BSC THESIS INDUSTRIAL ENGINEERING AND MANAGEMENT

ASSESSING THE EFFECT OF A VIRTUAL CARE CENTRE ON CAPACITY IN AN OPAT CARE PATHWAY

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Assessing the Effect of a Virtual Care Centre on Capacity in an OPAT Care Pathway

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Preface

Dear reader,

Before you lies my bachelor thesis, which I have written to conclude the Bachelor of Industrial Engineering and Management at the University of Twente. For a little over half a year, I have been working on this thesis. Although it was difficult at times to take on such a big research problem on my own, it was also very interesting and it taught me a lot about myself. I want to thank everybody who has supported me during the process of conducting this research and writing this bachelor thesis.

I want to thank Isala Hospital for giving me the opportunity to work on this assignment and providing me with the necessary support. It was a very interesting challenge to apply my knowledge in a previously unknown field, and I learned a lot from it. I hope my research will prove useful in the hospital's future.

Most importantly, I want to thank my supervisors, without whom the completion of this thesis would not have been possible. Jedidja, who served not only as a supervisor from Isala but also provided valuable insights from her experience studying at the UT. Your guidance was invaluable, especially during moments when I was struggling to stay motivated, and your infectious enthusiasm contributed to my enjoyment of this assignment. After all these months, I am still amazed at your infinite amount of patience with me. Gréanne, I express my thanks for your constructive criticism and support with important decisions. It was very valuable to get a chance to work with such an experienced supervisor. Sebastian, thank you for your interest in my research topic and the extensive feedback you provided, which greatly enhanced the quality of this work.

Lastly, I want to thank my friends and family, who helped me tremendously throughout this project. Your support and encouragement played a huge role in navigating the challenges of the past few months.

Marijke Agaart

Enschede, November 2023

Management Summary

Introduction

Isala Hospital is a prominent medical facility that offers high-quality care across various specialties. Demographic changes and staff shortages have led to a capacity issue in healthcare, prompting Isala to establish the Connected Care Centre, which focuses on bringing hospital-level care to patients' homes. One significant initiative within the Connected Care Centre is the Virtual Care Centre (VCC). The research uses the medication@home project within department X as a case study. This project focusses on patients who have undergone surgery X, after which they present with an infection. We identified a lack of literature on VCCs' impact on healthcare capacity and Outpatient Parenteral Antimicrobial Therapy (OPAT) care pathways, motivating the study's significance.

The research design is based on a problem identification method, culminating in the main research question:

"What effect does the implementation of a virtual care centre in an OPAT care pathway have on the capacity of transmural care organised by Isala?"

Capacity in Healthcare

In literature, hospital capacity used to be described as the upper limit of a hospital's performance, often measured by KPIs such as bed occupancy rates and patient throughput. However, the evolving healthcare landscape necessitates a broader understanding of capacity assessment, considering the shift toward community-based and home-centred care. Therefore, the concept of capacity is redefined as 'a description of the pathways travelled by patients followed by identification of those elements that can constrain them', emphasizing the availability to deliver processes rather than mere bed numbers (Rechel et al., 2010).

In this context, we emphasize the importance of assessing health outcomes, including survival rates, readmissions, time between discharge and readmissions, and quality of life. For the case study, specific KPIs are selected, which are the Length of Stay, Duration of OPAT, Total working time of healthcare professionals per patient, Wage costs per patient, and Number of Readmissions. These KPIs provide a comprehensive framework for evaluating capacity and performance in the medication@home project within department X.

Methods

The research design consists of many different components, all using information gathered from different sources and from the results of previous steps. In the flow diagram below we visualise these different components, from defining OPAT care pathways using literature to performing our final data analysis (Figure 0). The results from each component provide information used in the next component, which is connected by an arrow. Data gathered from external sources is shown in blue.

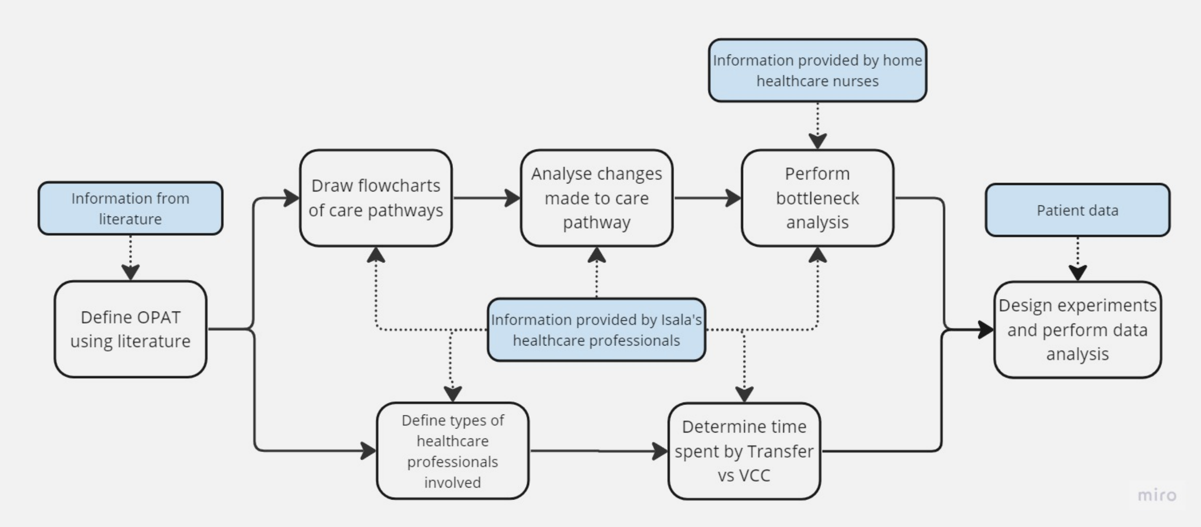

Figure 0: Flow diagram of methods used

Results

Our research considers the impact of the intervention on the capacities used throughout the OPAT care pathway. In the conventional pathway, patients with infections experienced hospitalization, a transition to home healthcare, and lab tests. The intervention pathway streamlined antibiotic delivery, improved discharge flexibility, and implemented a VCC with a directing role for post-discharge patient care. Notable changes included revised discharge deadlines, VCC's involvement in arranging laboratory tests, and altered transfer agency responsibilities. While the care pathway after the intervention appears more streamlined, it also introduces new challenges, primarily a communication bottleneck that requires attention. Furthermore, unrelated challenges in documentation, material supply, and communication gaps among patients, home healthcare nurses, and VCC nurses warrant consideration to optimize the care pathway effectively.

The data analysis of the Connected Care intervention in the OPAT setting in care pathway X at Isala reveals several findings. The Length of Stay was reduced by 1.4 days, indicating enhanced efficiency. Conversely, the Duration of OPAT increased by 0.8 days, signifying a shift from inpatient to outpatient treatment. Total Working Time of Healthcare Professionals shifted, with less time spent by medical specialists and secretaries and more by VCC nurses. The data suggests an overall reduction in working time of 25 minutes per patient when we compare the control and intervention groups. Wage Costs per patient decreased, particularly in an optimistic scenario aimed at minimizing communication issues, which makes for a €21 per patient decrease compared to the control group. Although a slight decrease in Number of Readmissions, from 26% to 23% in the intervention group, is calculated, the small sample sizes limit the statistical significance of these findings.

Conclusion

In conclusion, this study examined the impact of the Connected Care intervention, which introduced a VCC into the OPAT care pathway in department X at Isala Hospital. While little statistical significance was achieved, several practical insights were gained. Notably, the intervention demonstrated a reduced length of stay of 1.4 days, cost savings of €21 per patient, and fewer readmissions (26% before, and 23% after intervention), suggesting the promise of the virtual care pathway. This research recommends to continue the use of the VCC, with further research to solidify its effectiveness. Improvement in communication among stakeholders within the care pathway is essential, as is the development of a structured framework for assessing project effectiveness.

The healthcare system is complex and requires continuous assessment and adjustment to improve care pathways and increase efficiency. Following these recommendations can improve healthcare provision and the quest for more efficient and effective healthcare systems.

The overall results do not show significant differences in wage costs per patient between experiments, though they demonstrate the potential for cost savings with the implementation of the VCC.

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List of Abbreviations

ABBREVIATION	MEANING	PAGE
AB	Antibiotics	23
ADL	Algemene Dagelijkse Levensverrichtingen	22
CCC	Connected Care Centre	8
KPI	Key Performance Indicator	10
LOS	Length Of Stay	29
OPAT	Outpatient Parenteral Antibiotic Therapy	8
PA	Physicians Assistant	19
PICC	Peripherally Inserted Central Catheter	21
SD	Standard Deviation	31
VCC	Virtual Care Centre	8

1 Introduction

This research is executed in the Connected Care Centre (CCC) of Isala Hospital in Zwolle. This chapter discusses Isala Hospital, the CCC, the virtual care centre (Section 1.1), and the challenges experienced in the measurement of capacity in healthcare (Section 1.2). Lastly, we describe the research design we use to answer our research questions (Section 1.3).

1.1 About Isala

Isala Hospital is a large general hospital with its main location in the city of Zwolle in the Netherlands. It is one of the largest hospitals in the country, serving a wide range of medical specialties and providing high-quality medical care to patients from the surrounding regions. The hospital's goal is to continuously improve its services through research and education. They aim to do this under the motto ‘close if possible, further away if necessary’ (Isala, 2023).

Because of demographic changes like population aging, combined with a general shortage of staff in healthcare, there is a lack of capacity in hospitals. This problem is expected to keep growing in the coming years (CBS, 2023; KPMG, 2020). To combat this problem, Isala has founded the Connected Care Centre, a dedicated programme focusing on creating capacity in hospitals by moving hospital-level care (close) to the home situation of the patients. The centre aims to help patients recover and manage their health conditions at home, where they can be more comfortable and independent. The Connected Care Centre provides a range of services, such as remote monitoring, telemedicine, and home visits by home healthcare professionals.

On the 1st of November 2021, the Connected Care Centre established a virtual care centre called the Medisch Coördinatie Bureau (English: Medical Coordination Office). During the COVID-19 pandemic, this department started monitoring patients that went home with extra oxygen. Their work has been extended to arranging virtual care like telemonitoring and parenteral medication administration at home (so-called medication@home) for various care pathways. In this report, Isala’s virtual care centre (VCC) refers to the Medisch Coördinatie Bureau.

In this research, we focus on one of the medication@home projects that is part of department X. This department particularly addresses patients who have undergone like procedure 1 and procedure 2. Following such surgeries, patients can potentially contract an infection, which is also treated within this department. This means that a patient needs a second surgery, after which they receive intravenous antibiotic therapy to treat the infection. The medication@home project focuses on discharging these patients earlier and organizing the outpatient administration of antibiotics by home healthcare organizations. The parenteral administration of antibiotics at a patient’s home is known as Outpatient Parenteral Antimicrobial Therapy (OPAT), a term we use throughout this report. We will describe this care pathway as the OPAT care pathway in department X, or as care pathway X. Previously, care pathway X was organised by the transfer agency of the hospital, but since 2022 it has been organised by the VCC. Since this change in management, some adjustments have been made to optimize the care pathway even more and free up extra hospital capacity.

1.2 Research Motivation

In literature, virtual care centres are a known concept, used increasingly around the world. The performance of these centres has been assessed in aspects related to the implementation and scalability (Gracanin et al., 2019), yet we can find little information about the effects these centres have on the capacity of healthcare systems. Furthermore, there is a lot of information available about the use of OPAT care pathways, since they have been used for more than 40 years already. Shorter inpatient hospital stays are reported after OPAT implementations(Williams et al., 2015), yet it is unclear exactly by how much the length of stay is reduced. Moreover, to the best of our knowledge, there has not been research on the capacity of human resources in an OPAT setting. Lastly, the use of a virtual care centre within an OPAT care pathway is also a new practice, meaning that little is known about how effective it is. This, in combination with the lack of research into human resource capacity, makes our research a good addition to the existing literature.

In Isala, we find the medication@home project in department X, which is a project that combines the use of a virtual care centre with an OPAT care pathway. As we find a gap in existing literature for this combination, we want to perform a case study on this project to find out whether the use of a VCC is beneficial for the hospital capacity. The outcomes of the study may influence decisions pertaining to the hospital's strategic resource capacity planning (Hans et al., 2012). Furthermore, the knowledge gained from this case study can then be applied to other medication@home projects within Isala, and to similar projects in other hospitals.

