Opinion
Backtransfer from Erasmus to Amphia	0.97	General Procedure at Erasmus/ Expert Opinion	0.97	General Procedure at Erasmus/ Expert Opinion

Discharge from Amphia (after stay at Erasmus)	1.00	General Procedure at Amphia/ Expert Opinion	1	General Procedure at Amphia/ Expert Opinion
Pass Away from Amphia (after stay at Erasmus)	0.00	General Procedure at Amphia/ Expert Opinion	0	General Procedure at Amphia/ Expert Opinion
Reconsultation from Amphia (after stay at Erasmus)	0.00	General Procedure at Amphia/ Expert Opinion	0	General Procedure at Amphia/ Expert Opinion
No Transfer	0.19	Pilot Data	0	General Procedure at Erasmus and Amphia/ Expert Opinion
Pass Away from Amphia	0	General Procedure at Amphia/ Expert Opinion	0	General Procedure at Amphia/ Expert Opinion
Discharge from Amphia	1	General Procedure at Amphia/ Expert Opinion	1	General Procedure at Amphia/ Expert Opinion

The modeled probabilities illustrate key differences between Telemedicine and Usual Care. The availability of teleconsultation reduces the proportion of patients requiring transfer (81% vs. 100%). Therefore, the Telemedicine pathway introduces the possibility of local management without transfer, which has a 0% chance in Usual Care. In both scenarios, backtransfer and eventual discharge are modeled as near-certainties for survivors, reflecting typical care pathways.

These pathway probabilities form the basis for weighting the various cost components within the decision model. By assigning costs to each step in the patient journey and applying the corresponding probabilities, the model generates expected cost outcomes for both the Telemedicine intervention and Usual Care scenarios. This approach ensures that differences in clinical pathways, such as the reduced transfer rate, are directly reflected in the comparative economic evaluation. The following sections describe how these probabilities and cost parameters are combined to estimate total and incremental costs from healthcare, societal, and parental perspectives.

5.4.10 Model Assumptions

Every economic model requires a series of assumptions to make the analysis feasible and to compensate for incomplete or unavailable data. These assumptions simplify real-world complexity and allow for the translation of clinical pathways, behaviors, and cost structures into a structured model. However, they also introduce uncertainty and must therefore be transparently reported. The following Table 20 summarizes the key assumptions applied in the construction of the economic evaluation model for TeleNeonatology. They reflect modeling decisions made regarding patient trajectories, parental behavior, cost allocation, and data limitations.

Table 20: Overview of Assumptions

Assumption	Explanation
Clinical Pathway Assumptions	
Patients follow a single care pathway	Each neonate is modeled to either be transferred to Erasmus or treated locally at Amphia, no mixed or looping pathways are included.
All backtransferred patients survive	Patients transferred back from Erasmus to Amphia are assumed to survive and be discharged.
No reconsultation occurs	The probability of follow-up consultations is set to 0%; each patient receives only one consultation.
Clinical outcomes are equivalent	No difference in mortality or morbidity between TeleNeonatology and Usual Care is assumed; cost minimization analysis is used.
One consultation per episode	Each patient receives either one TeleNeonatology or one phone consultation; multiple consultations are not modeled.

Maternal Transport	Since neonates are transferred early on, the mother is always assumed to be transported one way with her own ambulance. The backtransfer is within the travel costs faced by the parents.
Parental Behavior and Family Assumptions	
Parents travel daily	Parents travel back and forth between home and hospital each day of their child's admission.
Personal car used for all travel	Travel costs are based on car use; public transports are not considered.
Full Ronald McDonald House stay	Parents are assumed to stay for the full NICU length of stay when applicable (e.g., 24 days for death, 6.7 for backtransfer).
Parking charged at a flat discounted rate	Discounted parking fees are applied based on average case duration (e.g., €45 for 14 days).
Productivity loss not monetized	Parents lost work time is the same, whether the baby stays at Amphia or Erasmus.
Resource Use and Costing Assumptions	
Consultation times are fixed	TeleNeonatology consultations last 13 minutes; phone consultations last 8 minutes across all cases; based on the average
Only one hearing test post-discharge	A single follow-up appointment is included; other aftercare is not modeled.
Staff costs use standardized hourly rates	Hourly wages include social security, overhead, and are averaged across roles and settings.
Technology cost per use based on 31 consults	Implementation and license costs are divided over 31 consultations in the pilot year.
No maintenance or upgrade costs included	Only depreciation and licensing costs are considered for TeleNeonatology technology.
Inflation is applied for the cost inputs outside of 2024	All cost inputs are adjusted to 2024 values using a uniform inflation rate.
LoS is based on the mean value	Mean length of stay is used for cost estimation; no distribution or variability is modeled.
Scope and Modeling Boundary Assumptions	
Only neonates >32 weeks are modeled	The model is restricted to late preterm and term infants included in the pilot study.
Only Amphia and Erasmus MC are included	The model reflects only care between these two hospitals; other regional centers are excluded.
Reimbursement equals cost	Reimbursed Diagnosis Treatment Combinations (DBCs) are used as proxies for actual institutional cost.
No opportunity costs are modeled	Unused NICU beds or reallocated staff time are not valued or accounted for in the model.

5.5 Model Output

The models simulate the average cost per patient under two scenarios: Telemedicine intervention (where remote consultation may prevent transfer) and Usual Care (standard referral and transfer practices). The resulting decision trees are illustrated in Figure 11 - Figure 14, and the cost outcomes are summarized in Table 21.

Reader's Guide – How to interpret the decision tree:

The decision tree illustrates two alternative strategies—telemedicine (upper branch) and usual care (lower branch)—and their associated cost outcomes.

Squares denote decision nodes, circles represent chance nodes where events occur with specified probabilities, and triangles indicate terminal nodes where pathways end. Each branch is read from left to right and displays the corresponding probability and cumulative cost.

At the terminal nodes (triangle), the total cost of each pathway is obtained by summing the costs along that branch. This is multiplied by the probabilities. The expected cost of a strategy is the overall sum of all the terminal nodes for this specific strategy.

Table 21: Overview Outcomes Telemedicine vs Usual Care

Perspective	Telemedicine (€)	Usual Care (€)	Difference (€)
Amphia	[redacted]	[redacted]	[redacted]
Erasmus	[redacted]	[redacted]	[redacted]
Healthcare	[redacted]	[redacted]	3 940
Societal	[redacted]	[redacted]	4 081

In each case, telemedicine shows lower overall costs than usual care. The size of the cost difference increases when moving from the level of an individual hospital to the broader healthcare system and finally to the societal perspective, where the largest difference is observed.

However, it is important to interpret these results, which follows in the next sub chapter.

[redacted]

Figure 11: Decision Tree TeleNeonatology Hospital Amphia Perspective

[redacted]

Figure 12: Decision Tree TeleNeonatology Hospital Erasmus Perspective

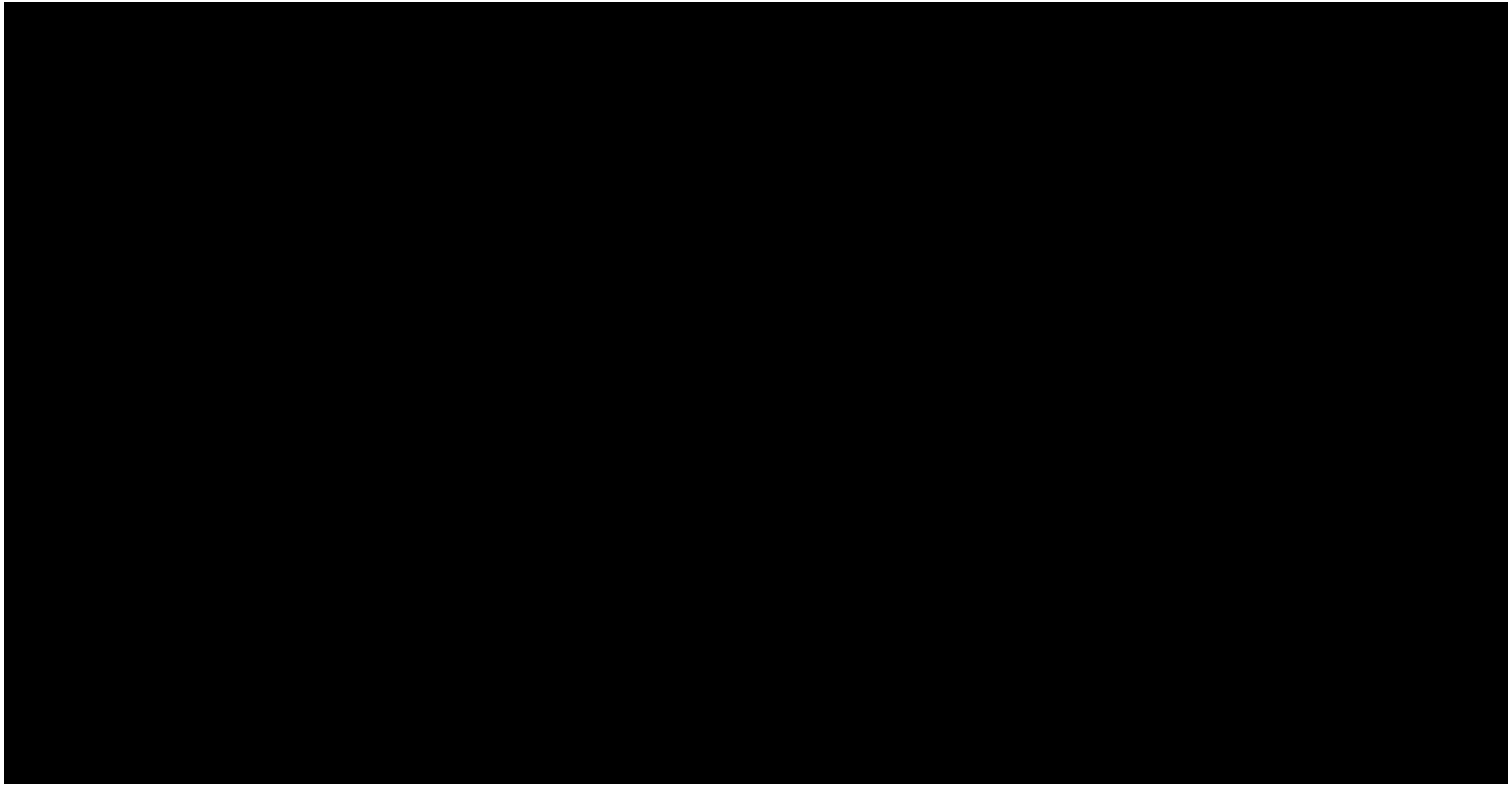


Figure 13: Decision Tree TeleNeonatology Healthcare Perspective

[redacted]

Figure 14: Decision Tree TeleNeonatology Societal Perspective

5.6 Interpretation of the Results

The outcomes of the decision tree model (Table 22) indicate that TeleNeonatology lowers the average cost per patient across all perspectives considered. From a healthcare system and societal perspective, the modeled savings are substantial: [redacted] per patient, respectively. These gains derive primarily from avoided NICU admissions, fewer inter-hospital transfers, and the mitigation of indirect family burdens. Such results highlight the efficiency of TeleNeonatology in reducing resource overutilization and improving the allocation of specialized neonatal care.

Payer-Provider Logic

Interpreting these results from a hospital perspective requires an inversion of the payer–provider logic. In Dutch specialist medical care (medisch-specialistische zorg), hospital care is reimbursed through the DBC/DOT[5] system (Diagnose-Behandelcombinatie/DOT). Each treatment trajectory is registered either as a Diagnosis Treatment Combination (Diagnose-Behandelcombinatie, DBC) or as an Other Care Product (Overig Zorgproduct, OZP) and declared to insurers at regulated or negotiated tariffs (NZa, n.d.). For insurers, these payments represent expenditures (costs), but for hospitals they constitute income (revenues) (Rijksoverheid, n.d.).

For hospitals, however, the values represent changes in revenue rather than savings, since insurer expenditures equal hospital income under the DBC/DOT reimbursement system. Accordingly, the modeled differences should be interpreted as shifts in hospital revenue resulting from changes in the volume of billable products.

In other words:

$$Payer\ Cost = Hospital\ Revenue$$

for any billable event. Consequently, the modeled differences in Table 22 must be reinterpreted as revenue changes for hospitals.

Formally, hospital revenue under scenario s can be expressed as:

$$\Delta Revenue_{hospital} = \sum_e (\Delta Volume_e \times Tariff_e)$$

With $\Delta Volume_e$ representing the change in case volume of a billable product (e.g., NICU admission DBC, intensive care add-on, neonatal transfer) and $Tariff_e$ the associated reimbursement level.

Amphia Hospital Perspective

Amphia, as a referring hospital without a NICU, sees a modeled reduction in average payer cost of [redacted] per patient when TeleNeonatology is introduced. Interpreted as revenue, this means Amphia earns [redacted] less per case. This paradox arises because, although Amphia performs more

[5] The DBC/DOT system is the Dutch reimbursement model for specialist care. The original DBCs (Diagnose-Behandelcombinaties) were replaced in 2012 by DOT (DBC's op weg naar transparantie), which simplified and standardized the system. DOT is the model currently in use.

complex care locally under TeleNeonatology (monitoring and treating infants who previously would have been transferred), the hospital no longer bills for high-revenue activities linked to NICU transfers and backtransfers. Thus, TeleNeonatology introduces a financial risk: Amphia assumes greater clinical responsibility without receiving proportionate financial compensation.

Erasmus MC Perspective

For Erasmus MC, the tertiary NICU center, the financial consequences are even more pronounced. Under Usual Care, Erasmus receives an average of [redacted] per transferred patient in DBC reimbursements, compared to [redacted] under TeleNeonatology. This difference [redacted] per patient represents a direct loss in revenue. Since NICU operations involve high fixed and semi-fixed costs (specialized staff, equipment, and infrastructure), reduced patient inflow does not translate into proportional cost savings. Instead, it results in underutilized capacity and reduced financial stability. The payer's saving thus directly translates into lost hospital income.

Healthcare and Societal Perspectives

From the aggregated healthcare system perspective, TeleNeonatology reduces average expenditure by [redacted] per patient, while from the societal perspective the reduction is [redacted] per patient. These savings arise from avoided transfers, shorter hospital stays, and fewer indirect family burdens. Unlike hospitals, insurers and society capture these benefits directly in the form of reduced expenditures and alleviated non-medical burdens.

Misaligned Incentives and the Wrong Pocket Problem

This divergence illustrates the wrong pocket problem (Alami et al., 2023). The costs of adopting TeleNeonatology (e.g., infrastructure, staff training, local case management) are borne by hospitals, particularly Erasmus MC and Amphia, yet the majority of financial and societal benefits accrue to insurers and society. Without corrective mechanisms, hospitals face a rational financial disincentive to adopt or scale the intervention, even though it improves efficiency and outcomes system-wide.

5.7 Model Validation

Given the influence of the healthcare models on decision making and how resources are allocated, ensuring the validity of such models is essential for further decision-making (Corro Ramos et al., 2024). Model validation extends beyond detecting technical errors in the implementation. It also requires evaluating the conceptual set up of the model, verifying the input data, and assessing whether model predictions reasonably reflect real-world outcomes (Corro Ramos et al., 2024). In this context, validation is defined as the process of determining whether a model adequately and accurately represents the system it is meant to simulate, providing a reliable foundation for policy and clinical decisions (Corro Ramos et al., 2024).

As seen, the model depends on complex assumptions and draws from multiple data sources, a thorough validation process is necessary to ensure credibility and relevance. This includes reviewing the model structure, scrutinizing input data, testing assumptions for realism, comparing outcomes to external data where available, and managing potential bias when involving expert opinion (Corro Ramos et al., 2024).

To verify that the model structure, logic, and assumptions accurately reflect the neonatal care pathway and the implementation of TeleNeonatology, expert interviews were conducted with a range of stakeholders. These included neonatologists, hospital managers, health economists, and representatives from insurers and patient organizations. Their feedback was used to refine the decision tree structure, validate key assumptions (e.g., transfer patterns, likelihood of backtransfer, frequency of reconsultations), and ensure the plausibility of modeled outcomes. An overview of the protocol for the conduction of the validation interviews is attached in Appendix 6: Model Validation Protocol (Page 140).

