# *Evaluating the Impact of Decision Aids that Support Shared Decision Making*

***Helping hospitals to bridge the transition period to value based healthcare.***

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## Abbreviations

| Abbreviation | Description |
|---|---|
| DA | **D**ecision **A**id |
| DBC | Diagnosis Treatment Combination (in Dutch **D**iagnose **B**ehandeling **C**ombinatie) |
| FMS | **F**ederation of **M**edical **S**pecialists |
| FNV | Dutch Trade Union Federation (in Dutch **F**ederatie **N**ederlandse **V**akbeweging) |
| IZA | Integral Care Agreement (in Dutch **I**ntegraal **Z**org **A**kkoord) |
| NZa | Dutch Healthcare Authority (In Dutch **N**ederlandse **Z**org**a**utoriteit. |
| RIVM | National Institute for Public Health and Environment (in Dutch **R**ijks**i**nstituut voor **V**olksgezondheid en **M**ilieu) |
| SDM | **S**hared **D**ecision-**M**aking |
| VBHC | **V**alue-**B**ased Healthcare |
| ZA | Care Activity (in Dutch **Z**org **A**ctiviteit) |
| ZPK | Care Profile Class (in Dutch **Z**org **P**rofiel **K**lasse) |

**List of Tables**

**List of Figures**

# Executive Summary

**Context.** Care for all is no longer guaranteed according to the Dutch Healthcare Authority as Dutch hospitals face increasing pressure. Hospitals have to deal with a rise in healthcare demand, staff shortages and financial uncertainty. To address these challenges, the Dutch Government introduced the Integral Care Agreement in which Shared Decision Making (SDM) is introduced. SDM is a process in which a patient and doctor make treatment decisions together based on the values and preferences of the patient. Adoption of SDM and tools that support it are lagging. SDM is seen as a complex and challenging process for patients and healthcare professionals. The complexity is caused by several factors, one of them being patient knowledge on their medical condition. To help overcome this factor Decision Aids have been developed. Decision Aids are tools that contain evidence-based information on the patient's medical condition and possible treatment methods.

**Problem.** Not only the implementation of SDM faces barriers, the adoption of Decision Aids by hospitals is also lagging. A key barrier is the lack of clarity about the financial consequences for hospitals operating within the Dutch Diagnosis Treatment Combination (DBC) System. This lack of clarity is due to a misalignment between a hospital's internal budgeting and the financial reimbursement from insurers. Hospitals have a wish to treat more patients and reduce unnecessary procedures. This is achievable through Value Based Healthcare (VBHC) methods such as SDM. However, transitioning to VBHC in general is seen as a challenge. Hospitals go through a **transition period** filled with financial uncertainty as their revenue sources change. Dutch Hospitals are reimbursed through Diagnosis Treatment Combinations (DBCs). DBCs can be categorized in different ways, in this thesis DBCs are distinguished as either surgical or non-surgical. A direct consequence of effective Decision Aid implementation is that patients are reported to choose for more conservative treatment methods. This shift causes for a decrease in revenue as surgical DBCs are reimbursed at higher amounts than non-surgical DBCs. If this decrease in revenue is not anticipated by a hospital they might suffer financially as their expenses regarding staff, equipment and infrastructure are not aligned with their projected income.

**Research objective.** This thesis aims to provide a method to evaluate the implications for the costs and operational efficiency when a decision aid is implemented and patient distribution shifts to more conservative treatments. The study focuses on the consequences effective decision aid implementation has on **hip fracture** cases. The research question to guide this study is as follows: *How do the costs of the implementation of a Decision Aid compare to its impact on a hospital's operational efficiency?*

**Research approach**. The study consisted of four phases. The first phase was a literature review from which a conceptual model was developed for further evaluation of decision aid implementation. The conceptual model contains three components. These components are the adoption of decision aids, impact of decision aid implementation on patient distribution and the financial and resource effects of decision aids. The second phase entails data collection from semi-structured interviews with healthcare professionals and data collection from the Open Portal of the Dutch Healthcare Authority. The third phase entails data analysis on the collected data. The fourth phase consisted of System Dynamics modeling, a five-stage model

development approach was used based on literature by Sterman (2000) to create a model which simulates the flow of hip fracture patients through a hospital.

**Results.** The interviewees consistently placed a focus on the urgency for concepts like Shared Decision-Making to be implemented as soon as possible. Some of the interviewees were involved in either pilots or extensive research programs in which decision aid implementation was evaluated. Different methods to evaluate the financial impact of decision aid implementation were found during these interviews, two of them were to assess how decision aids impact patient distribution across treatment alternatives and their impact on revenue from DBCs. To incorporate these methods, a System Dynamics model was used to simulate hip fracture patient flow through a hospital. Their binary treatment choice (e.g. conservative or invasive) has consequences for volumes of care activities and for the distribution of patients registered with surgical or non-surgical DBCs. Based on current data from the Dutch Healthcare authority, a baseline model was created where 6.7% of patients chose for conservative care. An important modeling assumption was that effective decision aid implementation causes for a 5% increase in conservative treatment choices from patients. Therefore, two what-if scenarios were simulated where there was a 5 and 10% increase in conservative care. In all three scenarios, 238 patients were simulated. These patients either followed a conservative or invasive flow. These flows resulted in different distributions across DBCs. Results showed that a 5% increase of patients choosing for conservative care resulted in revenue losses of around €40000 for a hospital in a year. A 10% increase in conservative care resulted in almost €80000. The increase in income in non-surgical DBCs was around €10200 in the first scenario and almost €20400 in the second scenario.

**Conclusion.** This study concludes that under the current financial reimbursement system for Dutch healthcare, hospitals need to adjust their internal processes proactively during the transition to VBHC. They must anticipate losses and should restructure their organization. This may be done through both reduction of operational personnel and through reorganization of their internal processes. By doing so, hospitals may be able to overcome financial losses and implement VBHC sustainably.

**Evaluation of results.** The results show that losses in revenue are not compensated by an increase in income from non-surgical DBCs. This was something that could be expected beforehand. However, this study does highlight a possible shortcoming in current evaluation methods on decision aid implementation. Evaluating the implementation of decision aids solely through income from DBCs does not do right by the quality improvement of care when hospitals transition to VBHC. Helping hospitals bridge the transition to VBHC might require a complete change in the way Dutch healthcare is financed.

**Future research recommendation.** This study aimed to evaluate the implementation of decision aids through current evaluation methods. These same evaluation methods are used by hospitals and insurers during annual contract negotiations. As these methods do not sufficiently capture the added value of decision aids for hospitals, a call is made for different evaluation methods. This study invites future research to find new and financially supportive methods for decision aid evaluation.

# Preface

This thesis concludes my career as a student at Delft University of Technology. The thesis was conducted as part of the Master Complex Systems Engineering & Management from the faculty of Technology, Policy and Management.
The study took place between December 2024 and April 2025. It has been a long and hard process, but it was very rewarding.

I would like to thank my first supervisor Dr. Naomi van der Linden for her personal guidance during my thesis. Her willingness to be my supervisor allowed me to apply my passion for healthcare directly to my study. From the first meeting we had Dr. van der Linden was very enthusiastic, supportive and also very wise. Dr. van der Linden often pointed out that I might be too ambitious with my research goals, and I adjusted my research accordingly. Thank you for your advice and the opportunity for me to do my thesis with you.

I would also like to express my gratitude towards Dr. Kateřina Staňková. Given my tight timeframe she not only was very facilitating, but also very facilitating. She made sure all administrative needs were met and was available even though she had a very busy schedule herself. To help she even introduced Arina Soboleva (PhD) as extra support. Arina was also very helpful in the starting phase of my research. I was struggling with modeling principles, and she made sure to ask me the right guiding questions to get me going. Also, during the midterm review she gave very useful constructive feedback which helped me a lot.

Finally, I would like to thank Ir. Regina The and the entire team from ZorgKeuzeLab. They have been very supportive during my thesis and offered me help whenever I needed. From brainstorm sessions with Ir. Klemens Karssen, warm conversations with Ir. Asako Takahashi, Lina Wang and Ir. Natasha Snel to office coordination with Annette van den Berg. Dr. Sophie Kurk also helped me to find inspiration for the modelling part of my thesis. Regina always made sure I was doing fine not only academically, but also personally. It was a complicated process to learn how Shared Decision-Making comes to play within Dutch healthcare and I often found myself diving in rabbit holes to try and figure it out. However, the effective coaching from Regina helped me to keep looking at the 'bigger picture'. I would like to make sure that her patience during my learning process and personal leadership style does not go unnoticed. Especially her patience is something that allowed me to not feel pressured or overwhelmed during stressful moments, which helped me stay focused and most importantly: **motivated** throughout the thesis experience. I look back on a very warm and positive experience at Zorgkeuzelab.

Writing this thesis inspired me to do more for Dutch Healthcare and I hope to be a positive contributor to it in the future.

Poya Maleki Seifar
Delft, April 2025.

# Table of contents

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# Introduction

This introduction provides the reader with both a preview and an overview of the content of the thesis. It starts off with describing the problem context and ends with an overview of the study. The context is within Dutch Healthcare. This section will help the reader gain a comprehensive understanding of the central issue, research objective and relevance of the study.

## Problem Context

> "*Care for all is no longer guaranteed*"
> – Dutch Healthcare Authority (2024)

In 2024 the Dutch Healthcare Authority (or the NZa) issued a daunting warning: "Care for all is no longer guaranteed". This statement is increasingly becoming a reality as the Dutch Healthcare System is facing challenges regarding its accessibility and availability. The pressure of an aging society causes an increase in demand for care, which the current healthcare workforce can no longer adequately meet (Nederlandse Zorgautoriteit, 2024). Currently there is a shortage in healthcare workers and this shortage is predicted to increase in 2033 of 231,700 people (AZW-programma, 2024). As of now already one in seven people in the Netherlands are working in healthcare, and in 2040 one in four people will need to do so (VGZ, n.d.). Many ways have been introduced to tackle this anticipated shortage. Short term solutions include increasing wages, tackling workload and increasing staff control over schedules (Wageman, 2024).

Another reason for the increasing pressure on hospitals are the rising costs of healthcare. According to the Dutch National Institute for Public Health and the Environment (RIVM) healthcare expenditure will increase annually around 3% until 2060 (RIVM, 2020). This increase in expenditure is mainly due to a higher prevalence of comorbidity and chronic diseases, which are the result of an aging population (Polder, 2008).

These developments raise concerns about the long-term sustainability of Dutch healthcare, with many influential parties already ringing the alarms (Wageman, 2024). In particular, the financial position of Dutch hospitals has increasingly become vulnerable under the current healthcare system (Scheres, 2024). In 2022, only two hospitals reported financial losses and a year later in 2023 this number was eight (BDO, 2024).

Operational costs for hospitals are rising due to inflation and wage increases of healthcare staff and the rigid financial system of Dutch healthcare limit hospitals to manage these financial pressures effectively. One striking example is the recent reporting of the Haga Hospital. They have suffered a loss of more than 35 million euros due to inflation and rising wages (Brandriet, 2024; Haga Ziekenhuis, 2024). The challenges presented in this section highlight the need for reforms to ensure financial and organizational sustainability of healthcare delivery. To address these long-term challenges the Dutch Government introduced the Integral Care Agreement (or IZA) in 2022 (Kroon, 2024).

## What is Shared Decision Making?

The IZA represents a collective agreement in which the healthcare system is redesigned for sustainability. Within this agreement, Shared Decision-Making (SDM) is identified as a key component of Value-Based Healthcare and that it should be implemented in all healthcare institutions by 2025 (Ministerie van Volksgezondheid, Welzijn en Sport, 2022).
SDM is an approach to patient-clinician interaction where both a patient and healthcare provider make decisions on the patient's treatment together. It allows for a choice between treatments based on evidence and on the personal preferences of a patient (Coronado-Vázquez et al., 2020; Elwyn, 2020). A key component of SDM is the provision of high quality information to patients in regard to their medical condition and possible treatment options (Elwyn et al. 2012).

Stiggelbout et al. (2015) distinguish four steps within the SDM process. The first step is a **choice talk** where the patient is activated. They are made aware that a choice needs to be made between possible treatment methods and their opinion in this matters. The second step is an **option talk** where the patient is informed about their medical options. This is followed by a **preference talk** where the patient weighs the options against what matters most to them. The last step entails a **decision talk**, where the medical perspective and patients' preference come together, and a decision is made on the most appropriate treatment option.

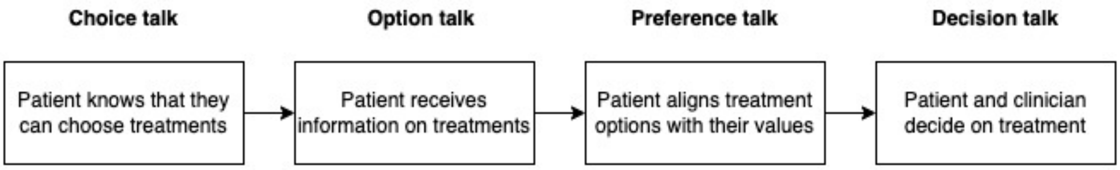


*Figure 1: Shared Decision-Making model as defined by Elwyn et al. (2012) and Stiggelbout et al. (2015)*

SDM has proven to improve patient knowledge on treatment options and informed patients tend to favor more conservative treatments (Stacey et al., 2017). However, studies have shown that SDM can offer several other benefits. These benefits include higher patient satisfaction, increase of treatment adherence and a decrease of decisional regret (Barry & Edgman-Levitan, 2012). Despite these advantages, applying SDM is not without challenges. SDM not only requires patients to be well informed, but it also demands a shift in the mindset from healthcare professionals. Ankolekar et al. (2021) found that one obstacle to SDM adoption was initial skepticism, and they concluded that one way to overcome this skepticism was through tools such as **decision aids**. Riedl et al. (2022) also argue for decision aids, claiming that they can facilitate the effective implementation and adoption of SDM as it faces significant challenges (De Graaf et al., 2023).

# What are Decision Aids?

SDM is seen as a challenging process for both patients and healthcare professionals (Coronado-Vázquez et al., 2020). Van Der Weijden et al. (2007) stated that the challenge in SDM lies in delivering reliable and evidence-based information in a way that is understandable for patients. As patients generally have lower levels of health literacy than healthcare professionals (Noordman et al., 2022). Other obstacles include time constraints to cover the options of complex of treatments, attitude of healthcare personnel and difficulties for patients to comprehend relevant information on possible treatment methods (Garvelink et al., 2024; Brackett & Kearing, 2014).

As a solution to the challenges in SDM, Decision Aids have been developed (Goldwag et al., 2019). An overview of the areas in which Decision Aids provide benefits is shown in figre 2. According to Stacey et al. (2017) decision aids support patients in the treatment decision process and they can be pamphlets, videos or websites. This is because decision aids contain standardized and evidence-based information on medical conditions and treatment options (O'Connor, 2003; van der Weijden, 2022). The treatment choices that patients make are therefore better informed and aligned with their personal values and preferences (Song et al., 2021).

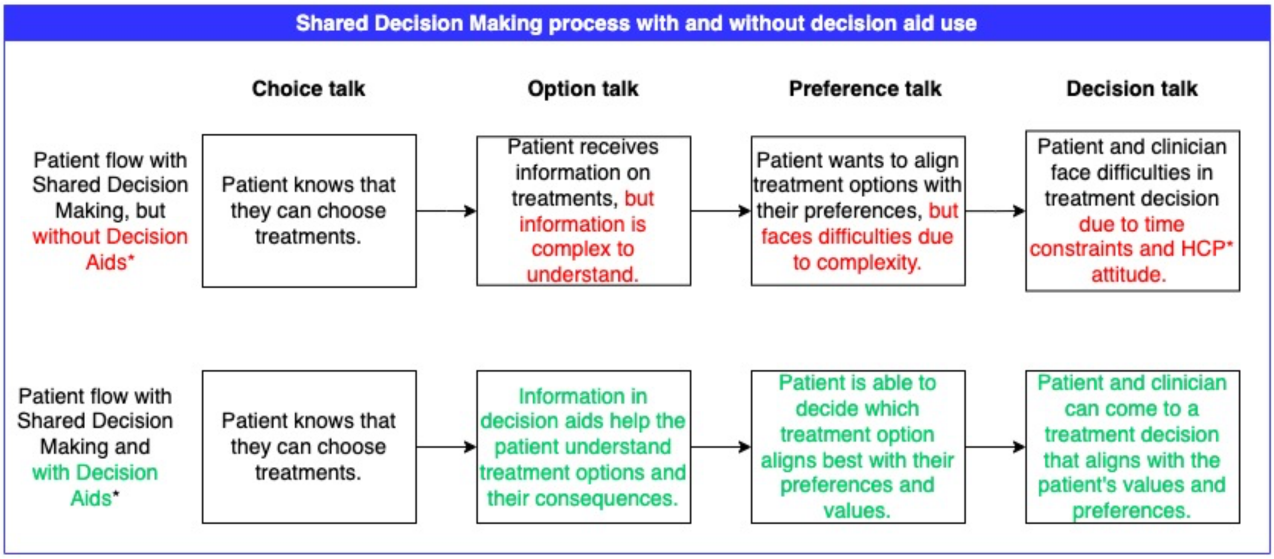


*Figure 2: Follow up on figure 1 where the SDM model was presented. This model shows the steps in which a patient faces difficulties in the SDM process (in red) and the positive effects decision aids have (in green).*

The use of Decision Aids has proven to be effective to stimulate SDM, if they are implemented as a routine part of the care path and consultations (Marques et al., 2021; Poprzeczny et al., 2020; Knops et al., 2013). However, it is the implementation has been lagging. Implementing decision aids on a structural basis within healthcare requires changes within hospitals. These changes pose significant operational and financial risks and are explored further in the next subsection.

## Difficulties in implementation: The transition period

During the transition towards Value-Based Healthcare, such as SDM, hospitals must deliver both the ‘old and new’ way of care until full transformation is realized. This phase is called the **transition period,** and it is when the patient distribution is slowly shifting towards new care pathways. The transition takes time, and positive effects are typically visible only years after the start of the transition (Zorginstituut Nederland, 2022).
One implication of an effective implementation of Decision Aids, is that a higher percentage of patients opt for conservative treatments rather than surgical treatments (Stacey et al., 2017). This shift can reduce hospital revenues, as there are fewer high-cost procedures performed through which hospitals are reimbursed. The Dutch Federation of Medical Specialists stated that healthcare institutions are responsible for realistic cost price calculations during the transition period (Federatie Medisch Specialisten, 2023). Cost prices are the costs of delivering care and they reflect the costs of staffing and infrastructure (Overheid.nl, 2023). The FMS explicitly state that when the income of certain treatments decreases, the operational costs of treating their respective diseases also needs to decrease.
Hospital reimbursements are largely determined by the Diagnosis Treatment Combination (DBC) infrastructure; a redistribution of patients can lead to changes in financial compensation. Moreover, these shifts influence annual negotiations with health insurers, as hospitals must justify the costs and benefits of implementing Decision Aids (Capgemini, 2022). Without a clear understanding of how Decision Aids affect patient flow and hospital revenue within the DBC system, hospitals risk financial uncertainty or reduced funding for specific procedures. Moreover, to the rigidness of the Dutch healthcare system, the implementation of transformative approaches such as decision aids, faces significant bureaucratic and structural barriers (Bijlsma, 2023). Integrating Decision Aids effectively requires hospitals to anticipate their financial shifts and incorporate them into their negotiations with health insurers to ensure sustainable funding and implementation.

A deeper exploration of this issue can be found in the case of the Bernhoven hospital. They wanted to go against the “fee-for-service”[1] mechanism of the financial healthcare system and implemented a new approach where the focus of healthcare delivery was on the quality of care (Van Leersum et al., 2019).
Bernhoven agreed to a multi-year budget plan with insurers to make sure that broad implementation of transformative approaches such as Shared Decision Making and Decision Aids, which decrease unnecessary procedures, do not lead to a decrease in income (Van Dulmen et al., 2020). However, the risk loomed in contract negotiations with insurers. Bernhoven is now in a financially challenging position which is ironically caused by successfully reducing unnecessary medical interventions (Wagenaar, 2024). Health insurers saw a decrease in in the number of surgical DBCs and after the multi-year agreement they renegotiated lower tariffs for future contracts. This renegotiation led to lower revenues for the hospital, exposing a critical weakness: many hospitals lack the financial resilience to absorb the transitional financial impact that follows such contract shifts.
The Bernhoven case highlights the need for predictive and data-driven strategies for hospitals to anticipate financial consequences and to ensure sustainable implementation of VBHC within the constraints of the DBC system.

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[1] It is important to note that the Dutch healthcare system is not an actual fee-for-service” system, even though it is sometimes perceived as one due to the volume-driven incentives it creates (Kroon, 2024). Healthcare providers receive a fixed payment per treatment pathway instead of a single medical activity (Westerdijk et al., 2011). This makes the DBC system more episode-based (Krabbe-Alkemade & Groot, 2017).

# Theoretical basis for the research problem

To ensure understanding of the research problem and relevant research questions, a strong theoretical foundation is necessary. The theoretical basis will cover the knowledge gaps in literature to provide the reader with a solid understanding of the role, application and impact of Shared Decision-Making and decision aids in healthcare.

Several studies that examined the effect of a Decision Aid on healthcare costs. The use of a Decision Aid has been reported to be more cost effective when compared to usual care (Stacey et al., 2017). Cost reductions in care are driven mostly by a reduction in unnecessary surgeries (Trenaman et al., 2014; Trenaman et al., 2020). However, Ankolekar et al. (2018) emphasize that there is a significant gap in literature on decision aid implementation. A reason for the limited research could be that the financial impact is highly context-dependent. Healthcare systems and reimbursement structures vary across countries and most studies focus on clinical outcomes and patient satisfaction rather than economic outcomes. To be able to evaluate the economic impact for Dutch Hospitals, an analysis of the Dutch healthcare reimbursement must be conducted.

Dutch healthcare operates under the DBC reimbursement system (Oostenbrink & Rutten, 2006). A DBC is defined as the total care activities a hospital and medical specialists provide for a patient's diagnosis and treatment within a specific care trajectory (Van Ineveld et al., 2006). Hospitals declare DBC codes to health insurers and receive financial compensation based on the assigned classifications, which bundle diagnosis and treatment costs into predefined tariffs (Gawałko et al., 2024). Health insurers determine reimbursement rates based on DBC classifications and negotiate these rates with hospitals annually (Oostenbrink & Rutten, 2006). During these negotiations contracts are drawn up that focus on costs and volume quotas (Van Leersum et al., 2019). This would mean that any shift in patient distribution due to Decision Aids could influence these negotiations and consequently a hospital's revenues and financial sustainability. A consequence of the DBC system is that there is an incentive for production[2], resulting in an incentive to perform more surgeries (Van Dulmen et al., 2021). A potential financial advantage for hospitals is that reimbursement within the DBC system is typically based on a bundled payment per DBC rather than the number of individual surgical interventions (Kikkert, 2023). This means that even if fewer procedures are performed within a given DBC, the hospital still receives the predetermined reimbursement, potentially mitigating revenue loss while still optimizing resource allocation. This also goes the other way around, meaning that multiple surgical interventions per patient will only cost more than what is reimbursed. Hospitals are navigating the financial consequences of the implementation of decision aids through pilot studies or other methods (Rijnstate, n.d.; Redactie – ICT&Health, 2024). Another potential method for hospitals is to have a more proactive stance through data-driven modeling.

[2] Within the Dutch healthcare setting the term 'production' is often used as a synonym for the amount of care that is delivered. However, this term has been under discussion as the Dutch Central Bureau for Statistics mentions that it is difficult to define the correct output for care due to the complexity of the sector (Van Hilten et al. (2005). 'Production' in this study refers to the definition of production within hospitals defined by Blank et al. (2016). They define production in hospitals as amount of care delivered.

If hospitals want to implement decision aids effectively, they must be able to anticipate their effect on their yearly revenue. They could do this by examining the effect decision aids have on DBC classifications, as shifts can alter the volume and type of procedures billed by specific DBC codes.
Zouo and Olamijuwon (2024) explored how predictive analytics could enhance resource allocation and reduce costs in healthcare financial planning. They found that by effective predictive analytics, healthcare organizations can have a better financial sustainability. Beyond predictive analytics, modeling approaches could also help hospital management understand how changes in one part of the system affects other parts (Demir et al., 2024). The healthcare system is interconnected, complex and dynamic as stated by Kielmann et al. (2022). It is therefore important to obtain a comprehensive understanding of the entire system and its dynamical and complex problems through systems science (Mahamoud et al., 2012).
A popular tool that uses mathematical modeling which could help understand and simulate a health system is System Dynamics Modeling (Homer & Hirsch, 2006; Milstein et al., 2010; Cassidy et al., 2019). The underlying structure of a system determines its overall behaviour (Mahamoud et al., 2012). System Dynamics modeling helps to understand how the use of decision aids impact patient distribution across different treatment options and eventually how these distributions affect hospital revenue (Sterman, 2000). The use of stock and flow diagrams as presented by Groesser and Schaffernicht (2012), provide a structured approach to capture how patient distribution across treatment methods affect DBC's. The system architecture is depicted in a simplified system architecture diagram in figure 3.
As it is common within System Dynamics to focus on one specific medical condition, this study will focus on the case of Proximal Femur Fractures (hip fractures) (Davahli et al., 2020). Ansah et al., 2023 also executed a Systems modelling approach within the context of hip fracture patients. This is because hip fractures are responsible for more than two-thirds of all clinic days for patients hospitalized with fractures (Federatie Medisch Specialisten, 2016). Another reason to focus on hip fractures was that they typically affect elderly patients, and elderly patients often involve complex clinical decisions (Greenwood et al., 2019). The decision on the treatment can be perceived as straightforward yet critical: either surgical or conservative (Federatie Medisch Specialisten, 2016).
By focusing on this medical condition, the study can model a context in which hospital resource use is high and the treatment choice is a binary choice between either conservative or surgical treatment.

By applying System Dynamics to analyze how decision aids impact a hospital's operational efficiency and financial sustainability, hospitals may be enabled to better inform their strategic planning (Vanderby & Carter, 2009; Cosenz & Noto, 2016; Kurnianingtyas et al., 2020). They could also strengthen the business case they present to insurers during negotiations on financial support for implementing decision aids, helping them bridge the challenges of the **transition period**.