The goal of medication@home projects is to free up capacity in the hospital for other patients. It has been claimed that with the implementation of the VCC in the OPAT project in department X, the length of stay of each patient has been reduced by 1.8 days. If this were true, it would mean that fewer physical and human resources are used in the hospital, meaning an increase in capacity. However, there is no proof of this claim yet, as there is very little insight into this project's impact on the capacity of the different parties involved. Furthermore, we do not know whether this reduction in length of stay would result in an overall increase in capacity, as we also have to take into account potential extra work for VCC nurses and home healthcare nurses. With this research, we gain the information necessary to determine the effects on capacity, and therefore support creating the most efficient care pathways.

1.3 Research Design

In this sub-chapter, we first define the research questions, together with a short explanation of the research design for each question (Section 1.4.1). Next, we describe the scope of our research in Section 1.4.2.

1.3.1 Research Questions

To get to our main research question, we follow steps from the managerial problem-solving method (MPSM) which is described by Heerkens & van Winden(2017). This is an established method used to move from an action problem towards a core problem with the help of a problem cluster (Appendix A). Based on this core problem, which is a root cause for the problem experienced by the stakeholder, we define research questions.

We want to work towards creating more capacity in hospitals with projects that organise more care at a patients home. To do this, more research into the performance of these alternative care pathways needs to be done. Therefore, the core problem we focus on in this research is the lack of insight into the performance of alternative care pathways, in our case the OPAT pathway in department X specifically. To solve this problem, we come to the following main research question:

What effect does the implementation of a virtual care centre in an OPAT care pathway have on the capacity of transmural care organised by Isala?

Here, transmural care is defined as care provided by nurses within the hospital, monitoring nurses working for the virtual care centre, and home healthcare nurses. To answer this question, we define four sub-questions to guide the research and answer our main research question.

1. What assessment methodology is the most effective to gain insight into capacity changes for all involved parties?

To choose the most fitting methodology, we answer the following questions:

a. *What is the best assessment methodology to select based on the requirements?*
b. *Which Key Performance Indicators (KPIs) effectively describe the capacity of the different organizations involved?*

We perform a literature review to identify relevant studies and publications that use KPIs in a healthcare setting. Based on this we make an overview of all KPIs that are suitable in this case.

2. How is the OPAT care pathway in department X of Isala organised?

Since the virtual care centre is already coordinating the OPAT care pathway, we can analyse both the situation before and after this change was made. This brings us to the following sub-questions:

a. *What did the care pathway look like before the Connected Care intervention?*
b. *What does the care pathway look like now, after the Connected Care intervention?*
c. *In what ways does the Connected Care intervention influence the care pathway?*

To answer questions a and b, the first step is to thoroughly read through any relevant documents that relate to department X in Isala Hospital and the medication@home care pathway. This helps to provide a baseline understanding of the hospital's processes and procedures. Subsequently, we interview employees to confirm the gathered insights, and to fill in any gaps in the information. Based on the gathered information, we visualize both situations in separate flowcharts. To accurately define what areas of the care pathway are changed, we compare the flowcharts, and discuss with employees. This is done by interviewing employees of the Connected Care Centre, the Transfer agency, the VCC, and home healthcare organizations.

3. How can we use the chosen assessment methodology to gain insight in the capacity changes of the OPAT care pathway?

We answer this sub question by carrying out the chosen assessment methodology, based on given data and requirements. To do this we need to answer two questions:

a. *What data is available and what is the quality of the data?*
b. *What capacity changes can we find when we analyse the data of the OPAT care pathway?*

We need to find out what data is available and if the quality of this data is sufficiently high to perform the data analysis. We discuss this with the data management team of Isala, and perform statistical tests.

Once we have the data we perform a data analysis based on the assessment methodology. This involves reviewing the data and identifying any patterns or trends. The output of this analysis is described with the help of graphs to visualise data.

4. What recommendations can be given to Isala regarding the implementation of the virtual care centre in an OPAT care pathway?

We make recommendations based on the results of our analysis. These recommendations can help to improve the care pathway or to make decisions on whether the virtual care centre should be organised as it is.

1.3.2 Research Scope

For this research project, there are some clear boundaries. The virtual care centre is monitoring many different projects within the Isala Hospital, yet, due to time constraints, we cannot assess the effect it has on all of these projects. Therefore, we focus on the OPAT care pathway of department X of Isala Hospital. As explained in Section 1.2, we perform a case study on this project as it makes for an interesting addition to literature currently available about the subjects of virtual care centres and OPAT.

Although we want to include data from home healthcare organisations in our research, we decide not to, for two reasons. First, according to a home healthcare nurse, the intervention in the care pathway was hardly noticeable for them, meaning that it likely did not have any major effect on time spent. Next to this, it is very complicated to gather data about the home treatment of these patients, as this data is not available for Isala Hospital.

The study encompasses patients treated for various infections in department X at Isala Hospital. It includes patients who have been discharged with intravenous antibiotics pumps after undergoing various surgical interventions for this diagnosis. No patients are excluded based on their specific characteristics, except in cases where insufficient data is available. The dataset primarily comprises information related to care activities, appointments, admissions, medication, and essential demographic data, including gender and age.

The handling and description of confidential information used in this study strictly adheres to the Dutch Algemene Verordening Gegevensbescherming (AVG) or General Data Protection Regulation (GDPR). Patient data used in this study is anonymized and processed in full compliance with the Dutch AVG regulations to protect patient privacy. All personally identifiable information is safeguarded to ensure that individual identities remain undisclosed throughout the research process. As we have taken the necessary precautions to ensure the research adheres to ethical standards, it has been approved by ethical committees from the University of Twente and Isala (Appendix B).

1.4 Conclusion

This study evaluates the impact of the implementation of a Virtual Care Centre (VCC) on the overall performance of care pathway X in the medication@home project. It addresses the knowledge gaps in understanding VCCs' impact on healthcare system capacity. Additionally, it aims to gain insights in the inclusion of a VCC in OPAT care pathways, to find the effects on patient length of stay and human resource capacity. The research involves a context analysis, bottleneck identification, and a data analysis that includes experiments to evaluate the VCC's effect on various key performance indicators in care pathway X.

2 Capacity in Healthcare

In this chapter we aim to get a better understanding of capacity in healthcare. With the help of a literature study we define capacity in healthcare, find the best way to assess this capacity and define indicators to help us measure performance in our case study. The chapter consists of a literature review (Section 2.1) and the definition of key performance indicators (Section 2.2).

2.1 Literature Review

A lot of research into hospital capacity has been done in the past. This allows us to gain valuable insights to help us assess capacity for our research. In literature, hospital capacity is defined as 'an upper bound that describes the best possible performance of the hospital in terms of productivity' (Burdett & Kozan, 2016). Productivity can be measured as output, or the number of patients treated (Humphreys et al., 2022). Capacity assessment can give valuable insight into required resources like staff and equipment, which is necessary to make decisions on strategic, tactical and operational level (Elkhuizen et al., 2007). A relatively new way of measuring capacity makes use of measurable health outcomes. As health outcomes can be useful in our research we elaborate on them in Section 2.1.2.

2.1.1 Capacity Assessment in Hospitals

The evaluation of hospital capacity has been the subject of extensive research in numerous prior studies (Burdett & Kozan, 2016; Humphreys et al., 2022; Masoompour et al., 2015; McCaughey et al., 2015). Many mathematical frameworks have been developed, for example to calculate nursing staff capacity and to describe opportunities for improvement of the processes (Elkhuizen et al., 2007). In another paper, Burdett et al. (2016) introduced an approach that not only assesses the theoretical capacity of an entire hospital but also devised a linear programming model aimed at aiding hospitals in their capacity planning and resource allocation endeavours. A common characteristic of these capacity models is the use of key performance indicators (KPIs) (Bahadori, 2011a; Franklin et al., 2023; Hilker et al., 2022). Capacity assessment in hospitals traditionally relies on KPIs to gauge their operational efficiency. These KPIs encompass metrics such as bed occupancy rates, patient throughput, and resource utilization. While these indicators provide valuable insights into hospital performance, they often fall short in capturing the broader healthcare landscape's complexities.

Modern healthcare is no longer confined to the walls of a hospital. The paradigm shift towards community-based and home-centred care has disrupted capacity assessment frameworks solely based on capacity within the hospital. In our case, a reduction in hospital workload might translate to a substantial increase in demand for home healthcare services. This dynamic shift is inherently challenging to quantify and assess solely through conventional KPIs.

An important paper recognising the need for new ways to define capacity in a time where outpatient care is becoming more common, is that of Rechel et al. (2010). Rechel et al. (2010) argue that the commonly used metric of 'bed numbers' fails to capture key aspects of the way hospital services are delivered. Instead we should try to define capacity based on the availability to deliver processes. Rechel et al. (2010) state that 'a new definition of capacity could start from a description of the pathways travelled by patients […] followed by identification of those elements that can constrain them (the bottlenecks)'. This definition is used in this research, as we describe care pathways and define bottlenecks in these pathways (Chapter 5).

2.1.2 Health outcomes

To comprehensively evaluate capacity, we need to embrace a more nuanced approach than with traditional KPIs like bed occupancy rates and patient throughput. This entails incorporating KPIs that track the time allocation of healthcare professionals across different care settings. Additionally, a shift towards value-based healthcare demands KPIs focused on health outcomes and satisfaction. These measures extend beyond hospital boundaries, encompassing the entire care healthcare system, and reflect the broader impact of healthcare decisions on patients' lives. While these KPIs are very valuable, they can be quite abstract and difficult to measure. For this reason we decide not to look into satisfaction of any stakeholders involved in our research.

To find useful health outcomes, we need some guidelines on what is deemed important for patients. 'Outcomes should include the health circumstances most relevant to patients. They should cover both near-term and longer-term health, addressing a period long enough to encompass the ultimate results of care.'(Porter, 2010, p. 2479). In general, health outcomes that are often used include survival, number of hospital readmissions, time between discharge and readmissions, length of initial hospital stay and subsequent readmissions, quality of life, and health care costs. However, Gordon et al. (2011) describe some health outcomes that are very specific to our case of OPAT in department X. They mentions the following outcomes: 'measures of pathogen/drug mismatch, antimicrobial costs, incidence of redundant therapy, compliance with antimicrobial drug restrictions (if applicable), days undergoing antimicrobial therapy, and number of cases of intravenous to oral conversion'. Once these indicators are measured, it enables the management of these types of pathways, and can help to improve the patient experience.

2.2 Definition of KPIs

For our data analysis we want to find KPIs that can be used to describe capacity in healthcare. We perform a literature review in which we find the KPIs shown in the conceptual matrix below. In this conceptual matrix, useful KPIs are written in bold. A search log for this literature review can be found in Appendix C.

KPI\Article	(Franklin et al., 2023)	(Hilker et al., 2022)	(Masoompour et al., 2015)	(Bahadori, 2011b)	(Li & Benton, 1996)	(Schneider, 2020)	(Gordon et al., 2011)	(Peters et al., 2022)	(Williams et al., 2015)	(Gruneir et al., 2018)	Relevance for this research
Length of Stay	x	x	x	x	x	x	x		x		• Very relevant for stakeholders • Easily measurable
Bed Occupancy Rate	x	x	x	x		x					• Difficult to measure • Not the focus of this research
Bed Turnover	x		x	x							
Total Admissions		x				x					• Does not provide information about care pathway performance
Blocking Probability	x					x					
Healthcare Costs							x	x			• Interesting for stakeholders • Shows pathway performance • Hard to measure

Mortality Rate		x					x				• Unlikely for deaths to occur • Not useful in this case
Readmission Rate							x		x	x	• Especially interesting in OPAT context • Relatively easy to measure
Duration of OPAT							x		x		• Interesting addition to Length of Stay

Table 1: Conceptual matrix of KPIs

This literature review of KPIs used in healthcare, in combination with our research on health outcomes, brings us to the following KPIs for our case study:

Length of Stay

As we find in our literature search, the main indicator to assess capacity and performance is the Length of Stay. Isala Hospital claims that since the implementation of the VCC, the Length of Stay per patient has been reduced by 1.8 days. Therefore, this is an especially interesting KPI to consider, since we will be able to confirm or disprove this statement.