Input parameters, such as costs, probabilities, and length of stay, were derived from a combination of standardized reference prices, internal hospital data from Amphia and Erasmus MC, and expert estimates. All data points were cross-validated where possible:

- Cost estimates were checked against national costing guidelines (e.g., Zorginstituut Nederland) and updated for inflation where necessary.
- Probabilities were triangulated between hospital records and interview responses to ensure consistency.
- In general the core assumptions were reviewed and confirmed.
- Where uncertainty exists, a range of plausible values was established for sensitivity analyses. These are analyzed in the next chapter.

One specific example is the adjustment of personnel salary levels used for consultation cost calculations. While the initial economic reference guide recommended applying intermediate step values within standardized salary scales (e.g., step 3.0 for neonatologists, step 7.0 for nurses), validation interviews provided more specific insight into actual staffing structures at both Amphia and Erasmus MC. Through direct feedback from financial controllers and clinicians, it became clear that the default intermediate step did not fully reflect the seniority and specialization of the staff involved in neonatology consultations. As a result, the model was updated to incorporate more representative salary structures, better aligning the estimated personnel costs with real-world financial expenditure. This accounts also for the additional parental expenses, that were added to the model after the validation.

To ensure the correctness of model calculations, technical checks were conducted in Excel and Python. This included:

- Manual recalculation of selected paths to confirm cost aggregation and probability weighting.

- Visual inspection of network diagrams and outcome trees to ensure proper branching logic.
- Testing of deterministic and probabilistic scenarios to detect anomalies or structural inconsistencies.

Model outputs were compared with known benchmarks where available. Although external data is limited, the outcomes fall within expected ranges for similar interventions. Additionally, several interview participants confirm that the modeled outcomes align with their expectations based on clinical experience.

While multiple steps are taken to validate the model, certain limitations remain. Not all input values can be verified with empirical data and must rely on expert estimation. External data on outcomes (e.g., reconsultations rates) is sparse, limiting broader benchmarking.

The model simplifies certain real-world dynamics (e.g., variability in hospital policies), which may affect generalizability.

The applied validation process, combining expert feedback, empirical cross-checking, and technical review, supports the credibility and robustness of the model. While some uncertainty remains due to data limitations, the model provides a reliable basis for evaluating the economic implications of implementing TeleNeonatology in the Dutch NICU care, specifically between Amphia and Erasmus MC.

5.8 Sensitivity Analysis

To uphold the academic integrity of the economic assessment conducted for this thesis, it is required to ensure that the model is valid. Validity in this case refers to the model's robustness to changes in the input parameters presented previously.

Two sensitivity analyses are applied: a deterministic approach, which varies individual parameters, and a probabilistic approach, which accounts for uncertainty across all parameters simultaneously. The results from these analyses not only test the model's robustness but also clarify which parameters most influence outcomes and under what conditions the conclusions hold, thereby offering practical insights for applying the findings in real-world contexts.

5.8.1 Purpose and Complementarity of Deterministic and Probabilistic Sensitivity Analyses

The use of both deterministic and probabilistic sensitivity analyses in this study serves distinct but complementary purposes in assessing the robustness of the economic decision tree model. The deterministic one-way sensitivity analysis isolates the effect of individual parameters by varying each within its plausible range while holding others constant. This approach identifies the key cost drivers and quantifies their individual influence on model outcomes from each stakeholder perspective. It is particularly valuable for highlighting parameters that warrant priority in data collection, policy design, or operational improvement.

In contrast, the probabilistic sensitivity analysis simultaneously varies all uncertain parameters according to their defined probability distributions, thereby capturing the combined effect of joint uncertainty on model outputs. This approach generates distributions of total costs for each strategy, allowing estimation of confidence intervals and the likelihood that one option is more cost-efficient than another.

While the deterministic analysis pinpoints which assumptions matter most, the probabilistic analysis evaluates the overall stability of conclusions under realistic uncertainty – both using the same changing values.

Together, these methods strengthen the validity of the model by addressing both the sensitivity to specific parameters and the robustness of results in aggregate. The combined use ensures that conclusions regarding the cost-effectiveness of Telemedicine are supported both in targeted parameter variations and in comprehensive uncertainty modelling.

5.8.2 Values for Sensitivity Analysis

Table 22 summarizes the base-case values and plausible low and high estimates used for the sensitivity analyses. The selected ranges reflect either statistical variation from empirical data (e.g., interquartile ranges from hospital records), margins informed by literature or expert opinion, or fixed percentage adjustments (e.g., ±10%); specified in the column "justifications". These ranges were applied consistently in both the deterministic and probabilistic sensitivity analyses to evaluate the impact of parameter uncertainty on the model's results.

Table 22: Values Sensitivity Analysis

Parameter	Base Value	Low	High	Justification
Day Charge (€) Erasmus	[redacted]	[redacted]	[redacted]	Based on estimated cost variation or inflation margin
Length of Stay Erasmus	5	3	6	IQ1, IQ3
Length of Stay Erasmus pass away	4	14	15	IQ1, IQ3
# Patients resulting in Consultation Cost per Patient	31	15	50	Internal hospital information
Transport Costs	2 939	2 645	3 233	+/- 10%
Backtransfer Costs	781	703	859	+/- 10%
Transport Costs Mother	567	510	624	+/- 10%
Mortality Rate	0.03	0.01	0.07	Internal hospital information, literature sources
Transfer Rate	0.81	0.6	0.9	Internal hospital information, literature sources
Day Charge (€) Amphia	691	622	760	+/- 10%
Length of Stay Amphia	13	4	21	IQ1, IQ3
Parental Costs alive	706	635	777	+/- 10%
Parental Costs pass away	2 043	1 839	2 247	+/- 10%

5.8.3 Deterministic Sensitivity Analysis

To assess the robustness of the model's outcomes and to identify the parameters with the greatest influence on total costs, a deterministic one-way sensitivity analysis was conducted. In this analysis, each input variable was individually varied within its plausible range (e.g. minimum and maximum values derived from literature or expert input), while all other parameters were held constant at their base-case value. The results are visualized in tornado diagrams.

Reader's Guide - How to interpret the tornado diagram:

Each bar represents the change in total cost when a single input parameter is varied from its low to high value, while all other parameters are kept constant at their base-case level. The length of the bar reflects the magnitude of this change, with longer bars indicating parameters that have a stronger influence on the model outcome. Bars extending to the left of the vertical baseline show a cost decrease relative to the base case, whereas bars extending to the right show a cost increase. By ranking parameters from most to least influential, the diagrams clearly identify the cost drivers that contribute most to variability in the results, providing a transparent view of which assumptions have the greatest impact on model conclusions.

This approach allows for identifying the key cost drivers and testing the sensitivity of model conclusions to uncertainty in individual input assumptions. Four tornado diagrams were generated, one for each stakeholder perspective: Societal, Healthcare System, Hospital Erasmus, and Hospital Amphia (Figure 15 - Figure 18).

Across all perspectives, the transfer rate was the most influential parameter affecting total costs. The only exception was the Amphia hospital perspective, where implementation costs per patient and internal cost structures such as daily charges played a more dominant role. This underlines the strong impact that referral decisions, whether patients are transferred to Erasmus MC or treated locally at Amphia, have on cost outcomes across stakeholders.

Parameters such as the length of stay at Erasmus MC and implementation cost per patient also contributed significantly in multiple perspectives. These results emphasize that both the intensity of medical care and the efficiency of system usage (i.e. the extent to which fixed implementation costs are spread across patients) are key cost drivers.

From a policy and operational point of view, the analysis suggests that reducing unnecessary transfers and increasing the use of telemedicine consultations could be important strategies to manage overall costs. The findings also indicate that cost is highly dependent on perspective, reinforcing the importance of tailored evaluations for different stakeholder groups, and understanding the qualitative aspects here as well.

[redacted]

Figure 15: Tornado Diagram – Deterministic Sensitivity Analysis – Hospital Amphia Perspective

[redacted]

Figure 16: Tornado Diagram – Deterministic Sensitivity Analysis – Hospital Erasmus Perspective

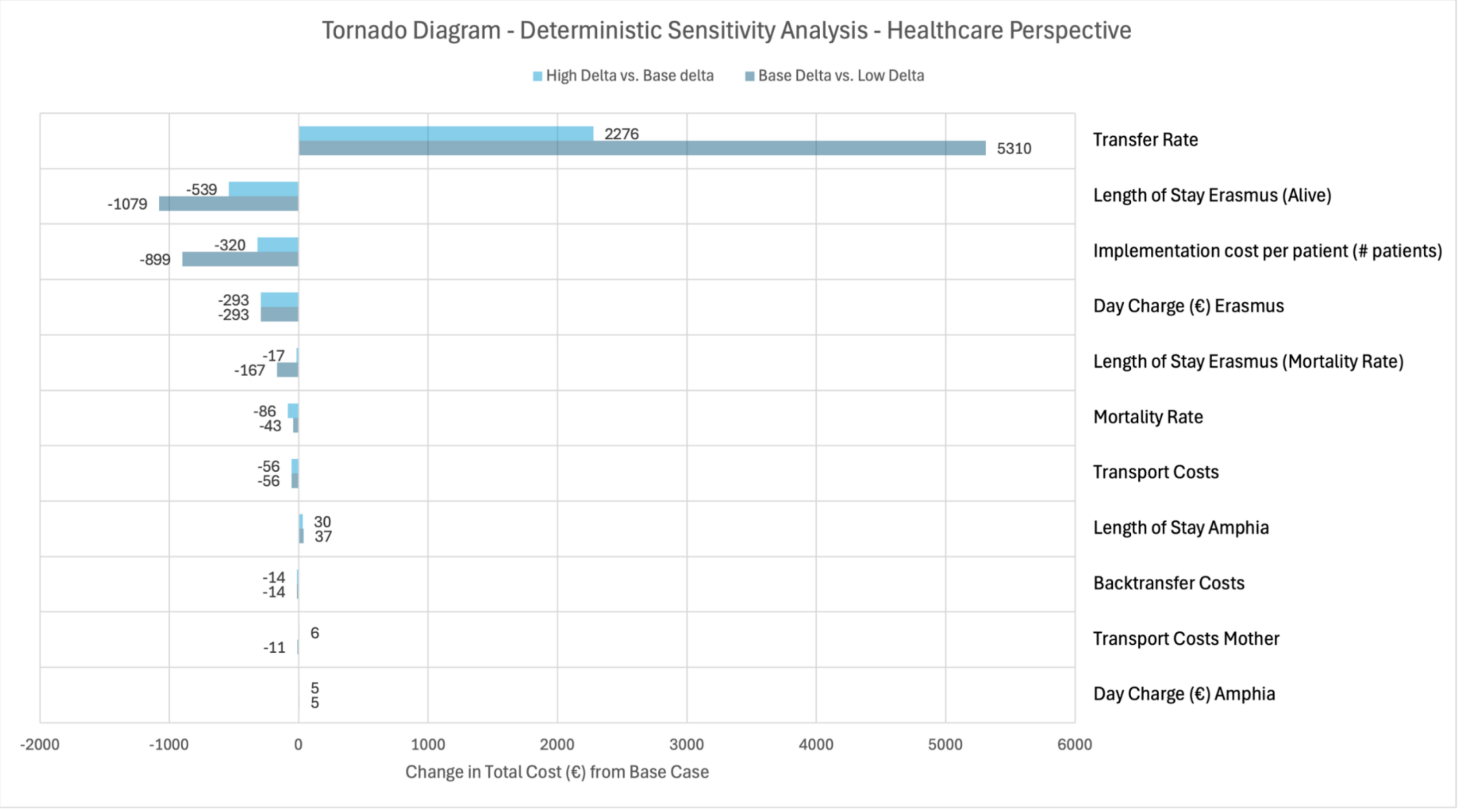


Figure 17: Tornado Diagram – Deterministic Sensitivity Analysis – Healthcare Perspective

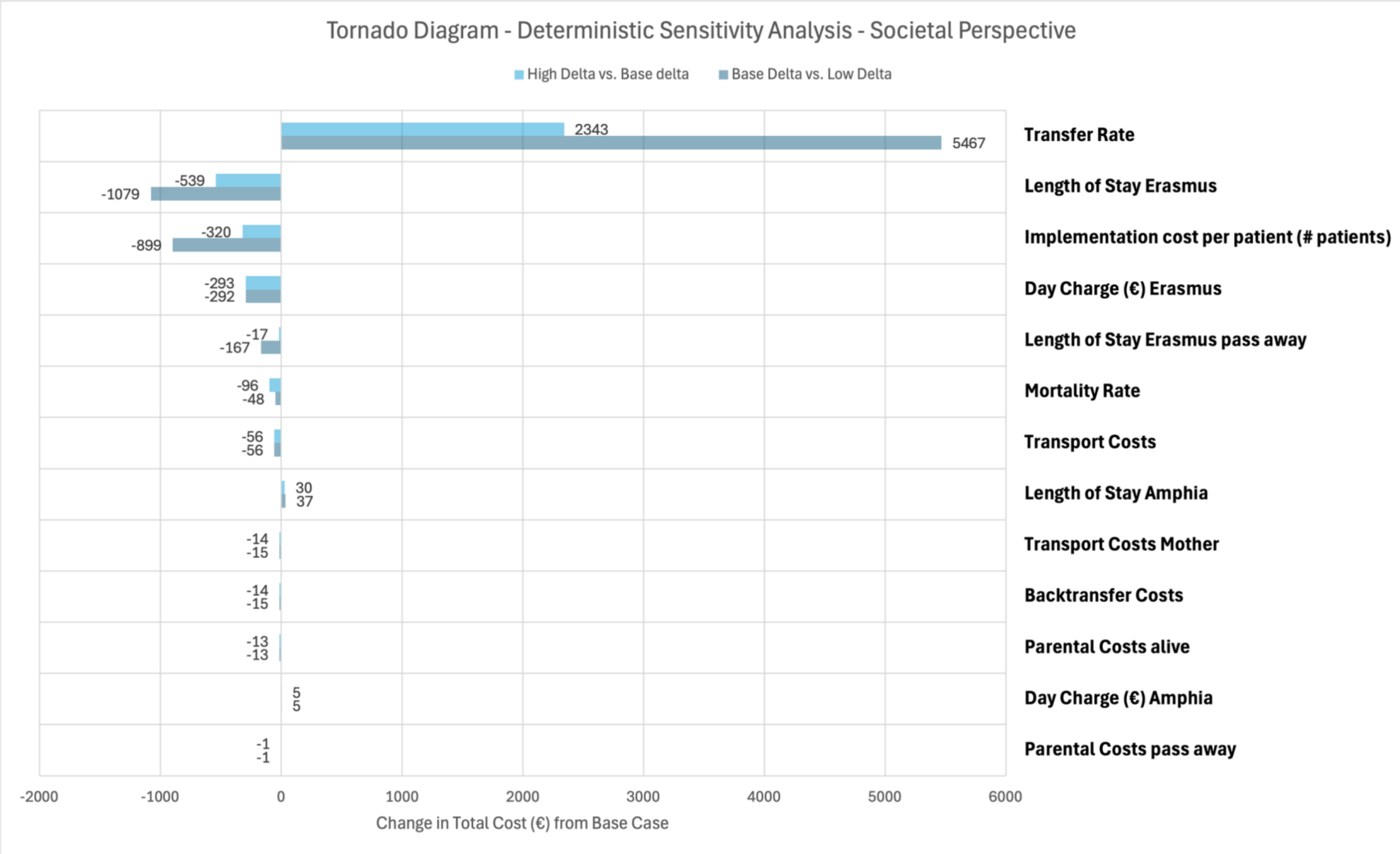


Figure 18: Tornado Diagram – Deterministic Sensitivity Analysis – Societal Perspective

5.8.4 Probabilistic Sensitivity Analysis

A probabilistic sensitivity analysis (PSA) is a method that can be described as follows: the parameters of the model are prescribed a distribution which is determined by available data, the model is then run utilizing the values within the distribution to gain a clear view of how different scenarios (described through differing values) impact the outcome of the model (Hatswell et al., 2018).