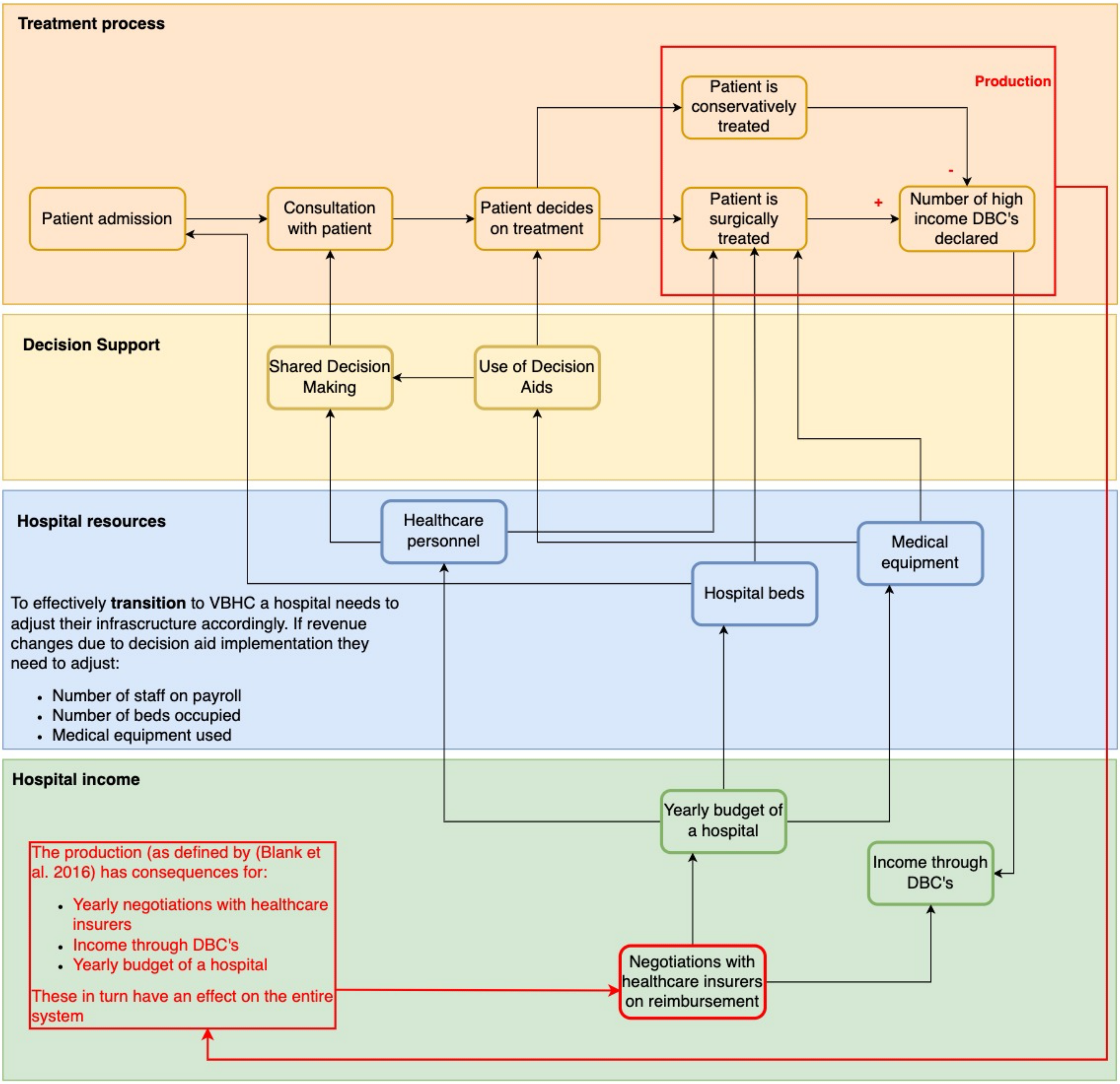


*Figure 3: System architecture of the effects Decision Aids and Shared Decision Making have on a hospital. This schematic overview shows how hospital income determines the use of hospital resources and these in turn determine the treatment of a patient. The treatment of a patient in turn has effects on the income of a hospital through DBC's. The changes in DBC's in turn influence the negotiations between a hospital and healthcare insurer (highlighted in red). These negotiations have impact on the entire system.*

## Research Objective

Under the Integral Care Agreement (IZA) hospitals are expected to implement approaches such as Shared Decision-Making. However, the successful implementation of Shared Decision-Making and decision aids require structural readiness to be able to go through the transition period. Hospitals must align their infrastructure and operational processes accordingly. Without such alignment SDM and decision aid implementation is far from – reality. To help hospitals successfully implement Value-Based Healthcare (VBHC), such as Shared Decision-Making and decision aids, this study will explore how decision aids impact patient flow and resource allocation through System Dynamics Modeling.

Therefore, the following research question was formulated:

**How do the costs of the implementation of a Decision Aid compare to its impact on a hospital's operational efficiency?**

To guide this process the following three sub-questions were formulated:

1. To what extent is it important for hospitals to gain insight into the outcome measures that reflect the impact of decision aids on their operational efficiency, and why are these insights valuable?
2. Which outcomes are likely always important, and which are specific to the context or type of decision aid?
3. What is the impact of decision aids on these outcomes?

## Link with CoSEM Programme

The aim of this thesis is to support hospitals in evaluating the impact of Decision Aids that facilitate Shared Decision Making within the healthcare sector. In this section the research goals of the study are aligned with the learning objectives of CoSEM.

**Clear design and/or engineering component:** The research uses a system dynamics model to assess the impact of a technological innovation.
**Technology component and technical issues are addressed:** The study assesses the financial feasibility of decision aids by studying the effects it has on its operational efficiency.
**Process management and system engineering:** The research uses System Dynamics modeling to simulate the effects of Decision Aids on a hospital's operational efficiency, incorporating different financial outcome measures as components in the model. It allows for strategic policy development.
**Complex design challenges:** The implementation of decision aids faces significant challenges. One of the challenges is the uncertainty of the effects of decision aids on the financial reimbursements of a hospital. This study aims to decrease the uncertainty around decision aid adoption for a hospital.
**Creativity in solutions:** The thesis uses an innovative approach by applying System Dynamics modeling to explore the financial implications of decision aids.
**Coverage of values from public and private domains:** The domain in which this study takes place is healthcare. Decision aids contribute to the quality of healthcare, they lead to higher patient knowledge on treatment options and higher patient satisfaction due to alignment of personal values and treatment.

## Thesis Scope

This thesis concludes the 2-year master program of Complex Systems Engineering & Management at The University of Technology in Delft. The study was conducted from December 2024 until April 2025. The research placed its focus on the hospital setting in the Netherlands. An important note is that the research is mainly applicable to general hospitals and less applicable for academic hospitals. This is due to the nature of the organizational structures in academic hospitals, which involve more complex governance, research-oriented priorities and mainly because of different funding mechanisms compared to general hospitals.

## Thesis Outline

This chapter gave an introduction into the research objective and the context in which this research takes place. This study has a mixed-methods approach which is outlined in chapter 2. The research methodology consists of a literature review, qualitative interviews and System Dynamics Modelling. The simulation results will be presented in chapter 4. In chapter 5 the results will be discussed and further recommendations for research are given. The conclusion of the study is discussed in chapter 6.

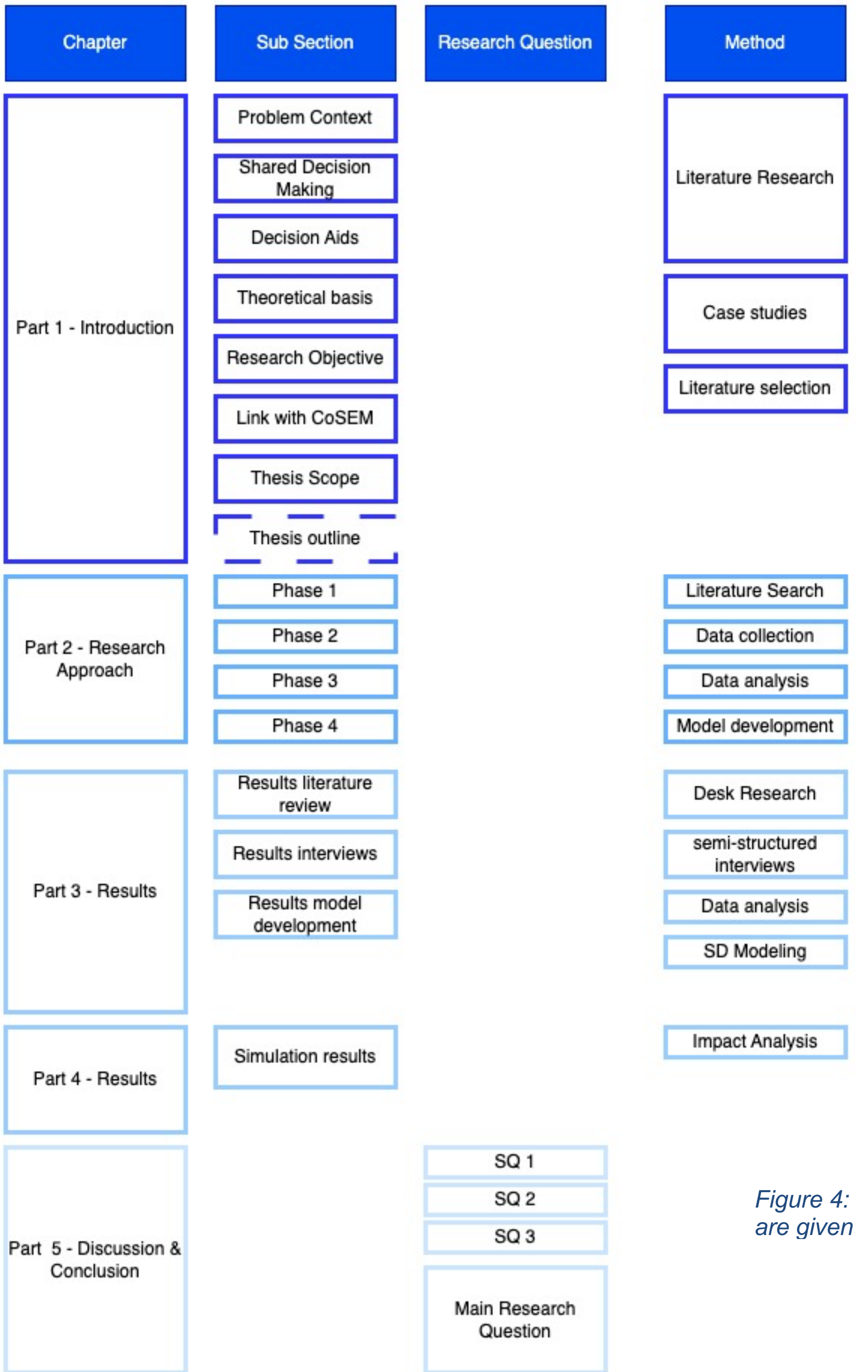


*Figure 4: Thesis outline per step. The research methods are given for every part of the research.*

# Research Approach

This chapter outlines the methodology of the research. The thesis adopts a mixed-methods approach that combines qualitative insights from stakeholders with quantitative System Dynamics modeling. The research structure is designed to build up from contextual understanding toward an integrated impact analysis through simulation outcomes.

The main research question is formulated as follows:

| |
|---|
| **How do the costs of the implementation of a Decision Aid compare to its impact on a hospital's operational efficiency?** |

The sub questions formulated to help answer the main research question are the following:

1. To what extent is it important for hospitals to gain insight into the outcome measures that reflect the impact of decision aids on their operational efficiency, and why are these insights valuable?
2. Which outcomes are likely always important, and which are specific to the context or type of decision aid?
3. What is the impact of decision aids on these outcomes?

First, it was essential to understand how healthcare stakeholders evaluate the impact of decision aids, including the criteria they use to assess the effectiveness and economic viability. Second, it was necessary to distinguish between universal and context-specific outcome measures, identifying which metrics consistently apply across different medical conditions and which are specific to medical conditions. Third, this study examined how decision aids influence both universal and context-specific outcomes and quantifies their impact on hospital operations and financial sustainability.

The study consists of four interconnected research phases. Each phase builds upon the previous one. To understand how important and valuable it is for stakeholders to know the impact of decision aid implementation, semi-structured interviews are conducted. However, before conducting the interviews, a conceptual framework is created. This framework is created in **phase 1** of the study. **Phase 2** of the study consists of quantitative and qualitative data collection. This entails conducting semi-structured interviews and data collection on hip fracture registrations from the NZa open portal. In **phase 3,** the conceptual framework will be used to analyze the collected data from phase 2. After phase 3, sub-questions 1 and 2 will be answered. The insights from phase 3 are then used to inform a system dynamics model developed in **phase 4**. This model aims to answer the third and last sub-question.

# Phase 1: Conceptual framework of decision aid implementation

This chapter defines the concepts that are crucial to this study. The aim is to create a conceptual framework which serves as a foundation for the next phases of the study. This framework is used as the foundation to structure the data collection during phase 2 of the study in phase 3. To develop the framework a structured literature review is necessary. The literature review is guided by the following research strategy.

**Research strategy**

Databases PubMed and the Journal of Clinical Pathways is used to find articles. PubMed is chosen due to the amount peer-reviewed health-related literature. The Journal of Clinical Pathways is chosen because of the focus of the journal on evaluating interventions that impact cost-efficiency and patient outcomes. The search focuses on finding articles that addressed decision aid adoption, their influence on treatment decisions and their operational impact on hospitals. To select a broad range of literature on decision aids and Shared Decision-making the first search term that is used in PubMed is **(Shared Decision Making) AND (Decision Aids).** The second and third search terms that are used to find literature on possible decision aid implementation obstacles and facilitators are "*(Decision Aids) AND (barriers and facilitators)*" and *"(Shared Decision Making) OR (Decision AIDS) AND (Attitude Healthcare Personnel)*"**.** It is important to find articles that assessed the attitudes towards decision aids and Shared Decision-Making to inform an interview guide for the semi-structured interviews. The fourth search term consists of keywords entered in the Journal of Clinical Pathways. These keywords are **Shared Decision-Making, Patient Decision Aids, Cost, Utilization**. They are used to find more specific literature on the financial and operational implications of Shared Decision-Making and decision aids. In figure 5 the flow diagram can be found which describes the selection process of the literature used to create the conceptual framework.

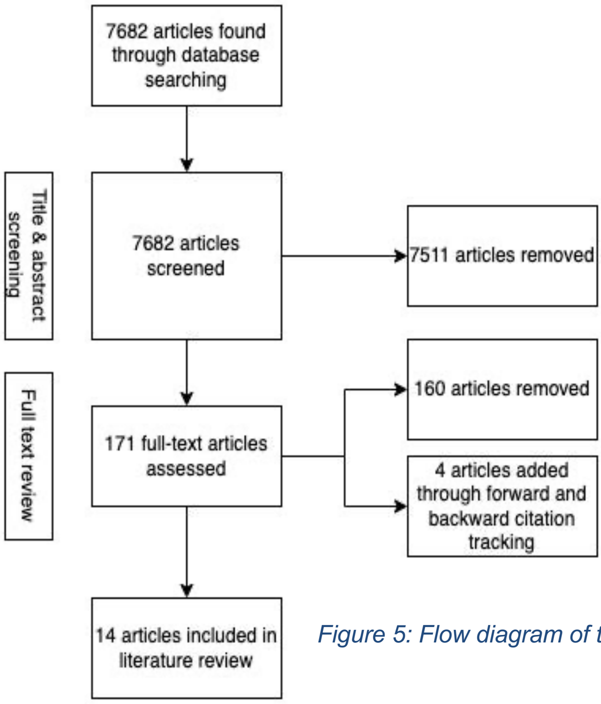


*Figure 5: Flow diagram of the article selection*

## Literature review

A Cochrane review by Stacey et al. (2017) assessed the impacts of decision aids within several areas. They found compelling evidence that decision aids improve patient knowledge and lower invasive treatments. They did emphasize that further research was necessary on the implication decision aids have on costs and resource use. This gap shaped the focus of the literature review, which in turn resulted in the conceptual framework. The objective of the literature review in the first phase of the study, was to understand the context of financial and resource aspects of hospital care and to provide a foundation for composing questions in the interview guide. This framework consists of the following three key components and is detailed in figure 6.

1. Adoption of decision aids

This component of the framework is needed to understand the mechanisms, barriers and facilitators that influence decision aid adoption. Adoption depends on a combination of clinical culture and organizational barriers.

2. Impact on Patient Distribution across treatment alternatives

This component addresses how decision aids influence the distribution of patients across pathways. By providing patients with structured and evidence-based information patients are more likely to choose conservative treatment (Stacey et al., 2017). This change in patient distribution often leads to a measurable reduction in surgical treatments. Understanding how this shift takes place is crucial to examining financial and resource effects of decision aids.

3. Financial and Resource utilization effects.

This component examines how changes in treatment distribution affect hospital operations and financial performance. Fewer surgeries could reduce demand for operating rooms or specialized staff. Fewer surgeries could also lead to revenue loss under the Dutch financial reimbursement system.

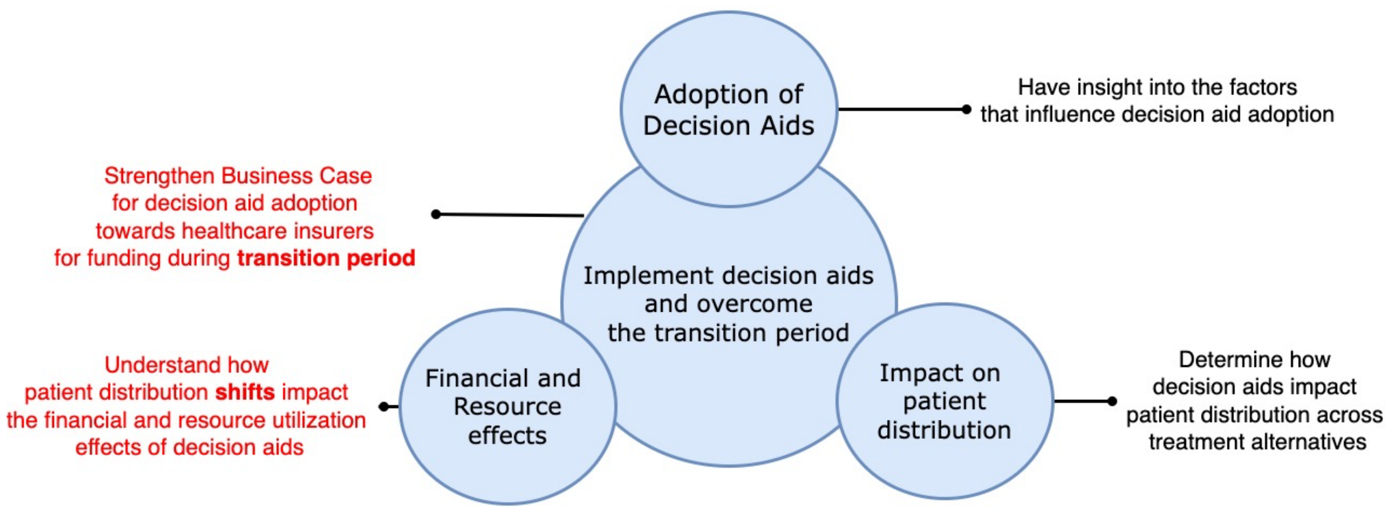


*Figure 6: Conceptual theoretical framework for hospitals on how to overcome the transition period towards Value-Based Healthcare.*

### Composition of the interview guide

An interview guide is designed to explore how healthcare stakeholders evaluate the impact of decision aids. A semi-structured interview approach is preferred as they allow for a balance between consistency and flexibility (Liu et al., 2023).
Its design is based on the earlier conducted literature review and through a targeted search on the attitudes of healthcare professionals towards shared decision making. This targeted search resulted into the study of Garvelink et al. (2024). These researchers developed a decision aid to integrate personal preferences into patient care pathways, to develop this decision aid they first collected perspectives and experiences of healthcare professionals on shared decision making.
The guide is further refined to capture hospital policies on decision aid implementation and to identify organizational factors that influence their adoption. These additions ensure that the interviews will not only explore personal attitudes but will also reveal systemic barriers such as the Dutch healthcare reimbursement system. The interview guide can be found in appendix C.

## Phase 2: Data collection

The second phase of this study focuses on gathering data to assess how decision aids impact a hospital's operational efficiency, and no sub-questions are answered yet. In this section the qualitative and quantitative data collection is described. First the qualitative data collection is outlined. This is followed by a detailed description of the quantitative data collection from the NZa Open Portal (*Opendisdata*, n.d.).

### Qualitative data collection

**Participant Selection**
For the semi-structured interviews various healthcare professionals are selected. The participants are selected based on expertise within healthcare decision-making, experience with Shared Decision Making and Decision Aids and representation from different disciplines. An overview of the selection criteria is presented in table 1.
Potential participants will be identified through LinkedIn, professional networks and websites of hospitals. The interviewees are approached through LinkedIn, e-mail addresses found on hospital websites and direct calls to hospital reception desks. The final sample of interviewees will include healthcare professionals from multiple domains, ensuring a broad yet relevant dataset for analysis.

*Table 1: Participant selection criteria. Criteria involved expertise, experience with SDM and Decision aids and how relevant they were to the study.*

| Participant | Expertise | Selection criteria | Relevance to study |
|---|---|---|---|
| Clinicians and nurses | Patient treatment and decision making within clinical context | Experience with SDM and Decision Aids. Involvement in operational efficiency | Practical knowledge on decision aid use, SDM and in general treatment of (hip fracture) patients |
| Advisors (IT, SDM, digital healthcare) | Hospital policy development, impact analysis of implementations such as SDM and decision aids | Experience with SDM and Decision Aids. Experience with product and procedure implementation | Theoretical and pracitcal knowledge on processes that are affected by decision aid implementation |

**Interview procedure**
Prior to all interviews the respondents are presented with an informed consent form. The form outlines the purpose of the study, data confidentiality measures and the right to withdraw at any time without consequences. The informed consent form can be found in Appendix A. Afterwards a general introduction of the research is provided. Each participant is asked for consent for an audio recording of the interview. In case a participant does not consent with being recorded, detailed notes are taken during the interview. To ensure accuracy and consistency across all interviews summaries were written immediately after the conversation. All collected data was anonymized to protect participants' confidentiality. The interviews had an average duration of 30 minutes, varying between 20 - 45 minutes.

**Performing Semi-structured interviews**
The semi-structured interviews were conducted in two stages. The first stage consisted of 9 semi-structured in-depth interviews that were conducted to explore how healthcare professionals perceive and evaluate the impact of decision aids. In the second stage an additional interview was conducted to validate model findings. The interviews were carried out through Microsoft teams or in person.
In the first stage 9 interviews were performed. The aim of the predefined topics of the interview guide were to ensure key area coverage across all interviews while the open questions enabled participants to elaborate on their perspectives. In table 2 the interviewees and their role are detailed. For anonymity purposes their names and workplaces were not provided.

*Table 2: Overview of the interviewees and their roles*

| ***Interviewee*** | ***Role*** |
|---|---|
| ***Stage 1: Contextual understanding*** | |
| *Interview 1* | *Digital Health Advisor* |
| *Interview 2* | *Neurologist* |
| *Interview 3* | *Parkinson Nurse* |
| *Interview 4* | *Quality and Safety advisor* |
| *Interview 5* | *Quality and Safety advisor* |
| *Interview 6* | *Quality and Safety advisor* |
| *Interview 7* | *DBC Advisor* |
| *Interview 8* | *PhD Researcher performing research decision aids within the domain of orthopedic surgery* |
| *Interview 9* | *Cardiologist* |
| ***Stage 2: Model validation*** | |
| *Interview 10* | *Orthopedic Surgeon* |

### Quantitative data collection

To support system dynamics modeling in later phases, data was collected from the Open Data Portal of the Dutch Healthcare Authority (NZa) (*Opendisdata*, n.d.). This data underwent preprocessing to ensure accuracy, consistency, and completeness.

Every specialism (e.g. surgery or orthopedics) treats patients within their own area of expertise. Patients with a certain diagnosis, for example a hip fracture (or Femur, Proximal and Femur (remaining), can only be treated by doctors from the surgery or orthopedics specialism. Based on their medical condition (which is represented by the diagnosis code) they receive a specific collection of care activities. The **total collection** of care activities a patient receives are in turn represented by DBC's (Federatie Medisch Specialisten, 2024).

The NZa has classified the diagnosis code for hip fractures as 218, 219, 3019 and 3020. The departments that perform surgeries on patients with hip fractures are general surgery and orthopedics. Respectively the department codes for these departments are 0303 and 0305. An overview of the filters applied can be found in table 3 below. DBCs were only taken in this study if the number of patients registered was around 50 and if the average reimbursement price was presented in the portal of the NZa.

*Table 3: Applied filters in the open data portal of the NZa and their description*

| **Specialism code** | **Description** | |
|---|---|---|
| 0303 | Surgery | |
| 0305 | Orthopedics | |
| **Diagnosis Code** | **Description** | **DBCs excluded** |
| 218, 3019 | Femur, Proximal (+ Collum) | 8 |
| 219, 3020 | Femur (Remaining) | 32 |

The NZa open portal shows the completeness of their datasets for every year (*Opendisdata*, n.d.). This research took place between December 2024 and March 2025, during this period the data from 2024 was still incomplete at the time of analysis and was therefore excluded. To ensure both reliability and relevance the next most recent and complete dataset was chosen. Therefore, only data from 2023 was selected from the portal.

## Phase 3: Data Analysis

In this phase the data collected through the interviews and from the NZa open portal were analyzed. This was done to inform the model development in the next phase.

**Interview analysis**

The interviews were summarized and imported to Atlas.ti to keep track of recurring themes. A hybrid approach was used. **Inductive coding** was applied to identify emerging themes without having predefined categories, based on a similar approach by Belay et al. (2024). These emerging themes were then structured using the predefined categories from the theoretical framework in figure 6. The theoretical framework had three themes which were the adoption of decision aids, impact of patient distribution across treatment alternatives, and financial and resource utilization effects. Inductive coding allowed for an extra theme to be defined, this theme was regarding the current challenges in healthcare and the need for Shared Decision-Making.

**Predefined themes** based on System Dynamics (SD) Terminology were also used to code the interviews. Adding of System Dynamics terms to the coding themes allowed for a structured method to ensure that findings could be integrated into the quantitative simulations for phase 4 of the research.

**NZa data preprocessing**

The portal has data on the total number of patients per department and diagnosis. The applied filters, which ensured data relevance, are detailed in table 2.

After the filters were applied the registered care products (DBCs) were retrieved from the portal. The registered care products were accompanied by the number of patients per DBC, average reimbursement price per DBC and the care activities registered under the DBCs.

These data points formed the basis for analyzing the financial and operational impact of decision aids on hospital workflows.

The NZa dataset was analyzed to identify the distribution of patients across care activities for the treatment of hip fractures in DBCs in 2023. This was done by tracking the total number of registrations of care activities within a DBC. In table 4 common care activities for the treatment of hip fractures are listed together with the care profile class (ZPK) they belong to. Care activity codes with N < 100 were not included in the study. In appendix D all the included care activities and DBCs from the NZa open portal are detailed.

*Table 4: Care activity codes seen in DBCs for patients with hip fractures across Care Profile Classes (ZPKs)*

| ZPK | Care activity codes |
|---|---|
| 1 | 190013, 190060 |
| 3 | 190218 |
| 5 | 038533, 038534, 038535, 038565, 038567, 038570 |
| 6 | 038528 |

## Phase 4: Scenario Development and Simulation

In the fourth and final phase of the study a System Dynamics model was created to be able to answer the research questions. In this section the development approach is detailed.