Duration of OPAT

With this KPI, the time that a patient receives intravenous antibiotics at home is measured. It is an important outcome to include, as it is very specific to the OPAT process (Williams et al., 2015). This KPI is especially interesting in combination with the Length of Stay, which gives the number of days a of inpatient intravenous antibiotics. When measuring both of these indicators, we can see whether a shift can be seen from a longer Length of Stay to a longer Duration of OPAT when the Length of Stay decreases, or vice versa.

Number of Readmissions

An important health outcome that was mentioned by Gordon et al. (2011) is the number of readmissions. This can be complicated, as the patient group we are looking at inherently has a readmission following their infection. It is possible however, that after their discharge, the patient's treatment at home does not go well, and the patient is readmitted for a second time. We check for each patient whether they were readmitted within 30 days of their discharge. This time frame is often used in literature when assessing readmissions (Gruneir et al., 2018; Henderson et al., 2023).

Wage costs per patient

The capacity indicator "costs per patient" is a fundamental metric used in healthcare management to assess the financial efficiency of providing care to individual patients. By monitoring and optimizing costs per patient, healthcare organizations can strive for greater efficiency while maintaining or even improving the quality of care provided to their patients. In literature, different variations of cost KPIs exist, such as cost per patient per day (Peters et al., 2022), or health outcomes per dollar spent (Gordon et al., 2011). For our research, we chose a variation of the KPI mentioned by Peters et al., namely 'wage costs per patient'. We want to assess costs not only based on billable activities, but instead by looking at time spent by different employee types and multiplying this with their hourly wages, to get a more complete overview. To gather this information, we need one final KPI.

Total working time of Healthcare Professionals per patient

The time spent by nurses is frequently overlooked in academic literature due to its non-billable nature. Instead of quantifying it solely in terms of time spent, the focus has traditionally been on patient-related activities and their associated financial implications. However, as the healthcare landscape evolves towards becoming more value based, there is a growing emphasis on studying time allocations. In our research, this will be done by adding up the time spent on all appointments and calls that were registered for the patient, together with time spent on monitoring and organising the process. Here, we divide care professionals into three groups: , secretaries, and transfer agency, or VCC nurses. For each of these three groups we will calculate the time spent per patient before and after the implementation of the VCC. Afterwards, we find the effect of the intervention by comparing the capacity changes for all care professional groups. The results found with this KPI are used to calculate wage costs per patient.

2.3 Conclusion

In this chapter, the focus is on understanding healthcare capacity through a literature review, which enables the definition of capacity in healthcare, assessment methods, and performance indicators for a case study. Hospital capacity, defined as the upper limit of a hospital's performance in terms of productivity, is crucial and can be assessed using key performance indicators (KPIs) such as bed occupancy rates and patient throughput. However, the traditional approach to capacity assessment is evolving due to shifts in healthcare delivery towards community-based and home-centred care. The concept of capacity is redefined as ‘a description of the pathways travelled by patients followed by identification of those elements that can constrain them’, emphasizing the availability to deliver processes rather than mere bed numbers (Rechel et al., 2010). This shift underscores the importance of assessing health outcomes, including survival rates, readmissions, time between discharge and readmissions, quality of life, and healthcare costs, to comprehensively evaluate capacity. For the case study, specific KPIs are chosen, including Length of Stay, Duration of OPAT, Total working time of healthcare professionals per patient, Wage costs per patient, and Number of Readmissions. These KPIs allow a comprehensive evaluation of capacity and performance in the context of the medication@home project in department X.

3 Methodology

In this chapter, we outline the methodological framework that underlies our research. We provide insights into the study settings and the study design. This methodology is the foundation upon which we analyse care pathway X, aiming to assess its performance and possibilities for improvement. The chapter consists of the study settings, in which we give context on patient demographics and numbers of occurrences of infections related to care pathway X (Section 3.1) and the study design, in which we choose a strategy to answer our research question (Section 3.2).

3.1 Study Settings

[confidential]

3.2 Study Design

In this subchapter, we delve into the study design employed for our research. It encompasses various subchapters, each describing a part of the total study design. This includes data sources and data preparation to sample selection, as well as descriptions of how we will perform a context and bottleneck analysis, data analysis, experiment design. Lastly, we include a critical examination of assumptions and simplifications. Together, these components lay the foundation for an elaborate and structured exploration of our research objectives.

As this research design consists of many different components, all using information gathered from different sources and from results of previous steps, a flow diagram was made to get a better overview (Figure 1, page 18). In the text boxes without any fill colour, we find the different research components for which we get results. The arrows connecting these boxes show where the information gathered in each step is used. The blue text boxes represent external information sources. From each source dotted lines are drawn to show in what research step their information is used. So, for example: Drawing flowcharts of the care pathways requires our definition of OPAT from literature, and information provided by Isala Hospital. The results from this step are used in their turn to analyse changes made to the care pathway.

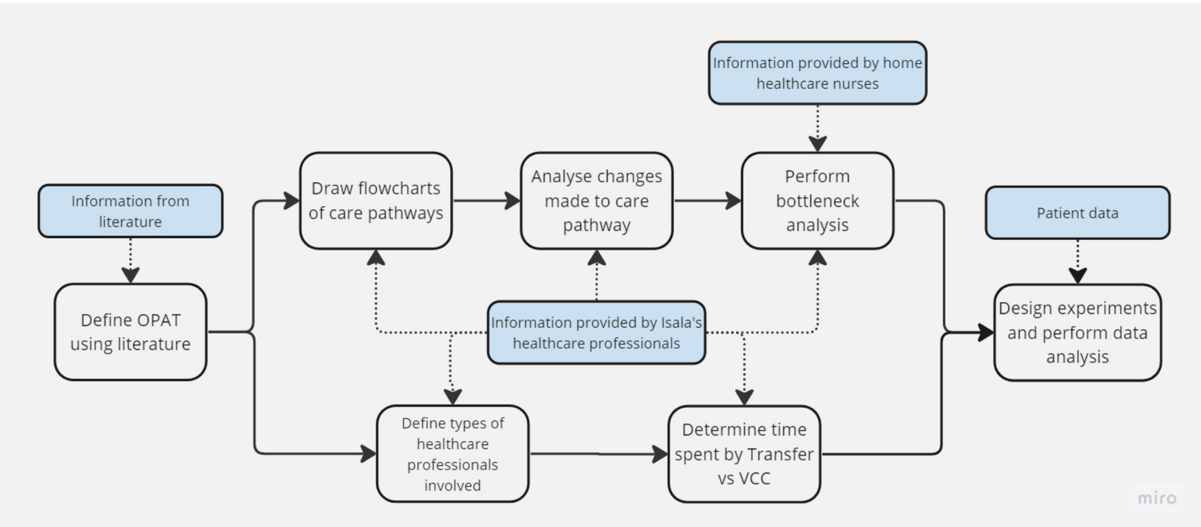

Figure 1: Methodology flow diagram

3.2.1 Data Sources and Data Preparation

Our primary data source is the electronic patient register of Isala, HiX, which encompasses a large amount of information. This includes details about appointments, admission periods, the patients' medical conditions, prescribed medications, and patient reports. Healthcare professionals such as nurses and doctors record and maintain this data to monitor a patient's medical history and facilitate the scheduling of appointments. For the purpose of this study, we use a broad range of data, namely the patients' demographic information, their appointment history, the providers and duration of these appointments, their care activities, admission period, and finally the medication prescriptions. We retrieve patient data from HiX using CTCue, a search engine for patient registers.

Other data used to calculate the KPIs for the care paths was also provided by Isala and its employees. This includes, but is not limited to, information about the hourly wages per healthcare employee type (Appendix D), and time spent by transfer agency, and VCC nurses on tasks regarding patients following care pathway X.

Prior to initiating our data analysis, we screen our data for inconsistencies and other factors that could hinder the analysis. The first part of the data preparation is done with the help of CTcue, which is a data extraction tool and search engine used to collect data from the electronic patient register. Afterwards, inconsistencies in the data are identified and rectified in Excel.

Criteria in CTcue

We use CTcue, our data extraction software, to retrieve patient data meeting specific criteria:

- Patients treated in department X who received medication through infusion at home.
- Patients who have undergone surgery specifically for infections.

Data Filtering in Excel

After exporting the data into an Excel sheet, we further refined the patient dataset. Patients with the following characteristics were removed:

- Patients with no registered admission period: Given that our data collection questions were all related to the admission period of the patient, we excluded individuals for whom no admission period was documented. This not only ensures that our dataset contains relevant data but also aligns with the care pathway we seek to investigate.
- Patients without hospitalization records: Patients who received only day treatment or observation without hospitalization are removed from the dataset. This step allows us to focus exclusively on patients who have undergone significant hospital care, consistent with the objectives of our research.
- Patients with no appointments listed: Finally, we exclude patients from our analysis if their records do not contain any listed appointments. It is standard procedure to have at least one appointment after discharge, so it is highly unlikely that no follow-up appointments are found in the data. Because of this, it is likely that data is missing for these patients, which is why we exclude these patients. Furthermore, this ensures that our dataset exclusively consists of patients for which the necessary data for our analysis is available.

By carrying out these detailed data preparation steps, we aim to create a dataset that truthfully reflects the aspects we are studying. This, in turn, helps us uncover valuable insights into the OPAT care pathways.

3.2.2 Sample Selection

For our research, we define two patient groups, namely the *control group* and the *intervention group*. Patients from the 1st of November 2018 until the 1st of March 2020 are used for the *control group*. We decide on these dates because HiX was first used in November 2018, and after March 2020 the data might be influenced by the COVID-19 pandemic. From this period, we find 125 patients matching the criteria in CTcue. However, after data cleaning, this leaves us with 58 patients with 1087 registered appointments in total. These are all appointments registered after discharge from the patients' hospital admission following their infection surgery.

For the *intervention group*, patients that were treated from the moment the VCC was introduced into the care pathway, which is the 2nd of June 2022, until the 1st of May 2023 are used. This results in a collection of 98 patients in CTcue, and 53 patients left after data cleaning, that altogether have 568 registered appointments. As well as in the control group, these are also appointments registered after discharge.

We want to know whether this leaves us with enough patients to accurately represent our population size. To determine the necessary number op patients, we use Yamane's Formula (Yamane, 1967) for Sample Calculation:

$$n = \frac{N}{(1 + Ne^2)}$$

Where n= corrected sample size, N = population size, and e = Margin of error.
Every year, about 80 patients follow care pathway X. As patient data for the control group are collected over 1 year and 4 months, and 11 months for the intervention group, our population sizes are respectively around 100 and 70. Filling this in in the Yamane's formula using a margin of error of 5% results in sample sizes of 80 and 60 patients respectively. While the original number of patients in CTcue meets this sample size requirement, the number of patients after the data preparation is insufficient, since only 58 and 53 patients are left in respectively the control and intervention group. Unfortunately, there are not more patients we can use to fill this gap, so this will cause the outcomes of our research to be less reliable.

3.2.3 Context Analysis

After establishing the data we use for our research, we now explain the different analyses we perform to establish the performance of the care pathways before and after the intervention, starting with the context analysis. Analysing the context serves several key purposes. Firstly, it aims to deepen our understanding of both current and past processes, enabling us to identify strengths and weaknesses within them. Secondly, it facilitates a comprehensive evaluation of patient flows, encompassing a performance assessment. Lastly, this analysis plays a crucial role in pinpointing areas that can be improved and opportunities for optimization.

First, we gather information on Outpatient Parenteral Antimicrobial Treatment (OPAT). We gather information from literature and from Isala to pinpoint the definition of OPAT, and to find out what the process looks like.

For the next part of our analysis, we focus on describing the healthcare professionals involved in the pathways. Gaining insight into their roles and activities is essential for conducting meaningful data analysis and drawing informed conclusions. This includes an overview of the differences in time spent on each patient of both the transfer agency and the VCC.

Lastly, we create flowcharts to visualize both the pathways before and after the implementation of a virtual care centre with a monitoring functionality. Using insights from earlier sections, we provide a comprehensive depiction of the hospital's internal processes regarding the care pathways. Next to this visualization, we provide a comprehensive list describing every change made to the care pathway resulting from the intervention.

3.2.4 Bottleneck Analysis

Bottleneck analysis helps organisations improve efficiency, increase productivity, reduce costs, and enhance product or service quality by identifying and addressing critical areas in their processes. It leads to optimized operations and resource allocation, ultimately benefiting the organization.