When considering the applicability of a PSA, it is important to re-examine the structure of the decision model and the sources of data used in the model. The predetermined paths means that the uncertainty solely lays in the applied input parameters.

While deterministic sensitivity analysis was conducted from multiple perspectives (hospital, healthcare, and societal), the probabilistic sensitivity analysis was limited to the societal perspective. This choice was based on the fact that the societal perspective encompasses the widest range of uncertain input parameters and reflects the most comprehensive cost structure. As such, it is the most informative perspective for assessing overall uncertainty in the model outcomes.

The probabilistic sensitivity analysis was conducted using a Monte Carlo simulation with 1,000 iterations. Each iteration represents a full run through the decision tree model from a societal perspective, incorporating stochastic variation in parameter values.

A triangular distribution was assigned to all input parameters for which uncertainty was expected, with minimum, mode, and maximum values defined based on literature, cost estimates, or expert consultation. These align with the values used for the Deterministic Sensitivity Analysis.

Each simulation iteration used random draws from these distributions to calculate the total societal cost associated with each pathway in the decision tree for both the Telemedicine intervention and the Usual Care scenario. The final output is a distribution of total societal costs for each strategy. The python code can be seen in Appendix 3: Python Code: Decision Tree Model and Sensitivity Analysis (Page 132).

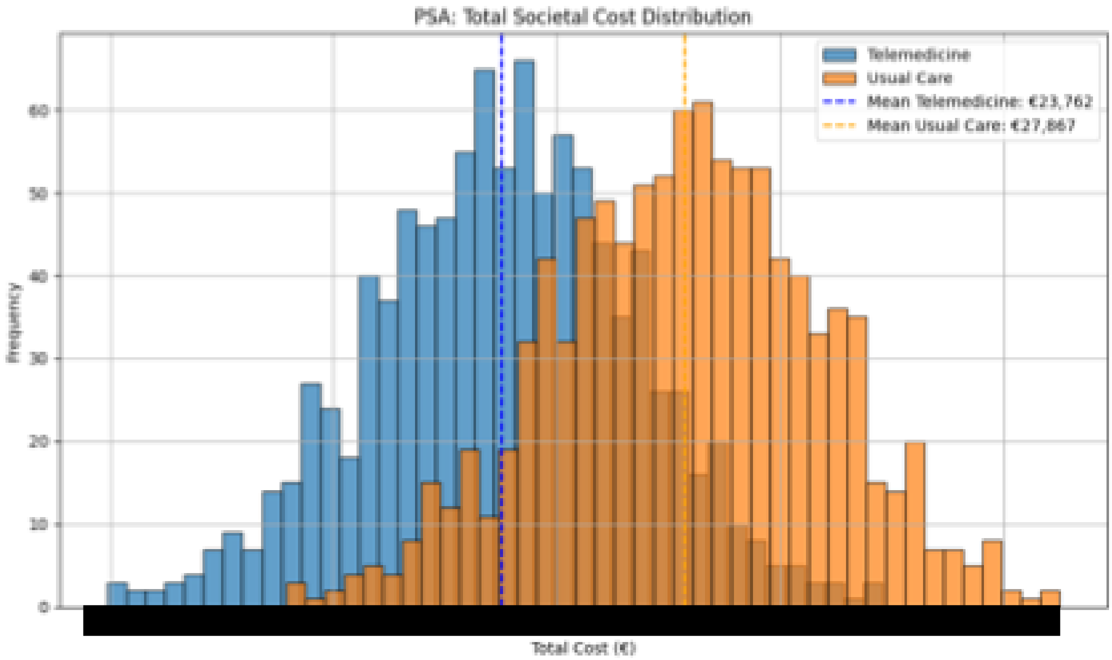


Figure 19: Probabilistic Sensitivity Analysis - Total Societal Cost Distribution

The results show (Figure 19) that Telemedicine is associated with a lower mean societal cost [redacted] compared to Usual Care [redacted]. The 95% confidence interval for Telemedicine ranged from approximately [redacted], whereas for Usual Care it spanned 21 981€ to 33 531€. These results indicate that, even when accounting for uncertainty, Telemedicine remains the more cost-efficient option from a societal perspective in most simulation runs.

The cost distribution histograms further illustrate this difference. Telemedicine not only demonstrates a lower average cost but also a tighter distribution, implying reduced cost variability and potentially lower financial risk.

5.9 Discussion and Conclusion

The economic evaluation conducted in this chapter demonstrates that TeleNeonatology can reduce average costs across several perspectives, most notably from the societal and healthcare system viewpoints. However, beyond the aggregated cost differences, the results reveal underlying shifts in resource use, responsibility, and institutional burden that pose important challenges for implementation and broader adoption. These findings not only quantify the financial effects of TeleNeonatology but also expose structural misalignments within the existing healthcare financing and delivery systems, which are particularly visible when examined through the NASSS framework.

At Amphia, the model reports a modest cost saving under the TeleNeonatology scenario, this outcome obscures a deeper institutional burden. [redacted]

[redacted] This results in a situation where the institution implementing a clinically innovative and cost-reducing intervention may simultaneously experience reduced revenues and increased responsibilities.
Under the existing Diagnosis Treatment Combination (DBC) reimbursement system, Erasmus's income is closely tied to the number and complexity of admissions. Fewer transfers, even when clinically appropriate, result in lower financial inflow without reducing fixed costs such as NICU staffing, equipment, and overhead. This produces a structural disincentive to support telemedicine-based triage, even when it leads to more efficient system-wide outcomes.
The sensitivity analysis further shows that the most decisive levers are transfer rates and length of stay, alongside the extent to which fixed implementation costs are spread across consultations. These drivers shape whether the intervention produces substantial savings or creates additional burdens at the institutional level.
The findings therefore highlight both the potential and the limitations of quantitative cost analysis. While the model confirms that TeleNeonatology can generate economic value, it also shows that adoption cannot be explained by financial outcomes alone. Questions of cost distribution, institutional burden, and sustainability fall outside the model's scope but are central to understanding real-world implementation. This limitation is also visible when viewed through the NASSS framework: the analysis primarily addresses the Technology and Value Proposition domains, but does not capture the full range of organisational and wider system factors. These aspects are therefore explored in the subsequent qualitative analysis, where the broader organisational and systemic dimensions of TeleNeonatology are examined.

6 Stakeholder Perspectives on Economic Factors for the Implementation of TeleNeonatology

6.1 Introduction

This qualitative chapter builds upon the findings of the preceding systematic literature review, which analyzed the influencing economic factors for the implementation of Telemedicine; and the quantitative economic evaluation, which assessed the costs of implementing TeleNeonatology compared to standard care. Placing the economic evaluation in the NASSS framework showed that it does not capture the overall picture and complexity behind the implementation of TeleNeonatology.

Therefore it also becomes clear that there is growing recognition that purely quantitative approaches may not fully capture the factors that influence implementation decisions. Qualitative methods, such as interviews and case studies, can offer insights into how economic data is perceived, negotiated, and acted upon by different stakeholders. When combined with quantitative analyses, they help explain not only whether an intervention is cost-effective, but also under what conditions it is likely to be adopted or sustained (Dopp et al., 2019).

To address this, the qualitative chapter explores the different stakeholder perspectives. The goal of this chapter is to provide an understanding of the economic considerations that stakeholders identify as important for the adoption, scaling, or sustainability of telemedicine interventions, particularly in the neonatal care context, within the previously introduced NASSS domains.

Therefore, the qualitative analysis follows this given sub-research question:

- What economic considerations influence the implementation of TeleNeonatology from various Stakeholder perspectives?

6.2 Methods

For this analysis a qualitative method was followed, conducting interviews with selected stakeholders. The stakeholder analysis previously conducted in chapter 2.4 served as a foundation for selecting interview participants by identifying key actors across different levels of the healthcare system. Interviewing the different stakeholders, at least one stakeholder from each of these introduced layers, ensured that the qualitative analysis captured a wide range of views on economic enablers and barriers across different levels of the healthcare system, in the broader context of Telemedicine but also more specifically on TeleNeonatology.

A semi-structured interview format was used to enable in-depth exploration of stakeholder perspectives while maintaining a consistent structure across interviews. This format strikes a balance between thematic focus and the flexibility to follow up on relevant issues raised by participants. An overview of the guiding questions is given in Appendix 7: Overview Guiding Questions for the Interviews (Page 142).

All interviews were coded using the MaxQDA software, applying the NASSS framework as a coding structure. This approach facilitated an overview of how frequently each domain was referenced across the interviews.

As outlined in Chapter 1.5, ethical considerations were carefully addressed throughout the research process. Prior to each interview, participants received an information letter and an informed consent form, which they were required to sign and return before the interview took place. All interviews were audio-recorded with the participant's permission to ensure accurate transcription. The collected data was treated confidentially and was anonymized during the analysis. Any identifying information was removed to protect participant privacy. Only anonymized insights are presented in this chapter. Data is stored securely and handled in accordance with institutional data management policies.

In total 7 interviews were conducted, with the following stakeholders:

- Neonatologist (US-based)
- Neonatologist & Innovation Lead
- Insurance Employee
- Health Economist
- Parental Representation
- Health Innovation Business Manager
- Financial Controller Hospital

6.3 Results

An initial overview of the results of the interviews is given. This is followed by detailed explanation of the domains and the specific insights of the stakeholder interviews. Lastly, a comparison is given to the literature review. This is to understand the alignment and the different aspects that stakeholders considered towards the implementation of TeleNeonatology. For each of the conducted interviews a summary was created including the guiding questions. This can be seen in Appendix 8: Summaries Stakeholder Interviews (Page 143).

6.3.1 Analysis of the Interviews

To synthesize the findings across the NASSS framework domains, Table 23 summarizes the key themes that emerged from the stakeholder interviews. Each domain captures specific barriers, enablers, and context-dependent insights related to the implementation of TeleNeonatology.

Table 23: Summary of the main key takeaways from the interviews

NASSS Domain	Key Takeaways from Stakeholder Interviews
1. The Condition	- Innovation must address a clear clinical problem to justify implementation
2. The Technology	- Upfront costs are a key barrier - Implementation requires both equipment and care process restructuring - Pilot funding is feasible via transformation budgets
3. The Value Proposition	- Value extends beyond cost: includes e.g. family impact, and staff support - Different Stakeholders focus on different values and value perspectives - Indirect effects (e.g. parent productivity loss) are underrepresented
4. The Adopter System	- Financial incentives shape adoption decisions - Dutch stakeholders stress early business case development and funder engagement - Hospitals may be disincentivized due to production-based financing
5. The Organization	- Internal budgeting structures and cost-neutrality drive decisions - Physician awareness of financial flows is limited - NICU capacity and revenue models determine perceived financial benefit
6. The Wider System	- Reimbursement structures are misaligned with preventive care models - Negotiating new reimbursement codes is slow and uncertain - Current NZa pricing often does not reflect real costs
7. Embedding and Adaptation	- Long-term sustainability requires early financial planning and system alignment - Many pilots fail due to lack of structural funding and institutional inertia Scale-up needs cross-actor leadership and regional funding models

This Table 24 presents the number of coded references to each NASSS domain made by individual interviewees during the stakeholder interviews.

Table 24: Overview of mentioned NASSS Domains within the Stakeholder Interviews

Interviewee	**Domain**							
	The Condition	The Technology	The Value Proposition	The Adopter System	The Organization	The Wider System	Embedding and Adaptation over Time	Sum
Neonatologist US based	0	4	8	12	11	3	8	46
Neonatologist & Innovation Lead	0	0	2	5	2	8	2	19
Insurance Employee	0	2	1	2	2	13	9	29
Health Economist	3	3	9	3	0	8	1	27
Parental representation	0	0	12	1	0	0	0	13
Health Innovation Business Manager	0	0	5	8	3	11	6	33
Financial Controller Hospital	0	1	1	4	11	6	1	24
Sum	3	10	38	35	29	49	27	191

The most frequently referenced domains are The Wider System (49 references), The Value Proposition (38), and The Adopter System (35). This indicates that stakeholders predominantly focus on external regulatory and policy environments, the perceived benefits of the intervention, and the processes by which individuals and teams engage with and adopt telemedicine and specifically TeleNeonatology. In contrast, The Condition (3) and The Technology (10) received comparatively limited attention, suggesting that the underlying clinical problem and technical setup is either perceived as unproblematic or considered less critical in the context of implementation discussions.

The Health Innovation Business Manager (33 references) and the Health Economist (27) contributed insights across a wide range of domains, reflecting their broader system-level and evaluative perspectives. In contrast, the Parental Representative focused almost exclusively on The Value Proposition (12 out of 13 references), highlighting a strong emphasis on user-relevant outcomes and the direct value offered by the intervention.

The Financial Controller Hospital emphasized The Organization and The Wider System, indicating a focus on institutional alignment, operational feasibility, and financial structures. Similarly, the Insurance Employee placed significant emphasis on The Wider System and Embedding and Adaptation over Time, likely reflecting concerns related to long-term integration, reimbursement, and system-level sustainability.

Taken together, the table illustrates a shared emphasis among stakeholders on institutional, regulatory, and adoption-related factors, while domains concerning long-term embedding and the clinical problem were less prominently addressed. This distribution may point to areas where further alignment, engagement, or clarification is required to support the sustainable implementation of TeleNeonatology across stakeholder groups.

In the following each of the seven NASSS domains is analyzed based on the provided insights from the interviews.

Domain 1: The Condition

"*Not technology driven innovation, but like a problem driven innovation*." (Health Economist, personal communication, 13.05.2025) During the interview with the Health Economist, the importance of grounding telemedicine initiatives in clearly defined healthcare problems was emphasized. Therefore, innovation should not be technology-driven but rather problem-driven, aiming to address concrete deficiencies in current care pathways. Without demonstrating clear added value, adoption and reimbursement are unlikely (Health Economist, personal communication, 13.05.2025).

In this context, the restructuring of care pathways is seen as essential. Telemedicine should not be regarded merely as a technological device, but as a tool that enables more efficient or effective clinical processes. This implies the need for alignment between the identified healthcare problem, the proposed intervention, and the outcomes it seeks to improve (Health Economist, personal communication, 13.05.2025).

In general, it can be said that this domain was not discussed in greater detail, due to the fact that the economic factors are not directly linkable to this domain.

Domain 2: The Technology

“I think that's the biggest barrier, there's upfront investment that needs to happen.” (Neonatologist (US-based), personal communication, 17.04.2025) Stakeholders identified the upfront investment required for telemedicine equipment as a barrier to implementation. While the service itself may generate cost savings, the initial capital outlay must be covered by one of the involved parties (Neonatologist (US-based), personal communication, 17.04.2025). Unlike common communication tools such as phones, which are widely accessible and inexpensive, telemedicine systems entail additional infrastructure and operational costs that are not reimbursed within current frameworks (Neonatologist (US-based), personal communication, 17.04.2025; Health Economist, personal communication, 13.05.2025).

A key implementation issue is the lack of clarity regarding who will pay for the technology. The Health Economist raised concerns that innovators often fail to address this fundamental question early in the process, leading to feasibility challenges later.

Technological integration thus extends beyond equipment and demands process redesign and institutional openness to innovation (Health Economist, personal communication, 13.05.2025).

Despite these concerns, funding pilot projects was generally not viewed as problematic. Transformation funds, such as those provided through the Integral Care Agreement (IZA), can be used to support pilot-phase financing (Insurance Employee, personal communication, 06.06.2025).

The Financial Controller acknowledged that technology-driven projects are typically justified by their expected healthcare benefits rather than by cost considerations alone. Nonetheless, high costs can still trigger proposals or shape project framing, indicating that financial arguments may still play a role in the justification process (Financial Controller Hospital, personal communication, 13.05.2025).