**Model development approach**

The SD model development followed five stages found in established literature (Sterman, 2000; Wang et al., 2021; Mona, 2024). First the problem was defined through stakeholder perspectives and literature research. Second, a conceptual model was constructed to map key variables. Third, the conceptual model was transformed to a simulation model. Fourth, the model underwent validation and testing to ensure consistency and behavioral realism. In the fifth stage scenario analyses were conducted to explore the impacts of decision aids on the patient distribution across DBC's. In the results section these development stages are elaborated on extensively.

**Experimental design**

The model version used was Vensim PLE version 10.2.2. The model was run over a time horizon of 365 days with a timestep of 1 day, and the integration method of Euler.

The System Dynamics model was constructed to represent a real-world care pathway of hip fracture patients in a hospital. It incorporated stocks for care activities accumulated and flows such as the inflow of patients. Capacity constraints, like the number of beds available, limited the inflow of patients and were built into the model to reflect how patient admission might be limited by resources. The model's parameters were determined by using data from Phase 2. Before running experiments, the model structure and assumptions were validated with an orthopedic surgeon to ensure the model reflects reality. According to Sterman (2000), qualitative validation through expert interviews is an essential step in System Dynamics modeling. In their research they have conducted interviews to understand issues and to collect valuable data. They did this by walking through the model with the experts and evaluating the model results.

The **baseline scenario** represents the status quo as of 2023. In this study, the baseline conservative treatment rate was 6.7%, based on analysis of national NZa registration data for hip fracture care activities in 2023. This figure represents the presence of care activity 038528. Although this value deviates slightly from the 5% found in the annual report of the DICA (2023) and the 7-10% range estimated during expert interview it was chosen for the following reason:

The 6.7% figure is empirically derived from a comprehensive national dataset. The filters applied (explained in research approach for phase 2) resulted in a reduced number of conservative cases counted. Using the exact proportions found in data analysis ensured internal consistency between phase 2 and 3 of the study. This approach also ensured that a robust and representative model could be created.

Once confidence in the baseline-model was established, it was used to simulate two primary what-if scenarios:

- Scenario 1: An increased decision aid effect where the conservative choice rate rises by 5% to 11.7%
- Scenario 2: An increased decision aid effect where conservative choice rises by 10% to 16.7%.

## Research flow diagram

In this subsection the Research Flow Diagram is presented. This research flow diagram outlines the steps described in this research approach section. As seen from the figure, all research phases follow from previous phases. In the most left column, the first phase is presented. The subsequent phases are listed in the next columns. The final phase, which is the synthesis and is presented in red, concludes the research.

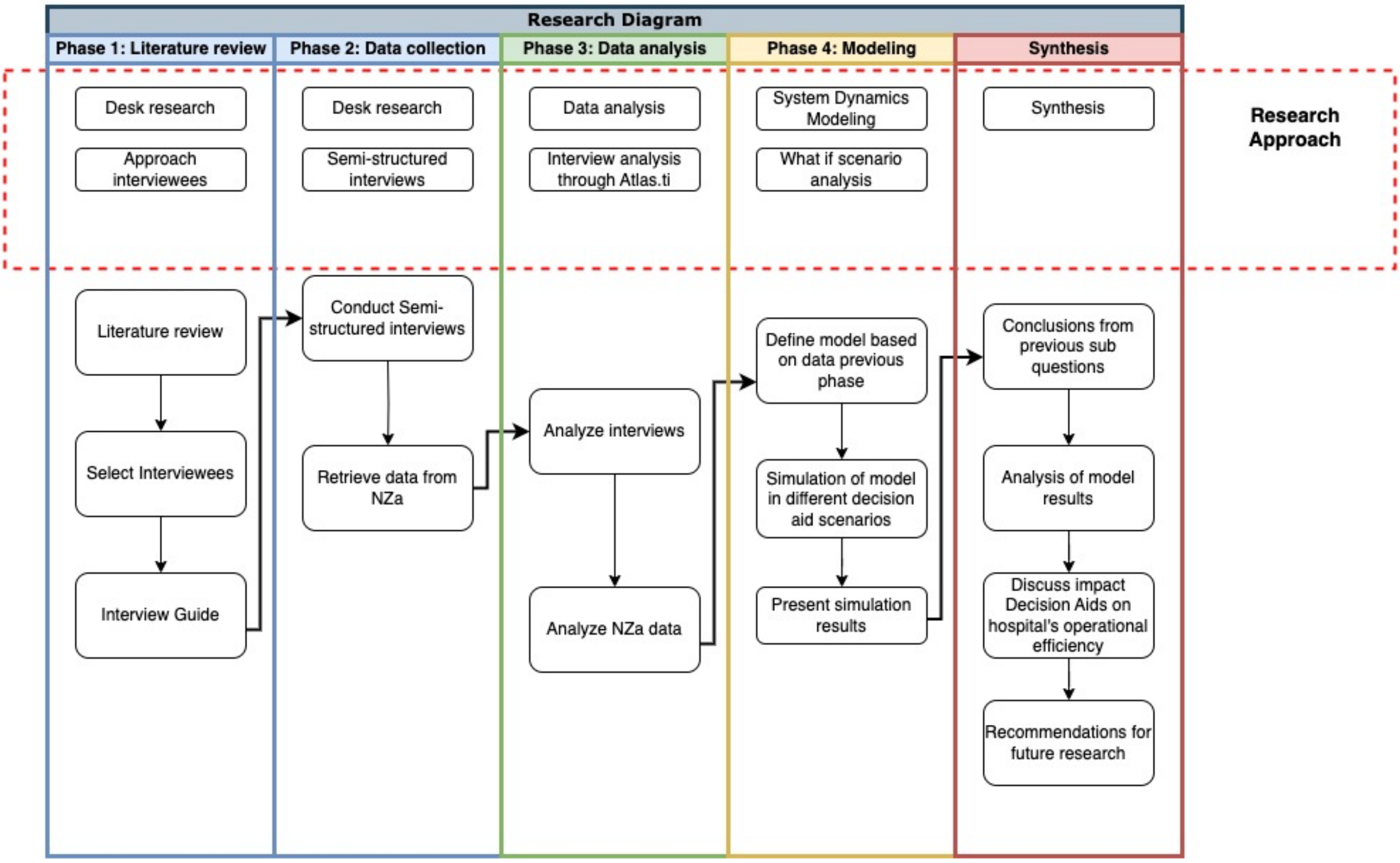


*Figure 7: Research Flow Diagram for the study. The phases are depicted as columns. The research approaches are noted in the red-lined rectangle and the boxes in the columns describe the steps in more detail.*

# Results

This chapter provides the findings of the first phase of the research. The first phase entailed exploration of Decision Aid and shared decision-making context through a determined theoretical framework. This framework is first addressed through the literature review and then through interview results. After the interview results the results of the quantitative data collection are given. These results form the basis for the final phase of the research, which was scenario development and simulation.

## Key Insights from Literature Review

The theoretical background framework rested addressed three components. These are Adoption of decision aids, impacts on patient distribution and financial and resource utilization effects.

**Adoption of Decision Aids**
The benefits of Decision aids are increasingly recognized by healthcare professionals, however broad adoption has not yet occurred (Joseph-Williams et al., 2020). Barriers to implementation are various. These range from attitudes of healthcare professionals in regard to decision aids to organizational barriers. For example, Bunzli et al. (2017) reported that some healthcare professionals already believe that their patient outcomes are already optimal. Garvelink et al. (2024) even found that some healthcare professionals believed that they already performed SDM and did not see an added value of an intervention such as a decision aid. A concept that has overlap with Shared Decision Making is the one of patient activation and empowerment (P-PAE). Chen et al. (2015) found that the U.S. faces obstacles in successfully implementing P-PAE due to insufficient payment incentives for healthcare providers. This obstacle has been discussed in the Bernhoven case study in the introduction section and is also applicable to the implementation of decision aids. The discrepancy lies between the financial incentives that reward procedural interventions and lack of reimbursement for patient-centered approaches such as SDM.
Van Der Weijden et al. (2022) build further on this and even make the call for a reimbursement system where SDM and other value-driven care is rewarded.

**Impact of Decision Aids on patient distribution**
Decision aids play a crucial role in guiding patients through treatment decisions. An effect that is extensively studied is the impact that decision aids have on patient distribution across surgical treatments. Multiple studies have found that patients who are exposed to decision aids are more likely to opt for conservative treatment options (Stacey et al., 2017; Raphael et al., 2021; Peters et al., 2022). Conservative treatment refers to procedures which aim to treat a patient with no surgical interventions (Saunders, 2006).
Lee & Emanuel (2013) reported that 20% of patients who use decision aids opt for more conservative treatments. Similarly, Arterburn et al. (2012) found that the use of decision aids for hip osteoarthritis resulted in 26% fewer hip replacements, resulting in up to 21% surgery cost savings over a span of 6 months. Stacey et al. (2015) reported a 7% decline in surgical interventions regarding hip or knee osteoarthritis patients using decision aids. Additionally,

Treneman et al. (2020) found that within two years, **73.9% of patients** who used Decision Aids had undergone surgery compared to **79.1% of patients** in the usual care group.
The reported impact of decision aids suggests that a reduction in unnecessary surgeries that not only a reduction in surgical interventions is possible, but also a decrease in healthcare costs is a viable impact of decision aid implementation.

**Financial and resource utilization effects**

Shared Decision Making and Decision Aids have mixed financial effects. Schmidt et al. (2022) analyzed 51 articles and found that 61% of these reported reductions in healthcare costs and utilization when SDM and DAs were applied. Schmidt et al. (2022) also found that the impact on costs could be limited by the type of reimbursement models within the healthcare setting. In the US the majority of health care payments are fee-for-service (HCPLAN, 2019). E. Hess et al. (2018) performed a study on the use of decision aids for patients with low-risk chest pains. They have found that the use of decision aids increased patient knowledge and decreased healthcare utilization. Schaffer et al. (2017) also found that Shared Decision-Making decreased diagnostic testing for low-risk chest pain patients. Highlighting once more that decision aids and shared decision making can have beneficial effects on healthcare costs and utilization. However, Kennedy et al. (2002) found that a decision aid alone has less effect in reducing costs than the combination of both a decision aid and an interview.
A final study that was found which supports this notion is the one of Van Peperstraten et al. (2010). They found that the use of a decision aid increased patient knowledge and also reduced healthcare costs. These findings illustrate that decision aids have the potential to reduce healthcare utilization and costs. However, their actual financial impact depends heavily on the context in which they are implemented. There is still a gap in understanding how these dynamics come to play in the financial reimbursement system of Dutch healthcare. Van Leeuwen et al. (2023) focused on internal budget allocation in hospitals. They found that there is a limited interaction with the reimbursement model (DBC-system) and the way a hospital organizes their internal processes and resources. Confirming the need for more studies where consequences of decision aid implementation are not clinically assessed, but financially.

## Key insights from stakeholder interviews

This subsection presents the findings from semi-structured interviews with key stakeholders, including clinicians, hospital administrators and policy advisors. A total of 10 healthcare professionals were interviewed. The results will be discussed per topic identified in the literature review. A summary of the findings can be found in table 5.

Before diving into the interview findings in relation to the theoretical framework, it is important to outline relevant challenges stakeholders face. This topic was found due to inductive coding, and this topic was essential to ensure that the interview results were grounded in the real-world context. Many stakeholders emphasized their situation

### Current challenges in healthcare and the need for Shared Decision Making

From interviews it became evident that healthcare professionals (HCPs) recognize both the potential and the challenges of implementing Decision Aids in clinical practice. Many acknowledged that Decision Aids could enhance patient engagement, improve shared decision-making, and optimize treatment pathways. They expressed their concerns on current trends within healthcare, one being the expected rise in patient inflow and healthcare demand due to population aging.

> "*I see 15-20 patients every day and we expect an exponential growth of patient inflow if we examine past trends within neurology. 11 years ago we had 600 Parkinson's patients and now we have 1400.*"
> - Interview 2: Parkinson Neurologist

Due to a rising patient inflow, one method to be able to manage this increase is by reducing the number of surgeries through appropriate care. This will allow for more patients to be seen while still managing the costs. That is why hospitals wanted to evaluate the impact of innovations such as decision aids, as they had a desire to provide more appropriate care.
On the hospital level, decision aid evaluation started with the idea that hospitals wanted to deliver more 'fitting' care. They wanted to eliminate unnecessary surgical interventions as much as possible.

> "*Shared Decision Making can contribute to current challenges in Dutch Healthcare. Especially when we look at the overtreatment of patients and its costs.*"
> Interview 3: Quality and Safety Advisor
>
> "*We started the pilot with the idea to reduce unnecessary surgical interventions as much as possible.*" - Interview 8.

## Adoption of Decision Aids

The adoption of decision aids varied between hospitals and specialties, with some institutions fully integrating decision aids while others had no structured implementation. Some specialties used decision aids in the shape of informative brochures or highly detailed explanations on websites. However, decision aids were deemed insufficient as a disease progressed and the patient had to switch to a more advanced treatment.

> "*Every parkinson patient is informed on their medical condition through our brochures, videos on our website and through consultations with our parkinson nurses. However, these interventions, with exception of consultation, fall short when their disease progresses and we have to switch to a more advanced treatment.*"
> - Interview 2: Parkinson Neurologist

Shared Decision Making and use of decision aids also varied significantly depending on complexity of the treatment. Many stakeholders pointed to the fact that adoption and evaluation of decision aids is highly dependent on the complexity of the medical condition and treatment. There is also a big difference in treatment volumes between hospitals for the same medical conditions as well, this occurrence is called "**practice variation**". The differences in treatment volumes can be substantial. The difference is caused by referral patterns from the **first line**, hospital specialization and available resources.

> "*A simple gallbladder surgery can be performed after just one consultation, whereas a complex medical condition (e.g. within oncology) often requires multiple consultations before a treatment can take place.*"
> - Interview 3: Quality and Safety Advisor
>
> "*Due to practice variation it is also important to keep into account how complex treatments are for general evaluation across different hospital settings. Some hospitals may handle a higher proportion of complex cases. A comprehensive evaluation should consider standardized benchmarks to ensure meaningful comparisons across hospitals.*"
> - Interview 8: PhD researcher

The focus of decision aid adoption varies for each stakeholder. Clinicians primarily prioritize the quality of care rather than the number of procedures they perform. While hospital management considers efficiency and capacity. Understanding these priorities is crucial when assessing decision aid adoption. Efficiency metrics are part of the key metrics that hospitals use to evaluate decision aids. These efficiency metrics include consultation frequencies, rate of unnecessary procedures avoided and patient flow. These reasons also provide a reason why decision aid adoption and Shared Decision Making are not yet broadly implemented. The efficiency metric was explained by a digital care advisor:

"*If decision aids enable a specific department to treat more patients within the same timeframe compared to a scenario without them, they can contribute to reducing waiting lists. This would make decision aid implementation valuable.*"

- Interview 1: Digital Care advisor.

## Impact on patient distribution in case mix

As different stakeholders were interviewed a distinct discrepancy emerged between how clinicians and hospital management evaluate decision aids. Hospital management looks at operational efficiency and financial sustainability while clinicians focus on the implications decision aids have for the quality of care.

Clinicians noted the variability in how decision aids impacted treatment choices across different patient groups and hospital settings. From literature it became evident that decision aids have the potential to shift patient treatment preferences to more conservative treatment options (Stacey et al., 2017). Interview findings revealed more nuanced insights. From interviews 2 and 4 it was found that treatment adherence is just as important for an effective impact of decision aids. Medication intake by Parkinson patients is often obstructed by patient health literacy and cognitive function of the patient. This issue is also caused by the time clinicians have for consultation relative to the amount of information they need to convey to the patient. This contributes to a higher number of hospital admissions than necessary, which can be avoidable through early intervention, lifestyle modifications or outpatient management. Decision aids may be able to mitigate this issue by providing patients with structured and accessible information on their medical condition and lifestyle implications (Stacey et al., 2017).

"*For the first half of 2023 we had 80 Parkinson's patients admitted in the hospital for fractures, infections and more. Many of these admissions could have been prevented if there was more focus on prevention.*"

- Interview 2 - Parkinson neurologist.

Hospital management measures the impact of decision aids on patient distribution through assessing the number and type of care activities registered within treatment pathways. By analyzing shifts in care activity distribution hospitals can identify whether decision aids lead to changes in the proportions of patients choosing for either conservative treatment options or for surgical interventions. To quantify this impact, hospitals track changes in the frequency of specific procedures. However, a key challenge identified from interviews is the lack of standardized data collection methods.

"*The number of patients is important, but also the time they spend in the hospital and which treatment they choose.*"

- Interviews 5 & 6

"*For inguinal hernias there are two treatment methods. Through physiotherapy or through surgical intervention. To evaluate the impact of decision aids you can look at the number of care activities a patient group receives over a certain period of time.*"

- Interview 1

"*I see more and more that doctors approach me and ask what the trends are in the number of DBCs their department has registered. They often ask this when they either changed a procedure or when they have implemented an intervention such as a decision aid.*"

- Interview 7

While decision aids have the potential to improve efficiency by reducing overtreatment, hospitals still face operational barriers. The current reimbursement system does not directly incentivize Shared Decision Making.

## Financial and resource utilization effects

Financial consideration plays an important role in decision aid evaluation. Some respondents highlighted the misalignment between Decision Aid-driven care adjustments and the current DBC reimbursement model (Interview 1, 4 and 5).

Hospitals operate within a fixed budget and must ensure that hospital operations are financially sustainable. Insurers and hospitals play in a dynamic field where both parties negotiate treatment costs, reimbursement structures and efficiency incentives. Insurers aim to reduce unnecessary healthcare expenditures while hospitals must secure sufficient funding to cover operational costs and maintain service levels. This dynamic creates tensions in decision aid adoption as hospitals might suffer in the short-term while insurers benefit from long-term cost savings.

As seen from the case study in Pillar 3 in the literature review, a reduction in care is not always a positive effect of SDM and Decision Aids. Less care delivery can lead to less income for the hospital. Interviews 1 and 7 shared interesting perspectives on this issue. Costs can be divided into two parts. Costs for the hospital and costs for a healthcare insurer. If a patient receives multiple care activities for the same care demand the activities will be grouped under one DBC. It does not matter if it is three care activities or six. The hospital will receive the same reimbursement. However, the costs for the hospital go down if due to the implementation of Decision aids the number of care activities per DBC goes down. This results in a higher cost per care activity for insurers, as the total DBC price remains unchanged, but fewer activities are performed per patient.

However, if less care is delivered and the same quality of care is achieved through a value-based care approach, insurers can use this evidence to renegotiate lower prices in future contracts. Ultimately resulting in revenue loss for a hospital in the long term.

Without aligned incentives hospitals may struggle in the implementation of decision aids if they lead to a reduction in high-revenue procedures without direct compensation. The implementation of decision aids costs money and the payback needs to be carefully argued with health insurers. This became clear from interview 1.

"*As a hospital we can argue that we treat less patients due to decision aid implementation and thus will have less operational costs. However, there are still high costs that need to be covered for the decision aids themselves.*"

- Interview 1

The saved costs can be used for re-education of nurses, licensing costs or for equipment to further specialize hospital departments. Hospitals need a clear financial argument to justify decision aid implementation, not only to insurers but also within their own healthcare system. Cost savings may emerge from reduced hospitalizations and unnecessary procedures, they must be weighed against upfront licensing fees, staff training and integration costs. Without structural financial support the financial effects of decision aids and shared decision making remain limited.

To address this issue, hospitals need clear evidence on the added value of decision aids to build a strong argument for their reimbursement and financial support by health insurers. Without measurable outcomes, insurers may perceive decision aids as an added cost rather than an investment. Insights into the effects allow hospitals to justify their implementation.

"*We get paid per DBC. Meaning that we save costs if we perform 1 consultation instead of 3 for a patient. The use of a decision aid could lead to cost savings for us.*"

"*If we can reduce patient inflow in one department with the use of decision aids, we could reskill our personnel for other departments. We could then advocate for the same funding from healthcare insurers.*"

- Interview 1: Digital Care advisor

## System Dynamics Terminology

As determined in the research approach section, System Dynamics modeling provides a structured way to analyze complex healthcare systems. The interviews were analyzed for underlying System Dynamics structures. This was done to identify key stocks, flows and feedback loops related to decision aid effects.

**Stocks**

A consistent finding from interviews was a focus on patient distribution across treatment options. Interviewees 1 and 7 indicated that when they must analyze implications of a new treatment method, procedure or product they analyze their impact on care activities.

The result was to identify care activities as treatment alternatives and to incorporate these in the model as **stocks** which are filled by patient flow. The DBC advisor highlighted that this shift in patient distribution is measurable through hospital data and NZa data on care activities.

**Flows**

This patient **flow** is in turn influenced by decision aids. This would mean that the **flow rate** is divided into patients choosing for a treatment method (**either conservative or invasive**). Another dependency of the patient flow are hospital resources. An interviewed cardiologist, orthopedic surgeon and neurologist all stated that the inflow of patients is regulated by planners. These planners assess available hospital resources such as bed capacity, available surgeons, nurses, available OR rooms and most important budgeting.

Additionally, the scheduling of procedures is influenced by urgency classifications. Elective care and non-elective care both must be able to take place at any time and emergency cases take priority over elective procedures.

**Relevance for model**

These insights were essential for translating qualitative stakeholder perspectives into dynamic components of the model. By identifying treatment options as stocks and current ratios identified through NZa data analysis as flows, the model could simulate how decision aids influence real-world treatment distributions.

## Summary of interview findings

*Table 5: Summary of interview findings*

| Domain | Key take away | Example quote | Recurrence across interviews |
|---|---|---|---|
| **Current challenges in healthcare and the need for Shared Decision Making** | Many clinicians experience a growing number of patients and rise in demand for healthcare | "We expect an exponential growth of patient inflow in 10 years" | 4 |
| | Shared Decision Making can help in reduction of unnecessary treatments | "As a society we have many benefits if we implement SDM broadly" | 9 |
| | One of the main challenges is giving sufficient information to patients | "Complex treatments require comprehensive patient understanding of treatment. I only have 10 minutes for a consult with a patient." | 6 |
| | The financing of Dutch healthcare poses challenges to quality improvement initiatives such as SDM. | "Shared Decision Making could be a solution to current healthcare challenges if the financing of healthcare facilitates it." | 7 |
| **Adoption of decision aids** | Adoption and shapes varies across hospitals | "We use pamphlets and a website to inform our patients" | 3 |
| | Complexity and practice variation of the treatment has implications for evaluation | "Evaluation of a decision aid during our pilot study was simple, it was either conservative or invasive" | 8 |
| | One of the biggest barriers to decision aid implementation is the absence of financial incentives | "Outcomes are not always in beneficial to hospitals in the short-term, insurers can argue that due to lower costs the reimbursements can also be lower" | 1 |
| **Impact on patient distribution** | Decision aids shift patient preferences towards conservative care | "During a pilot we found that the number of conservative treatments increases." | 7 |
| | Decision aids can influence hospitalizations in the long-term | "Many hospitalizations can be prevented with the use of decision aids. Patients could adjust lifestyles accordingly" | 2 |
| | Measuring the impact can be done through care activity tracking | "To analyze the impact on patient distribution shifts in care pathways we look at the number of care activities for a | 2 |

| | | | |
|---|---|---|---|
| | | specific diagnosis.” | |
| | Focus on decision aid adoption and its wanted effects are different for each type of stakeholder | “Decision aids should help in treatment adherency for my patients”<br><br>and<br><br>“We want to reduce unnecessary treatments with the use of decision aids” | 8 |
| **Financial and resource utilization effects** | Decision aids have the potential to reduce hospital costs | “Decision aids can reduce to cost savings in regards to unnecessary treatments” | 4 |
| | Cost reduction due to decision aids is not always beneficial to the hospital | “Outcomes are not always in beneficial to hospitals in the short-term, insurers can argue that due to lower costs” | 5 |
| | In negotiations with insurers on funding hospitals need to align the costs of decision aid implementation with insurer reimbursement. | “If we can reduce patient inflow in one department with the use of decision aids, we could reskill our personnel for other departments. We could then advocate for the same funding from healthcare insurers” | 1 |
| **SD terminology** | Stocks can be used to track changes in patient distribution across treatment alternatives | “To analyze the impact on patient distribution shifts in care pathways we look at the number of care activities for a specific diagnosis.” | 3 |
| | Inflow of patients is determined by several factors such as available beds and surgeon availability. | “Surgeries are only possible if there are enough OR rooms available and enough surgeons to operate.” | 2 |

## Data collection from the NZa open portal

To support the quantitative foundation of the System Dynamics simulation model, data was collected from the NZa open portal (Opendisdata, n.d.). The data collection rested on data points from hip fracture patients from all registrations in Dutch Healthcare over the year 2023. The aim of this data collection was to determine which care activities are commonly registered, how they are bundled into Care Products (DBCs) and under which Care Profile Classes (ZPKs) they are categorized. The filters that were applied in this portal can be found in the research approach section in table 2.

### Care activity distribution across Care Profile Classes (ZPKs)

Before diving into the data selection made from the open portal it was important to understand how care activities are categorized. Care activities are typically grouped under a Care Profile Class, or in Dutch, Zorgprofielklasse (ZPK). To interpret the ZPK classification, the guidelines from the Federation Medical Specialists (FMS) were consulted. The FMS publishes a guideline each year to clarify how medical treatments are documented within the Dutch healthcare system (Federatie Medisch Specialisten, 2024). A comprehensive list of all the ZPKs according to the guideline published by the FMS in 2024, can be found in the Appendices. The relevant ZPKs are listed in the table 6 below. The relevance was based on the presumed impact decision aids have on care activities delivered to hip fracture patients. Descriptions of the care activities that were selected from the NZa open portal can be found in table 24 in Appendix D. From the literature review in section 4, it became evident that the use of decision aids to support Shared Decision-Making, causes for patients to opt for more conservative treatments rather than surgical treatments. This effect would be visible in the number of care activities a hospital registers under ZPK groups 3, 5 and 6.
To break this down it is important to understand the coherency between the ZPK groups. ZPK 5 entails surgical procedures. A decrease in surgical care activities due to decision aids, would result in fewer care activities registered with a ZPK 5 classification. ZPK 3 entails clinic days for a patient. Meaning the days spent by a patient in a hospital after surgery. This number would also decrease for the orthopedic department[3] if less patients are registered with care activities from ZPK 5. The NZa has also provided a care activity code (038528) from ZPK 6 (Opendisdata, n.d.). This code represents conservative treatment of a hip fracture. If more patients choose for conservative treatment the number of registrations for this care activity increases.