Based on conversations with healthcare professionals holding different positions within the care pathway we formulate bottlenecks within the process. These are bottlenecks that are the result of the intervention, as well as bottlenecks of which the likelihood of occurrence decreased since the intervention. For each bottleneck, the implications are analysed, and the chance it occurs is given.

This analysis is useful as it encompasses the broader healthcare environment, instead of merely the problems within hospital walls. The bottlenecks found can form the basis for recommendations on how to further improve the care pathway.

3.2.5 Data Analysis

To draw meaningful conclusions from our patient data, we perform a retrospective data analysis. This involves a comprehensive examination of key performance indicators (KPIs) selected based on our extensive literature review in Chapter 2. We further continue with a descriptive and diagnostic analysis, showing performance in the past and explaining the performance results.

Another part of our data analysis consists of the performance of a few experiments, which are explained in Section 3.2.6. The goal of these experiments is to show different possibilities for future scenarios, and to enable us to make recommendations based on the performance of these scenarios.

All experiments are scored on performance based on 5 KPIs: Length of Stay, Total Working Time per Patient, Total Wage Costs per Patient, Total Duration of OPAT, Time Between Discharge and Readmission. All of these can be retrieved from the patient data in Microsoft Excel and Visual Basic, except for the total wage costs. To determine total wage costs, we use a manual calculation method, which makes use of the already calculated time in minutes spent per patient by each healthcare professional type. This time is converted to time in hours, and multiplied by the hourly wage for each healthcare professional type, which was provided by Isala (Appendix D). This results in the following formula:

$$\frac{Total\ time\ orthopedist}{60} * 33.14 + \frac{Total\ time\ secretary}{60} * 18.67 + \frac{Total\ time\ (transfer\ or\ VCC)\ nurse}{60} * (25.99\ or\ 29.53) = Total\ wage\ costs$$

Here, we use an hourly wage of €25.99 for transfer nurses and of €29.53 for VCC nurses, when calculating wage costs for the control group and the intervention group respectively.
To determine whether or not the KPI outcomes are significantly different from each other, we use statistical tests. We do this with the use of independent, or two-sample t-tests. These tests are performed on two unequal populations using a level of significance of 95% percent. Furthermore, we visualize the standard deviation of each KPI in a graph. This shows whether the variance of the data is small or large.

3.2.6 Experiment Design

As mentioned in our sample selection (Section 3.2.2) we defined a control and intervention patient group. These two groups form the basis of our experiments, the control group being scenario 1 and the intervention group being scenario 2. Based on results from our bottleneck analysis (Chapter 4.4, page 30) we want to define some experiments to add to these scenarios. We find that problems with communication moments are a bottleneck that was largely caused by the intervention. Communication problems lead to extended Length of Stay, correction time, extra costs, and image damage. We think that these problems can be decreased over time, as the staff gets used to the new way of working. Therefore, we add three scenarios (scenario 3, 4 and 5) to showcase the future potential of the care pathway after the intervention.

1. **Control group**

This scenario represents the performance of care pathway X at Isala Hospital before the Connected Care intervention. It serves as a benchmark to understand how the care pathway operated in its previous state.

2. **Intervention group: No improvements in Communication Moments**

This scenario represents the current state of the care pathway, without any improvements or changes made after the initial intervention. Comparing this group to the control group allows us to assess whether the intervention had a lasting impact or if additional improvements are needed. Based on the data gathered for the intervention group, we further define some experiments that could help to show the future performance of the care pathway.

3. **Intervention group: Optimistic Improvement in Communication Moments**

In this scenario, we assume large improvements in communication moments are made, which has a highly positive impact on the care pathway. As such, we assume that the Length of Stay of patients is reduced by 10% and the working time of the VCC is reduced by 20% per patient.

This could happen if the hospital chooses to focus on eliminating this bottleneck as much as possible. If more research is done, we might find out what causes the communication problems, and we may be able to solve them, which will reduce the Length of Stay of patients and working time of VCC nurses.

4. **Intervention group: Moderate Improvement in Communication Moments**

In this scenario, assume a more moderate improvement in communication moments compared to the first scenario. Because of this, we assume that the Length of Stay of patients is reduced by 5% and the working time of the VCC is reduced by 10% per patient.

This experiment shows what could happen if the hospital tries to eliminate some of the communication problems, but is not entirely successful. This results in moderate improvement of the care pathway.

5. **Intervention group: Pessimistic Improvement in Communication Moments**

In this scenario, assume that improvements in communication moments have a minimal impact. We assume that the Length of Stay of patients is reduced by 2% and the working time of the VCC is reduced by 4% per patient.

This could be the case if the process continues without any further intervention. As employees get more used to the new way of working, some problems regarding communication will naturally decrease. However, only a small difference with the current situation can be noticed, since there is no focus on improving communication.

Including these 5 experiments enables us to draw meaningful comparisons between the control group, the intervention group, and the various improvement scenarios we outline. It helps in assessing the long-term effectiveness of the changes and whether further refinements are necessary to optimize the care pathway.

3.2.7 Assumptions & Simplifications

The patients' age at the time of a care activity is not given in the data. Therefore, we calculate this based on the year of birth, and the date of the care activity. As we do not know the exact date of birth for privacy related reasons, this means that the age can be off by one year, depending on whether the day and month of birth is before or after the day and month of the activity.

To simplify our research, we have grouped together different types of healthcare professionals with similar levels of expertise in a group called medical specialists. This is done because all of these care professionals, while their exact function may be different, are providers of the same types of appointments after discharge. Since we do not have the exact wage costs of medical specialists combined, we assume these costs to be equal to the wage costs of a physicians assistant (PA). This is further solidified based on information provided by the salary table for medical specialists from the Nederlandse Vereniging van Ziekenhuizen (NVZ Werkgeverszaken, 2017).

We assume the impact of reducing communication problems. We know that problems with new communication moments cause a longer admission period and more time spent by employees since the process is not fully efficient. However, we have to make estimations based on information provided by nurses and project leaders to assume by how much these measures decrease when communication moments improve. To account for the uncertainty of the implications of improving communication, we have included an optimistic, moderate, and pessimistic scenario, which gives us different possibilities for future outcomes.

We simplify our research by excluding activities of home healthcare nurses from our data analysis. Since home healthcare nurses did not perceive a significant difference between the situation before and after the intervention, we decide not to examine the time spent by home healthcare nurses. However, it is evident that home healthcare may have more work if the average OPAT duration is longer per patient. On the other hand, home healthcare nurses might not need to visit on the first day if the first IV AB bag is already connected. Another crucial reason for excluding home healthcare organisations is the fact that we cannot acquire any data from these organisations, which would be necessary for inclusion in the data analysis. However, while we may not be able to include this important stakeholder in a data analysis, we still want to provide include information we gathered in our bottleneck analysis and discuss possible improvements for the care pathway from the point of view of a home healthcare nurse.

3.3 Conclusion

In this chapter, we presented the methodological framework for our research. It is designed to comprehensively investigate the performance of care pathway X. Through a detailed description of study settings, data sources and sample selection, data preparation, context analysis, bottleneck analysis, data analysis, experiment design, and the examination of assumptions and simplifications, we have outlined a roadmap for our research.

4 Results

The results chapter provides a comprehensive overview of the outcomes and insights obtained from our research study. Our exploration of the results is organised into several subchapters, each contributing to a comprehensive understanding of the research findings. In Section 4.1, we focus on the definition and structure of OPAT care pathways. Types of Healthcare Professionals (Section 4.2) provides insights into the diverse categories of healthcare professionals participating in our research. Explanation of the Care Pathways (Section 4.3) offers an in-depth look into the conventional and intervention care pathways. In Section 4.4, we perform a bottleneck analysis to examine potential challenges and areas for improvement within the care pathways. Lastly Section 4.5 explores various key performance indicators. This comprehensive data analysis provides valuable insights into the efficiency and effectiveness of the care pathways.

4.1 Outpatient Parenteral Antimicrobial Treatment

Outpatient Parenteral Antimicrobial Treatment (OPAT) is a critical component of modern healthcare, offering an effective alternative to inpatient care for patients experiencing infections. OPAT is defined as the provision of parenteral antimicrobial therapy in at least two doses on different days without the need for hospitalization (Wijnakker et al., 2019). It allows patients to receive parenteral antimicrobial therapy without the need for prolonged hospitalization, thereby promoting cost-effectiveness, improved patient comfort, and efficient resource utilization. This section will provide a comprehensive explanation of the OPAT process in department X, detailing the steps involved in managing infections. In different care pathways the OPAT process may look slightly different, but this gives a good indication of the main steps involving the peripheral administration of antibiotics:

Patient Evaluation: The OPAT journey begins when a patient is diagnosed with an infection. This may manifest as pain, swelling, or other clinical symptoms indicative of an infection.

Surgical Intervention: Upon diagnosis, the patient typically undergoes surgical intervention. During this procedure, the infected area is cleaned, and in some cases, a replacement needs to be made. Surgery is a critical step in addressing the source of the infection.

In-Hospital Antibiotic Administration: Following surgery, the patient is admitted to the hospital, where they receive intravenous antibiotics via infusion. The choice of antibiotics is based on culture results, as well as blood and urine tests. This tailored approach ensures the most effective treatment for the specific infection.

Discharge Planning: Once the patient's condition stabilizes, they are discharged from the hospital. At this point, a peripherally inserted central catheter (PICC) line is often in place to facilitate ongoing intravenous antibiotic therapy.

Pharmacy Supplies: Upon discharge, the patient picks up the necessary materials and medications from the pharmacy, including antibiotics, infusion equipment, and instructions for care.

Home Healthcare Referral: The patient is referred to a home healthcare service, where skilled nurses are responsible for administering and managing the antibiotics. These nurses replace the intravenous antibiotics every 24 hours, ensuring a consistent and controlled delivery of the antimicrobial treatment.

Monitoring: Regular monitoring is a key component of OPAT. A testing team collects weekly blood and urine samples, either at the patient's home or in the hospital. These samples are used to determine the appropriate antibiotic levels in the patient's bloodstream.

Adjustment of Treatment: Based on the results of the level determinations, the medical team may adjust the antibiotic regimen. This can include altering the dosage or even changing the type of antibiotic used to optimize the treatment's efficacy.

Transition to Oral Treatment: As the infection subsides and the patient's condition improves, there may come a point where a transition from intravenous to oral antimicrobial treatment is feasible. This step marks progress in the patient's recovery and ultimately leads to the completion of the OPAT journey.

4.2 Types of Healthcare Professionals

In this study, we examine three distinct categories of care professionals who play essential roles in the care pathway:

Medical Specialist

In this employee type, we group together different types of healthcare professionals with similar roles within the care pathway. This group includes the following care professionals:

- Specialist Surgeons: Highly specialized medical professionals with expertise in diagnosing and treating conditions, including infections.
- Physicians Assistants: Healthcare providers who work under the supervision of specialist surgeons and contribute to patient care by assisting in surgeries, conducting assessments, and providing treatment.
- Nursing Consultants: Experienced nurses who offer expert advice and guidance in managing patient care, ensuring that it aligns with established protocols and standards.

Medical specialists are responsible for any follow up appointments with the patient. Often, telephonic consultations are held with a medical specialist. Before the intervention, the medical specialist was tasked with monitoring the patient and organising laboratory tests, but since the intervention, this role is taken over by VCC nurses.

Secretary

Secretaries in healthcare settings play a crucial administrative role by managing appointments, patient records, and communication within the care team. They facilitate the smooth operation of the care pathway by coordinating various administrative tasks and occasionally making calls to patients. They usually assist medical specialists in these tasks once the patient is treated at home.

Transfer Agency Nurse and VCC Nurse

Transfer Agency Nurses played a critical role in facilitating early discharges for patients care pathway X before the intervention. Their primary responsibilities involve coordinating the logistics of patient discharge and ensuring a smooth transition from the hospital to the patient's home or outpatient setting. These nurses focus on the administrative aspects of discharge planning and do not monitor patients post-discharge or arrange for laboratory tests. Even after the intervention, transfer agency nurses are involved in the care pathway, in case the patient is in need of help with activities of daily living (ADL) or wound care. These patients are handed over from the VCC to the transfer agency as they are more experienced in organising these special needs.