Domain 3: The Value Proposition

“Where does my innovation add value?” (Health Economist, personal communication, 13.05.2025) Stakeholders highlight that value extends beyond economic return and includes clinical, societal, and experiential benefits. However, “It's really difficult when you have all these stakeholders that you involve. Because then there's never a right decision because the patient representative will say the only good option for us is what's good for the patient and most of the time, they're not willing to look at the other perspectives." (Insurance Employee, personal communication, 06.06.2025)

There is a divergence between perspectives. While clinicians focus on patient benefit and long-term societal gains, economists tend to emphasize short-term cost-effectiveness (Neonatologist & Innovation Lead, personal communication, 13.05.2025). The latter argue that strong evidence for improved outcomes may not be sufficient unless paired with an acceptable return on investment (Health Economist, personal communication, 13.05.2025). Some institutions, particularly in the Netherlands, remain focused on hospital-level business cases, which are rarely aligned with societal or healthcare system-level cost-benefit assessments (Health Economist, personal communication, 13.05.2025). This connects also to the economic evaluation, where it "just adds everything independently on the incentive or which stakeholder or perspective wins or loses. It's just added up." (Health Economist, personal communication, 13.05.2025)

Insurance representatives argue that value assessments should balance benefits across all stakeholders, including patients, hospitals, and system accessibility, and not prioritise a single perspective (Insurance Employee, personal communication, 06.06.2025). For example, even when patient benefit is clear, funding decisions also require alignment with healthcare system goals (Insurance Employee, personal communication, 06.06.2025).

Parental perspectives further reinforce the importance of non-clinical benefits. Long NICU admissions delay return to work and affect career trajectories (Parental Representation, personal communication, 14.05.2025). Socioeconomic background influences the degree of impact, as lower-income families face more difficulties in affording travel, childcare, or time off work (Parental Representation, personal communication, 14.05.2025). These indirect effects remain under-researched and underrepresented in formal economic evaluations (Parental Representation, personal communication, 14.05.2025). The insurance employee makes that clear, by specifically saying "Your whole social network is in Breeda. It's not in Rotterdam." (Insurance Employee, personal communication, 06.06.2025)

Telemedicine is seen as a preventive investment with value beyond hospital budgets. It helps upskill local providers and distributes expertise, thereby improving care delivery efficiency (Health Innovation Business Manager, personal communication, 02.05.2025).

Lastly, the financial controller noted that comprehensive, system-level value assessments are rarely implemented in practice. Evaluations tend to focus on single-institution impacts, which may obscure broader benefits (Financial Controller Hospital, personal communication, 13.05.2025). "I've never heard a lot of any examples at all where the total perspective is being". (Financial Controller Hospital, personal communication, 13.05.2025).

Domain 4: The Adopter System

"What does it do with our revenues?" (Financial Controller Hospital, personal communication, 13.05.2025) Adoption decisions are heavily influenced by financial feasibility, structural incentives, and perceived return on investment.

Avoidance of unnecessary medical transports can represent a key cost-saving opportunity, both in direct transport costs and in the higher costs associated with NICU admissions compared to local nursery stays (Neonatologist (US-based), personal communication, 17.04.2025).

However, from the systemic level, production-based healthcare financing, as seen in the Netherlands, discourages preventive interventions and limits support for innovations like

TeleNeonatology. Activity reduction directly translates into lost income, which can deter hospitals from participating in models that transfer care elsewhere (Health Innovation Business Manager, personal communication, 02.05.2025). In settings where payments are tied to bed occupancy, reducing inpatient numbers via telemedicine may create a perceived negative financial return unless beds can be repurposed (Neonatologist (US-based), personal communication, 17.04.2025). “To make these kinds of innovations if we are being punished financially, for these kinds of initiatives.” (Financial Controller Hospital, personal communication, 13.05.2025) Financial losses due to reduced patient volume or infrastructure underutilization may act as deterrents (Financial Controller Hospital, personal communication, 13.05.2025).

When value is only demonstrated late in the process, resistance from funders and managers is more likely (Neonatologist & Innovation Lead, personal communication, 13.05.2025). While financial incentives shape behaviour in many systems, some warn against overly economic reasoning that risks undermining clinical motivations (Neonatologist & Innovation Lead, personal communication, 13.05.2025).

Physicians are often less attuned to financial considerations within their own institutions, especially in the Netherlands, where economic incentives are perceived as less central to clinical behavior than in countries like Germany or the U.S. (Neonatologist & Innovation Lead, personal communication, 13.05.2025).

From the parental perspective, adoption also concerns indirect financial impacts. Extended NICU stays can increase out-of-pocket costs (e.g., travel, meals) and delay return to work, affecting career trajectories (Parental Representation, personal communication, 14.05.2025). These financial burdens underline the importance of considering user-side economic factors in adoption planning.

Domain 5: The Organization

“Financial consequences of the project are estimated based on the business case and we will give an advice.” (Financial Controller Hospital, personal communication, 13.05.2025)

TeleNeonatology implementation at the organizational level is closely linked to internal financial structures, decision-making responsibilities, and strategic alignment. Hospitals must remain financially viable while navigating new initiatives, and this tension is particularly evident in departments like NICUs, where bed utilization and case acuity directly influence reimbursement (Neonatologist (US-based), personal communication, 17.04.2025).

In the Dutch context, stakeholder engagement is emphasized as critical from the start of a quality improvement initiative. Delayed engagement of key actors, particularly those responsible for funding decisions, is likely to generate resistance later in the process (Neonatologist & Innovation Lead, personal communication, 13.05.2025).

Hospitals face internal trade-offs between service innovation and financial performance. ICU beds generate high margins, and a decline in occupancy due to telemedicine may negatively affect revenue (Financial Controller Hospital, personal communication, 13.05.2025). A formal business case must be developed and approved through multiple committees, illustrating the importance of aligning projects with organizational priorities to secure approval (Neonatologist (US-based), personal communication, 17.04.2025). Financial departments typically assess new initiatives based on business cases that estimate cost and revenue impact. If the initiative results in substantial losses to the P&L, particularly at the departmental level, financial controllers tend to offer more restrictive advice (Financial Controller Hospital, personal communication, 13.05.2025). Investment-heavy proposals trigger review by an investment committee, while smaller projects may be approved within departmental budgets (Financial Controller Hospital, personal communication, 13.05.2025).

Budget planning begins with patient and revenue forecasts and is managed at the department level. Departments are responsible for their own profit and loss and are granted discretion in decision-making as long as they remain within their budget envelope (Financial Controller Hospital, personal communication, 13.05.2025). Financial advisors aim to remain objective but may suggest alternative funding sources or strategies if a proposal appears valuable but financially unfavorable (Financial Controller Hospital, personal communication, 13.05.2025). Still, there is recognition that cost savings from innovations like TeleNeonatology are difficult to demonstrate, especially where benefits are diffuse or accrue to other stakeholders (Financial Controller Hospital, personal communication, 13.05.2025).

Limited transformation capacity, even in large academic institutions, is also cited as a constraint. The need for internal restructuring and cautious leadership may slow adoption, even when strategic interest exists (Health Innovation Business Manager, personal communication, 02.05.2025). Ultimately, alignment with institutional goals and early integration into planning processes are viewed as central for organizational support (Neonatologist (US-based), personal communication, 17.04.2025; Financial Controller Hospital, personal communication, 13.05.2025).

Domain 6: The Wider System

“I would say the reimbursement structure, that's I think the main obstacle for this initiative.” (Financial Controller Hospital, personal communication, 13.05.2025) Reimbursement structures and payer policies are repeatedly identified as critical determinants for the implementation of TeleNeonatology. Uncertainties around whether, and to what extent, consultations will be reimbursed create substantial planning difficulties and financial risk (Neonatologist (US-based), personal communication, 17.04.2025). A clear reimbursement framework enables accurate forecasting of costs and revenues, which is particularly important when initiating a new service without precedent (Neonatologist (US-based), personal communication, 17.04.2025). Delays in adapting reimbursement pathways and lack of flexibility within the healthcare financing system remain core structural barriers (Health Economist; Insurance Employee, personal communication, 06.06.2025).

In the Dutch context, healthcare providers must engage with insurers and governmental bodies to negotiate coverage for telemedicine services. These negotiations are necessary to secure long-term financial viability, as continued unpaid provision of care is not feasible (Neonatologist & Innovation Lead, personal communication, 13.05.2025). The process is often lengthy, requiring supporting evidence, endorsement by the Dutch Healthcare Institute (Zorginstituut Nederland), and the creation of formal reimbursement codes (Insurance Employee, personal communication, 06.06.2025). During this period, innovations may stagnate or fail altogether due to lack of structural financial support (Insurance Employee, personal communication, 06.06.2025; Health Economist, personal communication, 13.05.2025).

From the insurer's perspective, it is inefficient for general patients to occupy beds in top clinical hospitals when care could be delivered in lower-cost settings. Bed reallocation has budgetary implications, which may end cooperation if perceived to disadvantage certain institutions (Insurance Employee, personal communication, 06.06.2025).

Health insurance companies in the Netherlands operate as private organizations with limited incentive to deviate from standard financial arrangements (Health Innovation Business Manager, personal communication, 02.05.2025). This disconnect between innovation and financing is described as a systemic issue, contributing to slow transformation and institutional resistance to change (Health Innovation Business Manager, personal communication, 02.05.2025). Leadership and change management are considered essential for overcoming these systemic barriers (Health Innovation Business Manager, personal communication, 02.05.2025).

From the perspective of insurers, TeleNeonatology is seen as offering limited improvements in the traditional healthcare value triangle of cost, quality, and accessibility (Insurance Employee, personal communication, 06.06.2025). Reallocating budgets between hospitals, such as from Erasmus MC to Amphia, remains politically sensitive and may hinder collaboration despite readiness among institutions (Insurance Employee, personal communication, 06.06.2025).

The insurance employee suggest specific facilitators, such as regionalized budgeting are proposed to support local pilot implementation and enable smoother transitions into reimbursed care products (Insurance Employee, personal communication, 06.06.2025).

Domain 7: Embedding and Adaptation over Time

"To find the money, not for the pilot, but for the longer." (Insurance Employee, personal communication, 06.06.2025) Stakeholders expressed consensus on the importance and challenge of achieving long-term sustainability and embedding of TeleNeonatology. In the Dutch system, financial sustainability requires alignment with government priorities and support from key actors such as health insurers (Neonatologist & Innovation Lead, personal communication, 13.05.2025).

The financial controller emphasized the necessity of estimating the structural, long-term impact of scaling the intervention beyond pilot settings, particularly if more children are included in the programme (Financial Controller Hospital, personal communication, 13.05.2025). The US-based neonatologist stressed that while the early phase focused on feasibility, future implementation requires stronger technology, ongoing contract management, and business case development.

They highlighted that once systems are in maintenance mode, operational costs stabilize, but upfront investment and strategic alignment remain essential (Neonatologist (US-based), personal communication, 17.04.2025). From their perspective, platforms can be leveraged for multiple telehealth services, creating economies of scale and broader institutional value (Neonatologist (US-based), personal communication, 17.04.2025).

The Dutch neonatologist and innovation lead underscored that long-term impact, rather than short-term financial gains, should drive implementation decisions. Sustainability should focus on societal benefit and reduced healthcare costs, not hospital revenue generation (Neonatologist & Innovation Lead, personal communication, 13.05.2025). The insurance employee offered a systemic view, noting that formal product classification and NZa approval are prerequisites for reimbursement. However "in the Netherlands you don't have one party, you have health insurance companies and we compete with each other and that prevents the scaling."(Insurance Employee, personal communication, 06.06.2025) This process is lengthy and fragmented, often undermining sustainability and leading to failure post-pilot. They argued that planning for sustainability must begin at the start of a pilot and proposed regionally allocated budgets to support long-term embedding (Insurance Employee, personal communication, 06.06.2025).

Similarly, the health innovation business manager pointed to the "graveyard" of promising digital health pilots that failed due to structural financing gaps. They emphasized the urgency of moving from pilot to scale-up by resolving financing barriers, integrating innovations into broader health system planning, and acknowledging the macro-level risks of increasing healthcare spending and workforce shortages (Health Innovation Business Manager, personal communication, 02.05.2025). They also stressed the need for leadership and system change to enable sustainable innovation (Health Innovation Business Manager, personal communication, 02.05.2025). Lastly, the health economist observed a general conservatism in evaluating long-term change, which may further slow embedding (Health Economist, personal communication, 13.05.2025).

Overall

Many interviewees emphasized that successful adoption depends on involving all relevant actors from the outset: "Identify all stakeholders and then you include them in the whole project from the beginning" (Neonatologist & Innovation Lead, personal communication, 13.05.2025). At the same time, several highlighted the need for strong leadership to overcome resistance and initiate change. As one insurer put it, "It's an opinion leader. You need someone who starts, someone who destroys the first barriers," while the innovation manager noted, "It takes courage and a leader, a leadership to get transformation done. Because there's always some friction that you have to overcome." These voices underscore that both inclusive collaboration and decisive leadership are critical to moving beyond pilot stages and toward sustainable implementation.

6.3.2 Connection to the Systematic Literature Review

To further explore how the interview findings complement or contradict upon the existing literature, Table 25 systematically compares insights from the stakeholder interviews with the findings of the systematic literature review, organized by NASSS domain. While the literature on telemedicine often addresses economic considerations in general terms, the interviews reveal more specific, context-dependent insights related to TeleNeonatology. This comparison highlights where stakeholder perspectives add nuance, confirm prior knowledge, or expose overlooked implementation challenges.

Table 25 Comparison Literature Review and Interview Insights

Domain	Literature Review (Telemedicine)	Interview Insights (TeleNeonatology)	Difference / Contribution
1. Condition	- No direct connection made	- grounding telemedicine initiatives in clearly defined healthcare problems	- this domain does not relate in further detail with economic factors, seen in the review and interviews
2. Technology	- Upfront investment needed: including technology, maintenance, training	- Low-cost video sufficient for pilots - Scaling requires infrastructure, training	- Interviews identify hidden tech costs, real-world usability barriers, and training needs for effective scaling – adding additional perspective
3. Value Proposition	- General system savings expected - Some family and provider benefits recognized - ROI as an KPI	- Erasmus loses NICU revenue - Amphia and families save costs - Legal risk reduction a key but unrecognized value - Added value for Families	- Stakeholders expose revenue conflicts, unmonetized benefits (e.g., legal safety), and misaligned incentive distribution
4. Adopter System	- Economic incentives - Financial consequences of workload/ workflow - Perceived cost-benefit alignment	- Lack of early involvement delays adoption - Engagement of financial roles improves feasibility - Financial incentives shape adoption decisions -	- Reveals cultural-economic barriers, late stakeholder inclusion, and generational skill gaps impacting adoption
5. Organization	- Budget availability and internal funding prioritization - Strategic alignment with financial goals	- Internal budgeting structures and cost-neutrality drive decisions - Physician awareness of financial flows is limited - NICU capacity and revenue models determine perceived financial benefit	- Interviews are able to confirm the discussed points from the literature, however they are able to showcase direct examples and emphasize the importance of this domain
6. Wider System	- Reimbursement delays innovation - Pilots lack structural support - Policy slow to adapt	- Reimbursement structures are misaligned - Negotiating new reimbursement codes is slow and uncertain	- These findings align between the literature and interview, the interviews
7. Embedding Over Time	- Long-term sustainability of financial models - Flexibility to adapt to funding structures - Integration into routine care	- Long-term sustainability requires early financial planning and system alignment - structural funding and institutional scale-up needs cross-actor leadership	- dynamic implementation processes, importanceearly collabortation and alignment on sustainable financing

Figure 20 and Figure 21 illustrate the proportion of discussed NASSS domains across the systematic literature review and stakeholder interviews, respectively.