*Table 6: Relevant ZPK groups for this study. The relevance is based on the impact decision aids could have on Hip Fracture patients*

| ZPK | Description | Care activity codes |
|---|---|---|
| 1 | Outpatient visit, first aid visit, and remote consultation | 190013, 190060 |
| 3 | Clinic | 190218 |
| 5 | Surgical procedures | 038533, 038534, 038535, 038565, 038567 |
| 6 | Other therapeutic procedures | 038528 |

[3] According to the orthopedic surgeon interviewed, some hip fracture patients who do not opt for surgery are transferred into palliative care. This typically occurs at another department either within the hospital or in an external hospice. They would be registered under ZPK 3, but for another department and for different DBCs than for hip fractures. This would remove the patients from the scope of this study and therefore they are excluded from the analysis in this study.

## Visualizing hip fracture care pathways based on NZa Data

To structure all the information found from the open portal, a simplified visualization of the hip fracture care pathway is given in figure 8. This figure maps the typical treatment trajectory from admittance to discharge. There are two branches, and each branch represents a treatment choice. For simplification purposes all surgical procedures are within the same branch which is defined as the surgical treatment. The branch on the right-hand side shows the conservative pathways of a patient.

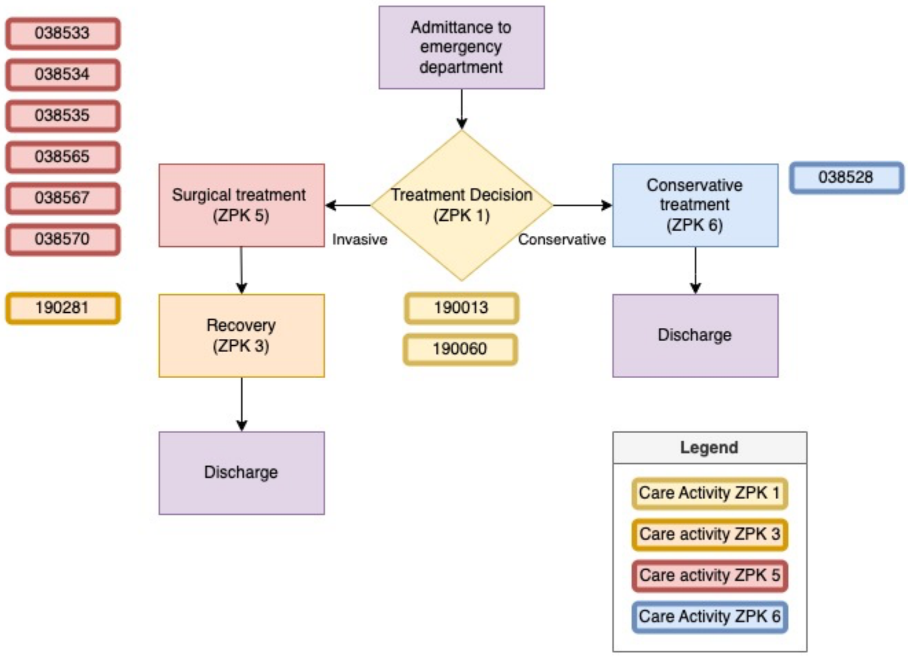


*Figure 8: Care pathway exposition of hip fracture patients and corresponding care activities and ZPKs per step. The care activities were found in the open portal of the NZa (Opendisdata, n.d.)*

The invasive (surgical) pathway on contains the care activities from ZPK 1, 3 and 5. While the conservative pathway on the right-hand side contains care activities from ZPK 1 and 6. The figure illustrates how treatment decisions affect the bundles of care activities a patient receives. Importantly, this diagram reflects the assumptions that were built into the model. One of these assumptions was that patients leave the hospital immediately after receiving conservative care. This structured visualization helped define the model's stocks (care activities and resources) and flows. In the next section the developed model, based on the insights of this figure is presented. It is important to note that decision aids are used for the decision phase which is during ZPK 1.

## How care activity distribution impacts reimbursement

The different types of care a patient receives are registered as care activities (Federatie Medisch Specialisten, 2024). The combinations of the different care activities result in a 9-numbered DBC code. This DBC code is then used to declare healthcare delivered to a patient (Van Oosten et al., 2020).

In table 7 an overview of the DBCs related to hip fractures are presented. The DBCs are represented by the 9-numbered code in the column on the left-hand side. The DBCs are sorted by their reimbursement. Each DBC is marked with an "X" in the corresponding ZPK column if it includes that type of care activity. It is very important to note that additional ZPKs may also be part of these selected DBCs. However, only the ZPKs that were included in table 5 and figure 6 were part of the scope of the study. Other ZPKs or care activities within these DBCs were not explicitly listed. The description of these DBC's can be found in Appendix G. The initial results show a clear correlation between the complexity of care and the average reimbursement. DBCs that include only ZPK 1 and 6 have the lowest reimbursement rates, ranging between €210 and €1065. DBCs involving ZPK 5 show significantly higher reimbursement values, some exceeding €10,000. Moreover, the average price for DBCs This analysis highlights the financial differences between surgical and non-surgical care paths.

These results form a basis for further data analysis.

*Table 7 Overview of DBCs and their compositions based on included ZPKs and their corresponding average reimbursement. An "X" indicates the presence of the respective ZPK within the DBC.*

| DBC | ZPK 1 | ZPK 3 | ZPK 5 | ZPK 6 | Average reimbursement (€) |
|---|---|---|---|---|---|
| *199299115* | X | | | X | 210 |
| *199299120* | X | | | | 295 |
| *199299114* | X | | | X | 600 |
| *199299119* | X | | | X | 610 |
| *199299113* | X | | | X | 880 |
| *199299118* | X | | | X | 1065 |
| *199299015* | X | X | | X | 2445 |
| *199299013* | X | X | | X | 2465 |
| *199299043* | X | | X | X | 4005 |
| *199299037* | X | | X | X | 4660 |
| *199299053* | X | | X | X | 5725 |
| *199299024* | X | X | | X | 6925 |
| *199299018* | X | X | | X | 7120 |
| *199299044* | X | X | X | X | 8760 |
| *199299088* | X | X | X | X | 10210 |
| *199299038* | X | X | X | X | 10270 |
| *199299009* | X | X | X | X | 10540 |
| *199299054* | X | X | X | X | 11915 |
| *199299026* | X | X | X | X | 12340 |

## Comparing costs of surgeries to their reimbursement

Figure 9 shows the difference between the average reimbursement of DBCs with surgical care activities and from DBCs without surgical care activities. The reimbursement of DBCs has a direct link to the costs to deliver care to patients. The difference between the DBCs with and without surgical care activities highlights the financial implications of treatment choices.

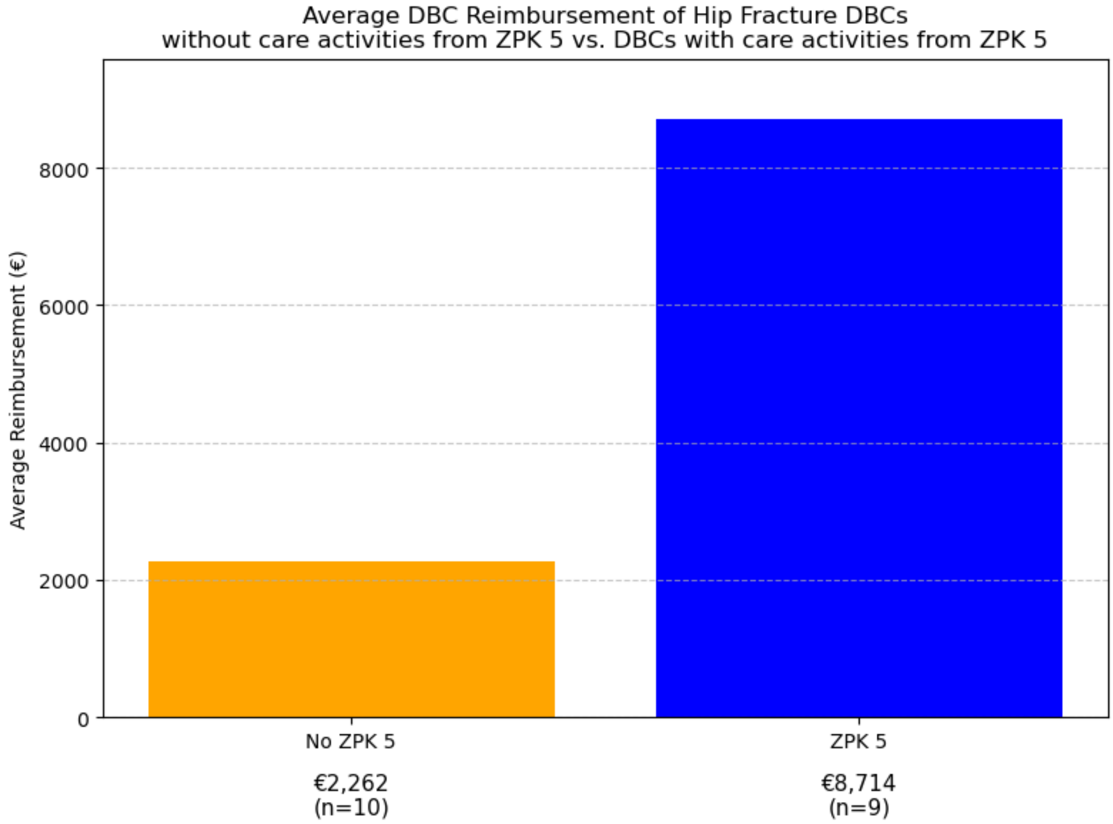


*Figure 9: The average price and prevalence of DBCs without surgical care activities (orange) and with surgical care activities (blue).*

According to the orthopedic surgeon interviewed in interview 10, surgeries are resource intensive. A surgery needs an operation room (OR), surgeons and specialists, nurses and the patient requires in hospital recovery. Zeelenberg et al. (2023) conducted a nationwide study in the Netherlands between 2000 and 2019 and found that mean healthcare costs for hip fracture patients was around €20,537 euros. Moreover, a healthcare insurance expert found that the costs of a hip fracture surgery ranges between €10,000-€20,000 (Koning, 2024).

The exact costs of individual care activities were difficult to obtain, a detailed exposition of this is given in the discussion section. A closer look at the combinations of care activities within DBCs may still offer very valuable insights, especially for the development of a System Dynamics Model.

## Final data selection for predictive analysis

A closer look at the contents of the DBCs resulted in a deeper understanding of how care activities are distributed across treatment pathways and how this distribution influences reimbursement levels. Table 7 provides a more complete overview of the relevant DBC codes related to hip fracture treatments than the initial table 6. In table 6 there were 19 DBCs included, in table 8 this number was reduced to 15 DBCs. The decrease in DBCs selected for further analysis was due to the presence of either surgical care activities in ZPK 5 or the presence of care activity code 038528 in ZPK 6. This allowed the analysis to focus on DBCs that represent the trade-off between surgical and non-surgical treatment pathways, as depicted in figure 8. The table shows exactly which care activities were found within each DBC, grouped by their ZPK category.

*Table 8: Overview of DBCs with corresponding care activity codes grouped by ZPK category and associated reimbursement.*

| DBC | ZPK 1 | ZPK 3 | ZPK 5 | ZPK 6 | Reimbursement (€) |
|---|---|---|---|---|---|
| 199299009 | 190013, 190060 | 192018 | 038533, 038534, 038535 | | 10540 |
| 199299013 | 190013, 190060 | 192018 | | 038528 | 2465 |
| 199299015 | 190013, 190060 | 192018 | | 038528 | 2445 |
| 199299018 | 190013, 190060 | 192018 | | 038528 | 7120 |
| 199299024 | 190013, 190060 | 192018 | | 038528 | 6925 |
| 199299026 | 190013, 190060 | 192018 | 038533, 038565 | 038528 | 12340 |
| 199299037 | 190013, 190060 | | 038533, 038534, 038535, 038565 | | 4660 |
| 199299038 | 190013, 190060 | 192018 | 038533, 038534, 038535, 038565 | 038528 | 10270 |
| 199299043 | 190013, 190060 | | 038533, 038534, 038535, 038565 | 038528 | 4005 |
| 199299044 | 190013, 190060 | 192018 | 038533, 038565 | 038528 | 8760 |
| 199299053 | 190013, 190060 | | 038534, 038535 | | 5725 |
| 199299054 | 190013, 190060 | 192018 | 038534, 038535 | | 11915 |
| 199299113 | 190013, 190060 | 192018 | | 038528 | 880 |
| 199299114 | 190013, 190060 | | | 038528 | 600 |
| 199299119 | 190013, 190060 | | | 038528 | 610 |

It is evident that DBCs that contain care activities from ZPK 5 are associated with higher reimbursement than DBCs that do not contain care activities from ZPK 5. Examples of this can be seen from table 8, the prices for DBCs 199299009, 199299026 and 199299054 (which contain surgical care activities) are higher than DBCs without any care activities from ZPK 5. This observation reinforces the idea that treatment choices have financial implications for a hospital. To understand the operational impact of treatment decisions, it is important to assess

how often care activities occur in practice. Table 9 builds on table 8 and shows the frequency at which different specific care activities occurred in DBCs in 2023.
In the selected data points, the number of registrations for care activity 038528 amounted to 1576 registrations. The contents of this table were used to inform the modeling process by clarifying how often specific care activities occur within each DBC. After preprocessing steps (described in the next section) this data served as critical input for the System Dynamics model which was developed. This allowed for a more accurate representation of patient distribution and resource consumption in the simulation model based on different projected effects of decision aids.

*Table 9: Distribution of care activities across DBCs, categorized by ZPK group and individual care activity codes. The values represent the frequency of the care activities for the corresponding DBC.*

| | ZPK 1 | | ZPK 3 | ZPK 5 | | | | | | ZPK 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| **DBC** | 190013 | 190060 | 192018 | 038533 | 038534 | 038535 | 038565 | 038567 | Remaining | 038528 |
| *199299044* | 4778 | 8979 | 58038 | 3224 | 920 | 5722 | 0 | 0 | 701 | 478 |
| *199299115* | 11343 | 2329 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *199299038* | 1586 | 5225 | 36517 | 135 | 0 | 0 | 5803 | 0 | 448 | 299 |
| *199299114* | 4242 | 1831 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 341 |
| *199299015* | 210 | 1284 | 3764 | 0 | 0 | 0 | 0 | 0 | 0 | 224 |
| *199299009* | 190 | 643 | 4172 | 12 | 0 | 0 | 727 | 0 | 28 | 0 |
| *199299043* | 84 | 297 | 0 | 133 | 132 | 190 | 1 | 0 | 34 | 11 |
| *199299024* | 73 | 280 | 3025 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| *199299037* | 11 | 129 | 0 | 2 | 0 | 0 | 189 | 0 | 2 | 0 |
| *199299026* | 963 | 1517 | 10127 | 4 | 4 | 0 | 5 | 1915 | 338 | 68 |
| *199299113* | 296 | 410 | 1387 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| *199299120* | 3464 | 559 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *199299054* | 1953 | 1961 | 17906 | 0 | 1935 | 635 | 0 | 0 | 251 | 0 |
| *199299119* | 2502 | 872 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 |
| *199299053* | 54 | 80 | 0 | 0 | 201 | 41 | 0 | 0 | 0 | 0 |
| *199299018* | 300 | 303 | 3811 | 0 | 0 | 0 | 0 | 0 | 0 | 24 |

Of all the DBCs collected from the open portal, 8 contained surgical care activities from ZPK 5. The total number of care activities (ZPK 5 (+ residual) and ZPK 6) add up to 23786. The sum of the conservative treatments was 1576.

The open portal of the NZa also provided the number of patients per DBC. However, this number could not be used reliably. Patients may receive multiple DBCs over the course of their treatment. This would inflate the number of patients beyond the actual number of individuals treated for hip fractures. That is why the analysis focused on the number of care activities rather than the reported number of patients per DBC.

## System Dynamics Model Development

This phase focused on the development of the System Dynamics model. The modeling approach was outlined in the research methodology section. 5 stages were followed in the model development phase. The first stage entailed redefining of the problem definition based on literature review results and interviews, this was followed by the second stage where a conceptual model was created. The third and fourth stages are presented per sub-model in this section. These stages were model development and validation. In the last stage a baseline scenario was simulated and compared to two scenarios where an increased effect of decision aids was simulated.

### Problem Definition

The in-depth interviews revealed a deeper layer of practical and organizational complexity. On an individual level stakeholders mentioned that they are under constant pressure due to the rising patient inflow, capacity shortages and financial disincentives. On a systemic level hospitals are under pressure to deliver more efficient care with limited budgets, and they need tools to quantify how decision aids affect operational metrics.

One important insight from both literature and stakeholder interviews was the prevalence of **evidence-based principles**. This was explicitly expressed in interviews 1 and 8. The digital care advisor from interview one had already conducted a pilot study on decision aid effects to create a business case for negotiations with healthcare insurers. The respondent in interview 8 was in the process conducting a large scientific study on the effects of decision aids on orthopedic care. The respondent's rationale for conducting the study was to find differences between the frequencies of surgical interventions before and after decision aid implementation for four medical conditions (Rijnstate, n.d.). These examples suggest that there has to be an evidence-based justification before new practices are widely adopted and accepted. While there are many studies that confirm the beneficial effects of decision aids, the implementation of both Shared Decision-Making and decision aids are lagging. This illustrates that there is more to it than just clinical factors which influence the implementation of decision aids, such as the uncertainty of their financial implications (Interview 1). A context-specific and predictive model would allow hospitals to estimate the effects of decision aids on their income through DBCs. This insight would help them overcome the transitional period to financially sustainable Value-Based Healthcare where concepts such as Shared Decision-Making is part of standard care.

## Conceptual model development

To structure the model a Causal Loop Diagram (CLD) was developed and depicted in figure 10 (Götz et al., 2024). This CLD mapped key system interactions such as balancing loops, reinforcing loops, key variables. **Balancing loops**, such as surgical capacity, are freed up due to more conservative treatments. However, a key consideration in modeling healthcare system dynamics is whether these balancing loops realistically occur. System Dynamics models assume that reducing the demand for one type of care (such as surgical interventions) allows for resources to be reallocated elsewhere. Real-world situations may prevent this from happening. According to gray literature from the Dutch medium "Medisch Contact", the Dutch healthcare system is not only facing staff shortages, but also a sustained high demand for care across sectors (Nieboer, 2021). **Reinforcing loops**, such as an increase in the use of decision aids could lead to cost savings. This could in turn incentivize further use of decision aids leading to more cost savings. The CLD illustrates the broader dynamics of decision aid implementation, the developed SD model focuses specifically on **hip fractures**. This choice allows for a detailed quantitative analysis of the impact of decision aids

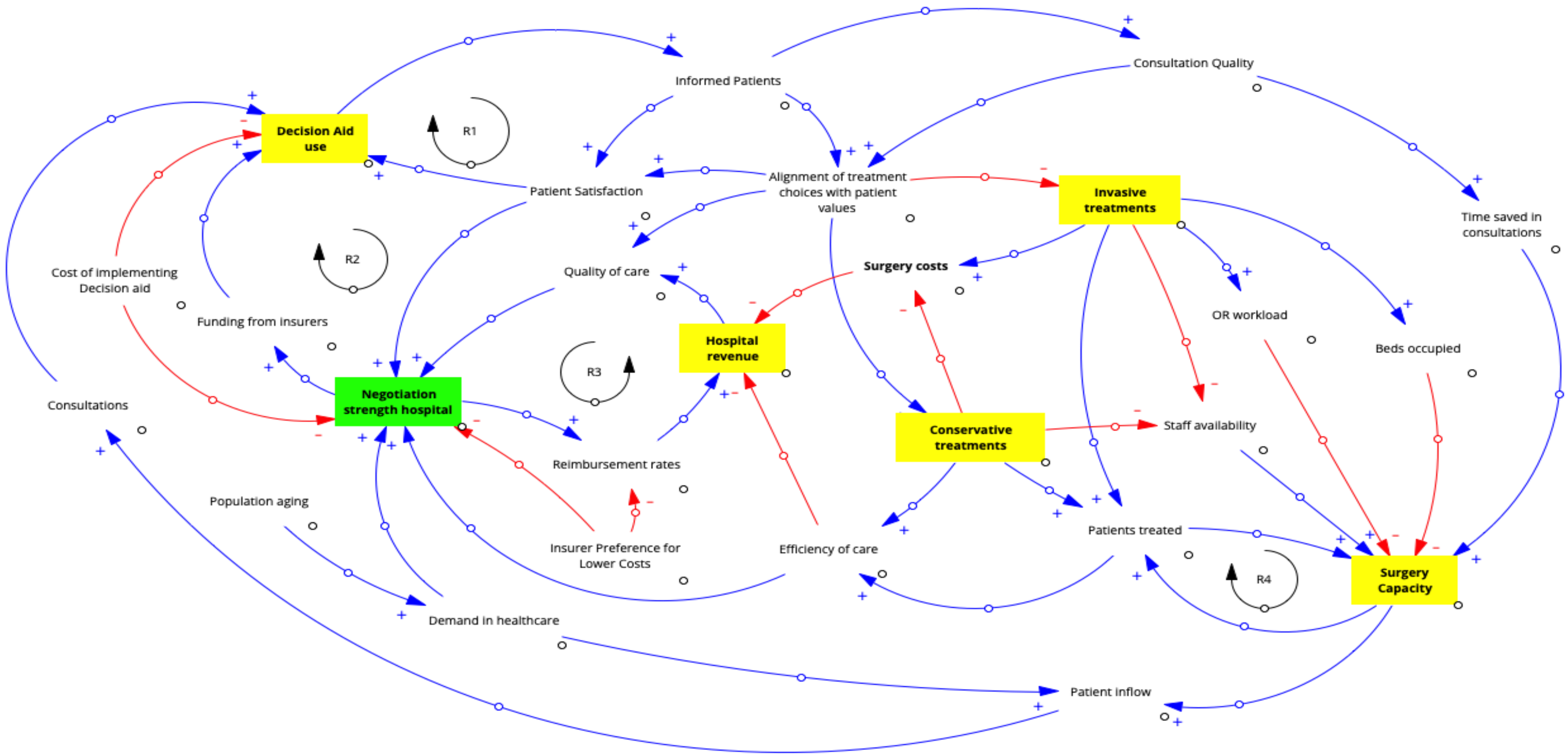


*Figure 10: General Causal Loop Diagram (CLD) of decision aid context.*

## Model development

This sub-section will provide an overview of the model and its submodels. The complete model is presented in figure 11. The model can be divided into three connected sub-models, each capturing a distinct component of the hip fracture care pathway. The first sub-model will dive deeper into how patient inflow is restricted by patients occupying beds.

The second sub-model shows how the treatment choice for surgery is reflected in care activities and how these result the number of DBCs. This part of the model is very important as it shows how the effect of decision aids, which is more people choosing for conservative treatment, results into different distributions of DBC registrations. This was a core research objective of the study.

The third sub-model is used as a constraint for patient inflow. This sub-model represents hospital resources and how different levels of these resources influence the number of DBCs. This sub-model tried to capture the reality that even though there is a rise in demand for healthcare, a hospital is limited by their operational capacity.

A unique feature of this model is the inclusion of care activities as stocks, allowing for a direct link to how hospitals register care. Detailed tables of the model components (stocks, variables and flows) are listed in Appendix E.

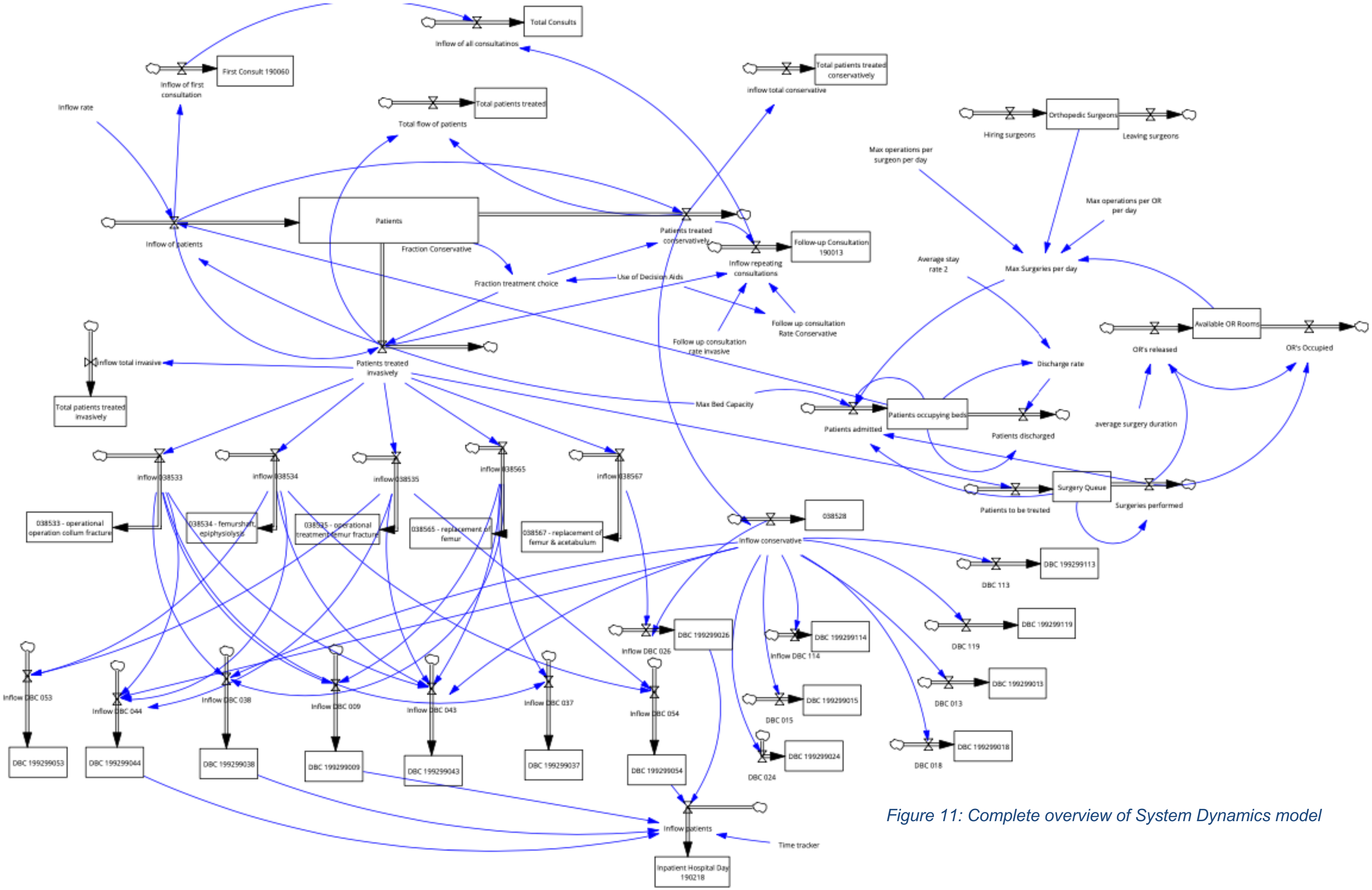


*Figure 11: Complete overview of System Dynamics model*

### Sub-model 1: Patient flow and treatment choice

This submodel simulates the general trajectory of patients from admission to treatment and discharge.