VCC Nurses have taken on a broader role in care pathway X since they have been involved in the care pathway following the intervention. They oversee administrative and organizational tasks, taking over responsibilities previously handled by the transfer agency. In addition to coordinating discharges, VCC Nurses monitor patients after they have been discharged and are responsible for arranging necessary laboratory tests. Their role extends beyond discharge logistics to encompass ongoing patient care and support in the home or outpatient environment.

Each of these care professionals contributes uniquely to the care pathway, and their roles are essential in providing comprehensive care to patients with infections in the context of department X. In our research, we use these three categories as they give interesting insights in how time allocation shifts from one category to another following the intervention. As the goal of the virtual care centre is to take over tasks from medical specialists, these are logical and interesting groups to analyse.

Time spent by transfer agency and VCC nurses

The data in this study was collected by a Transfer Nurse and a VCC Nurse for the purpose of our research. The Transfer Nurse estimated average times through discussions, while the VCC Nurse recorded times for various patients in care pathway X over two weeks.

Activity	Time spent Transfer in minutes	Time spent VCC in minutes
Process order in electronic patient register	10	10
Contact home healthcare organization	5	10
Order Antibiotics (AB) and pump	8	10
Organize AB at Politheek	5	-
Inform/visit patient	12	7
Organize lab	-	10
Enter patient data in system		3
Fill in aftercare module	-	20
Stop AB iv	-	10
Total per patient	**30**	**80**

Table 2: Time spent by nurses on activities related to OPAT

One key observation is the difference in time spent on informing the patient about the process of their discharge. Transfer Agency Nurses visit patients in the ward, taking more time due to in-person interactions. VCC Nurses primarily use informative methods like discharge letters and emails, resulting in shorter interactions.

The table clearly shows time differences between Transfer Nurses and VCC Nurses, reflecting VCC Nurses' expanded responsibilities, formerly handled by Physicians Assistants. Notably, VCC Nurses spend more time on activities such as organizing lab tests and aftercare modules, aligning with their broader role in patient care, including monitoring and coordinating laboratory exams for patients receiving intravenous antibiotics at home. This shift underscores healthcare professionals' adaptability to evolving patient needs.

4.3 Explanation of the Care Pathways

Based on a patient’s diagnosis, the patient enters a certain care pathway. A care pathway is defined as ‘a method for the patient-care management of a well-defined group of patients during a well-defined period of time’ (de Bleser et al., 2006). The aim of these pathways is to improve quality of care, reduce risks, increase efficiency and increase patient satisfaction.

For this research we look at care pathway X of Isala, which has been subject to change in the past years. We analyse the care pathways before and after the CCC made an intervention with the aim of improving the pathway.

We have talked to Isala and home healthcare organisation employees to gather information on the care pathways before and after the intervention. Based on this personal communication we describe both pathways, and analyse in what ways the actions changed after the intervention. Both care pathways are visualized in flowcharts.

4.3.1 The Conventional Pathway

When a patient presents with an infection, the patient is hospitalized and a surgery is planned. During the surgery, a sample for a culture is taken, which is sent to the lab to determine the nature of the infection. Following the surgery, a patient is hospitalized for around 5-14 days, until the patient is physically mobile enough to go home, and does not have a fever. Furthermore, the results of the lab test must be known before the patient can be discharged. This ensure that the patient gets sent home with the correct antibiotic type.

When a patient is ready for discharge, the discharge file needs to be complete by 12:00, such that the patient can go home the next day. Medication is ordered at the Politheek, which is the outpatient clinic pharmacy of Isala. 12:00 is the deadline that was set by the Politheek. A transfer nurse visits the patient on the ward to explain the discharge process to the patient and to explain what care at home entails. Once the patient is at home with their IV pump, a home healthcare nurse visits every 24 hours to change the antibiotics. Once a week, a blood sample will be taken from the patient, either at a blood testing station nearby or at the patient's home. Based on the lab results of this sample, the new AB dose will be determined. Most patients receive intravenous AB at home for 2 weeks, after which they switch to a 3 month long oral AB treatment. Once this switch is made, home healthcare nurses are no longer involved.

In this process, the transfer agency closes the patient file once the patient is discharged. The blood tests to determine the correct antibiotics doses are organised by the physicians assistant.

A flowchart showing this care pathway can be found in Figure 2 on the Page 29.

4.3.2 The Intervention Pathway

Since the Connected Care intervention, changes have been made to optimize the care pathway and make it more efficient. With the help of a flowchart (Figure 3, Page 29) we explain what the new care pathway looks like.

In this new situation, the patient is admitted to the hospital in the same way as before. During the surgery, the PICC line is already connected, such that this does not have to be done in the roentgen department later on. The patient then receives infusion in the hospital until they are fit to go home. This again means that the patient should not have a fever anymore, and should be mobile. The patient can already be discharged before the lab results come back, if they meet the other criteria. This is possible because the type of AB the patient receives can still be changed when the patient is at home.

When a patient is ready for discharge, the discharge file needs to be complete by 15:00, such that the patient can go home the next day. This deadline changed when medication orders started to be placed at Appo instead of the Politheek, because Appo uses this later deadline. Appo is a nationally working pharmacy delivering medication to hospitals and patients' homes. This gives the nurses more flexibility, so in case they miss the morning blood test they might still be able to send the patient home the next day. Another service of Appo is the delivery of the pump and first antibiotics dose at the ward of department X. This enables the nurses to already connect the first dose in hospital, meaning that the home healthcare nurses can start one day later.

When a patient is ready for discharge, they will receive information regarding their discharge via e-mail or on paper. Once they are home, a VCC nurse calls the patient to explain everything that is arranged for them and to answer any questions. During the time that the patient receives antibiotics via IV pump, the VCC arranges their weekly lab tests. The VCC closes the patient file once the patient switches to oral antibiotics. This is the biggest difference with the conventional pathway, because it means that the patients are still monitored by the VCC after discharge.

4.3.3 Change Analysis

Based on the analysis of both care pathways, we list the most important changes made to care pathway X:

- The first dose of antibiotics is delivered to the ward (by Appo) and connected by a nurse. This means that home healthcare will only come a day later.
- Because the VCC partnered with Appo the 12:00 deadline for the discharge file has disappeared. Since the Politheek wants to keep supplying the antibiotics they will likely move their deadline to 14:00 or 15:00 in the afternoon, allowing for more flexibility.
- Blood tests are managed by VCC/monitoring nurse, instead of the PA. This increases the capacity of the PA (who has more specialized training and is more costly).
- The transfer bureau is stricter. If there is no prescription before 12:00, discharge must be postponed by a day because the medication can not be delivered on time. The VCC sometimes follows up more on this. This can lead to the patient being discharged a day earlier, but it requires a lot of time and effort. The VCC has enough time available to do this.
- The transfer agency has more experience and knowledge. This is why complex patients, such as those needing wound care, are still handed over to the transfer agency by the VCC.
- The distance between VCC and the patient/ward is greater. The transfer agency used to visit patients on the ward to explain the discharge process and provide information on who they can contact and how. Additionally, they also explained that patients need to collect their own medication from the pharmacy. Now, this information is emailed to patients by the VCC, or handed out on paper by the nurse of department X. Sometimes a VCC nurse will also call the patient to inform them about the discharge process.
- Patients can go home before getting the results of their culture test because the type of antibiotics given can still be changed at home.
- In general there was less documentation when the care pathway was still managed by the transfer bureau. They worked hard but documentation was lacking. This might be more efficient in the short term, but in the long term, it makes it difficult to research how the process unfolds.

Knowing what the changes resulting from the intervention are, we can progress with our research to find how these changes influence the performance of care pathway X.

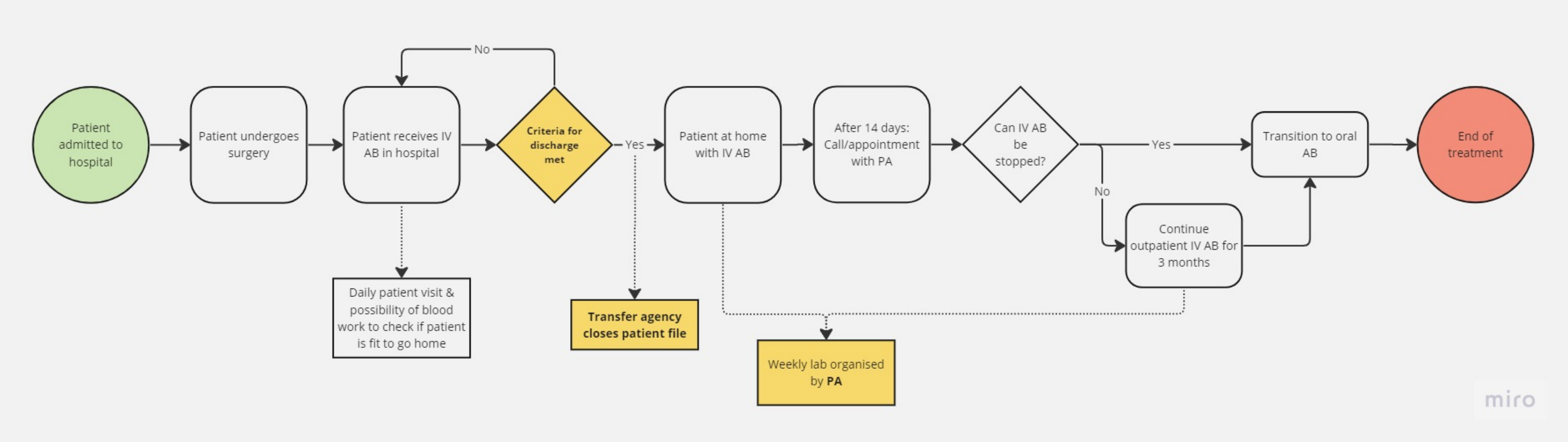

Figure 2: Flowchart of the conventional pathway

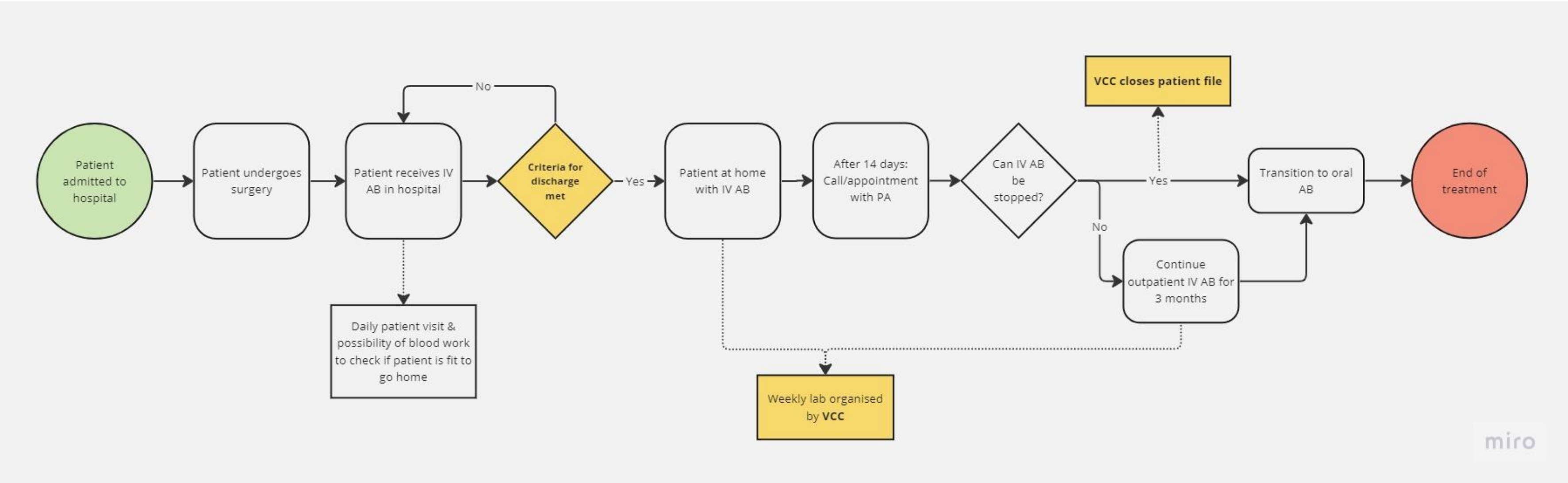

Figure 3: Flowchart of the intervention pathway

4.4 Bottleneck Analysis

To gain a comprehensive understanding of the bottlenecks within care pathway X, we conducted an analysis that involved conversations with various healthcare professionals involved in different stages of the patient journey. Conversations were held with the project leader of the medication@home project, a transfer agency nurse, a VCC nurse and a home healthcare nurse. These conversations allowed us to tap into the practical insights and experiences of the individuals directly engaged in delivering care, as well as insights from a manager that supervises the process.