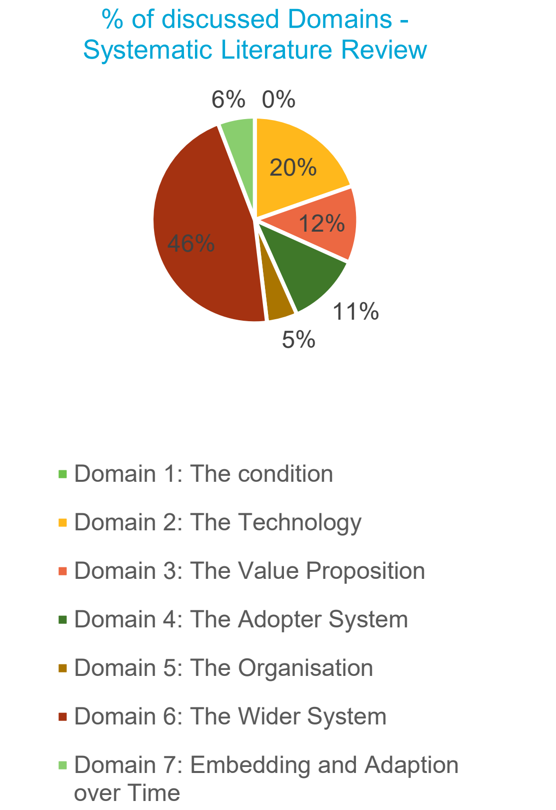


Figure 20: Pie Chart Percentage of discussed Domains – Systematic Literature Review

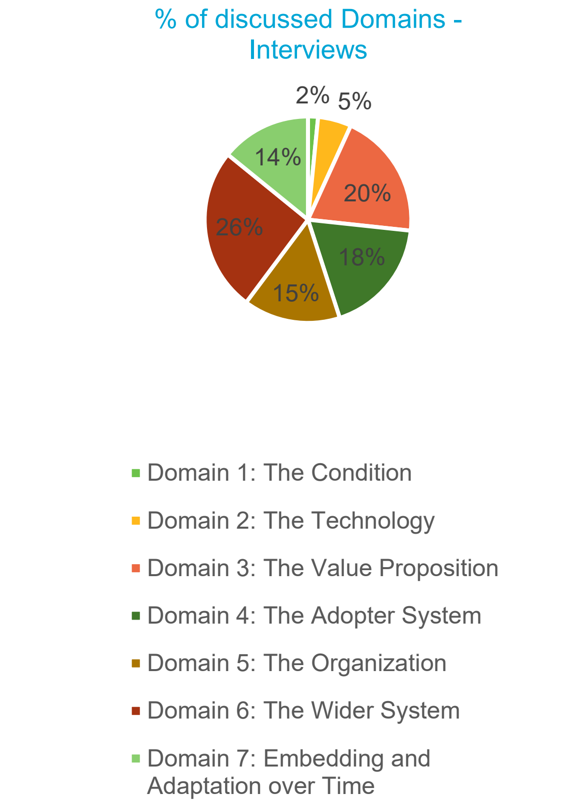


Figure 21: Pie Chart Percentage of discussed Domains - Interviews

While the literature primarily emphasizes technological investment as a major barrier to telemedicine implementation, the interviews reveal that such costs may be less critical than initially assumed. Instead, the interview insights place greater emphasis on the adopter system and organizational domains. These domains highlight internal cultural barriers, late stakeholder involvement, and financial misalignments that were not sufficiently addressed in the literature. Furthermore, the complexity of reimbursement mechanisms is explored in far greater depth in the interviews. Whereas the literature tends to mention reimbursement as a generic barrier, stakeholders offered concrete examples of institutional disincentives and fragmented budget structures, particularly affecting university hospitals like Erasmus MC.

Overall, while no radically new factors emerged, the interviews provided a more nuanced, actor-specific understanding. That shifted the attention from broad systemic challenges to operational and organizational realities.

6.4 Discussion and Conclusion

This chapter sought to uncover the economic considerations that influence the implementation of TeleNeonatology from diverse stakeholder perspectives, enriching and contextualizing the preceding economic evaluation and literature review. The interviews provide a more nuanced, actor-specific understanding of how financial incentives, reimbursement structures, value perceptions, and organizational capacities shape implementation decisions.

A key insight emerging from the interviews is that the barriers and enablers to TeleNeonatology are not uniformly experienced. While cost minimization analyses might suggest overall benefits, the real-world adoption and scaling of such interventions are mediated by institutional revenue models, regulatory rigidity, and fragmented stakeholder incentives. This divergence illustrates that implementation success is not solely determined by system-level efficiency, but also by local financial consequences and perceived fairness of budget redistribution.

Another important finding is the systemic tension between preventive, collaborative care models and production-based healthcare financing. TeleNeonatology, despite its potential to reduce unnecessary transfers, support families, and redistribute workload-faces difficulties in systems where activity-based payments still dominate. Several interviewees emphasized that unless such financing models are adjusted, innovations that reduce clinical activity risk being penalized rather than rewarded.

Interestingly, initial concerns about high investment costs appear overstated. Most stakeholders perceived pilot-phase funding as manageable through transformation budgets or internal resources. Instead, structural, long-term reimbursement and organizational alignment were cited as more critical obstacles for sustained implementation.

Leadership and early stakeholder inclusion emerged as consistent themes across interviews. Successful implementation requires not only a strong business case but also individuals who can initiate change and dismantle institutional inertia. Several interviewees highlighted the importance of identifying leaders and ensuring that funders, clinicians, and decision-makers are engaged from the beginning to build ownership and prevent late-stage resistance.

When comparing the interviews to the literature, the interviews added specificity and context. For example, where literature described general reimbursement delays, stakeholders pointed to specific institutional misalignments, decision-making bottlenecks, and political sensitivities that constrain reallocation of budgets or slow adoption. The interviews also reinforced that embedding telemedicine over time requires systemic flexibility, political will, and institutional readiness, none of which can be assumed based on positive pilot outcomes alone.

While the stakeholder group was diverse-including clinicians, insurers, economists, parents, and financial managers-it was limited in size (7 participants). The views expressed, especially by institutional actors such as insurers or hospitals, may not reflect the full diversity within those stakeholder groups. For instance, insurance companies in the Netherlands operate competitively, and insights from a single employee cannot be generalized to all insurers or their internal policies.

7 Discussion and Conclusion

This thesis explored the economic considerations influencing the implementation of TeleNeonatology in the Netherlands through a mixed-methods approach grounded in the NASSS framework. This study offered a multi-layered understanding of the challenges that hinder sustainable adoption of TeleNeonatology.

7.1 Answers to Research Questions

SQ 1: What economic factors contribute to the success of the implementation of telemedicine?

The systematic literature review identified several key economic factors that influence the implementation of telemedicine. Central enablers include demonstrable cost-effectiveness, availability of reimbursement mechanisms, and the scalability of technological solutions. The NASSS framework highlighted that economic challenges span multiple dimensions. This ranges from investment and maintenance costs (Technology domain) to reimbursement policies and regulatory uncertainty (Wider System domain). These findings emphasize that successful implementation depends not only on positive financial evaluations but also on systemic and structural readiness to support adoption.

SQ 2: What are the outcomes from an economic evaluation of TeleNeonatology from different perspectives?

The quantitative economic evaluation applied a cost minimization model to assess TeleNeonatology from four perspectives: Erasmus Hospital, Amphia Hospital, healthcare, and societal. The findings show that from both the societal and healthcare system perspectives, TeleNeonatology is cost saving, mainly due to reduced neonatal transfers and fewer NICU admissions. Across all perspectives, the neonatal transfer rate emerged as the most influential factor in determining economic outcomes. However, the value of the intervention is perceived differently depending on the viewpoint. For hospitals, especially Erasmus, avoided transfers translate into missed reimbursements under current activity based financing structures. While overall costs are reduced, these savings do not always result in direct financial benefits for all stakeholders. In some cases, they represent lost income, particularly when hospital resources and staffing levels remain fixed. This divergence highlights the importance of aligning reimbursement models with system level value creation to support more widespread adoption.

SQ 3: What economic factors influence the implementation of TeleNeonatology from various Stakeholder perspectives?

Qualitative interviews revealed that economic considerations vary significantly across stakeholders. Hospitals focus on direct implementation costs, required investments, and the impact on budgets. Health insurers prioritize long-term savings and risk equalization yet currently lack reimbursement models tailored to telemedicine. Parents value reductions in travel and emotional burden, which are difficult to monetize but relevant for societal assessments. These stakeholder-specific perspectives show that while the broader economic rationale for TeleNeonatology is clear, implementation is often hindered by misaligned financial incentives and a lack of system-wide coordination.

RQ: How do economic considerations impact the implementation of TeleNeonatology?

Economic considerations play a decisive role in shaping the implementation of TeleNeonatology. Although TeleNeonatology offers system-level efficiency and potential cost savings, its adoption is hampered by fragmented financial responsibilities, limited reimbursement structures, and divergent incentives across stakeholders. Successful implementation requires more than favorable economic evaluations, it demands alignment between stakeholder goals, tailored funding mechanisms, and long-term strategic commitment. The findings demonstrate that economic viability must be interpreted not only through aggregate cost minimization, but also through the lens of individual actors whose financial decisions ultimately determine whether and how TeleNeonatology is adopted and sustained.

7.2 Discussion of the Analysis and Research Outcomes

Triangulating evidence from the literature review, the cost minimization model, and stakeholder interviews yields a consistent pattern: TeleNeonatology generates system-level efficiencies and societal benefits primarily by preventing avoidable transfers and NICU admissions, yet provider-level incentives do not uniformly reward these efficiencies. The NASSS lens clarifies that the core economic friction does not stem from technological inadequacy, but from misaligned value flows between actors in the Wider System and Organization domains. This misalignment explains the coexistence of positive societal and payer value with hesitant hospital uptake.

The model indicates that the neonatal transfer rate is the principal driver of economic outcomes. Mechanistically, TeleNeonatology substitutes a high-cost pathway (transfer + potential NICU admission) with a lower-cost pathway (remote consultation + local management when clinically safe). This substitution reduces transport-related expenditures and downstream resource use. However, under activity-based revenue structures, avoided transfers can reduce hospital income, particularly for referral centers with relatively fixed staffing and capacity. Interviews corroborate that these revenue effects are salient in budget planning and can dominate adoption decisions even when the aggregate system value is positive.

Another common theme across methods is the incomplete visibility of economic effects. The model quantified savings from avoided transfers, but only interviews revealed how decision-makers perceive these savings in practice: hospitals focus on immediate budget impacts, insurers on long-term cost containment, and parents on indirect burdens such as travel and stress. The literature similarly noted that cost evaluations are rarely operationalized into real-world decisions.

Together, these findings suggest that the economic rationale for TeleNeonatology remains siloed, with no actor holding a complete system-wide overview. This lack of transparency impedes coordinated decision-making.

A further point of synthesis is that technological readiness was not identified as a major barrier in any of the three research components. Instead, structural and institutional misalignments dominate. The model showed favorable results at the macro level, while the interviews and literature both highlighted the absence of sustainable business models and clear reimbursement rules. The NASSS framework clarifies this as complexity in the Organization and Wider System domains rather than in the Technology domain.

Taken together, they suggest that the implementation of TeleNeonatology is not primarily constrained by questions of clinical effectiveness or aggregate cost savings, but by the way in which economic benefits and burdens are distributed across the healthcare system.

Together, the findings reveal a paradox: TeleNeonatology is simultaneously cost-saving and difficult to implement. The explanation lies in the divergence between aggregate efficiency and individual stakeholder incentives – the wrong pocket problem.

7.3 Limitations

This thesis inevitably operated within certain boundaries that shape the interpretation and transferability of its findings.

First, while the NASSS framework provided a structured lens to explore systemic, organizational, and financial dimensions, its extension to include economic considerations remains under-theorized. The adaptation of each domain to economic questions allowed for a more granular investigation of financial barriers and incentives. Nevertheless, NASSS is primarily designed to capture complexity in implementation but does not inherently prioritize economic causality or financial interdependencies between stakeholders. This limitation became evident when interpreting the fragmented nature of financial decision-making uncovered during the stakeholder interviews. A deeper engagement with economic theory, such as transaction cost economics, might have further enriched the understanding of why financial incentives misalign and how institutional inertia shapes adoption decisions.

A second boundary concerns the reliance on the Erasmus MC–Amphia pilot as the primary empirical basis for both the quantitative and qualitative phases. This pilot provided unparalleled access to real-world data and stakeholder experiences, but the findings are inevitably shaped by the specific institutional characteristics, and operational cultures of these two hospitals. As such, the results should be viewed as illustrative rather than universally representative. This also limits the generalizability of the findings, particularly for hospitals operating under different financial constraints or with less experience in telemedicine adoption. However, since this pilot was the first of its kind in the Netherlands it provided the most realistic data available.

A third consideration lies in the specificity of TeleNeonatology as a case study. Its highly specialized nature strengthens the analysis by offering a clearly delineated context in which the potential benefits of telemedicine are particularly visible. At the same time, this focus narrows the scope for generalization to other telehealth domains, where patient pathways, financing structures, and adoption drivers differ substantially. While TeleNeonatology can be seen as a model for high-stakes, niche applications, the broader applicability of its economic dynamics remains an open question for future research.

Finally, while this thesis centers on economic considerations, these factors cannot be fully disentangled from broader clinical, ethical, and systemic contexts. Particularly in neonatal care, implementation decisions are rarely based on economic factors alone. Interviews revealed that emotional, reputational, and logistical concerns, such as parental anxiety, clinical liability, or capacity strain, often weigh as heavily as financial indicators. Economic feasibility, as demonstrated here, is a necessary but broader alignment with institutional goals, cultural readiness, and policy frameworks must accompany financial modeling to achieve sustainable implementation.

Taken together, these boundaries reflect the scope of this thesis rather than deficiencies. By situating the findings within their methodological, institutional, and conceptual context, they provide transparency for interpretation while also highlighting where future research can extend, validate, or generalize the results.

7.4 Conclusion

Despite the promising clinical and economic potential of digital innovations such as TeleNeonatology, sustainable adoption remains a persistent challenge. This thesis reveals that economic feasibility on paper alone does not guarantee implementation success. Based on the integrated findings from the literature review, economic evaluation, and stakeholder interviews, three key takeaways emerge:

1. **Economic benefits are not evenly distributed across stakeholders**
   While societal and healthcare system perspectives show clear cost savings, hospitals face financial losses due to implementation and operational costs. This imbalance discourages investment at the institutional level, even when system-wide benefits are evident. The wrong pocket problem is here essential, where the party that bears the costs of an intervention is not the one that reaps the financial benefits, creating a misalignment that discourages implementation despite overall societal gains
2. **The adopter system and organizational perspective are often overlooked in literature and economic evaluations**
   The adopter system and organizational perspective are often underrepresented in both literature and economic evaluations. While existing studies frequently emphasize

aggregate cost-effectiveness, hospitals must make localized investment decisions with limited visibility on long-term returns or external funding support. Moreover, conversations with direct stakeholders reveal that problems often arise which had not previously been considered a priority, further widening the gap between theoretical feasibility and practical implementation.

3. **Stakeholders lack visibility and alignment**
   Most actors only understand their own financial implications and remain unaware of the broader value proposition. This lack of transparency limits collaboration and reinforces siloed decision-making across the healthcare system.

7.5 Practical Recommendations for the Implementation of TeleNeonatology

The findings of this thesis point to several areas where economic challenges in implementing TeleNeonatology can be addressed. Among these, three guiding steps stand out as particularly important for practice because they cover the most critical misalignments identified across the literature, the cost model, and stakeholder interviews. These suggestions are not exhaustive or sequential, but provide practical levers that hospitals, insurers, researchers, and policymakers can apply and revisit before, during, and after implementation to increase the likelihood of success.

A first suggestion is to establish **structured and transparent stakeholder alignment** from the start. The findings showed that misaligned incentives are one of the main barriers to implementation, and that no actor currently holds a full overview of system-wide costs and benefits. To overcome this, TeleNeonatology projects should begin by forming a formal steering group that includes representatives from hospitals (both referring and receiving), insurers, parent organizations, and policymakers. This group should agree on shared objectives before the project begins—for example, reducing unnecessary transfers, improving parental experience, or achieving long-term cost containment. Practical measures to operationalize alignment include: (1) scheduling regular joint review meetings where financial and clinical data are openly presented, (2) creating a shared dashboard that tracks outcomes relevant to each stakeholder (e.g., hospital budget impacts, avoided transport costs, parental travel time), and (3) setting up clear processes for dispute resolution if financial or operational conflicts emerge. By building this structured governance into the implementation process, projects can reduce siloed perspectives and create the trust necessary for long-term collaboration.