From the expert interview with an orthopedic surgeon, it was found that a patient with a hip fracture is always admitted to the emergency department. There they will be diagnosed and either prepared for surgery the same day or the next day. During initial diagnosis they are evaluated on several factors such as age, comorbidity, willingness to be operated on and more. The decision to operate is made either with the patient alone or with family present. This research focuses specifically on changes in operative choices and their impact on hospital operations. In cases where a patient is deemed unfit or chooses not to undergo surgery they are transitioned into palliative care. Since palliative patients are no longer part of the acute surgical workflow and do not contribute to surgical care activities they were excluded from the model.

The "**inflow of patients"** entails patients entering the hospital. To determine the input value for this variable the year report by the DICA was used together with input from the interview with the orthopedic surgeon. According to the DICA (2023) there were 18918 patients with hip fractures in the Netherlands in 2023. From the interview it was found that the hospital of the surgeon averaged 550 hip fracture treatments over 2024. It is crucial to note that the orthopedic department and hospital of the surgeon are a highly specialized center for orthopedics. This means that they treat a significantly higher volume of patients compared to the average orthopedic department in a general hospital. To adjust for this number the total number of hip fracture patients (according to the DICA) were divided by the number of hospitals in the Netherlands. According to the Dutch Ministry of Health there were 69 hospitals in the Netherlands in 2023 (Volksgezondheid en Zorg, 2023). This would result in around 274 patients with hip fractures per year per hospital. However, given that not all hospitals treat patients with hip fractures and some hospitals are specialized centers it was important to calibrate the model based on a more typical hospital setting. While this simplification could underestimate inflow in larger centers and overestimate in smaller hospitals, it provides a representative basis for national-level policy modeling.

**One feedback loop** in this model was that the inflow of patients is determined by the "**inflow rate"** and is limited by "**Max Bed Capacity"** and "**Patients Occupying Beds"**. The inflow rate is the average number of patients entering the hospital per month, which was a twelfth of 274 patients per year.

After admittance the patient flow is governed by the variable "**Fraction treatment choice**". This variable is in turn influenced by "**Use of Decision aids**" and "**Fraction Conservative**". The use of decision aids is incorporated as a decision lever, this variable is further detailed in the scenario section. The calculation to find the percentage of conservative treatments in 2023 was based on the data from table 8 in the previous section. The sum of the care activities (from ZPK 5 and 6) was divided by the sum of conservative treatments.

$$Ratio\ conservative\ treatments = \frac{Care\ activities\ ZPK\ 6}{Care\ activities\ ZPK\ 5 + Care\ activities\ ZPK\ 6} = \frac{1576}{25344} = 0.062 \qquad (1)$$

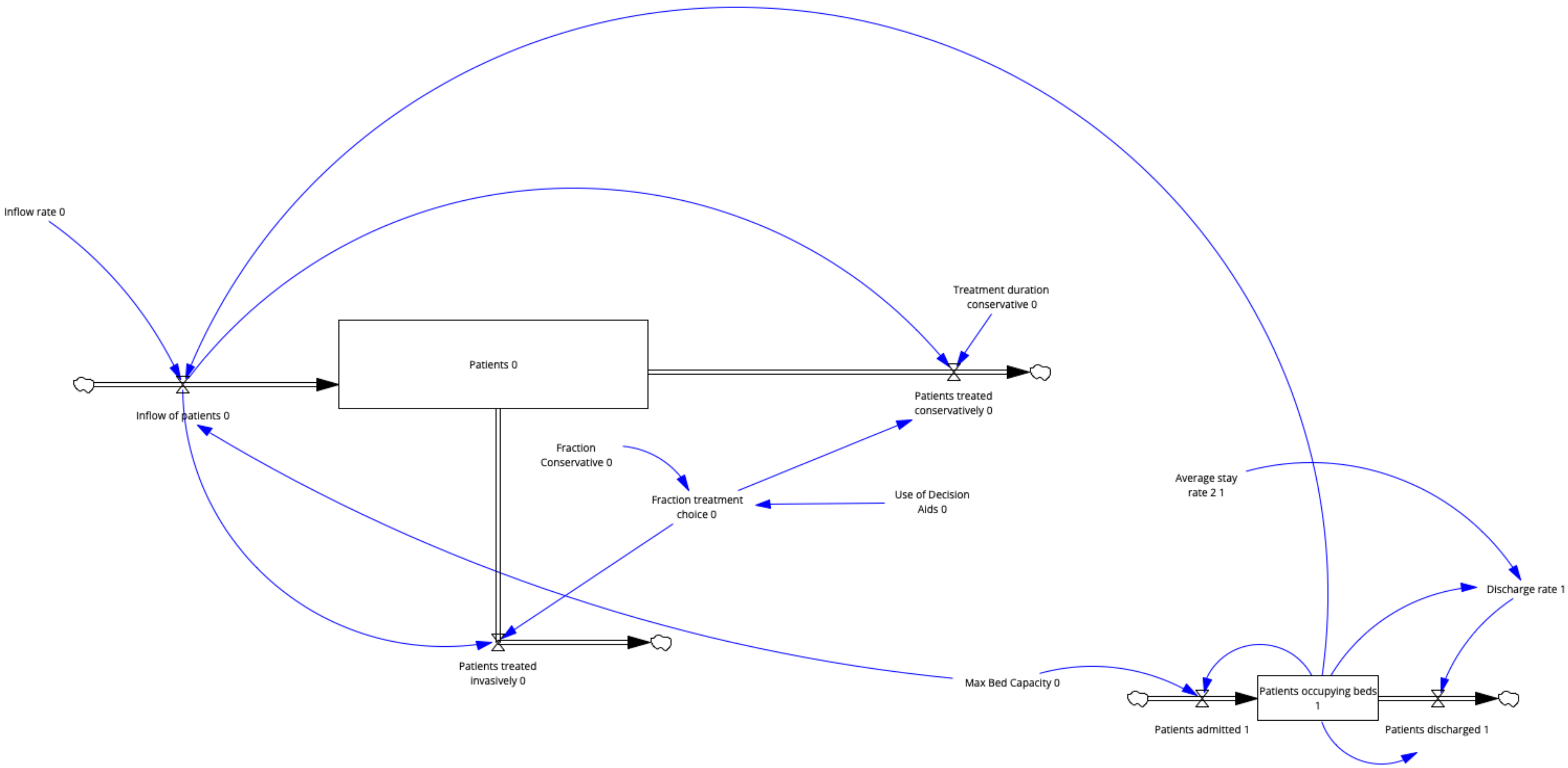


*Figure 12: Sub-model 1: describing patient flow through hospital*

### Sub-model 2: Care activity and DBC integration

This sub-model entails the integration of the care activities determined in the data analysis section. This was done to translate the effects decision aids have on clinical care activities on the DBCs. This sub-model shows performed care activities, both surgical and conservative, and how these flow into specific DBCs used by hospitals to register and declare care to insurers.

**Defining patient distribution across care activities and DBCs**

Every patient has a consultation with a clinician to decide on their treatment. This is represented in the model with care activity 190060. The model begins with the inflow of hip fracture patients into the hospital, and this branches immediately into the stock which contains the number registrations for care activity 190060, which is the first consultation.

Patients who are treated invasively are branched into 5 different care activities. These were 038533, 038534, 038535, 038565 and 038567. The descriptions of these and all other modelled care activities can be found in Appendix D.

These care activities (including code 038528 for conservative treatment) are detailed in table 10 together with the total number of registrations across all hospitals in the Netherlands in 2023. The last column represents the current distribution of patients receiving that specific care activity.

The proportions of patients undergoing each treatment were derived from the frequency of care activities presented in the previous section. The advantage of using this approach was that it was not necessary to differentiate between specific types of hip fractures or incorporate classification into the model. It was sufficient to model patient distribution solely on observed ratios of care activities. The patient flow that leads into invasive treatment is distributed through the proportions in the third column.

*Table 10: Total registrations and proportions of patients receiving care activities.*

| Modeled Care activities | Total registrations | Modeled proportions of care activities |
|---|---|---|
| 038533 | 3510 | 0.149 |
| 038534 | 3192 | 0.136 |
| 038535 | 6588 | 0.280 |
| 038565 | 6725 | 0.286 |
| 038567 | 1915 | 0.081 |
| 038528 | 1575 | 0.067 |

The initial calculation in Equation 1 of the ratio of conservative treatments resulted in 0.062. This was based on the full data set, including residual care activities from ZPK 5. These remaining care activities were not modeled due to their unclear attribution and marginal relevance to hip fracture care pathways. One example of such a care activity was care activity 038540, which was the "*Neurolytic blockade of one or more peripheral nerves*" (Opendisdata, n.d.). Since such care activities were not included in the model, the recalculation of the proportions based on the modeled care activities led to an adjusted ratio for conservative treatments of 0.067.

The same principle was applied to the DBC mapping. The frequency of care activities was used to estimate the distributions across the corresponding DBCs.

*Table 11: Proportional distribution of selected care activities from ZPK 5 across DBCs.*

| | Surgical | | | | | Conservative |
|---|---|---|---|---|---|---|
| DBC | 038533 | 0385334 | 038535 | 038565 | 038567 | 038528 |
| *199299044* | 0.920 | 0.289 | 0.870 | 0.000 | 0.000 | 0.303 |
| *199299038* | 0.038 | 0.000 | 0.000 | 0.860 | 0.000 | 0.190 |
| *199299009* | 0.003 | 0.000 | 0.000 | 0.110 | 0.000 | 0.000 |
| *199299043* | 0.038 | 0,041 | 0.029 | 0.001 | 0.000 | 0.007 |
| *199299037* | 0,001 | 0.000 | 0.000 | 0.028 | 0.000 | 0.000 |
| *199299026* | 0.001 | 0.001 | 0.000 | 0.001 | 1.000 | 0.043 |
| *199299054* | 0.000 | 0.610 | 0.096 | 0.000 | 0.000 | 0.000 |
| *199299053* | 0.000 | 0.063 | 0.006 | 0.000 | 0.000 | 0.000 |
| *199299114* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.216 |
| *199299113* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.016 |
| *199299024* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.029 |
| *199299015* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.142 |
| *199299018* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.015 |
| *199299013* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.016 |
| *199299119* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.023 |

Table 11 shows the proportions as to which the care activities flow from the care activities to the DBCs, which is based on the treatment path. In other words, these values represent how each care activity is distributed among the DBCs from the corresponding treatment (e.g. surgical or conservative). Based on the information given in this subsection a Sankey diagram is presented in figure 13 below. This diagram shows how care activity registrations flow into the DBCs in the model.

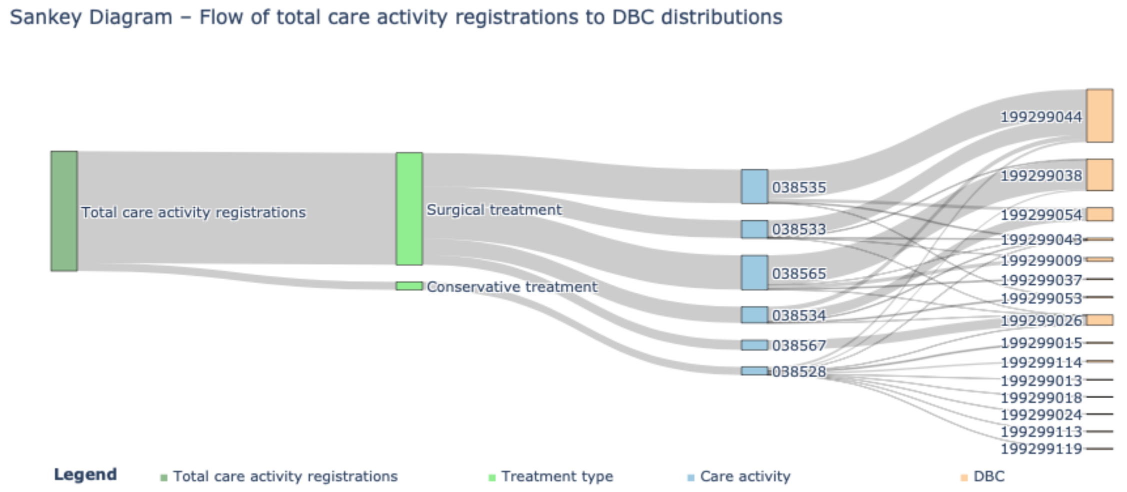


*Figure 13: Sankey diagram on total registrations through the System Dynamics Model. This Sankey Diagram visualizes how total registrations (rather than the individual patients) flow through the modeled hospital system. The model itself does start with patient inflow, but due to conversions presented in section 4.4.4, the results are given in number of registrations.*

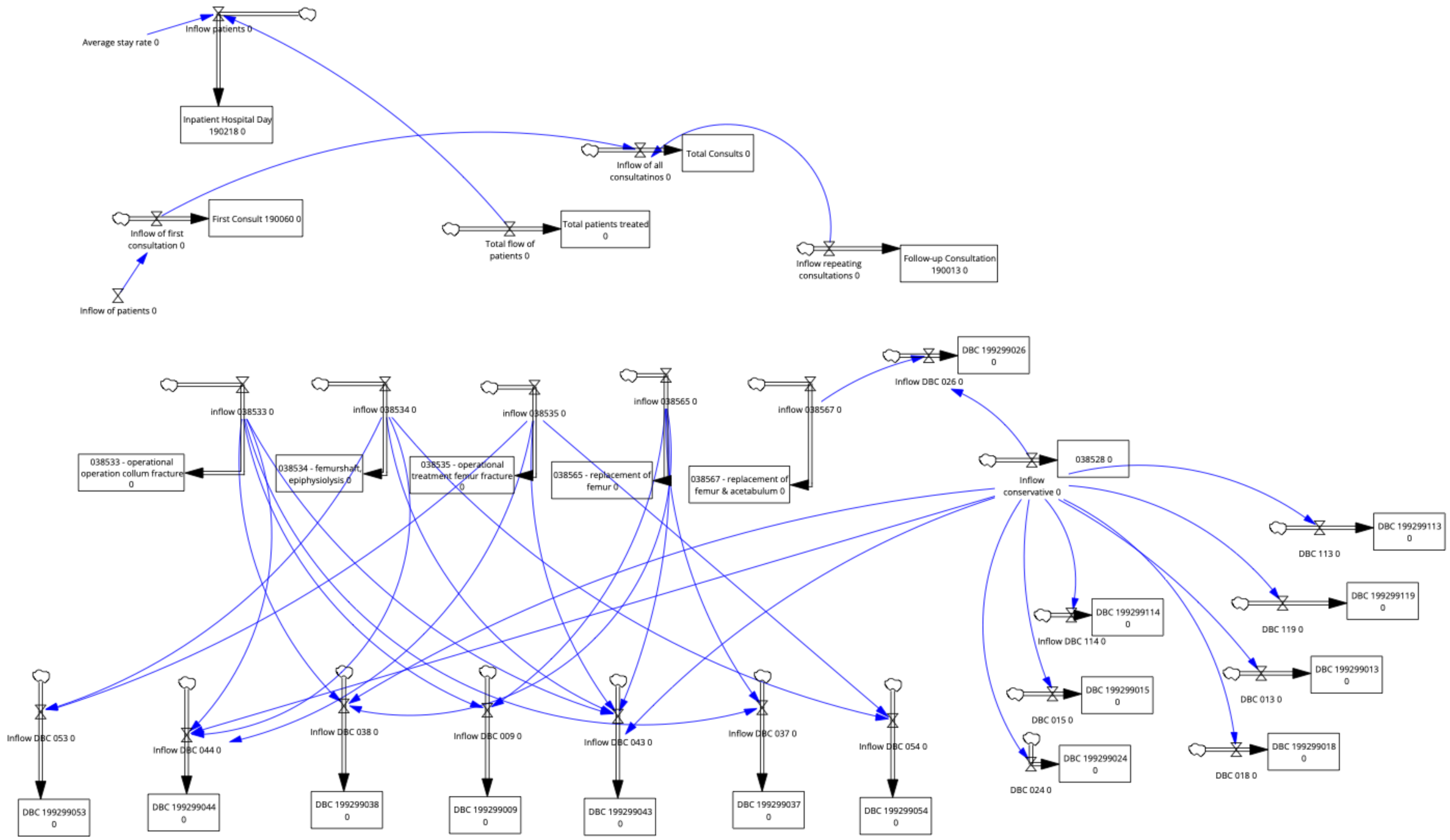


*Figure 14: Sub-model two, describing dynamics between treatment choices to care activities to DBC composition*

## Sub-model 3: Resource representation

To accurately reflect real-world hospital limitations this part of the model was dedicated to capturing key constraints. These were determined to be bed occupancy, surgical queuing, operating room availability and workforce limitations. Figure 15 illustrates the component which shows how different constraints limited the number of patients occupying beds which in turn limited patient inflow. This part of the model is crucial for simulating the process around the feedback loop on patient inflow.

The center of this sub-model is the stock of patients occupying beds, which reflects the inpatient capacity. The expert interview provided the insight that even though they are a specialized center, they still have to share beds and OR rooms with other departments. The expert estimated that their bed capacity for orthopedic patients is around 10 at any given time and they share about 10 operating rooms with other departments. Patients are admitted after being assigned to invasive treatment and remain in beds until they are discharged. The discharge is based on the average stay rate extracted from the DICA annual report. The combination of surgeons and OR rooms available determines the maximum amount of surgeries that can be performed per day. Staffing levels are dynamically modelled and based on the expert interview and literature research.

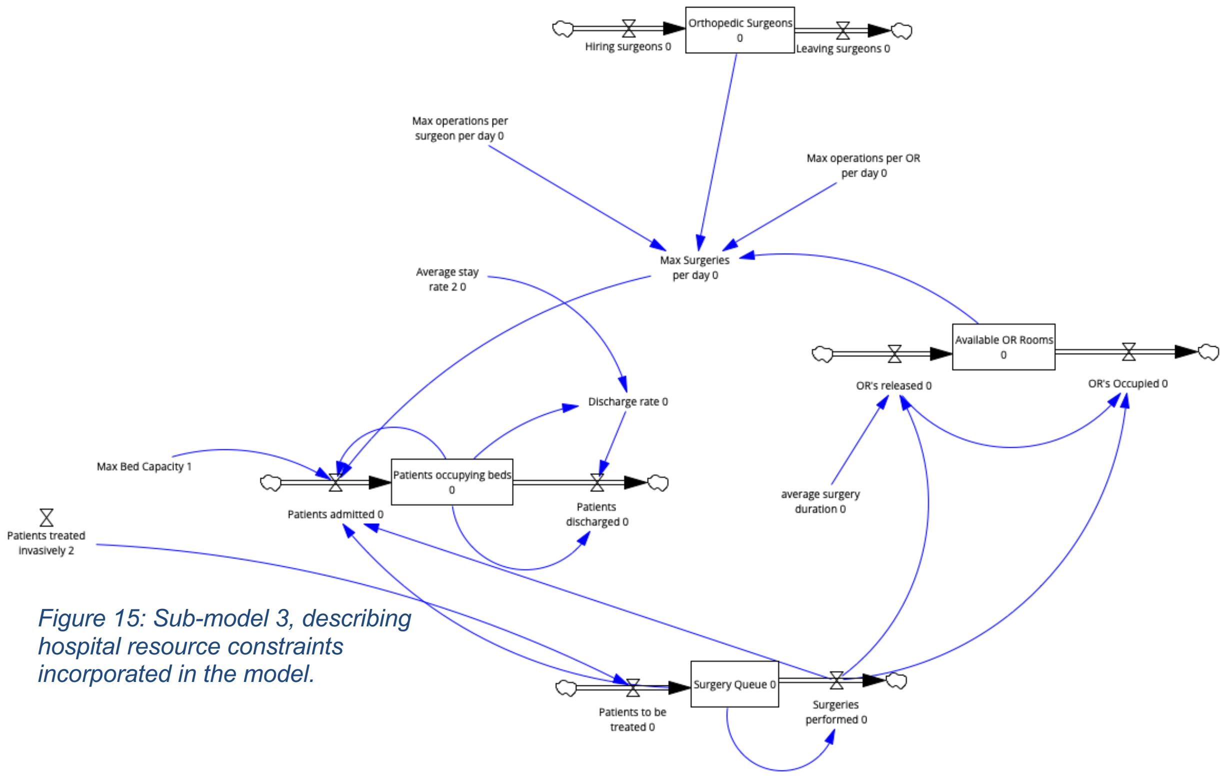


*Figure 15: Sub-model 3, describing hospital resource constraints incorporated in the model.*

**Decision levers**
The model includes one important decision lever which is systematically varied during scenario simulations.

*Table 12: Description of Decision Lever in the model together with its contents per scenario.*

| **Lever** | **Description** |
|---|---|
| Use of Decision Aid | Influences fraction of treatments (conservative or invasive). It is simply added to the existing ratio. |
| **Scenario** | **Description** |
| Baseline model | The fraction of patients choosing for conservative treatments is set at 6.7%. The variable itself is set at 0. |
| Scenario 2 | Moderate effect of decision aid. The variable is set at 0.05. Meaning that the conservative ratio results in 11.7%. |
| Scenario 3 | Significant effect of decision aid. Variable is set at 0.1. Meaning that the conservative ratio results in 16.7%. |

## Key Performance Indicators System Dynamics model

To evaluate the impact of decision aid implementation on hospital operations and finances the model tracks a set of Key Performance Indicators (KPIs). These KPIs were determined to be the number of care activities and the Diagnosis Treatment Combinations (DBCs), based on patient flow. For each scenario the model records the number of individual care activities performed in the hospital over the course of one year. The model also tracks the total number and type of DBCs generated. Because DBCs are the financial units a hospital uses to bill insurers, any shift in treatment distribution directly affects the hospital's income.

It is important to note that the model still has patient inflow as an initial basis. To correct for this factor, intermediate conversion steps were required to estimate the final counts of care activities and DBCs. This was to multiply the proportions used in the flows to the stocks of the care activities to their total registrations. To maintain consistency with patient inflow, which was the total number of hip fracture patients in the Netherlands divided by 69. The same principle was applied to the total care activity registrations. In figure 16 below a visual representation is given of the flow that goes through the model.

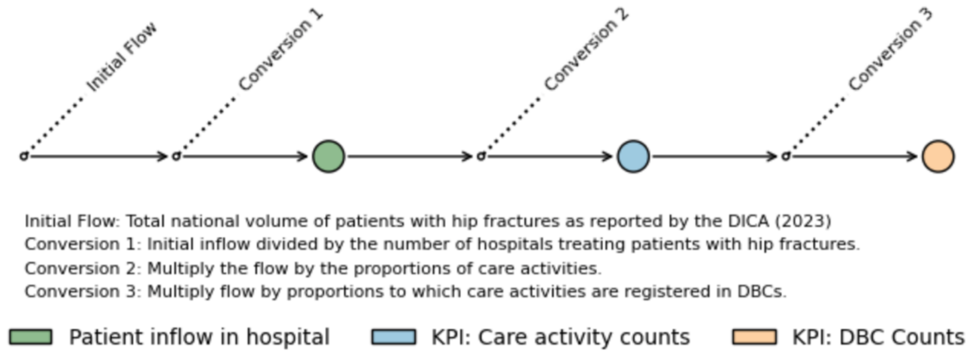


*Figure 16: Flow through System Dynamics model. The flow starts with the total number of patients registered with hip fractures in the Netherlands. This number was converted twice within the model to reach the care activity KPI and a final time for the DBC KPI.*

# Scenario Results

In this section the outcomes of the simulation runs are presented. The two key performance indicators were care activities and DBCs. These were influenced by the Decision lever “Use of decision aids”. To maintain clarity this section is split into two subsections, one for each KPI. Each of these sections discusses the different scenarios.

## General results

A total of 238 patients were treated in all simulations. The number of patients treated invasively and conservatively changes depending on the scenario. For each scenario the number of conservatively treated patients increased. The simulation results for the KPI of care activity counts are presented in table 13.

*Table 13: General simulation results from the model. These results can be used as a mental picture of the patient distribution over the scenarios.*

| Stock | Baseline - 6.7% | +11.7% | +16.7% |
|---|---|---|---|
| Number of patients treated | 238 | 238 | 238 |
| Patients treated invasively | 223 | 211 | 199 |
| Patients treated conservatively | 15 | 27 | 39 |

## KPI: Care activity counts and validation of the model

The results of the baseline scenario, which reflected the current or expected care activity volumes without any intervention is listed in table 14 in the third column. The most frequent care activity is 190218, which are clinic day registrations. The model simulated that on average a patient stays 6.2 days in a hospital. This number differs 5% from the one found by the DICA (2023), which was 6.5 days.

As determined from the expert interview with the orthopedic surgeon, every patient has a consultation at the emergency department, this is represented through the unchanging volume for care activity code 190060. The division between conservative treatment and invasive treatment in 2023 was set at 6.7%. This is also seen in the results in care activity 038528, which forms 6.7% of the care activities from ZPK 5 and 6.

As the scenario changes to an increase of 5% for conservative treatments all volumes for the care activities decrease except for care activity 038528. A notable increase is noticed for this care activity.

*Table 14: Care activity count over the different scenarios grouped by ZPK group.*

| ZPK | Care activity | Baseline | Scenario 1 | Scenario 2 |
|---|---|---|---|---|
| 1 | 190013 | 107 | 106 | 103 |
| 1 | 190060 | 238 | 238 | 238 |
| 3 | 190218 | 1385 | 1354 | 1324 |
| 5 | 038533 | 42 | 40 | 38 |
| 5 | 038534 | 12 | 11 | 10 |
| 5 | 038535 | 71 | 67 | 64 |
| 5 | 038565 | 64 | 60 | 57 |
| 5 | 038567 | 24 | 23 | 22 |
| 6 | 038528 | 16 | 28 | 40 |

The most interesting care activities to dive deeper into are the care surgical care activities (ZPK 5) and conservative care activity (ZPK 6). The results are given in figure 17. For every scenario a decrease is shown for the surgical care activities and an increase for the conservative care activity code 038528. When interpreting the results the conclusion is that the care activities that were first one of the surgical care activities from ZPK 5 are now redistributed to care activity 038528. That is why the increase for this care activity code is more than the individual decreases of the other care activities.