In Table 3, the most prominent bottlenecks are shown. These are bottlenecks of which the likeliness of occurrence was affected by the Connected Care intervention. This means that the likeliness before the intervention corresponds to control scenario, and likeliness after corresponds to the intervention scenario in our data analysis. A description of each bottleneck is given, together with the phase in which it occurs, the likeliness of occurrence before and after the intervention, and the implications it has. Since there is no data available on this, all of this information was gathered using personal communication.

Bottleneck description	Phase	Likeliness before intervention	Likeliness after intervention	Implications
The communication moments are new/different, which can cause problems in the process	All through the process	Very low	High	Extended Length of Stay, correction time, extra costs, image damage for the hospital
Culture results are not available on time for discharge	Before discharge	Moderate	Moderate	Discharge is delayed. Extra time spent. After intervention this does not cause a delay
Patient forgets to pick up medication at the pharmacy	Discharge	Moderate	Never	Patient or home healthcare nurse has to arrange medication unexpectedly when nurse first visits. Extra time spent
Discharge file is not completed in time. Deadline was 12:00 before intervention and 15:00 after	Before discharge	Moderate	Low	Discharge is delayed. Extra time spent

Table 3: Bottlenecks affected by intervention

In addition to these intervention-influenced bottlenecks, we also encountered the following challenges that, while not directly impacted by the intervention, are integral to the care pathway's overall effectiveness:

Documentation from Home Healthcare Organisations: The absence of comprehensive patient documentation from home healthcare within the electronic patient file (EPD/Hix) represents a significant bottleneck. This gap in information flow can hinder the provision of effective care, causing extra time to be spent on searching for the patients' information.

Supply of Incorrect Materials: There are occurrences of incorrect materials being supplied by the pharmacy. Though minimal, this remains an area of concern. Home healthcare nurses do not typically carry materials with them, so if something is missing from the materials given to the patient, it may need to be picked up, which can be time-consuming.

ADL or Wound Care Needs: About half of the patients requires assistance with ADL or wound care post-discharge. After the intervention, once the need for either of these is known, these cases are handed over to the transfer agency, as they have more expertise with extra needs. According to the project manager and VCC nurse, this does not cause any extra time to be spent. However, it can cause confusion, and slight organisational problems.

Patient and Home Healthcare Nurse Communication: Ensuring clear communication channels between patients, home healthcare nurses, and the hospital remains crucial, with the aim of facilitating smooth transitions and handling any medication-related emergencies. From conversations with the home healthcare nurse, it becomes clear that patients and home healthcare nurses are often unsure who to call, which is a problem that should be easily fixable if clear guidelines are set up.

It is crucial to address these bottlenecks comprehensively to optimize the entire care pathway efficiently. While some are a direct outcome of the intervention, others highlight wider healthcare challenges that require careful consideration and resolution.

4.5 Data Analysis

In this section, we process, examine, and interpret our data, covering sections on data preparation, demographics, data validation, and Key Performance Indicator assessment. This analysis aims to give insights into care pathway efficiency, guided by meticulous data preparation, demographic examination, data integrity checks, and a meticulous assessment of performance indicators.

4.5.1 Data Preparation

In Chapter 3 we described the data cleaning process we use for this research. Based on this description we remove patients from the selection.

	Control Group Patients	Intervention Group Patients
Data in CTcue	125	98
After selection from CTcue, before cleaning	72	68
Patients without registered appointments	8	4
Patients without registered admission period	3	8
Patients with only day treatment	3	3
Final patient set	58	53

Table 4: Amount of patient in each step of data cleaning process

We conduct our data analysis based on the final patient set.

4.5.2 Demographics

The control sample contains 58 patients, of whom 55% are women and 45% are men, with an average age of 71 years. Of these patients, 12% had an injury of type 1, and 88% had an injury of type 2. The intervention sample includes 53 patients of whom 40% per cent are women and 60% are men, also with an average age of 71 years. Of these patients, 34% had an injury of type 1, and 66% had an injury of type 2.

4.5.3 Data Validation

As mentioned in Section 3.2.1, the number of patients in CTcue meets this sample size requirement calculated with Yamane's formula. According to this formula, the sample size should be 80 for the control group and 60 for the intervention group. However, after cleaning the data, the patient count falls short, with only 58 and 53 patients remaining in the control and intervention groups, respectively. For the control group, we are missing 27.5% of patients, for the intervention group 11.7%. This results in a lower reliability of our research outcomes, especially for the control group.

For each KPI we further clean our data by removing outliers. Outliers are extreme data points with a value above or below the upper and lower bounds of the data sample, respectively. These upper and lower bounds are calculated using interquartile range calculations, which can be done by creating boxplots of the control and intervention group data in Excel (Figure 4). Outliers are often caused by mistakes in the data, or rare events, and they can disproportionately influence statistic measures. By removing them we aim to represent our data more accurately.

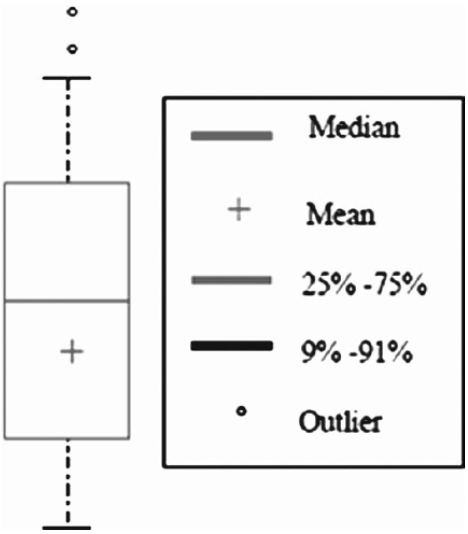

Figure 4: Legend for typical Box-plot(Michalsen et al., 2014)

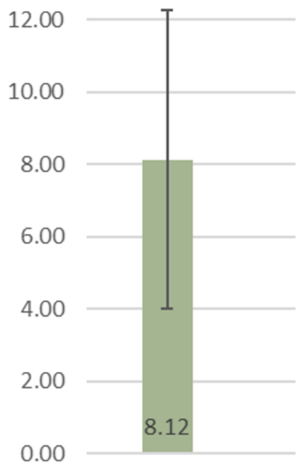

Figure 5: Graph showing mean of 8.12 (green) and SD of 4.12 (black error bars)

To further validate our data, we perform two-sample t-tests with a 95% confidence interval. With these tests we check whether the differences in the means of our KPIs are significant.

Furthermore, next to the mean, we show the standard deviation in each graph depicting a KPI (Figure 5). This helps us gain insight in the variance of the data. A large standard deviation implies a substantial variance in the observed data around the mean. Conversely, a small standard deviation would suggest that a substantial portion of the observed data is closely grouped around the mean.

4.5.4 Length of Stay

This section delves into a comprehensive analysis of the Length of Stay (LOS) KPI. As an important metric in evaluating the care pathway's efficiency, LOS offers valuable insights into patient hospitalization durations and the intervention's effectiveness. To calculate the Length of Stay, we first find the admission period of each patient following surgery for infections. We then subtract the start date of the admission period from the end date of the admission period, to come to our final Length of Stay in number of days.

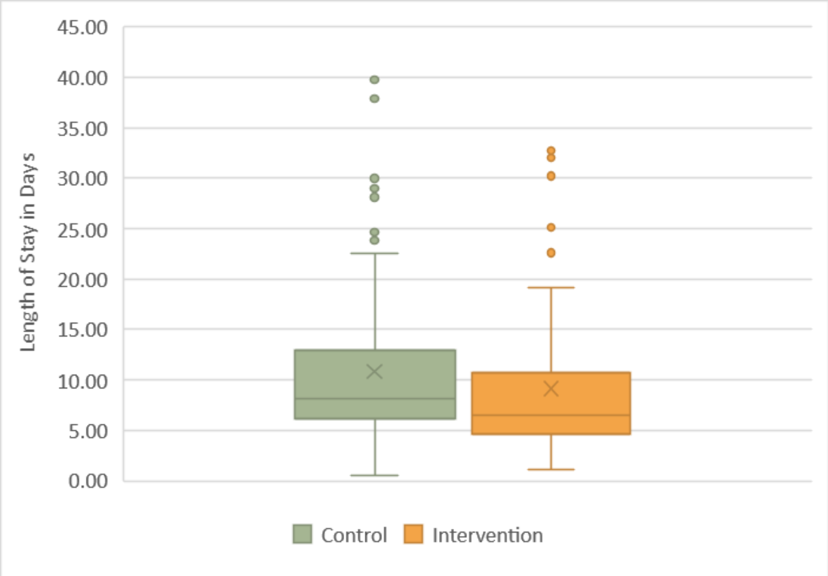

Figure 6a: Boxplots for Length of Stay

We first check our data for outliers, using the boxplots shown in Figure 6a. We eliminated six outliers from the intervention group, where LOS values exceeded the upper bound of 19.15 days, and seven outliers from the control group, with LOS values surpassing 22.50 days. This data refinement ensured a focus on more representative information.

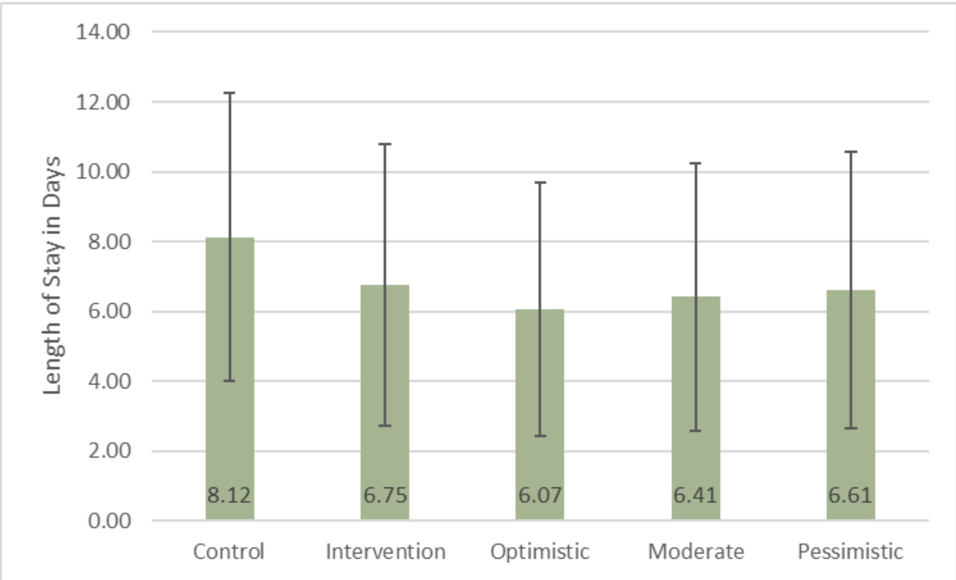

Figure 6b: Average Length of Stay per patient for each of 5 experiments

The mean of the length of stay of our experiments ranges from 8.12 days for the control group, to 6.07 for the optimistic scenario. In line with the insights provided by the project leaders of the medication@home project, the VCC's implementation should lead to a 1.8-day reduction in LOS. Our analysis suggests a slightly lower yet substantial reduction of 1.4 days, affirming the positive influence of the intervention.

With the optimistic scenario, we see a decrease in the admission period of more than half a day on average. This is a very desirable scenario, which could be reached if a lot of focus is put into improving communication within the care pathway.

It is important to note the relatively high standard deviation of each experiment, suggesting significant variance in the results. This variance largely stems from the extensive disparities among patients, including differences in diagnosis, treatment plans, and the severity of infection. Furthermore, from our tests of significance we find that none of the means for the experiments are statistically different (testing control and intervention group gives p=0.10). This means that we cannot state whether the LOS is different in any of our scenarios. This prevents us from drawing significant conclusions from our KPI analysis.

As the Length of Stay is our most important KPI, we want to calculate this KPI for a more homogeneous patient group, consisting only of patients treated for type 2 infections. This group consists of 51 patients from the control group and 35 patients from the intervention group.