A second suggestion is to **embed economic evaluation directly into pilot design**. One of the challenges identified in this thesis was that cost savings and financial burdens were often only visible retrospectively, and typically siloed by perspective. Pilots should therefore be designed with economic indicators built in from the outset, tailored to each stakeholder group. For example, hospitals could track transfer rates and related financial effects under current reimbursement schemes, insurers could monitor the balance between additional teleconsultation costs and avoided high-cost interventions, and parents could provide input on indirect costs such as travel and time. Collecting these data systematically during the pilot ensures that economic outcomes are made explicit and linked to the realities of each actor's perspective. Regular feedback of these data during the pilot ensures that results are not only measurable but also meaningful for the actors involved. Linking economic outcomes with stakeholder interpretation both strengthens decisions on whether and how to expand TeleNeonatology and highlights which financial mechanisms or organizational arrangements require adjustment before wider roll-out. At the same time, this process allows pilots to adapt in real time, addressing concerns early, building trust, and creating a shared learning environment where value creation and losses become visible. In doing so, scaling strategies can be based on evidence and stakeholder experience rather than assumptions.

A third suggestion is to develop **sustainable financial mechanisms** that directly address the "wrong pocket problem." The analysis demonstrated that both smaller hospitals and larger referral centers can face revenue losses under current activity-based reimbursement structures when transfers are avoided, even though the system as a whole saves costs. To prevent this misalignment from becoming a barrier to adoption, funding models should be tested that redistribute system-wide savings back to the hospitals. Examples include shared-savings contracts between insurers and hospitals, per-consultation reimbursements that compensate teleconsultations even when no transfer occurs, or regional pooling mechanisms where financial risks and benefits are shared across hospital networks.

One concrete approach would be to introduce an insurance-funded pool to mitigate hospital revenue losses. At the end of each fiscal year, hospitals would submit an overview of avoided transfers and their financial implications. If TeleNeonatology activities led to a net revenue loss, the pool would reimburse hospitals up to the breakeven point. This ensures that no hospital is penalized financially for contributing to system-wide efficiency, while overall savings from avoided transfers and NICU admissions are preserved. Such a mechanism could be piloted regionally and, if effective, scaled nationally to provide a sustainable foundation for broader adoption.

Taken together, these guiding steps represent central areas of action that can substantially improve the chances of sustainable adoption. While other factors—such as clinical readiness, technical interoperability, and cultural acceptance—remain relevant, these three economic levers address the most persistent barriers uncovered in this research. Hospitals, insurers, and researchers can implement them directly in practice: hospitals by convening steering groups and committing transparent data, insurers by testing reimbursement models that neutralize financial losses, and researchers by embedding economic evaluation in pilot design. By focusing on these steps, stakeholders can reduce the risk of stalled projects and create the financial and organizational foundations needed for TeleNeonatology and similar telemedicine innovations to scale effectively.

7.6 Societal and Managerial Relevance

The implementation of TeleNeonatology carries significant societal and managerial implications, particularly within the context of rising healthcare costs, capacity shortages, and the need for more equitable access to specialized care.

This thesis contributes to the societal relevance of TeleNeonatology by providing a clearer understanding of the factors that influence its successful implementation. By identifying key barriers and enablers across stakeholder groups, the research supports more targeted and justified efforts to scale up the intervention. A better understanding of these dynamics increases the likelihood of adoption and long-term integration, ultimately helping to expand access to specialized neonatal care and improving outcomes for families and the healthcare system as a whole.

Managerially, the research highlights the complex trade-offs that hospital decision-makers must navigate when assessing new interventions. While the economic model indicates potential system-level savings, these do not necessarily translate into immediate financial benefits for individual hospitals. For hospital managers and healthcare administrators, this raises important questions about the allocation of implementation costs, the availability of investment capital, and the need for more dynamic reimbursement structures. The findings point to a misalignment between institutional incentives and societal goals, suggesting that targeted policy reforms and adjusted funding models are necessary to bridge this gap.

For both public stakeholders and institutional leaders, this research demonstrates that innovations like TeleNeonatology require a coordinated, system-wide implementation strategy from an economic standpoint. This includes not only assessing aggregate cost-effectiveness, but also managing stakeholder interests, addressing organizational readiness, and creating the financial and operational conditions for sustainable integration into routine neonatal care.

7.7 Academic Reflection

This thesis contributes to the academic discourse on digital health implementation by integrating economic evaluation with a systems-oriented analysis of stakeholder dynamics. While prior studies have focused largely on clinical outcomes or cost-effectiveness in isolation, this research offers a more holistic approach by combining a cost minimization model with qualitative insights into the institutional, financial, and regulatory conditions influencing the implementation. In doing so, it extends the application of the NASSS framework to incorporate economic and financial dimensions across all domains. This is an area that remains underexplored in implementation science.

Academically, this study reinforces the notion that implementation success cannot be fully explained by quantitative outcomes alone. The use of a mixed-methods explanatory sequential design allowed for the exploration of underlying motivations, constraints, and perceptions that shape real-world decisions. This methodological approach proved particularly useful in uncovering why positive economic evaluations often do not lead to uptake, highlighting a gap between theory and practice that should receive more attention in future research.

Furthermore, this thesis adds to the emerging literature on stakeholder-informed health technology assessment by illustrating the importance of diverse perspectives in economic modeling. It also emphasizes the need for adaptive evaluation frameworks that reflect the complexity of multi-actor healthcare systems. While the analysis is context-specific to TeleNeonatology in the Dutch setting, the underlying challenges and insights are transferable to other digital health interventions seeking to bridge the gap between potential value and practical implementation.

7.8 Future Research Possibilities

This thesis opens up several promising avenues for future research.

A natural next step following this thesis is to investigate the scaling up of TeleNeonatology beyond the Erasmus–Amphia pilot. Scaling research could first focus on extending collaboration between Erasmus MC and additional regional hospitals, before expanding to a national perspective. Such stepwise scaling would allow researchers to study differences in institutional readiness, financial structures, and regional patient flows. The practical recommendations developed in this thesis offer a useful foundation for this next stage. Future studies could test these recommendations in practice and assess their impact in real-world settings. By iteratively applying and refining these measures, scaling research could generate not only economic evidence but also guidance on the nuanced adjustments required to translate system-level efficiency into sustainable hospital-level adoption.

This thesis highlighted that transfer rates and length of stay are the most decisive parameters influencing the economic outcomes of TeleNeonatology. By demonstrating their dominant role in both the cost minimization model and stakeholder perceptions, the study provides a strong foundation for future research to examine these variables in greater depth.

Further work could, for instance, analyze how transfer probabilities vary under different clinical and regional conditions, or how TeleNeonatology shifts referral patterns across hospital networks. Similarly, moving beyond mean values of length of stay towards modeling full distributions would capture the heterogeneity of neonatal care pathways and better reflect real-world cost implications, particularly for outlier cases. In this way, the findings of this thesis do not only identify transfer rates and length of stay as sensitive variables but also point to them as critical levers for future economic research. By focusing on these dimensions, subsequent studies can generate more precise and context-sensitive evidence, thereby strengthening the case for scaling TeleNeonatology and refining its implementation strategies.

A final avenue for future research lies in extending the methodological contribution of this thesis. By adapting the NASSS framework to explicitly incorporate economic considerations, this study developed a structured lens that clarifies how financial barriers and incentives shape adoption.

Future research could build on this approach by applying the adapted NASSS-economic lens to other telehealth domains, such as telecardiology, telepsychiatry, or tele-intensive care. Doing so would test the robustness of the framework across contexts while also generating comparative insights into how economic dynamics interact with clinical, organizational, and systemic factors in different areas of digital health. In this way, the methodological contribution of this thesis does not remain confined to TeleNeonatology but provides a transferable tool for analyzing economic complexity in telemedicine implementation more broadly.

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Appendix

Appendix 1: HREC Approval

Date 24-Mar-2025
Correspondence hrec@tudelft.nl

TU Delft

Human Research Ethics Committee TU Delft
(http://hrec.tudelft.nl)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Economic Evaluation of TeleNeonatology
Applicant: Peitz, Ann-Kathrin

Dear Ann-Kathrin Peitz,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your submission to the HREC which has been conditionally approved. Please note that this approval is subject to your ensuring that the following condition/s is/are fulfilled:

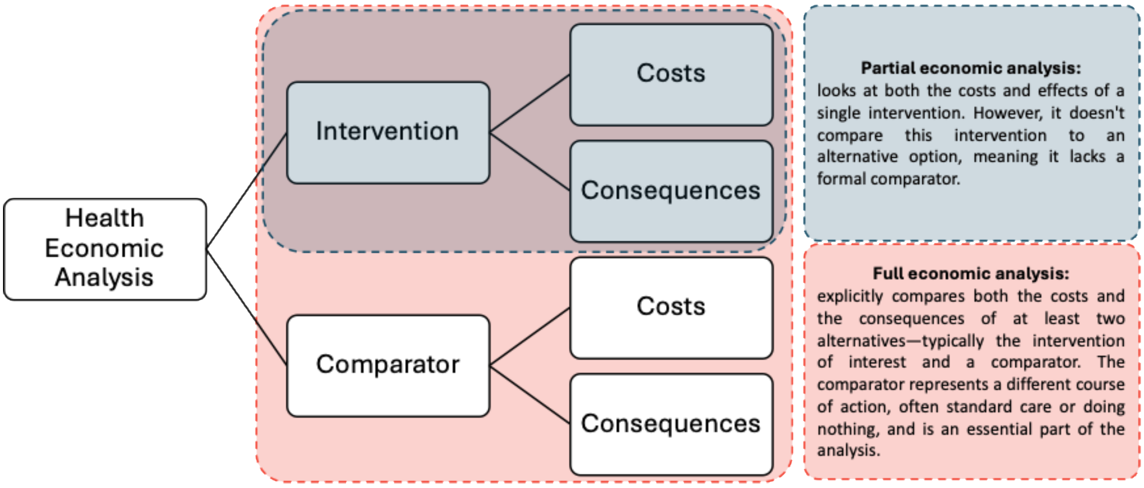
1. Please update the Informed Consent forms to specify the role and data access of Erasmus MC.
2. Please provide Informed Consent forms that are specific to the intended audience and their needs, making sure that they are readily understood.

In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:
• In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.
• Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor, and that ongoing covid risks and precautions are flagged in the informed consent - with particular attention to this where there are physically vulnerable (eg: elderly or with underlying conditions) participants involved.
• Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.
• Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent.

Good luck with your research!

Appendix 2: Economic Evaluation Overview

Health Economic Analysis (partial vs. full) (own creation after *(Turner et al., 2021))*



Different types of economic evaluations:

Type of Economic Evaluation	Input	Output	Description
Cost-Effectiveness Analysis (CEA)	Costs (monetary value)	Outcomes in natural units (e.g., life-years gained, disease cases avoided)	Compares alternatives based on cost per unit of health outcome; useful when outcomes can be measured in a single clinical unit.
Cost-Utility Analysis (CUA)	Costs (monetary value)	Utility-based outcomes (e.g., QALYs, DALYs)	A form of CEA that includes both quantity and quality of life in the outcome measure; allows for comparison across diseases and interventions.
Cost-Benefit Analysis (CBA)	Costs and outcomes (monetary values)	Net monetary benefit or cost-benefit ratio	Both costs and health outcomes are expressed in monetary terms, allowing for direct comparison; requires valuation of health outcomes based on preferences.
Cost-Minimisation Analysis (CMA)	Costs (monetary value)	Assumes equal outcomes	Applied when outcomes of alternatives are clinically equivalent; the least costly option is preferred.

Appendix 3: Python Code: Decision Tree Model and Sensitivity Analysis

Python Code for the Decision Tree model from the societal perspective:

(structure for all the other perspectives are the same, however the columns it refers to and the graph name differentiate)

```
import pandas as pd
import networkx as nx
import matplotlib.pyplot as plt

# Read COSTS and PROBABILITIES
df_costs = pd.read_excel('DecisionData.xlsx', sheet_name='Sheet1', usecols='E', skiprows=1, nrows=23, header=None)
df_costs = df_costs.apply(pd.to_numeric, errors='coerce').fillna(0)

df_probs = pd.read_excel('DecisionData.xlsx', sheet_name='Sheet2', usecols='E', skiprows=1, nrows=23, header=None)
df_probs = df_probs.apply(pd.to_numeric, errors='coerce').fillna(0)

# Define Edges, creating the decision tree branches
edges_with_labels = [
    ('Start', 'Telemedicine', 'Telemedicine Intervention'),
    ('Start', 'Usual Care', 'Usual Care'),
    ('Telemedicine', 'Transfer_Tele', 'Transfer'),
    ('Telemedicine', 'NoTransfer_Tele', 'No transfer required'),
    ('Transfer_Tele', 'Death1', 'Average LoS Erasmus + Pass away'),
    ('Transfer_Tele', 'Discharge1', 'Average LoS Erasmus + Discharge'),
    ('Transfer_Tele', 'BT1', 'Average LoS Erasmus + Backtransfer'),
    ('BT1', 'Discharge2', 'Average LoS Amphia + Discharge'),
    ('BT1', 'Death2', 'Average LoS Amphia + Pass away'),
    ('BT1', 'Reconsult1', 'Average LoS Amphia + Reconsultation'),
    ('NoTransfer_Tele', 'Discharge3', 'Average LoS Amphia + Discharge'),
    ('NoTransfer_Tele', 'Death3', 'Average LoS Amphia + Pass away'),
    ('Usual Care', 'Transfer_Usual', 'Transfer'),
    ('Usual Care', 'NoTransfer_Usual', 'No transfer required'),
    ('Transfer_Usual', 'BT2', 'Average LoS Erasmus + Backtransfer'),
    ('Transfer_Usual', 'Death4', 'Average LoS Erasmus + Pass away'),
    ('Transfer_Usual', 'Discharge4', 'Average LoS Erasmus + Discharge'),
    ('BT2', 'Discharge5', 'Average LoS Amphia + Discharge'),
    ('BT2', 'Death5', 'Average LoS Amphia + Pass away'),
    ('BT2', 'Reconsult2', 'Average LoS Amphia + Reconsultation'),
    ('NoTransfer_Usual', 'Discharge6', 'Average LoS Amphia + Discharge'),
    ('NoTransfer_Usual', 'Death6', 'Average LoS Amphia + Pass away')
]

# Build Graph
G = nx.DiGraph()
helper_counter = 0

for i, (src, tgt, label) in enumerate(edges_with_labels):
    cost = df_costs.iloc[i, 0] if i < len(df_costs) else 0
    prob = df_probs.iloc[i, 0] if i < len(df_probs) else 0

    helper_node = f"helper_{helper_counter}"
    helper_counter += 1

    G.add_edge(src, helper_node, label='', weight=0, prob=0)
    G.add_edge(helper_node, tgt, label=label, weight=cost, prob=prob)

G.add_node('Intro')
G.add_edge('Intro', 'Start', label='', weight=0, prob=0)

# this improves the space and the reading of the graph
pos = {
    'Intro': (-10, 45),
    'Start': (0, 45),

    'Telemedicine': (10, 61),
    'Usual Care': (10, 21),

    'Transfer_Tele': (20, 70),
    'NoTransfer_Tele': (20, 52),
    'Transfer_Usual': (20, 30),
    'NoTransfer_Usual': (20, 12),

    'BT1': (30, 65),
    'Death1': (40, 80),
    'Discharge1': (40, 75),
    'Discharge2': (40, 70),
    'Death2': (40, 65),
    'Reconsult1': (40, 60),

    'Discharge3': (40, 55),
    'Death3': (40, 50),
```

```
    'BT2': (30, 25),
    'Discharge4': (40, 40),
    'Death4': (40, 35),
    'Discharge5': (40, 30),
    'Death5': (40, 25),
    'Reconsult2': (40, 20),

    'Discharge6': (40, 15),
    'Death6': (40, 10)
}

# fixed the connection and 690 angle connection of the decision nodes
for u, v in G.edges():
    if "helper_" in v:
        tgt = list(G.successors(v))[0]
        pos[v] = (pos[u][0], pos[tgt][1])  # <- FIXED as per your requirement

# Define node types (circle, triangle, rectangle)
triangle_nodes = {n for n in pos if n.startswith("Death") or n.startswith("Discharge") or n.startswith("Reconsult")}
circle_nodes = set(G.nodes()) - triangle_nodes - {n for n in G.nodes() if "helper_" in n}
rectangle_nodes = {n for n in pos if n.startswith("Intro")}

# calculatue the cost impact with the cost and probabilities
cost_impacts = {}

for node in triangle_nodes:
    try:
        path = nx.shortest_path(G, source='Start', target=node)
    except nx.NetworkXNoPath:
        continue

    total_cost = 0
    total_prob = 1

    for i in range(len(path) - 1):
        u, v = path[i], path[i + 1]

        if v.startswith("helper_"):
            continue  # skip helper

        edge_data = G.get_edge_data(u, v)
        total_cost += edge_data.get('weight', 0)
        total_prob *= edge_data.get('prob', 1)

    cost_impacts[node] = round(total_cost * total_prob, 2)

# draw the graph
plt.figure(figsize=(24, 16))

nx.draw_networkx_edges(G, pos, edgelist=[('Intro', 'Start')], arrows=False, edge_color='gray', style='-')
nx.draw_networkx_nodes(G, pos, nodelist=['Start'], node_size=700, node_color='black', node_shape='s')
nx.draw_networkx_nodes(G, pos, nodelist=['Intro'],  node_color='white')
nx.draw_networkx_nodes(G, pos, nodelist=list(circle_nodes - {'Start'}-{'Intro'}), node_size=600, node_color='black', node_shape='o')
nx.draw_networkx_nodes(G, pos, nodelist=list(triangle_nodes), node_size=600, node_color='black', node_shape='<')

nx.draw_networkx_edges(G, pos, edgelist=G.edges(), arrows=False)

# Draw edge labels
for u, v in G.edges():
    edge_data = G.get_edge_data(u, v)
    x1, y1 = pos[u]
    x2, y2 = pos[v]
    xm, ym = (x1 + x2) / 2, (y1 + y2) / 2

    if edge_data.get('label', '') == '':
        label_color = 'white'
        label_text = ""
    else:
        label_color = 'black'
        label_text = f"{edge_data['label']}\nCost: {edge_data.get('weight', 0)}\nP: {edge_data.get('prob', 0):.2f}"

    plt.text(xm, ym - 1.0, label_text, fontsize=8, ha='center', va='center',
             bbox=dict(facecolor='white', alpha=0.0, edgecolor='none'), color=label_color)

nx.draw_networkx_labels(G, pos, labels={node: '' for node in G.nodes()})

for node in triangle_nodes:
    if node in cost_impacts:
        x, y = pos[node]
        plt.text(x + 1, y, f"{cost_impacts[node]}", fontsize=9, color='black', va='center')

plt.title("Decision Tree Societal Perspective", fontsize=18, y=0.95)
plt.axis('off')
plt.tight_layout()
plt.savefig("Decision Tree_Societal_Perspective.png", dpi=300, bbox_inches='tight')
plt.show()
```