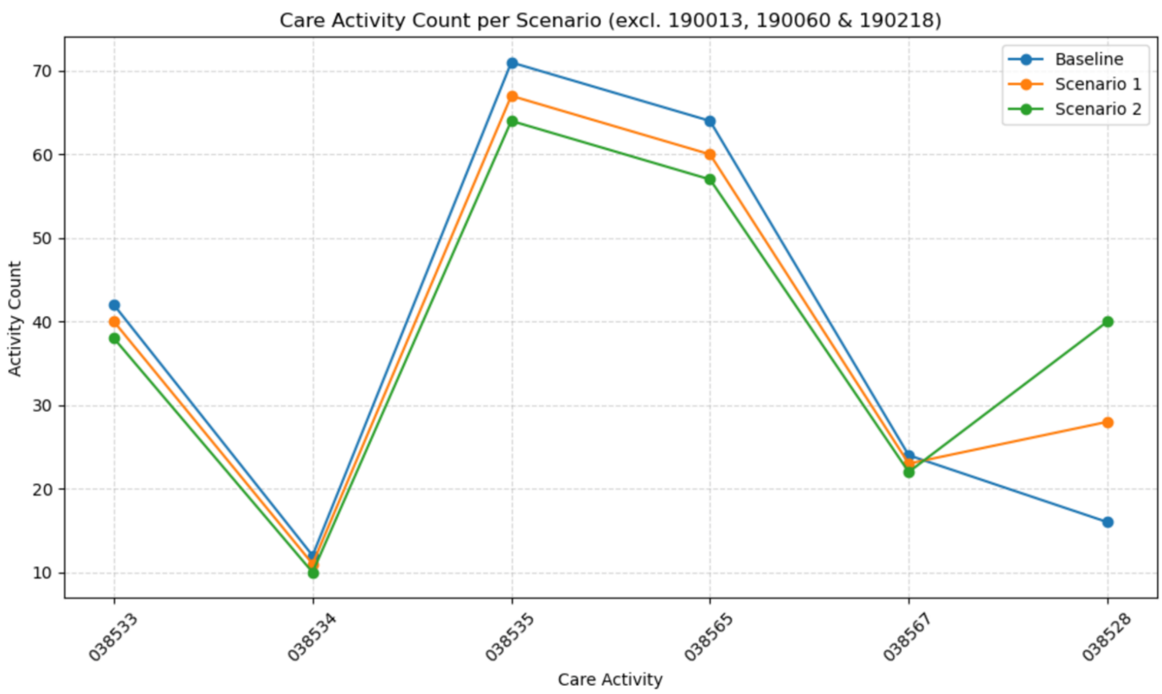


*Figure 17: Simulation results for the KPI: Care activity count for only the care activities from ZPK 5 and 6.*

## KPI: DBC volumes

In this section the impact of decision aids on the number of opened diagnosis treatment combinations is presented. Unlike the section on care activities the DBC results are reported per scenario for comprehensive analysis.

**General outcomes**

The results of the model report an average of 229 DBC registrations for hip fracture treatment per hospital. Most of these DBCs are surgical in nature, meaning that these DBCs contain care activities from ZPK 5.

*Table 15: General results of (Surgical) DBC volumes and their revenue over the scenarios*

| Model Scenario | # DBCs | # Surgical DBCs | Total income (€) | +/- (€) income |
|---|---|---|---|---|
| Baseline | 229 | 222 | 2158793.80 | 0 |
| Scenario 1 | 230 | 217 | 2119490.38 | -39303.43 |
| Scenario 2 | 230 | 211 | 2080178.12 | -78615.69 |

General results of the model also report a decrease in the average reimbursement per surgical DBC which is in line with statements made in expert interviews.
While the model only adjusts the number of surgical DBCs based on changes in treatment distribution, there are significant revenue drops to seen in both scenarios. This revenue drop is visualized in figure 18 below.

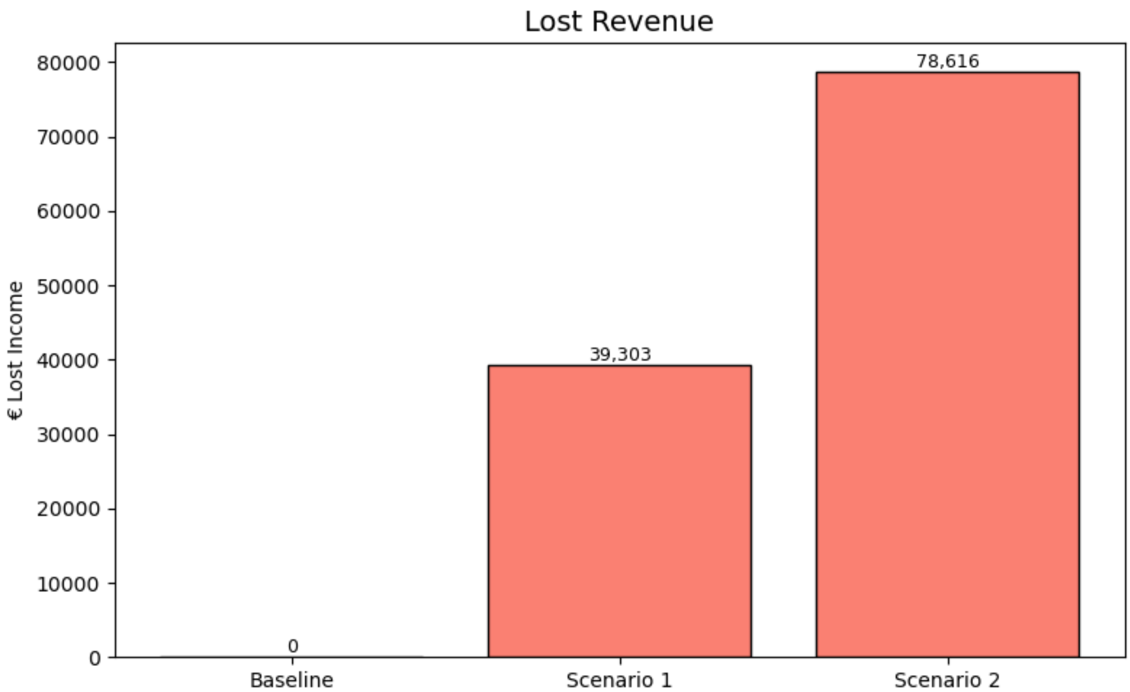


*Figure 18: Revenue drop in the simulated scenarios. The lost revenue is due to increased effects of decision aids and is visualized in absolute numbers.*

## Results Baseline Scenario

*Table 16: Results of the baseline scenario. DBCs in the left column, Baseline volumes in the middle column and the projected income in the right-hand column. The simulation results were not rounded off due to some being lower than 0.5. This would make it difficult to compare these results with the results in other scenarios.*

| ***DBC*** | **Scenario 1** | **Income *(€)*** |
|---|---|---|
| 199299009 (Surgical) | 7.12 | 75055.02 |
| 199299013 | 0.25 | 628.18 |
| 199299015 | 2.23 | 5451.96 |
| 199299018 | 0.24 | 1723.73 |
| 199299024 | 0.48 | 3308.92 |
| 199299026 (Surgical) | 25.08 | 309516.82 |
| 199299037 (Surgical) | 1.93 | 8985.83 |
| 199299038 (Surgical) | 59.90 | 615163.76 |
| 199299043 (Surgical) | 4.40 | 17539.82 |
| 199299044 (Surgical) | 108.51 | 950565.12 |
| 199299053 (Surgical) | 1.14 | 6519.058 |
| 199299054 (Surgical) | 13.58 | 161785.44 |
| 199299113 | 0.25 | 224.26 |
| 199299114 | 3.50 | 2102.42 |
| 199299119 | 0.37 | 223.46 |
| Total DBC registrations | 228.97 | 2158793.80 |
| Surgical DBCs | 221.64 | 2145130.87 |

Table 16 above presents the number of DBCs simulated by the model and the corresponding income per DBC type in the baseline scenario. A total of 229 DBCs were registered in the baseline scenario and 222 of these were surgical in nature.

The total income generated from all DBCs in this scenario amounts to approximately €2.15 million with surgical DBCs contributing to €2.14 million, indicating that the surgical DBCs account for nearly all revenue.

Among the surgical DBCs, code 199299044 is the most frequently registered DBC (109 instances) and it generates €950565.12.

This baseline model serves as a financial reference point for evaluating the impact of treatment shifts in the subsequent scenarios.

## Results Scenario 1 – 11.7% conservative treatments

*Table 17: Results of the first scenario (11.7% conservative). DBCs in the left column, scenario DBC volumes in the middle column and the projected income in the column next to it. Also, in the last column a comparison is given with the baseline model.*

| DBC | Scenario 1 | Income (€) | +/- (€) Baseline |
|---|---|---|---|
| 199299009 (Surgical) | 6.74 | 71032.85 | -4022.17 |
| 199299013 | 0.46 | 1096.97 | 468.79 |
| 199299015 | 3.89 | 9520.59 | 4068.63 |
| 199299018 | 0.42 | 3010.10 | 1286.37 |
| 199299024 | 0.83 | 5778.27 | 2469.35 |
| 199299026 (Surgical) | 24.29 | 299689.24 | -9827.58 |
| 199299037 (Surgical) | 1.82 | 8504.27 | -481.56 |
| 199299038 (Surgical) | 59.11 | 607055.59 | -8108.17 |
| 199299043 (Surgical) | 4.23 | 16957.01 | -582.81 |
| 199299044 (Surgical) | 106.52 | 933106.44 | -17458.68 |
| 199299053 (Surgical) | 1.08 | 6169.72 | -349.34 |
| 199299054 (Surgical) | 12.85 | 153116.09 | -8669.35 |
| 199299113 | 0.45 | 391.62 | 167.36 |
| 199299114 | 6.12 | 3671.39 | 1568.97 |
| 199299119 | 0.64 | 390.22 | 166.76 |
| Total DBC registrations | 229.44 | 2119490.38 | -39303.43 |
| Surgical DBCs | 216.64 | 2095631.21 | -49499.66 |

In this scenario the fraction of patients opting for conservative treatment was increased by 5% to a total of 11.7%. As a result, the number of non-surgical DBCs increased in this scenario. The number of surgical DBCs decreased from 222 in the baseline scenario to around 217 in this scenario. Even though the number of DBCs increased, the income decreased significantly with €39303.43.

Surgical DBCs that were most impacted by the treatment shift were 199299044, 199299026 and 199299038. Non-surgical DBCs that increased the most were 199299015, 199299024 and 199299018.

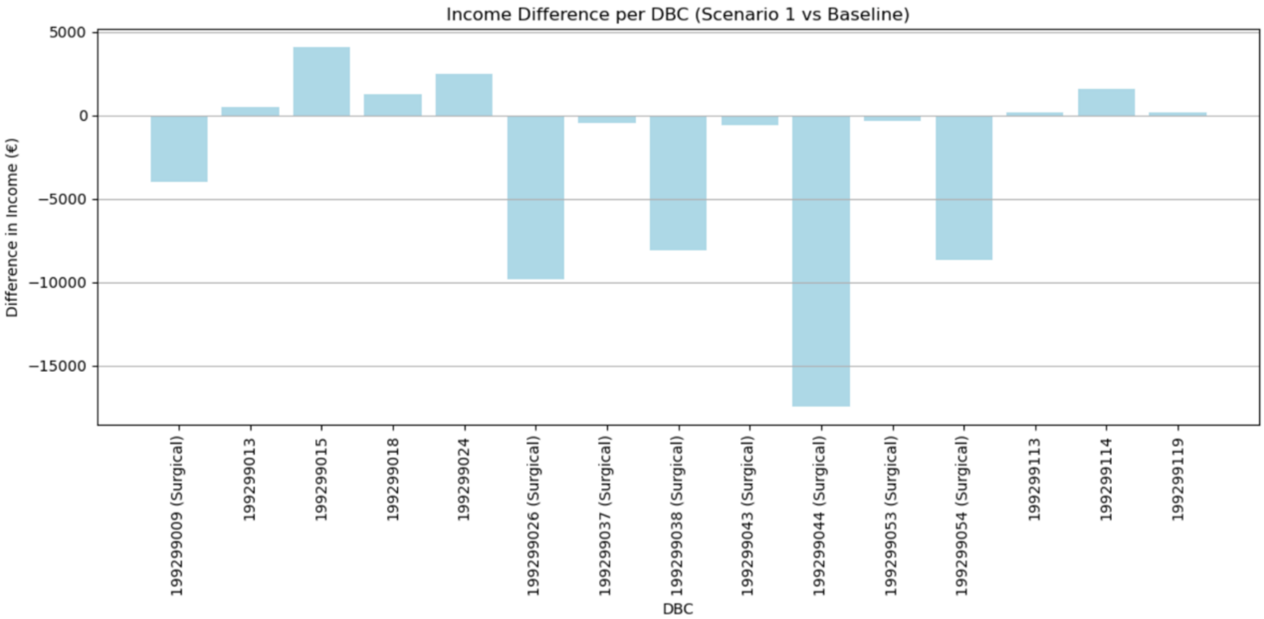


*Figure 19: Difference in income per DBC for scenario 1 compared to the Baseline scenario.*

### Results scenario 2 – 16.7% extra Conservative treatments

*Table 18: Results of the second scenario (16.7% conservative). DBCs in the left column, scenario DBC volumes in the middle column and the projected income in the column next to it. Also in the last column a comparison is given with the baseline model.*

| ***DBC*** | **Scenario 2** | **Income *(€)*** | ***+/- (€) Baseline*** |
|---|---|---|---|
| 199299009 (Surgical) | 6.36 | 67010.58 | -8044.44 |
| 199299013 | 0.64 | 1565.76 | 937.58 |
| 199299015 | 5.56 | 13589.24 | 8137.28 |
| 199299018 | 0.60 | 4296.46 | 2572.73 |
| 199299024 | 1.19 | 8247.61 | 4938.68 |
| 199299026 (Surgical) | 23.49 | 289862.90 | -19653.92 |
| 199299037 (Surgical) | 1.72 | 8022.75 | -963.08 |
| 199299038 (Surgical) | 58.32 | 598947.43 | -16216.33 |
| 199299043 (Surgical) | 4.09 | 16374.20 | -1165.62 |
| 199299044 (Surgical) | 104.53 | 915639 | -34926.12 |
| 199299053 (Surgical) | 1.02 | 5820.32 | -698.74 |
| 199299054 (Surgical) | 12.12 | 144445.55 | -17339.90 |
| 199299113 | 0.64 | 558.97 | 334.71 |
| 199299114 | 8.73 | 5240.37 | 3137.95 |
| 199299119 | 0.91 | 556.99 | 333.53 |
| Total | 229.91 | 2080178.12 | -78615.69 |
| Surgical DBCs | 211.64 | 2,179,790.20 | -10.00 |

In this scenario, the proportion of patients choosing for conservative treatment increased by 10% to 16.7%. As a result, there was a decrease in surgical DBCs from 221 (baseline) to 212 and a total of 230 DBCs registered overall. The overall income decreased by approximately €78.6 thousand. Resulting in a total revenue of €2.08 million.
The same DBCs as the previous scenario were responsible for the most losses due to decision aid implementation.

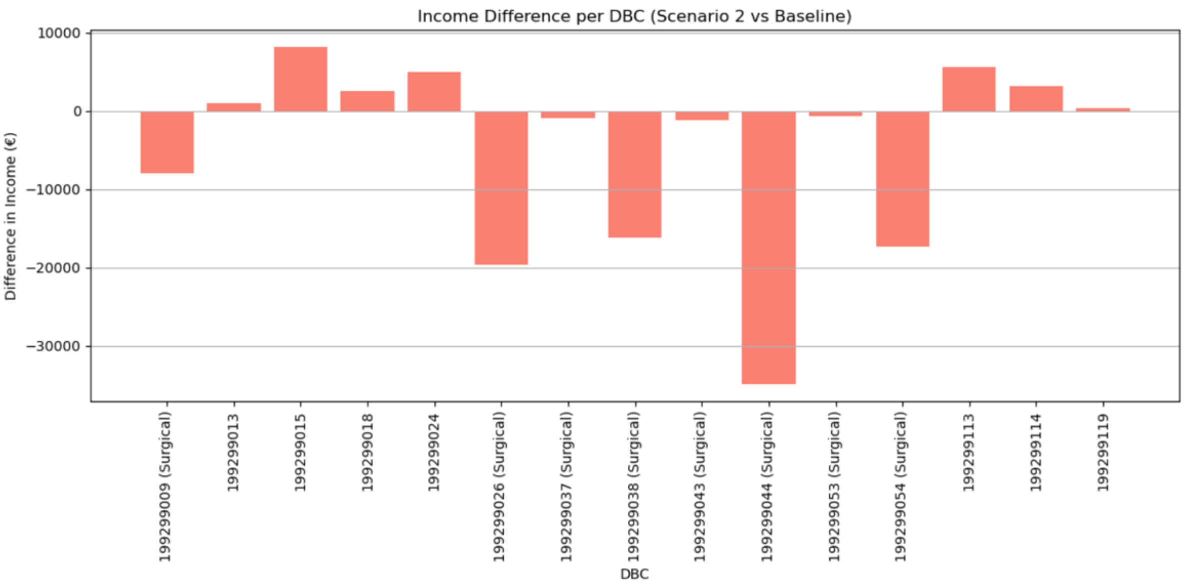


*Figure 20: Difference in income in scenario 2 vs the baseline scenario.*

## Summary of Results

*Table 19: Summary of the incomes given per DBC for every scenario.*

| ***DBC*** | **Baseline** | **Scenario 1** | ***Scenario 2*** |
|---|---|---|---|
| 199299009 (Surgical) | 75055.02 | 71032.85 | 67010.58 |
| 199299013 | 628.18 | 1096.97 | 1565.76 |
| 199299015 | 5451.96 | 9520.59 | 13589.24 |
| 199299018 | 1723.73 | 3010.10 | 4296.46 |
| 199299024 | 3308.92 | 5778.27 | 8247.61 |
| 199299026 (Surgical) | 309516.82 | 299689.24 | 289862.90 |
| 199299037 (Surgical) | 8985.83 | 8504.27 | 8022.75 |
| 199299038 (Surgical) | 615163.76 | 607055.59 | 598947.43 |
| 199299043 (Surgical) | 17539.82 | 16957.01 | 16374.20 |
| 199299044 (Surgical) | 950565.12 | 933106.44 | 915639 |
| 199299053 (Surgical) | 6519.058 | 6169.72 | 5820.32 |
| 199299054 (Surgical) | 161785.44 | 153116.09 | 144445.55 |
| 199299113 | 224.26 | 391.62 | 558.97 |
| 199299114 | 2102.42 | 3671.39 | 5240.37 |
| 199299119 | 223.46 | 390.22 | 556.99 |

The analysis explored the financial and operational impact of increasing the proportion of patients receiving conservative treatments. Three scenarios were examined. In the first scenario a baseline 5% of patients were modeled to choose for conservative care. In the the second and third scenario this number increased subsequently with 5%.

Across both alternative scenarios, a consistent pattern emerged:

- High-value surgical DBCs decrease in frequency, causing most of the financial loss.
- Conservative DBCs increase, but due to their lower reimbursement rates and relatively low volumes, the gains do not fully compensate for surgical losses.
- The overall financial impact remains negative.

These findings demonstrate that an increase in conservative treatment can impact the financial structure of a hospital's reimbursement. Strategic decisions to bridge the transition period or to make a strong business case towards insurers must be based on insights from these results.

# Discussion

This study was conducted to evaluate the impact of decision aids on hospital operations by combining stakeholder perspectives, data from the NZa and simulation modeling. This section aims to interpret the results from the previous section and what their implications are.
An important aspect is reflected upon within this discussion which is the review of the costs to implement a decision aid. Initially, a cost benefit analysis would have been the ideal approach to capture the financial and operational trade-offs. However, due to the complexity of the topic and the timeframe in which this study took place, this important aspect fell short. Which resulted in the study becoming almost a purely exploratory approach. To address this issue, the discussion incorporates a reflection on how to bridge the transition period for hospitals. The transition period was introduced in the introduction section to help the reader understand the financial and operational challenges hospitals face when implementing Value Based Healthcare. After addressing this transition period, the sub-questions are answered.

## Reflecting on the conceptual framework

To guide the reader through the discussion the conceptual framework is once again presented in figure 21 below. The framework addressed three components. First, a hospital needs to have insight into the factors that influence decision aid adoption. Second, a hospital needs to determine how decision aids impact patient distribution across treatment alternatives. Third, hospitals need to understand how the shift in patient distribution affects the hospital financially and resource wise. By understanding these dynamics between the three components a hospital can strengthen their business case towards healthcare insurers to overcome the transition period.

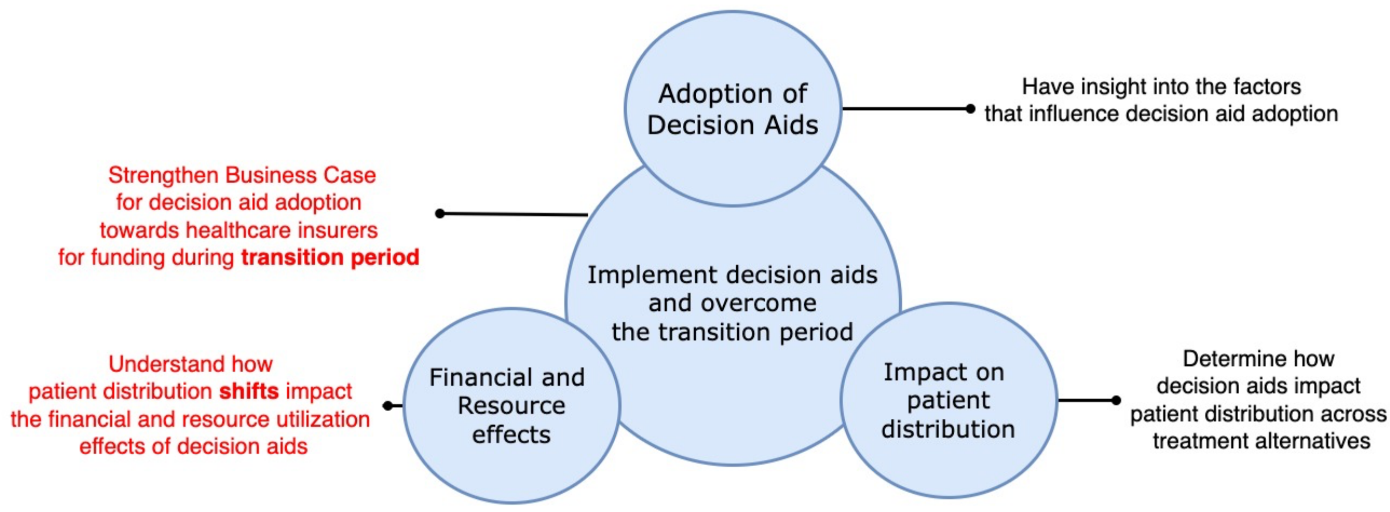


*Figure 21: Conceptual framework presented in the methodology section*

Of the 10 interviewees most stated that Dutch Healthcare faces significant capacity challenges. A neurologist interviewed (interview 2) stated that there is an exponential growth of Parkinson patients. 11 years ago, his hospital treated 600 patients with Parkinson and currently they treat 1400 patients with Parkinson. This is finding is also supported in literature, with one study saying that the number of patients with Parkinson's will increase from around 7 million people in 2015 to around 14 million people worldwide in 2040. (Dorsey & Bloem, 2017). The same goes for patients with hip fractures (Mahamoud, 2016).
The total number of patients in the Netherlands with hip fractures in 2023 was around 18 thousand (DICA, 2024). In the coming 10 years the expectation is that there will be almost a 30% increase of hip fracture patients (Netwerk Acute Zorg Midden-Nederland, 2023).
Why are these numbers significant? The root of these medical conditions is similar, which is the aging of society (Dorsey & Bloem, 2017; Netwerk Acute Zorg Midden-Nederland, 2023).

With a high prognosis of incoming patients, factors that influence the adoption of decision aids are not only financial, but they also include the operational capacity, staff workload and the ability to keep delivering high quality of care. This is reflected upon by interviewee 2 who states that he has consultations with almost 25 patients per day. He said that he only has around 10 minutes to see each patient during consultation and has to make sure they receive enough information on their complex disease. In scientific literature this observation was supported as consultation lengths ranged between 6 and 9 minutes (Das et al., 2021; Iskandar & Sundari, 2024; Zhan et al., 2024). Within this short time frame clinicians have to inform their patients sufficiently on their medical condition. The respondent ended with highlighting the need for a tool such as a decision aid to help patients understand their disease. Another interviewee (Interview 4) mentioned that they even draw on paper what the disease of the patient entails and how lifestyle decisions impact their recovery. Using a decision aid could help tackle staff workload given the high prognosis of incoming patients with not only Parkinson's, but all medical conditions. A digital care advisor builds on this and states that by using decision aids more patients can be treated within the same period. As discussed in section 3.2, interviewee 1 was involved in a pilot study on decision aid use within the surgery department. They found that a higher percentage of patients opted for conservative treatments. He expressed that outcome measures are not in favor of a hospital when more patients choose for conservative treatments as this means the prices of certain DBCs could be reduced. Thus, resulting in financial difficulty for a hospital. Having sufficient insight in the financial consequences of decision aid implementation to support SDM could be crucial for hospitals when transitioning to VBHC.

## A reflection on the simulation results

When decision aids are effective, the prognosis is that patients opt for more conservative treatments (Stacey et al., 2017). Choosing for conservative treatments leads to less surgical DBCs declared by a hospital over the time span of a year. Simulation results were in line with this finding and show a decrease in revenue for every simulated scenario.
Figure 16 showed a decrease in income in scenario 1 of almost €40000 and in scenario 2 almost €80000. Figure 22 shows two different sides of decision aid implementation. It shows that there is not only a decrease in revenue from the surgical DBCs, but also an increase in revenue from the non-surgical DBCs.