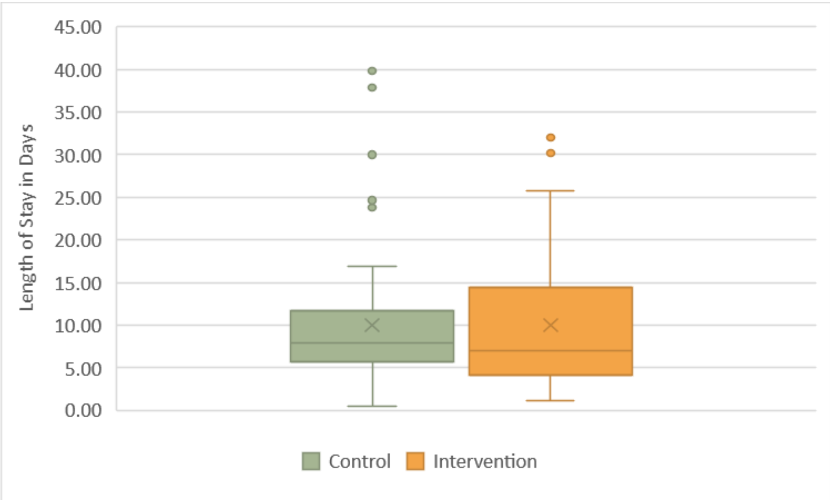

Figure 7a: Boxplots for Length of Stay for Injury type 2 only

For our control group, the upper bound is 16.91 days, meaning we eliminate 5 outliers. For the intervention group, the upper bound is 25.82 days, and we eliminate 3 outliers.

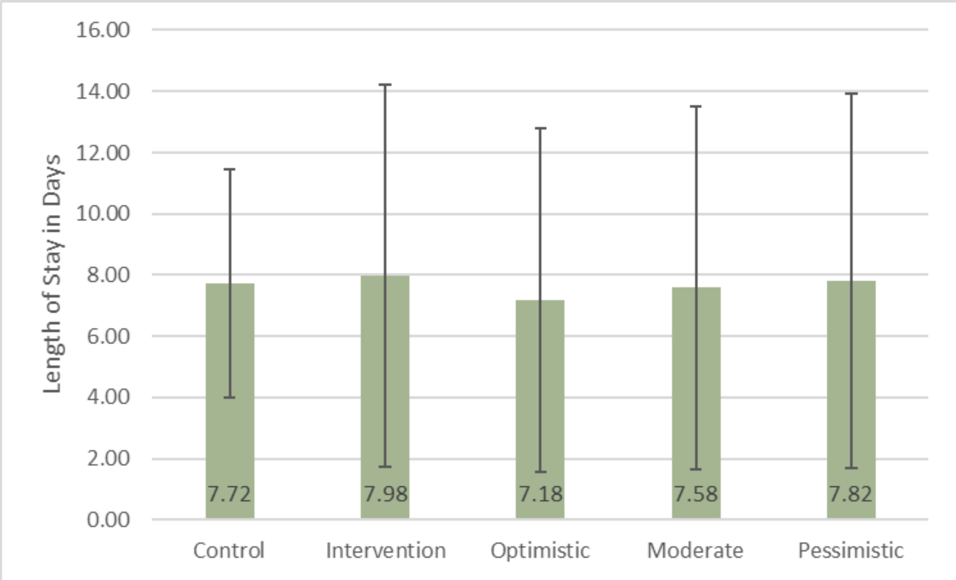

Figure 7b Average Length of Stay per patient for each of 5 experiments for Injury type 2 only

In this group we can see that the differences between LOS in each scenario become much smaller. The mean for the intervention group is slightly higher than in the control group in this more homogeneous group. This shows the importance of having a patient group with as little difference in diagnoses as possible, as this might have a major influence on the results. When we perform t-tests comparing the control and intervention group for type 2 patients, we see that there is no certainty on whether or not the results are different (p=0.82). Since this p-value is much higher than for the LOS of type 1 and type 2 patients together because of fewer data point, we decide not to check other KPIs for this group.

4.5.5 Duration of OPAT

The duration of Outpatient Parenteral Antimicrobial Treatment (OPAT) was a key metric examined in this study to assess the length of time patients received intravenous antibiotics at home. The calculation of OPAT duration was based on medication data obtained from the electronic patient register. Specifically, we determined the OPAT duration by analysing consecutive dates on which intravenous antibiotics were administered following surgery for an infection.

In the control group, medication records were available for 51 out of the 58 patients, while in the intervention group, 44 out of the 53 patients had recorded medication requests. These records provided valuable insights into the OPAT duration for most patients in the study.

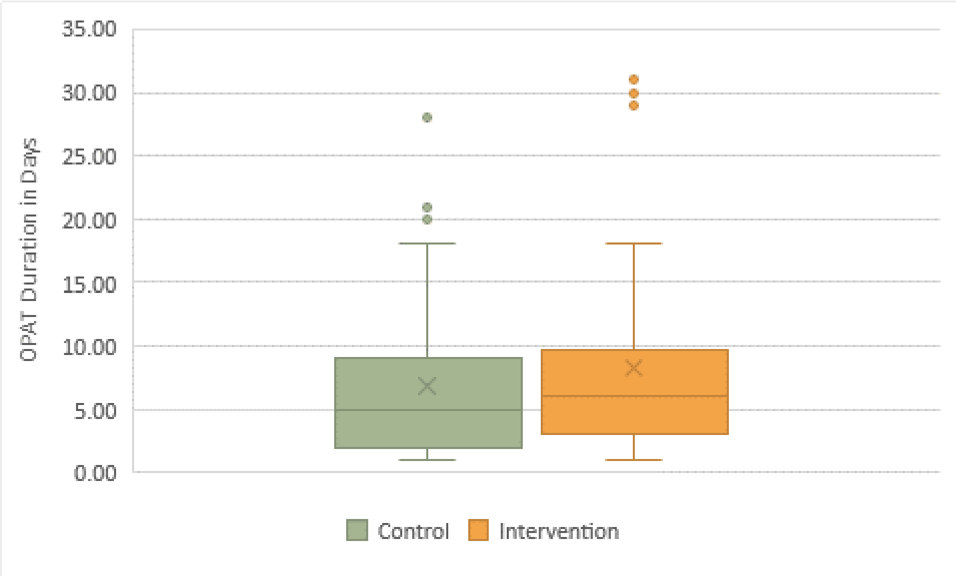

Figure 8a: Boxplot of OPAT duration

To visualize the distribution of OPAT durations, a boxplot was generated for both the control and intervention groups. The interquartile range calculation was employed to identify potential outliers, where we find an upper limit of 18 days for both groups. Figure 8a illustrates the distribution of OPAT durations, highlighting the removal of three outliers in each group.

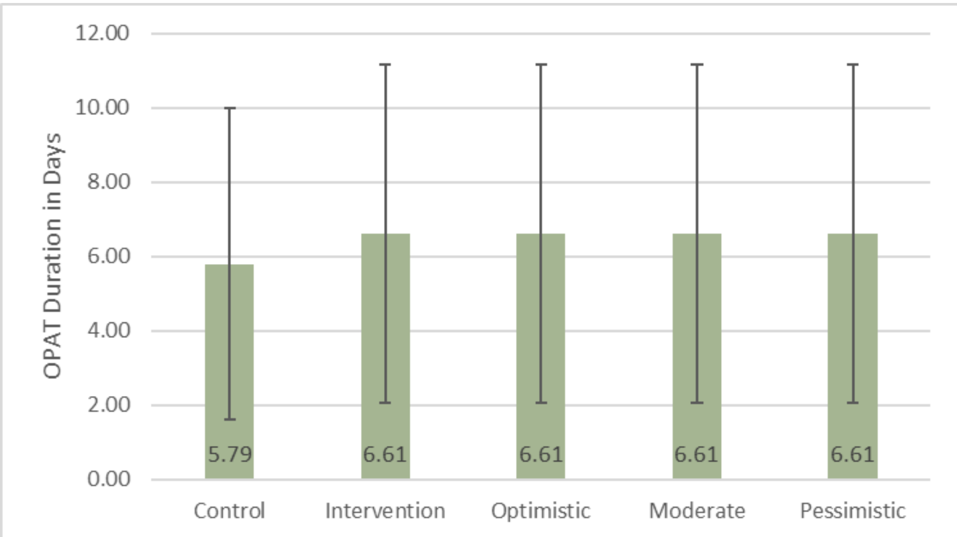

Figure 8b: Average OPAT Duration per patient for each experiment

In Figure 8b, the average OPAT duration per patient is displayed for each experiment, including the control group and the various intervention scenarios. Notably, the means of OPAT duration vary, ranging from 5.79 days in the control group to 6.61 days in the intervention group and the three future scenarios. This suggest an increase of the OPAT duration of 0.8 days since the intervention.

This is an interesting result, especially when comparing it with the outcomes for the Length of Stay, as it depicts the expected shift from a longer inpatient IV antibiotics treatment, towards a longer IV outpatient antibiotics treatment, which is mentioned by Williams et al. (2015).

An remarkable observation from this analysis is the lack of substantial differences in means between the intervention group and the various experimental scenarios. This is caused by our assumption that eliminating communication problems only affects the length of stay and time spent by VCC nurses. We do not have significant evidence to suggest a change in OPAT duration.

Similar to the Length of Stay KPI, our statistical tests show that the means across all experiments do not significantly differ. This implies that the differences in average OPAT duration observed in various experiments could be due to random variability rather than meaningful effects. This suggests that, regarding OPAT duration, the intervention and future scenarios do not significantly affect outcomes compared to the control group. Further analysis to explore potential influencing factors may be needed for a more comprehensive understanding.

4.5.6 Total Working Time of Healthcare Professionals per Patient

Total working time is calculated in total, and the division over three groups of employees will be given. These three groups are Medical specialist, Secretary and Transfer agency/VCC nurses. Each of these categories is described in Section 4.2. For the control group, the Transfer/VCC category shows time spent by transfer agency nurses, based also based on information provided in Section 4.2. In the intervention and future scenario groups, this same category depicts time spent by VCC nurses.

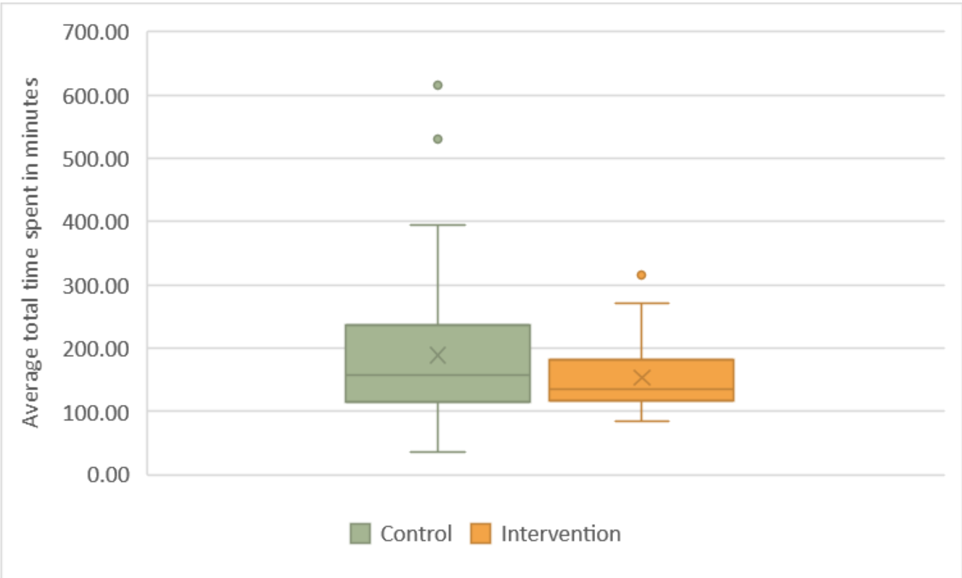

Figure 9a: Boxplot depicting Total working time per patient

To identify outliers, we assessed the total appointment duration for each patient and employed boxplots for visual representation (Figure 9a). The upper bound for the intervention group was found to be 270 minutes, while for the control group, it was 395 minutes. Consequently, we removed one outlier from the intervention group and two outliers from the control group.