Probabilistic Sensitivity Analysis Python Code

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

# Number of simulations
n_iterations = 1000

# Define triangular distributions
tri_params = {
    "ImplCost_Divisor": (15, 31, 50),
    "Transport_Cost": (2645.1, 2939, 3232.9),
    "Backtransfer_Cost": (702.9, 781, 859.1),
    "LoS_Amphia": (4, 13.4, 20.5),
    "Admission_Cost_Erasmus": ([redacted]),
    "Parental_Costs_Alive": (635.4, 706, 776.6),
    "Parental_Costs_Death": (1838.7, 2043, 2247.3),
    "Amphia_Day_Cost": (622.8, 692, 761.2),
    "Erasmus_LoS_Alive": (3, 5, 6),
    "Erasmus_LoS_Death": (4, 14, 15),
    "Prob_Transfer": (0.6, 0.81, 0.9),
    "Prob_Death_Erasmus": (0.01, 0.03, 0.07)
}

# Sample distributions
samples = {k: np.random.triangular(*v, n_iterations) for k, v in tri_params.items()}

# Define decision paths
paths = [
    # Telemedicine
    {"strategy": "Telemedicine", "path": "Transfer → Erasmus → Death", "p1": "Prob_Transfer", "p2": "Prob_Death_Erasmus", "cost_fn": "death"},
    {"strategy": "Telemedicine", "path": "Transfer → Erasmus → Discharge", "p1": "Prob_Transfer", "p2": "0.00", "cost_fn": "skip"},
    {"strategy": "Telemedicine", "path": "Transfer → Erasmus → Backtransfer → Amphia → Discharge", "p1": "Prob_Transfer", "p2": "1 -
Prob_Death_Erasmus", "cost_fn": "alive"},
    {"strategy": "Telemedicine", "path": "Transfer → Erasmus → Backtransfer → Amphia → Death", "p1": "Prob_Transfer", "p2": "0.00", "cost_fn":
"skip"},
    {"strategy": "Telemedicine", "path": "Transfer → Erasmus → Backtransfer → Amphia → Reconsultation", "p1": "Prob_Transfer", "p2": "0.00",
"cost_fn": "skip"},
    {"strategy": "Telemedicine", "path": "No Transfer → Amphia → Discharge", "p1": "1 - Prob_Transfer", "p2": "1", "cost_fn": "amphia_only"},
    {"strategy": "Telemedicine", "path": "No Transfer → Amphia → Death", "p1": "1 - Prob_Transfer", "p2": "0.00", "cost_fn": "skip"},

    # Usual Care
    {"strategy": "Usual Care", "path": "Transfer → Erasmus → Death", "p1": "1", "p2": "Prob_Death_Erasmus", "cost_fn": "death"},
    {"strategy": "Usual Care", "path": "Transfer → Erasmus → Discharge", "p1": "1", "p2": "0.00", "cost_fn": "skip"},
    {"strategy": "Usual Care", "path": "Transfer → Erasmus → Backtransfer → Amphia → Discharge", "p1": "1", "p2": "1 - Prob_Death_Erasmus",
"cost_fn": "alive"},
    {"strategy": "Usual Care", "path": "Transfer → Erasmus → Backtransfer → Amphia → Death", "p1": "1", "p2": "0.00", "cost_fn": "skip"},
    {"strategy": "Usual Care", "path": "Transfer → Erasmus → Backtransfer → Amphia → Reconsultation", "p1": "1", "p2": "0.00", "cost_fn": "skip"},
    {"strategy": "Usual Care", "path": "No Transfer → Amphia → Discharge", "p1": "0.00", "p2": "1", "cost_fn": "skip"},
    {"strategy": "Usual Care", "path": "No Transfer → Amphia → Death", "p1": "0.00", "p2": "0.00", "cost_fn": "skip"},
]

# Function to resolve probability strings
def resolve_probability(expr, sample):
    if expr in {"1", "1.0"}:
        return 1.0
    elif expr in {"0", "0.0", "0.00"}:
        return 0.0
    elif expr.startswith("1 - "):
        return 1.0 - sample[expr.replace("1 - ", "")]
    else:
        return sample[expr]

# Run simulation
results = {"Telemedicine": [], "Usual Care": []}

for i in range(n_iterations):
    s = {k: samples[k][i] for k in samples}

    for path in paths:
        p1 = resolve_probability(path["p1"], s)
        p2 = resolve_probability(path["p2"], s)
        prob = p1 * p2

        if path["cost_fn"] == "death":
            cost = (
                23308.3 / s["ImplCost_Divisor"]
                + s["Transport_Cost"]
                + s["Erasmus_LoS_Death"] * s["Admission_Cost_Erasmus"]
                + s["Parental_Costs_Death"]
            )
        elif path["cost_fn"] == "alive":
            cost = (
                23308.3 / s["ImplCost_Divisor"]
                + s["Transport_Cost"]
                + s["Backtransfer_Cost"]
```

```
            + s["Erasmus_LoS_Alive"] * s["Admission_Cost_Erasmus"]
            + s["LoS_Amphia"] * s["Amphia_Day_Cost"]
            + s["Parental_Costs_Alive"]
        )
    elif path["cost_fn"] == "amphia_only":
        cost = (
            23308.3 / s["ImplCost_Divisor"]
            + s["LoS_Amphia"] * s["Amphia_Day_Cost"]
            + s["Parental_Costs_Alive"]
        )
    else:
        cost = 0

    results[path["strategy"]].append(prob * cost)

# Aggregate totals
telemedicine_total = np.array(results["Telemedicine"]).reshape(n_iterations, -1).sum(axis=1)
usualcare_total = np.array(results["Usual Care"]).reshape(n_iterations, -1).sum(axis=1)

# Create DataFrame
df_results = pd.DataFrame({
    "Telemedicine_Total_Cost": telemedicine_total,
    "UsualCare_Total_Cost": usualcare_total
})

# Print summary
print("=== PSA Summary ===")
for label, data in {"Telemedicine": telemedicine_total, "Usual Care": usualcare_total}.items():
    print(f"\n{label}")
    print(f"  Mean: €{np.mean(data):,.2f}")
    print(f"  95% CI: (€{np.percentile(data, 2.5):,.2f} – €{np.percentile(data, 97.5):,.2f})")