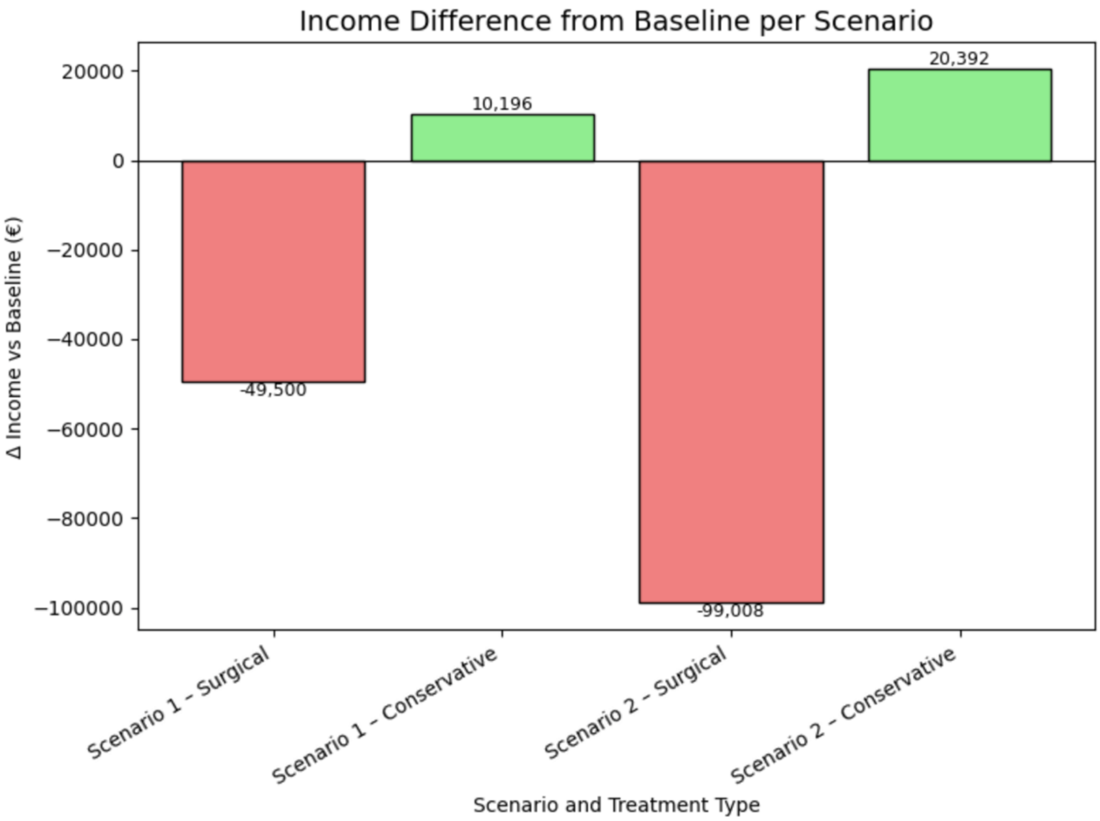


*Figure 22: Differences in income summarized based on results from previous section. The green bars show increases in income and the decreases are shown in red. Surgical revenue drops greater than what is recovered in non-surgical treatment.*

The literature review revealed that despite the benefits of decision aids, the adoption remains limited. It was interesting to see that the concept of P-PAE, which has contextual overlap with SDM, faces a similar obstacle in adoption (Chen et al., 2015). Even though the healthcare setting of P-PAE is set in the U.S., it faces the same structural barrier that SDM faces in the Netherlands. This obstacle is the financial disincentive for healthcare providers. This similarity underscores the notion set in the introduction, which is that even though a Shared Decision-Making has clinical benefits, structural readiness to overcome the **transition period** is very important. Moreover, Van Leeuwen et al. (2023) found the exact reason as to why hospitals might be struggling with bridging the transition period. They found that there is a misalignment within hospitals between the internal budgeting and the external financing system.

This leads to the answer to the first sub-question "*To what extent is it important for hospitals to gain insight into the outcome measures that reflect the impact of decision aids on their operational efficiency, and why are these insights valuable?":*

**The care optimization paradox: why insight into the impact is necessary to overcome the transition period.**

A paradox found in the current healthcare context, is that hospitals are expected to treat a growing number of patients every year, while dealing with a shortage of healthcare personnel (Interviews 1, 3, 4 and 5). When they find a solution to this issue, by reducing care delivery per patient, they are expected to justify financial implications and demonstrate improvements in quality of care to healthcare insurers. In turn, insurers may adjust reimbursement rates accordingly in their own favor. Effectively penalizing hospitals for delivering more appropriate care.

To properly anticipate this, hospitals must balance their costs, which are primarily composed of salary expenses, infrastructure, medical equipment and administration.

In that way they can strengthen their position in negotiations by not only presenting efficiency gains, but also through effective restructuring of personnel, infrastructure and scheduling of patients. By having clear insight into how decision aids influence patient flows hospitals can anticipate shifts in revenue and adjust their internal operations as needed. This insight is given in figure 25 below.

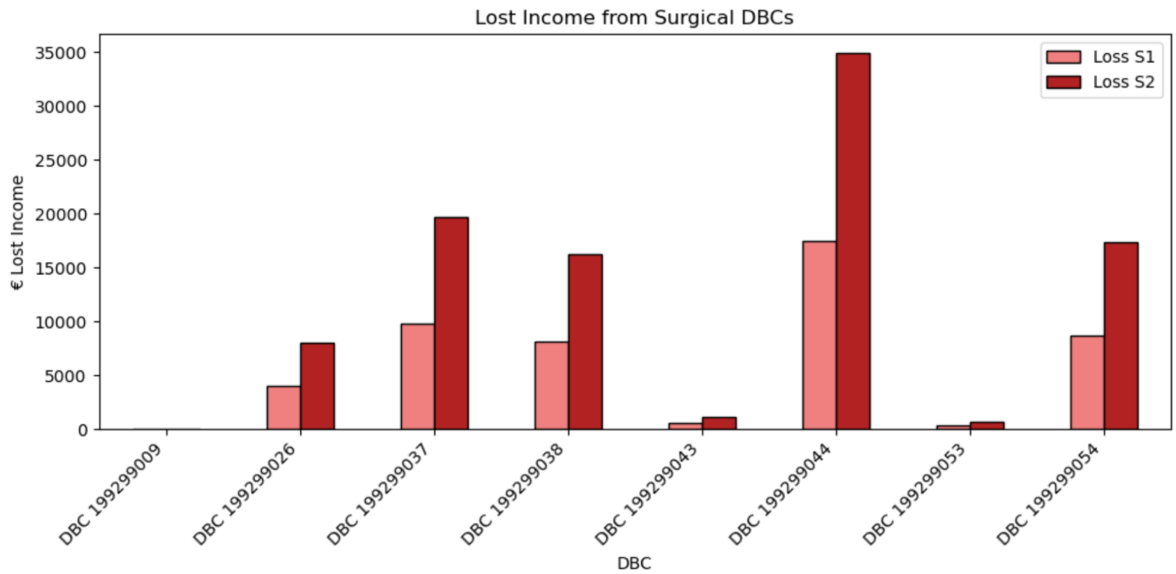


*Figure 23: Loss of surgical DBC incomes for scenarios 1 and 2.*

The results show that an increase of the fraction of patients opting for conservative treatments consistently reduces the number of surgical care activities (ZPK 5) and surgical DBC registrations. These decreases were already expected as found from literature (Stacey et al., 2017). However, the operational benefits of reduced resource use are countered by a substantial decline in revenue, due to the lower registration of high-reimbursed DBCs. To truly realize the efficiency gains hospitals should proportionally to the lost income, reduce their surgical workforce and associated resources. They could retrain or hire new personnel for positions where Value-Based healthcare is more needed. In doing so they could reap the benefits of the gains in income from the non-surgical DBCs presented in figure 26.

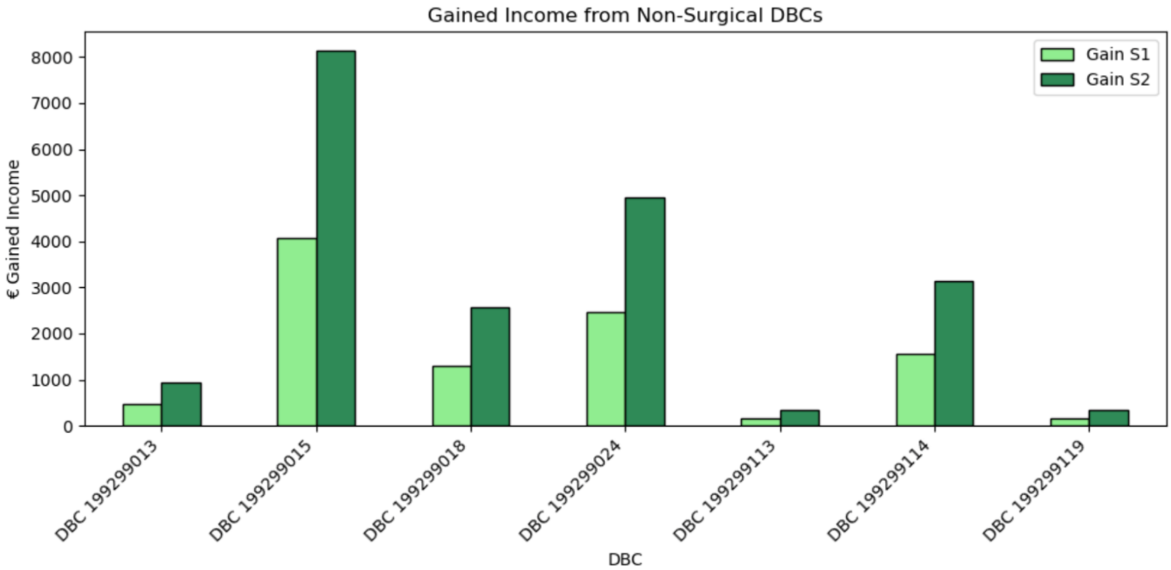


*Figure 24: Monetary gains in non-surgical DBCs in scenario's where decision aid effects are more conservative treatments than the current situation (2023).*

This highlights the core trade-off explored in this thesis: While decision aids might improve operational efficiency, they introduce short-term financial risk for hospitals operating under volume-based reimbursement models.

This insight is crucial to overcome the transition period in which the implementation of decision aids will not yield immediate beneficial financial results. Harshly said, instead of being ‘punished’ by having a reactive stance like Bernhoven, hospitals could have a more proactive stance and prevent unintended underfinancing during a period of internal transformation.

The second sub-question aimed to distinguish which outcome measures are always important and which are specific to the context or type of decision aid. The literature review and stakeholder interviews revealed several generic outcome measures.

Interviewees 1 and 8 mentioned that they look at the change in the number of DBCs and care activities when evaluating an implementation. In literature a similar outcome was found, Gawałko et al. (2024) have also standardized the reimbursement per DBC using data from the NZa open portal to evaluate changes in healthcare utilization.

While stakeholders evaluate this through quantifiable metrics such as DBC volumes or care activity codes, the concept is similar to what was found in literature. This universal outcome can be qualified as **patient distribution**.

Data analysis results showed that care activities from ZPK 1 (190060 and 190013) are present in all of the DBCs, while care activities from the other ZPK groups (3, 5 and 6) were found to be present in only subsets of DBCs. Their presence was dependent on whether a patient followed a conservative or surgical pathway.
However, in areas such as palliative oncology, decision-making and the role of decision aids is more focused on quality-of-life improvement of the patient (National Cancer Institute, 2021). Decision aids would in this context support patients in making nuanced treatment choices, such as pain treatment over chemotherapy. Context-specific outcomes measures here would focus on patient-reported quality of life and whether the patient is happy with the care they received. These are often measurable through PROMs (Sayah et al., 2021).
When looking closely at the care activities in this study the following table (20) can be drawn. In this table it is shown that certain care activities appear across all departments and may be qualified as universal outcome measures. These care activities are clinic days and consultations. Care activities that appear only in DBCs related to hip fracture entail the treatments delivered to hip fracture patients. Making them **context specific**.

*Table 20: Distinction between context specific outcome measures and universal outcome measures. Care activities from ZPK 1 and 3 appear in DBCs across all departments within a hospital, while care activities specific to hip fracture surgery only appear in DBCs for hip fracture patients.*

| Appears in DBCs across departments | Appears only in DBCs related to hip fracture patients |
|---|---|
| 190013, 190060, 190218 | 038528, 038533, 038534, 038535, 038565, 038567, 038570 |

In summary, while patient distribution and care activity volumes are generalizable, specific care activity codes and hospital stay duration are clearly tied to hip fracture care. One must consider the context of the medical condition when applying a similar model as different medical conditions have distinct treatment goals.

The third sub question: *What is the impact of decision aids on these outcomes?* – is answered through scenario analysis. Operationally, the shift to conservative treatments reduces surgical care activities from ZPK 5. This shift opens potential for capacity relief as less surgical care activities were predicted to happen, which reduce the pressure on operational resources and hospital costs. The hospital costs for hip fracture treatments even seem to be higher than the income of hospitals through registering and declaring surgical DBCs as presented in figure 21. In the context of rising patient inflow and healthcare personnel shortages, this operational advantage is valuable. Even though this is not directly rewarded through DBC revenue as high income DBCs decrease (figure 27). In addition to the model, several interviewees suggested that the decision aids could reduce the need for repeating consultations and unexpected follow-up consultations. This is hard to measure through a predictive model but is a very valuable finding.

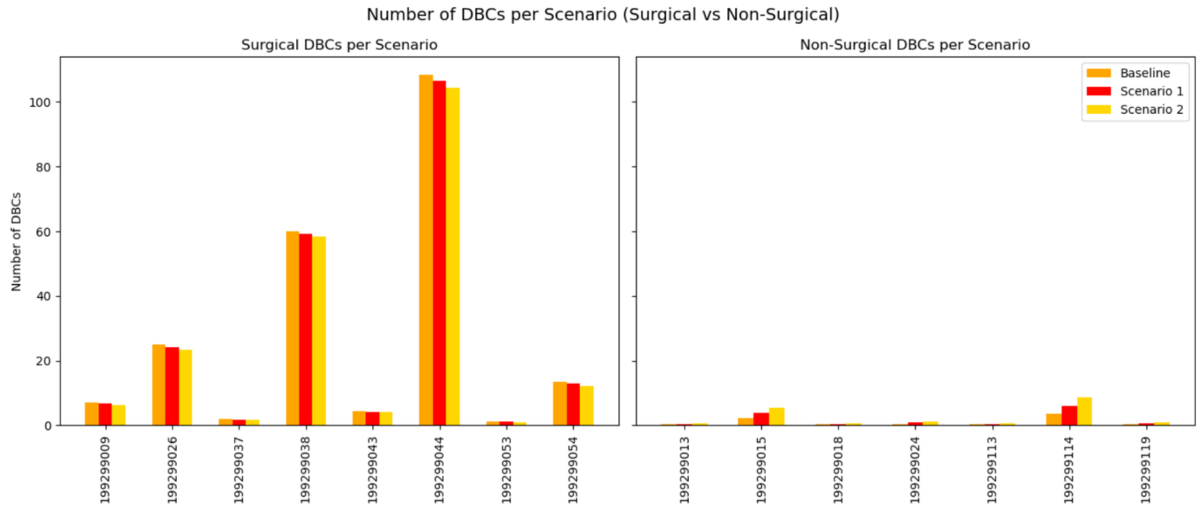


*Figure 25: Scenario exposition of all DBCs in support of the answer to the third sub-question. The left graph shows a gradual decrease in surgical DBCs and the right graph shows a gradual increase in non-surgical DBCs.*

To answer the main research question: **How do the costs of the implementation of a Decision Aid compare to its impact on a hospital's operational efficiency?**

This study finds that the costs of implementing decision aids are not offset by operational efficiency gains under the current reimbursement system. This is because of the way hospitals are currently budgeting their costs internally without much alignment with the DBC system (van Leeuwen, 2023). To add to this, the costs of implementing a decision aid add up to the projected financial losses. Although the costs of decision aid implementation were not included in the study, it is important to highlight that the study focuses on the broader financial consequences of decision aid implementation. This focus allows for a more comprehensive understanding of how decision aid implementation can influence the financial sustainability of a hospital. However, it is also useful to consider specific costs of decision aid implementation in addition to their financial consequences.
According to the Dutch Patient Federation the costs of implementing a decision aid is around €2500 per year (Patienten Federatie Nederland, 2018). The costs for additional implementation support brings the total costs to €7500. Taken together with the projected losses this could make the total financial burden for a hospital even greater in the first year of implementation. A hospital should therefore anticipate and prepare for the projected losses by aligning their internal resources and costs before decision aid implementation.

But does that mean that there is only a negative business case for hospitals to implement decision aids, or any value based-healthcare innovations for that matter? No, decision aids and value-based healthcare contribute to better clinical and operational outcomes. As demand for healthcare continues to grow budget remains under pressure, the system is approaching a breaking point in terms of affordability, efficiency and sustainability. In this context value-based healthcare ensures that Dutch healthcare remains accessible and available. The results advocate for greater alignment between hospital incentives and value-based care models and show how simulation tools can help hospitals and insurers negotiate more informed, data-driven implementation strategies.

## Bridging the transition period by adjusting the outcome measures

As seen from the simulation results, hospitals may suffer financial losses when implementing VBHC such as decision aids. To cover this decrease in revenue and to be able to transition to VBHC, systemic transformation is crucial for a hospital to remain financially sustainable (Lee et al., 2023). However, only adjusting infrastructure and expenses according to prognosed revenue losses, might not compensate hospitals sufficiently. What could effectively help is to change outcome measures from 'production', as defined by Blank et al. (2016), to value-driven outcomes (Lee et al., 2016). Changing outcomes to patient-centered values rather than volume incentives could improve quality of care could be beneficial for decision aid implementation (Scott et al., 2016 ). Van Veghel et al. (2018) found that focusing on outcome measures based on Porter's value-based principles may enable a sustainable framework for the implementation of decision aids.

In conclusion, while the effective implementation of decision aids might be beneficial for the quality of care and a hospital's operational efficiency, their financial impacts in the current healthcare system may be negative. This study has explored the impact of decision aid implementation through the lens of Diagnosis Treatment Combinations (DBCs) and care activities, which are currently the main outcome measures for hospital financing and performance evaluation according to interviewees 1, 7, 9 and 10. The study findings indicate that under these metrics' hospitals may experience increased financial pressure. This highlights a misalignment between the current financial system and the added value of decision aids in improving quality of care. A shift towards incentivizing Value Based Healthcare may be necessary to support hospitals during the transition period.

## Limitations of the study

This study had several limitations which need to be addressed. One of them being the lack of focus on the direct costs associated with decision aid implementation. The research primarily focused on the indirect costs associated with the operational impacts of decision aid implementation. The research also placed minimal focus on the costs for hospitals in the context of hip fracture patients.

The reason for this limitation lies in the difficulties experienced in obtaining scientific data on the costs for hip fracture surgeries.
A literature search was conducted on PubMed to find relevant scientific sources on healthcare costs for hip fracture patients. However, it was difficult to find recent (from 2019 onwards) scientific sources that stated the exact costs for hip fracture surgeries. Most studies focused on QALY's (Quality-Adjusted Life Years) and mortality rates. These are relevant long-term evaluations. However, the scope of this study was to help hospitals bridge the transition period in transitioning towards Value-Based Healthcare approaches such as Shared Decision-Making. To expand the search, grey literature was also consulted. However, due to their 'grey' nature this part of the research is not included in the main body of this thesis, but rather here in the discussion. The figure below shows some sources that were found.

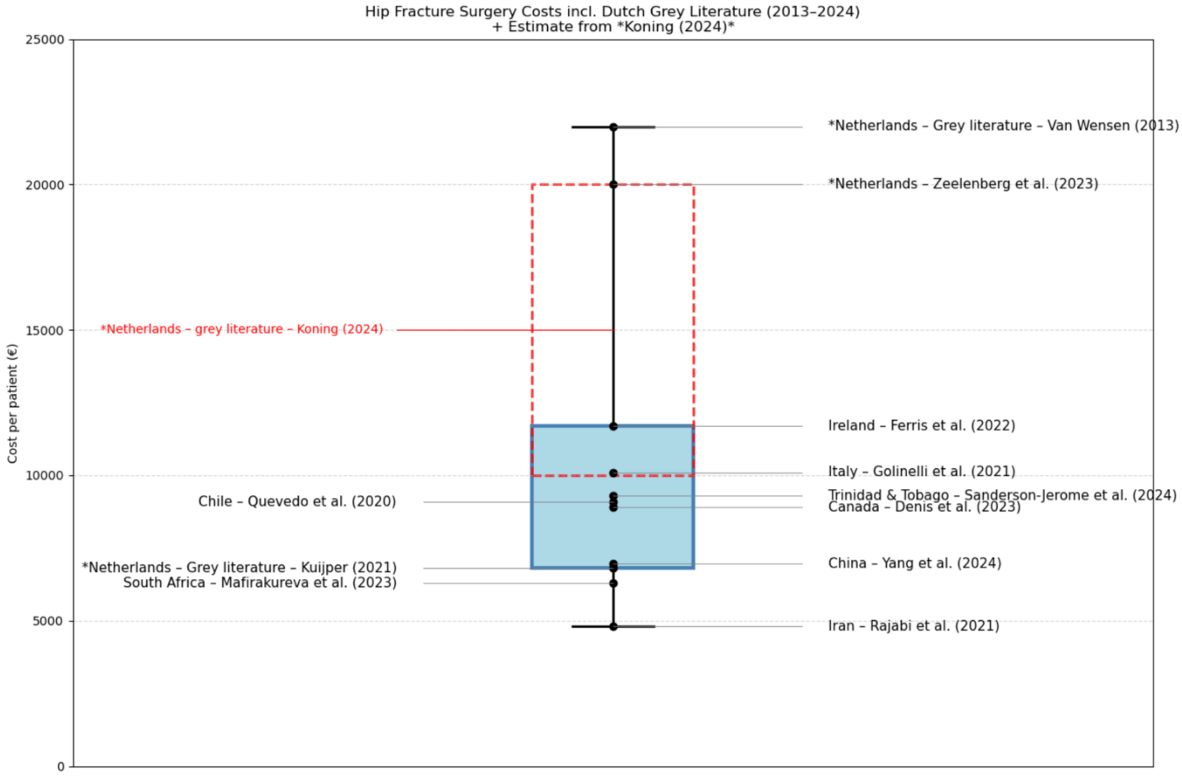


*Figure 26: Literature search results on hospital costs for hip fracture patients. Presented in an error boxplot. The articles are preceded with the country in which the research took place.*

A total of 10 scientific sources were consulted and 3 grey literature sources. Of these articles only the 3 grey literature articles and one scientific source within the Dutch healthcare setting presented the most relevant results for this study and were therefore selected. The grey literature sources by Koning (2024), Kuijper (2021) and Van Wensen (2013) showed exactly why it was difficult to find sources on healthcare costs for hip fractures. Koning (2024) stated that hip fracture costs for a hospital range between 10000 and 20000 euro. Kuijper found that it costs around 6500 euro to treat a hip fracture patient, and Van Wensen estimated the costs at around 22000 euro. The only scientific source by Zeelenberg et al. (2023) estimated the costs at around 20000 euro.

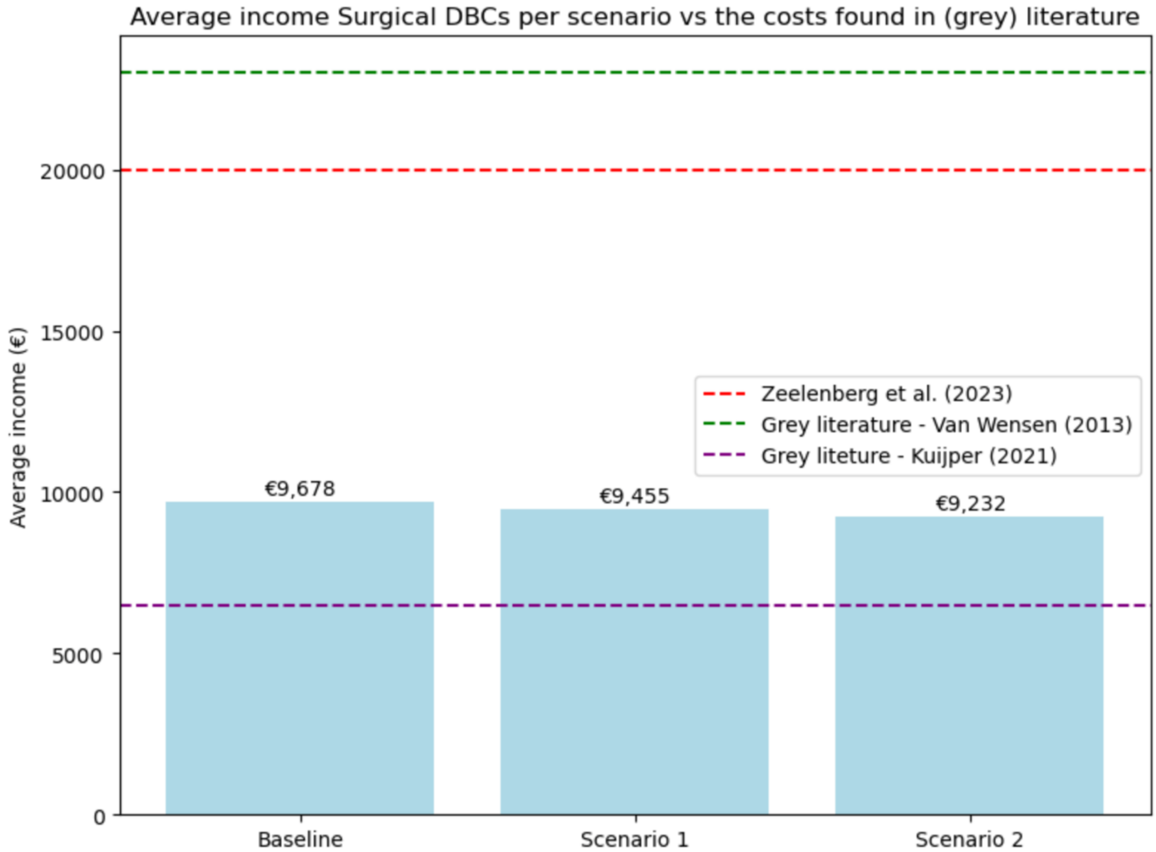

*Figure 27: Average income for surgical DBCs across different scenarios simulated by the System Dynamics Model compared to the costs of hip fracture surgeries found in both grey literature and scientific literature. Koning (2024).*

The results of this very limited literature review indicate that hospitals lose money on average for hip fracture surgeries. Implying that there is a financial benefit in performing fewer surgeries. A closer look at the costs showed that a clinic day, identified as care activity 190218, costs between 500 and 900 euro per day in 2021 (Kuijper, 2021). The exact costs may differ as they are dependent on the type of medical condition for which a patient needs care. The duration of a hip fracture surgery ranges between 1.5 hours and 3 hours and the costs per minute of on OR room is around 9.45 euro (Haaglanden MC, 2025; Groot Jebbink et al., 2021). Taking the average of the time, which is 135 minutes (2.25 hours) and multiplying this by 9.45 would lead to 1275.75 euro for an OR for a hip fracture surgery. Adding salary costs and more would increase the costs for surgery even more. Making the literature review results plausible. However, for future research it is recommended to find more precise and up-to-date data on all the costs related to hip fracture treatments.

## Modeling limitations

While System Dynamics Modeling might be suitable for exploring complex systems such as healthcare as determined by Mahamoud et al. (2016), it does have constraints. The Euler method was applied with a large time step of 1. An alternative, more probable method to reach reliable results in a complex system simulation was to use the Runge-Kutta method (Olatunji & Akeju, 2025). Runge-Kutta's method is known to yield more accurate results than Euler's method with large timesteps (Paudel & Bhatta, 2023).

There are also alternative methods to simulate complex healthcare systems. One of them being Agent Based Modeling, which can capture individual behaviors of patients (agents) in a complex healthcare system (Kittipittayakorn & Ying, 2016). However, as found in literature, the use of SDM is preferred when the goal is to study aggregate flows and to examine sub system performance within a complex system (Cassidy et al., 2019). The goal of this study was not to capture individual behavior of agents within a complex system. The objective of the study was to understand system wide effects of the behavior of these agents. This is why SDM was chosen as the modelling method for this study.

As the model was a Personal Learning Edition (PLE) not all preferred modeling tools were available. For example, the time step variable was not present but needed for tracking the days spent in a hospital. The solution was to find a workaround for this issue, even though found, this was not optimal. Another challenge was to refine the model due to the tight timeframe and the very complex field of Dutch healthcare. The Dutch DBC system is known for its complexity and every hospital has full time DBC advisors, next to their full-time financial controllers. I did have the advantage of having a little healthcare experience, very experienced supervisors and some connections within Dutch healthcare to help me understand the exact dynamics within the financial reimbursement system. However, it is advised for future studies to refine the model more extensively than how I have done.
Another shortcoming of the model was that the model was run over a fixed time horizon of one year, without the ability to model long-term financial consequences. This choice was consciously made as the data from the NZa was highly generalized and long-term predictions of the model would not yield reliable results.

The system dynamics model uses data from the NZa. This data contains all the data registered by Dutch healthcare institutions. While it offers nationwide coverage, it is inherently generic and aggregated, lacking hospital specific nuances (such as practice variation). The interview with the orthopedic surgeon highlighted this as well. He mentioned that his hospital is one of the two big hospitals in the area and only his hospital performs surgeries on hip fracture patients. This means that all patients in this area go to this hospital for hip fracture treatments leading to higher numbers of hip fracture treatments at that hospital compared to other hospitals.
As a result, it does not reflect differences in local care pathways, patient populations for specific areas or even organizational practices. For a more comprehensive and accurate study it is advised to use institution specific data. These would allow for more detailed modeling of operational efficiency and a more accurate estimation of the real impact of decision aid implementation. DBC revenues and care activities were modeled using average NZa

reimbursement tariffs. Prices may vary due to local negotiations, hospital specific agreements or specializations. This introduces uncertainty into the absolute financial estimates.
The final note on System Dynamics modeling is that it is not the only method to predict the financial impacts of decision aid implementation. Other modeling techniques such as Discrete Event Simulation or even econometric analysis may offer complementary or better insights (Butt, 2018).
The impact of decision aids was modeled by adjusting the treatment choice fraction in predefined scenarios (+6.7%, +11.7%, +16.7%). While this approach is transparent, it is still very primitive in nature. It also only presumes a 'positive' effect of decision aids on conservative treatment choices. These percentages also made it challenging to provide the reader with an easily comprehensible exposition of the research scenarios.

## Participant limitations

While expert interviews were conducted to inform the model and to interpret results, the number of participants was limited. Not all potential respondents were willing to participate in an interview or responded when contacted. This introduced a potential **selection bias**, as the insights gathered may not fully represent the broader population of healthcare professionals involved in decision aid implementation.

A final shortcoming of the study was determined through interview 8.
The PhD Researcher from interview number 8 pointed out that my research focus had a shortcoming in evaluating decision aids: "*A comprehensive research would not solely focus on the impacts of a decrease in surgical or conservative. It would also look at the type of conservative treatments*". She meant that a conservative treatment does not simply mean that patients do not receive any type of care. Conservative treatment could include pain management, physiotherapy and home-based care. By categorizing all conservative treatments under a single label, the model highly underestimates costs associated with conservative care for the society.

For future research I would advise to focus more on operational aspects of decision aid implementation. A shortcoming was the limited integration of hospital resources in the results. The results focused more on the financial implications through changes in DBCs. The KPI for care activity counts did shed some light on this aspect. However, due to the limited literature found on costs for surgeries as explained in the the discussion, the consequences of the changes in volumes of care activities did not offer a deep insight into the operational effects of decision aid implementation. If I had the opportunity to do the thesis again or to continue the research, I would prioritize finding more detailed data on salary costs, operating room utilization and maybe even time allocation per treatment path.

# Conclusion

By combining a literature review, stakeholder interviews, real-world NZa data and a System Dynamics simulation model, the study provides a comprehensive analysis of the operational and financial implications of Decision Aid implementation in Dutch hospitals. It aimed to answer the following question: **How do the costs of the implementation of a Decision Aid compare to its impact on a hospital's operational efficiency?**

There was a specific focus on hip fracture care and results demonstrated that shifts in treatment towards more conservative care leads to a measurable reduction in surgical interventions and care activities under ZPK 5. This shift can improve hospital efficiency by reducing resource strain on operating rooms, bed occupancy, staffing levels and more. However, under the current DBC -based reimbursement system, this operational gain translates into a significant reduction in surgical DBC income. Meaning that they create financial disincentives for hospitals, especially in the absence of structural support from insurers. Hospitals can make use of predictive tools such as System Dynamics modeling to forecast these impacts and to make more data-driven policy decisions. They can do this when they are evaluating trade-offs between clinical quality, operational efficiency and financial sustainability.

The first sub-question explored why hospitals must have insight into the operational outcomes of DA use. The findings clearly show that such insights are crucial. They allow hospitals to anticipate shifts in care activity distribution and reimbursements from insurers. They can either adjust their spending accordingly or enter negotiations with insurers with evidence-based arguments for more funding. The second sub-question asked which outcomes are universally important and which are context specific. The study shows that the impact of decision aids can be expressed through both care activity counts and through DBC income. DBCs are standardized units within Dutch Healthcare meant for reimbursement and are composed of care activities that are used in that specific department. However, care activities from ZPK 1 (such as 190060, 190013 and 190218) appear in DBCs across all departments within a hospital while care activities from ZPK 5 & 6 differ across departments. Finally, the third sub question focused on the actual impact decision aids have on these outcomes. It was found that the consequences of effective decision aid implementation results in fewer surgical DBCs and higher conservative DBCs. Resulting in lower financial reimbursement through the current financial model of Dutch Healthcare.

In conclusion, the implementation of decision aids presents a strategic trade-off: it improves the quality and appropriateness of care and may alleviate operational pressure, but it can negatively impact short-term hospital revenue. As hospitals are responsible for handling the prognosed increase in patient flow, they are also responsible for being financially sustainable. They should proactively provide evidence to insurers as to why value-driven outcomes may be effective incentives to tackle current healthcare challenges. By doing so they would advocate for different financial incentives which can help them bridge the transition period. If there is one thing this study has shown, it is that using ‘production’-based outcome measures poses significant challenges in transitioning to Value Based Healthcare.

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# Appendices

## Appendix A - ZPK table NZa

*Table 21: The ZPK groups and their descriptions as determined by the FMS.*

| ZPK | Description |
|---|---|
| 1 | Outpatient visit, first aid visit, and remote consultation |
| 2 | Day care |
| 3 | Clinic |
| 4 | Diagnostic activities |
| 5 | Surgical procedures |
| 6 | Other therapeutic procedures |
| 7 | Imaging Diagnostics |
| 8 | Clinical chemistry and hematology |
| 9 | Microbiology and parasitology |
| 10 | Pathology |
| 11 | Other laboratory procedures |
| 12 | (Para)medical and supportive functions |
| 13 | Special prosthetics and medical aids |
| 14 | Rehabilitation |
| 15 | Blood products |
| 16 | Geriatric rehabilitation |
| 17 | Complex chronic lung diseases |
| 18 | ICU care activities other than ICU treatment days |
| 19 | ICU treatment day |
| 23 | Tissue products |
| 79 | Other clinical days |
| 89 | Other healthcare activities related to derivation |
| 99 | Not included in profile |

# Appendix B - Consent form

**Purpose of the Study**
This study is conducted as part of a Master Thesis at TU Delft. In the study the impact of Decision Aids on a hospital will be evaluated. There are two main research methods which entail conducting interviews and modelling. The result of the study will be an insight into the effects of Decision Aids (that support Shared Decision Making)

**Role of participants and interviews in study**
As a participant, you will be invited to share your expertise on how you or your hospital evaluates the impact of Shared Decision Making and Decision Aids. The purpose of the interview is to gain insights into how hospitals assess the value of innovations like Decision Aids. The findings from the interview will help identify key outcome measures to develop a model that replicates the effects of Decision Aid implementation on hospital operations.

**Data Storage and Access**

- The collected interview data will be securely stored on servers at TU Delft.
- Only the researcher and their academic supervisors will have access to the raw interview recordings or transcripts.
- Partners of the study will not have access to all interview data. Only the responsible investigator conducting the interview will have full access to the data.
- Summaries of the interviews may be made publicly available, but these summaries will not contain any information that could identify participants or their specific statements.

**Anonymity and Confidentiality**

- Your statements and identity will not be traceable in any outputs or publications resulting from this research.
- Quotes or perspectives you provide may be used in research outputs but will always be presented anonymously.

**Data Retention**

- Interview recordings or transcripts will be retained only for the duration of the research and will be deleted one month after the completion of the study.

**Voluntary Participation**

- Participation in this interview is entirely voluntary.
- You may withdraw at any time, and there is no obligation to answer any questions that make you feel uncomfortable. If you wish to retract yourself from the study after the interview is conducted please let your wish be known

# Appendix C- Interview Guide

**Vormgeving Interviews:**
Er is een behoefte om met stakeholders over Samen Beslissen in gesprek te gaan. Er moet inzicht verkregen worden over hoe ziekenhuizen de impact van keuzehulpen beoordelen.

**Doel scriptie:**
Het eindproduct van de scriptie zal een raamwerk bedragen dat gebruikt kan worden door ziekenhuizen om de invloed van keuzehulpen te beoordelen. De interviews die uitgevoerd worden mogen maximaal 30 minuten bedragen.

Het verkrijgen van inzicht heeft als doel:

- Inventarisatie van belangrijke uitkomstmaten wat betreft keuzehulp beoordeling
- Inzicht in hoeverre er **behoefte** is om inzicht te verkrijgen in de effecten van keuzehulpen
- Inzicht krijgen over **welke effecten** van belang zijn om keuzehulpen te beoordelen
- Consistente data verzamelen van verschillende respondenten
- Focus behouden gedurende de interviews
- De interview guide kan helpen om de interview aan de context van de stakeholder aan te passen

<table>
<tr><th colspan="2">Ziekenhuisbrede visie en vraag</th></tr>
<tr><td>1</td><td>Is er een beleid op de implementatie van keuzehulpen?</td></tr>
<tr><td>2</td><td>Waarom is er wel/geen beleid opgesteld? (barriers & facilitators)</td></tr>
<tr><td>3</td><td>Voor welke ziektebeelden gebruikt het huis keuzehulpen?<br><br>OF<br><br>Bij welke ziektebeelden zou het huis keuzehulpen willen implementeren?</td></tr>
<tr><td>4</td><td>Wat zijn de speerpunten in het beleid van Samen Beslissen bij het ziekenhuis?</td></tr>
<tr><td>5<br><br>Indien geen beleid</td><td>Welke stakeholders zijn betrokken bij de implementatie van keuzehulpen?<ul><li>RvB</li><li>Medisch bestuur/staf</li><li>Management</li><li>Ondersteunende diensten (K&I, F&C etc)</li></ul></td></tr>
<tr><td>6<br><br>Indien wel beleid<br><br>Controle of de juiste stakeholder geinterviewd wordt</td><td>Welke stakeholders zijn betrokken bij het opstellen van het beleid keuzehulpen?<ul><li>RvB</li><li>Medisch bestuur/staf</li><li>Management</li><li>Ondersteunende diensten (K&I, F&C etc)</li></ul></td></tr>
<tr><td>7<br><br>Hulpvragen</td><td>Het kan zijn dat het interview stroef verloopt in dat geval kunnen de volgende hulpvragen gesteld worden:<br><br>Wat zijn bij deze ziektebeelden (vastgesteld in vraag 3) op operationeel niveau de knelpunten?<ul><li>wachttijden</li><li>inzet personeel</li><li>klachten patiënten</li><li>Bewustzijn personeel/patiënten</li></ul>Is een vermindering van het aantal aanvullende consulten in de ‘journey’ van een patiënt belangrijk?<br><br>Wat zouden barrières/facilitators zijn om keuzehulpen te implementeren?<br>Zijn er bestaande initiatieven binnen het huis mbt de inzet van keuzehulpen?</td></tr>
</table>

| Keuzehulp vragen (ziekenhuisbreed) | |
|---|---|
| 1 | Welke criteria zou u belangrijk vinden om hun invloed te beoordelen (bijv. patiënttevredenheid, operationele efficiëntie, kosten)? |
| 2 | Hoe zou uw ziekenhuis de effecten van keuzehulpen kunnen monitoren op processen zoals wachttijden en consultfrequenties? |
| 3 | Als keuzehulpen beschikbaar zouden zijn, hoe zou u beoordelen of patiënten beter geïnformeerd en tevreden zijn over hun behandeltraject? |
| 4 | Hoe zou uw ziekenhuis willen evalueren of keuzehulpen patiënten voldoende ondersteunen bij het maken van behandelkeuzes? |
| 5 | In hoeverre denkt u dat keuzehulpen zouden kunnen bijdragen aan een efficiëntere zorgverlening? Hoe zou u dit willen meten? |
| 6 | Stel dat keuzehulpen helpen patiënten beter te spreiden over behandelopties (bijv. conservatief versus invasief). Hoe zou uw ziekenhuis dat willen evalueren? |
| 7 | Hoe zou uw ziekenhuis de financiële impact van keuzehulpen willen evalueren, bijvoorbeeld in termen van besparingen op zorgkosten of efficiënter gebruik van middelen? |
| 8 | Als uw ziekenhuis zou overwegen keuzehulpen te implementeren, welke voordelen zouden essentieel zijn om een positieve businesscase te rechtvaardigen? |
| 9 | Als keuzehulpen zouden worden geïntroduceerd, hoe zou uw ziekenhuis feedback van patiënten en zorgverleners willen verzamelen om deze tools te verbeteren? |
| 10 | Welke indicatoren zou uw ziekenhuis in de toekomst belangrijk vinden om de waarde van keuzehulpen beter te begrijpen? |

# Appendix D - NZa Open Portal: Identified care activities and DBCs

*Table 22: Incorporated Care activity codes from the NZa open portal.*

| Care activity code | ZPK | Description | Conservative/Invasive |
|---|---|---|---|
| 190060 | 1 | First outpatient visit (or consultation) | - |
| 190013 | 1 | Follow-up consultation | - |
| 190218 | 3 | Clinic day | - |
| 038528 | 6 | Conservative treatment of a fracture of the femoral neck | Conservative |
| 038533 | 5 | Surgical treatment of a femoral neck fracture. | Invasive |
| 038534 | 5 | Surgical treatment, regardless of technique, of a femoral shaft fracture, or a supracondylar/transcondylar fracture and/or distal epiphysiolysis. | Invasive |
| 038535 | 5 | Surgical treatment of a per- and intertrochanteric femur fracture. | Invasive |
| 038565 | 5 | Replacement of the femoral head | Invasive |
| 038567 | 5 | Replacement of the femoral head and the acetabulum | Invasive |
| 038570 | 5 | Revision of a component of the hip prosthesis | Invasive |

*Table 23: DBC results from after selecting diagnosis of Femur, Proximal (+ Collum) on the NZa website.*

| **Department codes** | **0303** | **0305** |
|---|---|---|
| Diagnosis codes: **Femur, Proximal (+ Collum)** | 218 | 3019 |
| **DBC code** | **Number of patients** | **Number of patients** |
| 199299044 | 7270 | 2432 |
| 199299115 | 6743 | 5365 |
| 199299038 | 2792 | 2931 |
| 199299114 | 2629 | 1310 |
| 199299015 | 978 | 462 |
| 199299009 | 386 | 353 |
| 199299043 | 383 | 57 |
| 199299024 | 324 | 175 |
| 199299037 | 61 | 188 |
| 199299026 | - | 1813 |
| 199299113 | - | 73 |

*Table 24: DBC results after selecting diagnosis of Femur (Remaining) on the NZa website.*

| **Department codes** | **0303** | **0305** |
|---|---|---|
| Diagnosis codes:<br>**Femur (Remaining)** | 219 | 3020 |
| **DBC code** | **Number of patients** | **Number of patients** |
| 199299120 | 1774 | 1379 |
| 199299054 | 1580 | 857 |
| 199299119 | 987 | 696 |
| 199299013 | 202 | 268 |
| 199299018 | 176 | 188 |
| 199299053 | 163 | 41 |
| 199299118 | 139 | 74 |
| 199299088 | 43 | - |

*Table 25: DBC results after filtering for surgery and diagnosis code 218*

| **Department code** | **Diagnosis code: Femur, Proximal (+ Collum)** | |
|---|---|---|
| 0303 | 218 | |
| **DBC code** | **Number of patients** | **Average reimbursement** |
| 199299044 | 7270 | 8760 |
| 199299115 | 6743 | 210 |
| 199299038 | 2792 | 10270 |
| 199299114 | 2629 | 600 |
| 199299015 | 978 | 2445 |
| 199299009 | 386 | 10540 |
| 199299043 | 383 | 4005 |
| 199299024 | 324 | 6925 |
| 199299037 | 61 | 4660 |

*Table 26: DBC results after filtering for surgery and diagnosis code 219*

| **Department code** | **Diagnosis code: Femur (Remaining)** | |
|---|---|---|
| 0303 | 219 | |
| **DBC code** | **Number of patients** | **Average reimbursement** |
| 199299120 | 1774 | 295 |
| 199299054 | 1580 | 11915 |
| 199299119 | 987 | 610 |
| 199299013 | 202 | 2465 |
| 199299018 | 176 | 7120 |
| 199299053 | 163 | 5725 |
| 199299118 | 139 | 1065 |
| 199299088 | 43 | 10210 |

*Table 27: DBC results after filtering for Orthopedics and diagnosis code 3019*

| **Department code** | **Diagnosis code: Femur, Proximal (+ Collum)** | |
|---|---|---|
| 0305 | 3019 | |
| **DBC code** | **Number of patients** | **Average reimbursement** |
| 199299115 | 5365 | 210 |
| 199299038 | 2931 | 10270 |
| 199299044 | 2432 | 8760 |
| 199299026 | 1813 | 12340 |
| 199299114 | 1310 | 600 |
| 199299015 | 462 | 2445 |
| 199299009 | 353 | 10540 |
| 199299037 | 188 | 4660 |
| 199299024 | 175 | 6925 |
| 199299113 | 73 | 880 |
| 199299043 | 57 | 4005 |

*Table 28: DBC results after filtering for Orthopedics and diagnosis code 3020*

| **Department code** | **Diagnosis code: Femur (Remaining)** | |
|---|---|---|
| 0305 | 3020 | |
| **DBC code** | **Number of patients** | **Average reimbursement** |
| 199299120 | 1379 | 295 |
| 199299054 | 857 | 11915 |
| 199299119 | 696 | 610 |
| 199299013 | 268 | 2465 |
| 199299018 | 188 | 7120 |
| 199299118 | 74 | 1065 |
| 199299053 | 41 | 5725 |

# Appendix E - Model components

*Table 29: stocks in model*

| Stocks |
|---|
| Patients |
| Orthopedic Surgeons |
| Available OR Rooms |
| Surgery Queue |
| Patients |
| Patients occupying beds |
| Patients treated |
| First consult (190060) **(ZPK 1)** |
| Follow-up Consult (190013) **(ZPK 1)** |
| 038533 **(ZPK 5)** |
| 038534 **(ZPK 5)** |
| 038535 **(ZPK 5)** |
| 038565 **(ZPK 5)** |
| 038567 **(ZPK 5)** |
| 190218 **(ZPK 3)** |
| 038528 **(ZPK 6)** |
| 199299009 |
| 199299013 |
| 199299015 |
| 199299018 |
| 199299024 |
| 199299026 |
| 199299037 |
| 199299038 |
| 199299043 |
| 199299044 |

| |
|---|
| 199299053 |
| 199299054 |
| 199299113 |
| 199299114 |
| 199299119 |

*Table 30 Patient flow variables and their description. (1)*

| Flow | Content |
|---|---|
| Total flow patients | Patients treated invasively+Patients treated conservatively |
| Inflow of patients | IF THEN ELSE(Patients occupying beds < Max Bed Capacity,Inflow rate, 0) |
| Inflow rate | RANDOM UNIFORM( 0.55 , 0.75, 0 ) |
| Patients treated invasively | Inflow of patients*(1-Fraction treatment choice) |
| Patients treated conservatively | (Inflow of patients*Fraction treatment choice)/Treatment duration conservative |
| Inflow repeating consultations | (Follow up consultation Rate Conservative*Patients treated conservatively)+(Patients treated invasively*Follow up consultation rate invasive) |
| Hiring surgeons | 0 |
| Leaving surgeons | 0 |
| OR’s released | DELAY FIXED(Surgeries performed, average surgery duration, 0) |
| OR’s occupied | Surgeries performed-OR's released |
| Patients to be treated | Patients treated invasively |
| Surgeries performed | Surgery Queue |
| Patients discharged | Patients to be treated-Surgeries performed |
| Patients admitted | IF THEN ELSE(<br>Patients occupying beds < Max Bed Capacity,<br>IF THEN ELSE(<br>Surgery Queue + Surgeries performed <= Max Bed Capacity - Patients occupying beds,<br>MIN(Surgery Queue + Surgeries performed, Max Surgeries per day),<br>MIN(Max Bed Capacity - Patients occupying beds, Max Surgeries per day)<br>),<br>0<br>) |

*Table 31: Patient flow variables and their description. (2)*

| Variable | Ratio |
|---|---|
| 38533 | 0.19 |
| 38534 | 0.06 |
| 38535 | 0.32 |
| 38565 | 0.35 |
| 38567 | 0.11 |
| Follow up rate conservative | 0.596 |
| Follow up rate invasive | 0.302 |
| Average stay rate | 6.5 |
| Max operations per surgeon per day | Random uniform (3, 5, 0) |
| Max operations per OR per day | Random uniform (4, 6, 0) |
| Max surgeries per day | MIN(Available OR Rooms * Max operations per OR per day, Orthopedic Surgeons * Max operations per surgeon per day) |
| Average surgery duration | 0.13*24 |
| Max Bed Capacity | 10 |
| Treatment duration conservative | 4.8 |
| Fraction Conservative | 0.05 |
| Fraction treatment choice | MAX(0, MIN(1, Fraction Conservative + Use of Decision Aids)) |
| Use of Decision Aids | 0.05-0.10 (%) |
| Discharge rate | DELAY FIXED(Patients occupying beds / Average stay rate 2, Average stay rate 2, 0) |

# Appendix F – Data incorporation in SD model

The construction of the model followed the problem definition and the conceptual model development. Each variable was informed by literature, expert interviews and data from the NZa open portal.
The causal loop diagram was used to identify key variables, this is extensively detailed in the results section. The translation involved defining stocks, flows, auxiliary variables and more. To accurately distribute patient flows across treatment pathways, the **ratio of care activities** within DBCs were analyzed. This analysis provided insight into how frequently certain care activities occur within DBCs. This allowed for the model to reflect realistic distributions of patients across the DBCs. The entire model is detailed in the results section.
The flowchart in Figure 5 represents the data selection and processing steps for incorporating data from the NZa open portal into the SD model. The initial dataset included a broad collection of care activities and care products (DBCs). These were retrieved through application of the filters detailed in table 5. The first decision point was to distinguish DBCs from care activities. If the datapoint was a DBC the next step was to determine whether the DBC description was relevant to the study. A relevant DBC resulted in incorporation in the final SD model in the form of a stock. If the DBC was not relevant to the study the DBC was excluded from the final data selection. If the datapoint was not a DBC and it was a care activity, a check was done to see whether the care activity belonged in relevant care profile classes (ZPKs). The ZPK codes were chosen based on their direct relevance to the decision aid impact on hospital operations. Care activities grouped under ZPK 1 were deemed relevant as these care activities entail consultations between clinician, patient and family. Care activities from ZPK 3 (Inpatient days) and 5 (Surgical procedures) were included as the length of stay and surgical treatments both are efficiency metrics which affect resource utilization, bed capacity and costs. Care activities from ZPK 6 were chosen as these cover non-surgical treatments, in SDM some patients may opt for non-operative management instead of surgical treatment. Including this category ensures that the model can capture shifts between surgical and non-surgical treatments.

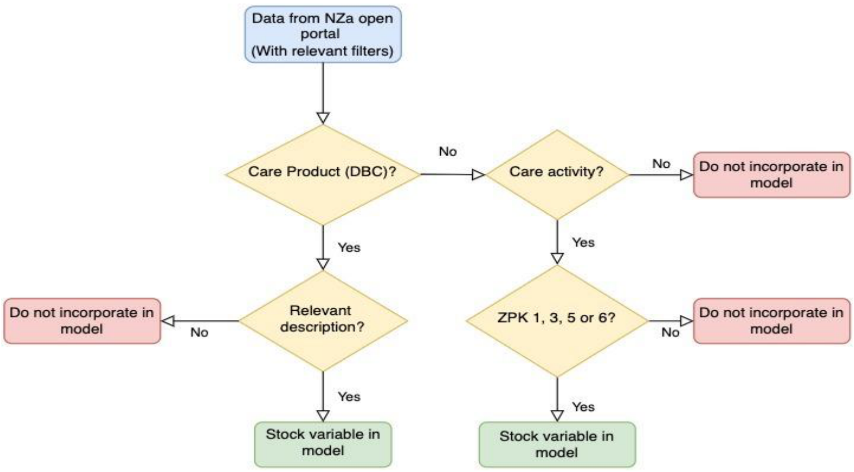

*Figure 28: data selection process from the NZa for incorporation in System Dynamics model*

With these variables and stocks defined the next phase focused on translating them into a system dynamics structure to explore the effects of decision aids on hospital operations.

# Appendix G – DBC's included in the study and their descriptions.

The DBC's introduced in section 3.3.3 are presented in table. These definitions are a literal translation of their Dutch definition presented on Opendisdata.nza.nl.

*Table 32: Definition of the DBCs included in the study ordered numerically*

| DBC | Description |
|---|---|
| 199299009 | Insertion of a long femoral neck prothesis for a femoral fracture |
| 199299013 | Hospital admission with a maximum of 5 inpatient days for injury |
| 199299015 | Hospital admission with a maximum of 5 inpatient days for a femoral fracture |
| 199299018 | Hospital admission with a 6 to maximum of 28 inpatient days for injury |
| 199299024 | Hospital admission with a 6 to maximum of 28 inpatient days for a femoral fracture |
| 199299026 | Insertion of a hip prothesis during hospital admission for a femoral fracture |
| 199299037 | Insertion of a short femoral neck prosthesis for a femoral neck fracture |
| 199299038 | Insertion of a short femoral neck prosthesis during hospital admission for a femoral fracture |
| 199299043 | Surgery in the hip and/or pelvis for a femoral fracture |
| 199299044 | Surgery on the hip and/or pelvis during hospital admission for a femoral fracture |
| 199299053 | Extensive surgery of the pelvis and/or hip for injury |
| 199299054 | Extensive surgery of the pelvis and/or hip during hospital admission for injury |
| 199299113 | Diagnostics/procedure and more than 3 outpatient visits/remote consultations for a fractured hip |
| 199299114 | Diagnostics/procedure and/or more than 2 outpatient visits/remote consultations for a fractured hip |
| 199299119 | Diagnostics/procedure and/or more than 2 outpatient visits/remote consultations for injury |