# Create plot
plt.figure(figsize=(10, 6))
plt.hist(telemedicine_total, bins=40, alpha=0.7, label="Telemedicine", edgecolor='black')
plt.hist(usualcare_total, bins=40, alpha=0.7, label="Usual Care", edgecolor='black')
plt.axvline(np.mean(telemedicine_total), color='blue', linestyle='dashed', linewidth=1.5, label=f"Mean Telemedicine:
€{np.mean(telemedicine_total):,.0f}")
plt.axvline(np.mean(usualcare_total), color='orange', linestyle='dashed', linewidth=1.5, label=f"Mean Usual Care: €{np.mean(usualcare_total):,.0f}")
plt.title("PSA: Total Societal Cost Distribution")
plt.xlabel("Total Cost (€)")
plt.ylabel("Frequency")
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()
```

Appendix 4: Salary Overview

Calculation overview:

- medical specialists, including the neonatologist and pediatrician, an additional 10% is applied to account for irregular working hours
- Social security contributions are estimated at 35% of the gross salary (including irregular hours compensation) for the neonatologist and pediatrician(reflects employer contributions for social insurance, pensions, and other statutory costs)
- For the remaining staff categorie, the nurse, a standard 41% overhead rate is applied (recommended by the costing guideline to account for indirect labor costs, such as training, paid leave, pension contributions, and institutional overhead)
- Annual gross salary is extrapolated by multiplying the average monthly value by twelve
- annual cost is then divided by the standard number of workable hours per year, which is set at 2,087 hours for medical specialists, and 1,543 hours for nurses.
- roles in which a substantial portion of time is assumed to be spent in direct patient care, namely, the neonatologist and pediatrician, an estimate is made that 70% of their total working time is patient-related (enables the calculation of a more targeted unit cost per patient-related hour, which is particularly relevant when assessing direct clinical service provision

Position	Neonatologist (Erasmus)	Pediatrician (Amphia)	Nurse (Amphia)
Schaal	UMS	AMS	55
Intermediate	8	3	7
01.01-2024-30.04.2024	13 521	13 764	4 324
01.05.2024-31.12.2024	13 767	14 219	4 540
Average 2024	13 685	14 029.42	4 450
Compensation irregluar working hours (10%)	1 368.5	1 402.94	No
Social security contributions per month (35%)	5 268.73	5 401.33	No
Total staff cost (41%)	No	No	1 824.5
Annual Gross Salary	243 866.7	250 004.21	75 294
Workable hours	2 087	2 087	1 543
Patient Related hours per year (70%)	1 461	1 461	No
Cost per hour worked	116.85	119.79	48.8
Cost per patient-related hour	166.92	171.12	48.8
Source	https://www.nfu.nl/sites/default/files/2024-09/Cao_2025-2025_NFU-24.01131_NL.pdf	https://cao-ziekenhuizen.nl/sites/default/files/2024-02/salaristabel%20AMS%20voor%20publicatie%202023-2025.pdf	https://competentiesvoorbeelden.nl/salaris/verpleegkundig-specialist

Appendix 5: Decision Tree Branch Costs per Perspective

Amphia			
Decision Tree Branch	**Included Costs**	**Costs in €**	**Sum**
Start to Telemedicine Intervention	Implementation Costs	[redacted]	[redacted]
	Consultation Costs	[redacted]	
Start to Usual Care	Consultation Costs	[redacted]	[redacted]
Telemedicine to Transfer	Preparation for Transport at Amphia	[redacted]	[redacted]
Telemedicine to NoTransfer	None		[redacted]
Transfer to Pass Away	None		[redacted]
Transfer to Discharge	None		[redacted]
Transfer to Backtransfer	Post Intensiv Care Surcharge at Amphia	[redacted]	[redacted]
Backtransfer to Discharge	Amphia Day Charge	[redacted]	[redacted]
Backtransfer to Pass Away	Amphia Day Charge	[redacted]	[redacted]
Backtransfer to Reconsultation	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Discharge	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Pass Away	Amphia Day Charge	[redacted]	[redacted]
Usual Care to Transfer	Preparation for Transport at Amphia	[redacted]	[redacted]
Usual Care to NoTransfer	None		[redacted]
Transfer to Backtransfer	Post Intensiv Care Surcharge at Amphia	[redacted]	[redacted]
Transfer to Death	None		[redacted]
Transfer to Discharge	None		[redacted]
Backtransfer to Discharge	Amphia Day Charge	[redacted]	[redacted]
Backtransfer to Death	Amphia Day Charge	[redacted]	[redacted]
Backtransfer to Reconsultation	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Discharge	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Pass Away	Amphia Day Charge	[redacted]	[redacted]
Erasmus			
Decision Tree Branch	**Included Costs**	**Costs in €**	**Sum in €**
Start to Telemedicine Intervention	Implementation Costs	[redacted]	[redacted]
	Consultation Costs	[redacted]	
Start to Usual Care	Consultation Costs	[redacted]	[redacted]
Telemedicine to Transfer	Transfer	[redacted]	[redacted]
Telemedicine to NoTransfer	None		[redacted]
Transfer to Death1	Erasmus Day Admission (LoS Pass Away)	[redacted]	[redacted]
Transfer to Discharge1	Erasmus Day Admission (LoS Backtransfer)	[redacted]	[redacted]
	Hearing Test	[redacted]	
Transfer to BT1	Erasmus Day Admission (LoS Backtransfer)	[redacted]	[redacted]
	Backtransfer	[redacted]	
BT1 to Discharge2	Hearing Test	[redacted]	[redacted]
BT1 to Death2	None		[redacted]
BT1 to Reconsult1	None		[redacted]
NoTransfer to Discharge3	None		[redacted]
NoTransfer to Death 3	None		[redacted]
Usual Care to Transfer	Transfer	[redacted]	[redacted]
Usual Care to NoTransfer	None	[redacted]	[redacted]
Transfer to BT2	Erasmus Day Admission (LoS Backtransfer)	[redacted]	[redacted]
	Backtransfer	[redacted]	
Transfer to Death4	Erasmus Day Admission (LoS Pass Away)	[redacted]	[redacted]
Transfer to Discharge4	Erasmus Day Admission (LoS Backtransfer)	[redacted]	[redacted]
	Hearing Test	[redacted]	
BT2 to Discharge5	Hearing Test	[redacted]	[redacted]
BT2 to Death5	None	[redacted]	[redacted]
BT2 to Reconsult2	None	[redacted]	[redacted]
NoTransfer to Discharge6	None	[redacted]	[redacted]
NoTransfer to Death6	None	[redacted]	[redacted]
Healthcare			
Decision Tree Branch	**Included Costs**	**Costs in €**	**Sum**
Start to Telemedicine Intervention	Implementation Costs Amphia	[redacted]	[redacted]
	Consultation Costs Amphia	[redacted]	
	Implementation Costs Erasmus	[redacted]	
	Consultation Costs Erasmus	[redacted]	
Start to Usual Care	Consultation Costs Amphia	[redacted]	[redacted]
	Consultation Costs Erasmus	[redacted]	
Telemedicine to Transfer	Transfer	[redacted]	[redacted]
	Preparation for Transport at Amphia	[redacted]	
	Maternal Care - Transfer Ambulance	[redacted]	
Telemedicine to NoTransfer	None	[redacted]	[redacted]
Transfer to Death1	Erasmus Day Charge (Pass away LoS)	[redacted]	[redacted]
Transfer to Discharge1	Erasmus Day Charge (Discharge LoS)	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	

Transfer to BT1	Post Intensiv Care Surcharge at Amphia	[redacted]	[redacted]
	Backtransport from Erasmus to Amphia	[redacted]	
	Erasmus Day Charge (Discharge LoS)	[redacted]	
BT1 to Discharge2	Amphia Day Charge	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
BT1 to Death2	Amphia Day Charge	[redacted]	[redacted]
BT1 to Reconsult1	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Discharge3	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Death 3	Amphia Day Charge	[redacted]	[redacted]
Usual Care to Transfer	Preparation for Transport at Amphia	[redacted]	[redacted]
	Transfer	[redacted]	
	Maternal Care - Transfer Ambulance	[redacted]	
Usual Care to NoTransfer	None	[redacted]	[redacted]
Transfer to BT2	Post Intensiv Care Surcharge at Amphia	[redacted]	[redacted]
	Backtransport from Erasmus to Amphia	[redacted]	
	Erasmus Day Charge (Discharge LoS)	[redacted]	
Transfer to Death4	Erasmus Day Charge (Pass away LoS)	[redacted]	[redacted]
Transfer to Discharge4	Erasmus Day Charge (Discharge LoS)	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
BT2 to Discharge5	Amphia Day Charge	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
BT2 to Death5	Amphia Day Charge	[redacted]	[redacted]
BT2 to Reconsult2	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Discharge6	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Death6	Amphia Day Charge	[redacted]	[redacted]
Societal			
Decision Tree Branch	**Included Costs**	**Costs in €**	**Sum**
Start to Telemedicine Intervention	Implementation Costs Amphia	[redacted]	[redacted]
	Consultation Costs Amphia	[redacted]	
	Implementation Costs Erasmus	[redacted]	
	Consultation Costs Erasmus	[redacted]	
Start to Usual Care	Consultation Costs Amphia	[redacted]	[redacted]
	Consultation Costs Erasmus	[redacted]	
Telemedicine to Transfer	Transfer	[redacted]	[redacted]
	Preparation for Transport at Amphia	[redacted]	
	Maternal Care - Transfer Ambulance	[redacted]	
Telemedicine to NoTransfer	None	[redacted]	[redacted]
Transfer to Death1	Erasmus Day Charge (Pass away LoS)	[redacted]	[redacted]
	Discount Parking 4-week (pass away)	[redacted]	
	Ronald McDonald House Personal Contribution (pass away)	[redacted]	
	Car Cost per Kilometer (pass away)	[redacted]	
	Additional Cost Parents	[redacted]	
Transfer to Discharge1	Erasmus Day Charge (Discharge LoS)	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
	Dicsount Parking 14 Days	[redacted]	
	Ronald McDonald House Personal Contribution	[redacted]	
	Car Cost per Kilometer	[redacted]	
	Additional Cost Parents	[redacted]	
Transfer to BT1	Post Intensiv Care Surcharge at Amphia	[redacted]	[redacted]
	Backtransport from Erasmus to Amphia	[redacted]	
	Erasmus Day Charge (Discharge LoS)	[redacted]	
	Dicsount Parking 14 Days	[redacted]	
	Ronald McDonald House Personal Contribution	[redacted]	
	Car Cost per Kilometer	[redacted]	
	Additional Cost Parents	[redacted]	
BT1 to Discharge2	Amphia Day Charge	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
BT1 to Death2	Amphia Day Charge	[redacted]	[redacted]
BT1 to Reconsult1	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Discharge3	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Death 3	Amphia Day Charge	[redacted]	[redacted]
Usual Care to Transfer	Preparation for Transport at Amphia	[redacted]	[redacted]
	Transfer	[redacted]	
	Maternal Care - Transfer Ambulance	[redacted]	
Usual Care to NoTransfer	None	[redacted]	[redacted]
Transfer to BT2	Post Intensiv Care Surcharge at Amphia	[redacted]	[redacted]
	Backtransport from Erasmus to Amphia	[redacted]	
	Erasmus Day Charge (Discharge LoS)	[redacted]	
	Dicsount Parking 14 Days	[redacted]	
	Ronald McDonald House Personal Contribution	[redacted]	
	Car Cost per Kilometer	[redacted]	

	Additional Cost Parents	[redacted]	
Transfer to Death4	Erasmus Day Charge (Pass away LoS)	[redacted]	[redacted]
	Discount Parking 4-week (pass away)	[redacted]	
	Ronald McDonald House Personal Contribution (pass away)	[redacted]	
	Car Cost per Kilometer (pass away)	[redacted]	
	Additional Cost Parents	[redacted]	
Transfer to Discharge4	Erasmus Day Charge (Discharge LoS)	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
	Dicsount Parking 14 Days	[redacted]	
	Ronald McDonald House Personal Contribution	[redacted]	
	Car Cost per Kilometer	[redacted]	
	Additional Cost Parents	[redacted]	
BT2 to Discharge5	Amphia Day Charge	[redacted]	[redacted]
	Hearing Test Erasmus	[redacted]	
BT2 to Death5	Amphia Day Charge	[redacted]	[redacted]
BT2 to Reconsult2	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Discharge6	Amphia Day Charge	[redacted]	[redacted]
NoTransfer to Death6	Amphia Day Charge	[redacted]	[redacted]

Appendix 6: Model Validation Protocol

Model Validation Protocol	
This protocol outlines the structured approach used to validate the economic model of TeleNeonatology through expert interviews. The goal was to assess the conceptual, structural, and data validity of the model by incorporating the insights of domain experts involved in neonatal care, healthcare management, and financing.	
1. Objective of the Validation	To verify that the decision model: - Accurately represents the clinical workflow and patient journeys in neonatal care - Uses realistic and context-specific assumptions - Includes cost and probability inputs that reflect current practice and expert judgment - Produces output values that are perceived as credible and meaningful by stakeholders
2. Stakeholders Interviewed	Experts were selected based on their knowledge of neonatal care pathways, hospital operations, health economics, or healthcare financing. The following stakeholder categories were represented: - Neonatologists and pediatricians (clinical validity) - Hospital innovation managers and implementation leads (organizational context) - Health economists (modeling methodology) - Insurer representatives (financial and reimbursement perspective) - Patient advocacy representatives (care experience and societal relevance)
3. Validation Aspects Covered in Interviews	Each interview followed a semi-structured format and focused on three key dimensions of model validation: *A. Conceptual Validity* Goal: To confirm whether the model's logic, patient pathways, and structure reflect the real-world neonatal care process and organizational setup. Topics covered: - Clinical accuracy of modeled pathways - Completeness of patient journey - Organizational feasibility of TeleNeonatology integration Example questions: - “Does the decision to transfer or not transfer reflect actual clinical decision-making?” - “Is the option of backtransfer commonly practiced in your setting?” - “Are there patient cases or pathways that are not captured in this model but should be?” - “Does the decision tree reflect the real structure of care collaboration between hospitals like Amphia and Erasmus MC?” *B. Input Validity* Goal: To verify whether the model uses realistic and context-specific estimates for key parameters (costs, probabilities, length of stay). Topics covered: - Accuracy and representativeness of cost items - Reasonableness of length of stay and consultation durations - Appropriateness of probability estimates Example questions: - “Does the average length of stay used match your clinical observations?” - “Are the consultation durations realistic across cases?” - “Is the assumed transfer rate under TeleNeonatology in line with what you’d expect in practice?” - “Are there important cost elements or resources missing that should be included?” *C. Output Validity and Relevance* Goal: To assess whether the model’s results seem plausible and useful for decision-making. Topics covered: - Interpretation and acceptance of results - Stakeholder-specific implications - Practical value in guiding reimbursement or implementation decisions Example questions: - “Do the estimated cost differences seem realistic to you?” - “How would you interpret the finding that Erasmus loses revenue when fewer transfers occur?” - “Would these results be convincing to decision-makers?” - - “Is there any concern that the model over- or underestimates certain effects?”

4. Procedure	*1. Preparation* - Interview guide developed based on model components and NASSS domains. - Experts received a one-page model summary before the meeting. - Visuals such as the decision tree and patient journey map were used during the interview. 2. Interview Conduct - Interviews lasted 60 minutes, conducted online - Informed Consent Form *3. Data Capture and Synthesis* - Key insights were noted - Changes were incorporated into the model or documented as limitations *4. Integration into the Model* - Direct feedback was used to refine assumptions and adjust value - Stakeholder quotes supported qualitative validation and interpretation *5. Documentation* A validation log was maintained for each interview, detailing: - Expert role and affiliation (anonymized), - Date and duration, - Validation categories discussed, - Summary of key feedback and follow-up actions.

Appendix 7: Overview Guiding Questions for the Interviews

Guiding Questions Interview	
- Semi-structure interview, therefore these questions were used as guiding questions	
General Background	- Can you tell me about your role and your involvement in TeleNeonatology or telemedicine? - What is your general view on how such innovations are adopted in your organization?
Implementation and Adoption	- How do you view the adoption process of TeleNeonatology in your institution? - What are the key challenges to implementing this in routine care? - What needs to happen for TeleNeonatology to be scaled up? - How do clinicians respond to this innovation? - What are barriers to implementation from your perspective?
Reimbursement and Financial Structures	- How is TeleNeonatology currently financed or reimbursed? - Are there financial incentives or disincentives that impact the adoption? - Who benefits financially from avoided transfers? Who loses? - How does reimbursement influence implementation decisions in your organization? - What changes in reimbursement would be necessary to make this sustainable?
Stakeholder Roles and Coordination	- Which stakeholders are essential for successful implementation? - Is the collaboration between hospitals, insurers, and policymakers working well? - Are all involved actors aligned in their goals for this pilot?
Technology and Usability	- Is the current technology sufficient for what is needed? - Are there usability issues or training needs for the staff? - Do digital skills among clinicians affect the adoption? - What would be required to make the technology scalable?
Economic Model and Evaluation	- What do you think of the economic evaluation results? - Are there assumptions in the model that don't reflect reality? - Do you think the decision tree model reflects actual processes? - Would you add anything to the economic evaluation framework?
Policy and Systemic Factors	- Does the national policy context help or hinder TeleNeonatology? - Are there structural barriers on the health system level?
Parental and Societal Perspective	- How do you think parents are affected economically by transfers? - Are indirect costs for families considered in current evaluations?
Sustainability and Future Planning	- What is needed to ensure the long-term viability of TeleNeonatology? - How can pilot projects like this be embedded in standard care? - How important is early financial planning for sustainability?

Appendix 8: Summaries Stakeholder Interviews

Interviewee: Neonatologist US-based

Guiding Questions:
- What lessons from the U.S. telemedicine experience are applicable here?
- What are the clinical and operational benefits of video consultations?
- How were pilots scaled?
- What financial or infrastructural elements are needed for sustainability?

Summary of Responses:
The discussion emphasized how telemedicine in neonatal care affects different stakeholders in distinct ways. For higher-level centers, financial outcomes depend heavily on occupancy rates and payment structures, while community hospitals often view the program favorably due to patient retention, potential cost savings, and reduced legal risks. Implementation was initially driven more by feasibility and patient benefit than economics, but scaling efforts required formal business cases and clear financial justification. Broader issues such as reimbursement policies, upfront technology costs, and alignment with organizational strategy emerged as key determinants of long-term sustainability.

Interviewee: Neonatologist and Innovation Lead

Guiding Questions:
- What are the clinical and economic motivations for implementing TeleNeonatology?
- How does it affect the hospital financially?
- Are clinicians included in financial decision-making?
- What challenges do you see for sustainable implementation?

Summary of Responses:
The neonatologist highlighted that while TeleNeonatology improves care continuity and reduces the emotional burden on families, it financially disadvantages the hospital due to a loss of NICU admissions and associated reimbursements. He expressed concern that efficient hospitals are paradoxically punished under current pricing systems like those of NZa. Clinicians are often excluded from economic discussions or not actively involved, creating resistance later in the process. Successful implementation would require realignment of hospital incentives and a stronger policy signal supporting telemedicine. He emphasized the importance of learning from past implementation failures and suggested early-stage ownership.

Interviewee: Insurance Employee

Guiding Questions:
- How is TeleNeonatology reimbursed or supported by the system?
- Are current reimbursement schemes flexible enough for innovation?
- What financial or regulatory barriers do you observe?
- What role do insurers or policy bodies play in supporting new interventions?

Summary of Responses:
The insurance advisor noted that current reimbursement structures do not adequately support innovations like TeleNeonatology. He explained that the insurer's role is reactive unless engaged early by hospitals or other stakeholders. Many promising digital health interventions are not adopted because they fall outside standard reimbursement paths. He stressed the need for shared savings agreements or bundled payment models to distribute costs and benefits fairly. Importantly, he acknowledged that insurers are often brought in too late, after hospitals have already invested in pilots, reducing flexibility and ownership. He advocated for more proactive collaboration and earlier insurer involvement in the design of telemedicine services.

Interviewee: Health Economist

Guiding Questions:
- How is TeleNeonatology reimbursed or supported by the system?
- Are current reimbursement schemes flexible enough for innovation?
- What financial or regulatory barriers do you observe?
- What role do insurers or policy bodies play in supporting new interventions?

Summary of Responses:
The advisor emphasized that reimbursement structures in the Netherlands are not sufficiently agile to accommodate innovations like TeleNeonatology. Current DRG-based models reward volume and high-cost inpatient care over preventative or collaborative solutions. There is no structural financial mechanism that encourages telemedicine adoption, especially in cross-institutional settings. While pilots can attract incidental funding, transitioning to long-term reimbursement requires multi-stakeholder coordination and early involvement of insurers. The advisor also noted that health economic evaluations should be designed with stakeholder expectations in mind, as current models often fail to reflect the financial logic of key decision-makers.

Interviewee: Parental Representation

Guiding Questions:
- What is the parent perspective on transfers and telemedicine?
- How does distance impact families financially and emotionally?
- Are parent voices included in decision-making?
- What would a family-centered implementation strategy look like?

Summary of Responses:

The parental representative described how transfers place a substantial financial and emotional burden on parents with lost income, travel expenses, and stress. She emphasized that staying close to home improves parental involvement, bonding, and mental health. She critiqued the lack of systemic recognition for these indirect costs, which often go unmeasured in evaluations. She called for family-inclusive planning processes and policies that reflect real-world parental challenges. TeleNeonatology was described as a tool for equity, and she stressed that any economic model or implementation plan must account for the lived experience of families.

Interviewee: Health Innovation Business Manager
Guiding Questions: - What are the economic consequences of reduced NICU admissions? - Is there a trade-off between clinical excellence and financial sustainability? - How can economic evaluations support internal decision-making? - What institutional changes are needed for innovation uptake?
Summary of Responses: The business manager emphasized that the hospital loses revenue when fewer NICU beds are used, as reimbursements are tied to patient days and specialized procedures. He pointed out that while medical and ethical benefits are clear, economic incentives are misaligned. He saw the need for economic evaluations to communicate value beyond cost savings, such as risk mitigation and strategic positioning. He suggested that financial logic often overrides clinical rationale unless properly translated. For TeleNeonatology to succeed, financial decision-makers must be involved early, and institutional incentives must be restructured to support collaborative innovation.

Interviewee: Financial Controller Hospital
Guiding Questions: - How does TeleNeonatology affect the financials of the hospital? - What is your view on avoided transfers? - Are reimbursement structures supportive of this innovation? - How does collaboration with other hospitals affect cost distribution?
Summary of Responses: The controller explained that the hospital benefits from retaining patients locally, avoiding transfers, and reducing associated non-reimbursable costs. He described the current financial system as one that inadvertently favors larger hospitals and penalizes collaborative care. According to him, the value of reduced transfers is not captured in existing reimbursement flows, making innovations like TeleNeonatology economically unattractive unless new mechanisms are introduced. He advocated for improved collaboration with insurers and the adaptation of insurance schemes to better reflect shared value creation across institutions.