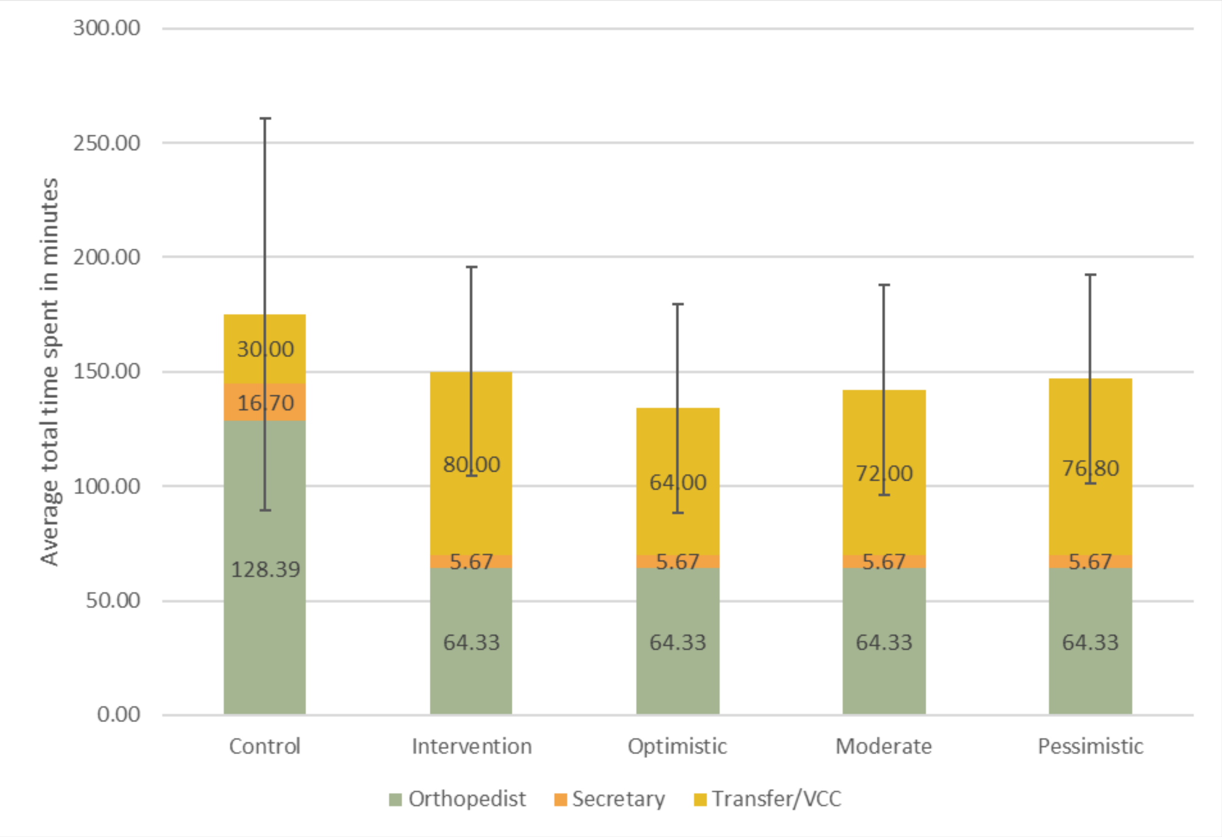

Figure 9b: Average total Time spent per Patient per Employee type for each experiment

In Figure 9b, the Time spent per Patient per Employee type is displayed for each experiment, including the control group and the various intervention scenarios. The means of total time spent range from a minimum of 134 minutes in the optimistic future scenario, to 175 minutes in the control group. One of the intervention's objectives was to reduce the time spent by medical specialists by transferring certain tasks to the VCC, such as organizing laboratory tests and making patient calls. From this graph, this shift in responsibility following the intervention seems evident, as we can see that much less time is spent per patient is spent by medical specialists, and more time is spent by VCC nurses. Furthermore, we see that time spent by secretaries is also reduced, as some of their tasks are also taken over by VCC nurses.

In the scenario depicting optimistic improvement in the communication problems, we observe a 16 minute reduction in working time per patient. Yearly, this reduction would apply to about 80 patients, meaning a total reduction in working time for VCC nurses of 21 hours and 20 minutes. This may not seem like a lot on a yearly basis, but if we consider that this reduction could also apply for other patient groups it seems like a valuable investment to aim for improving communication moments. Comparing this to the pessimistic scenario, which gives a yearly reduction in working time of 4 hours and 16 minutes, we can see that a lot of time can be won with a structural approach to eliminating this bottleneck.

While the initial reduction in total working times appears promising, it is crucial to consider factors that introduce uncertainty regarding this reduction. Notably, this result is largely based on registered appointments, which typically only encompass billable activities. This registration often excludes additional time spent on activities like telephone calls by VCC nurses and secretaries. In an effort to address this, we have factored in the estimated time spent by Transfer agency/VCC nurses, encompassing both billable and non-billable activities.

The total working time is extremely close to meeting the criteria for significance in a two-sample t-test with a 95% confidence interval, with a p-value of 0.06. Furthermore, when we separately compare the means of each care professional group in the intervention and control groups, we observe a significant difference according to our tests, which confirms the major shifts in time allocation observed.

It is important to note that the standard deviation is slightly biased primarily due to the absence of variance in the time spent by the Transfer Agency or VCC. This asymmetry has a more pronounced impact on the intervention group since the VCC contributes to over half of the total time spent, resulting in a relatively higher standard deviation in the control group.

4.5.7 Wage Costs per Patient

Based on the time spent by each employee type and the hourly wage costs provided by Isala (Appendix D), we calculate the average wage costs in each experiment. This is done using the formula given in Section 3.2.5. The wage costs provided by Isala were multiplied by a random factor, insuring compliance with data regulations of Isala. This means the results do not represent reality. However, since the same random factor is used for each employee type, this does not influence the results of our research.

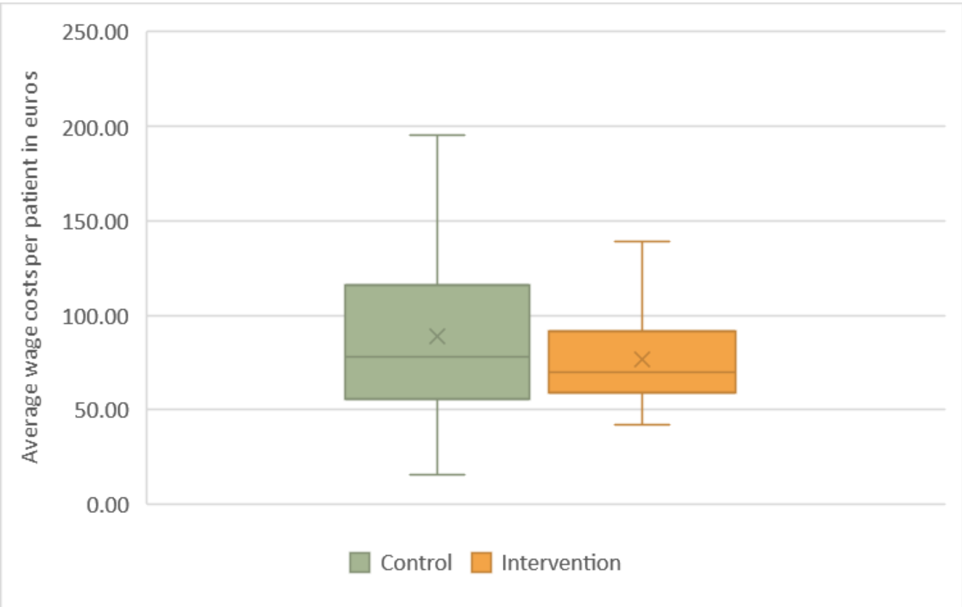

Figure 10a: Boxplot depicting Wage costs per patient

In Figure 10a, depicting the boxplot for wage costs per patient, no outliers were identified since the same patient dataset used for total time spent had already excluded them.

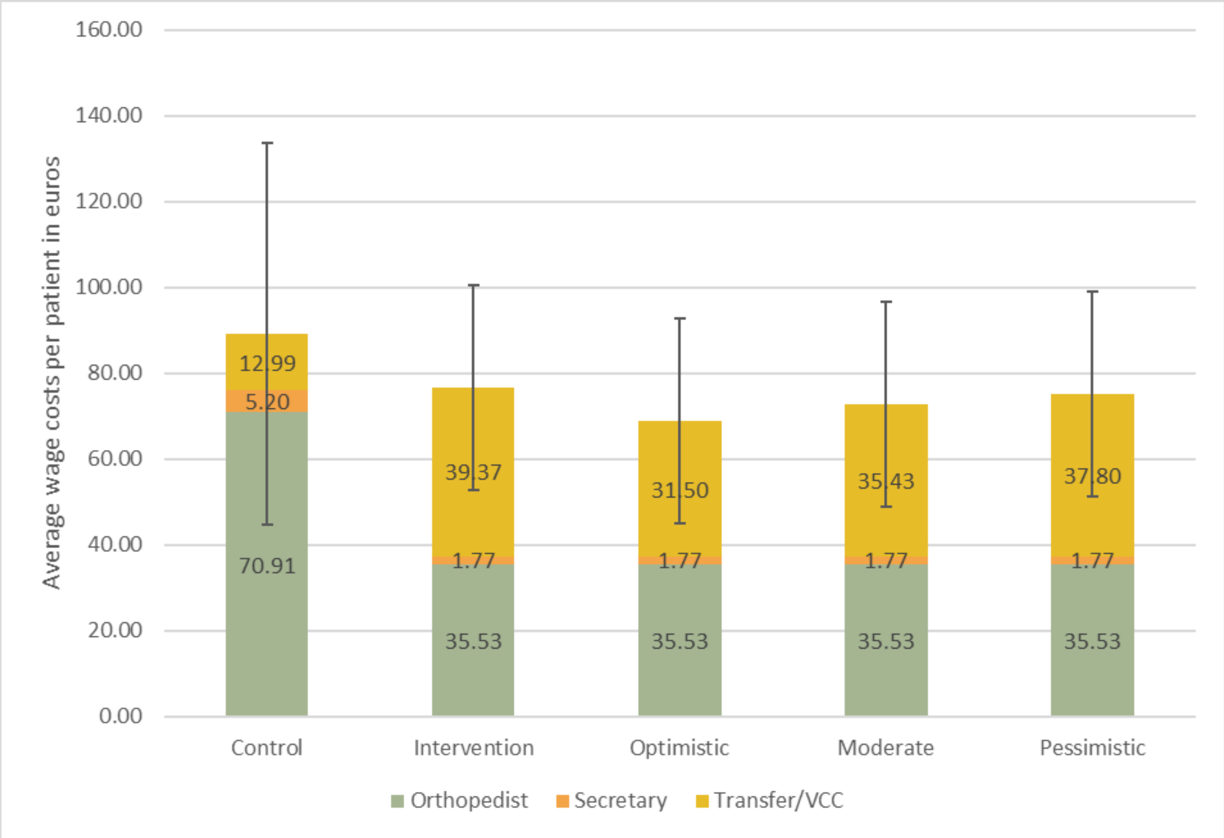

Figure 10b: Average total Wage costs per Patient per Employee type for each experiment

Figure 10b shows similar results as Figure 9b total working time per patient, however, in this case the wage costs are factored in, which vary per care professional type. The averages for wage costs per patient range from a minimum of €68.79 in the optimistic scenario to €89.10 in the control group. One of the objectives of the intervention was to reduce costs by redistributing certain tasks from medical specialists to the VCC. An interesting factor in this objective is the lower wage costs of VCC nurses compared to medical specialists. Our analysis indicates a reduction in the costs, specifically in the optimistic scenario. Following the intervention, the wage costs are lower for all healthcare professional groups combined, demonstrating an efficient utilization of resources.

It is important to note that these results do not show the total wage costs for each patient of the whole care pathway, since it does not include activities like surgeries. Instead, it shows all wage costs following the discharge of a patient, which allows us to compare the control and intervention groups with regards to this part of the care pathway.

Our analysis indicates that the average wage costs per patient are not significantly different across the experiments, with a p-value of 0.07. However, comparing the control group and intervention group means for each separate employee type does tell us they hold significant differences to form our conclusions.

While a reduction in costs of €12.43 comparing the control and intervention group may seem modest, it is worth noting that if the use of a VCC is extended to different projects and patient groups within Isala, it could ultimately translate into substantial cost savings for the hospital. From our results, it can also be shown that further reduction of costs is possible with a reduction in communication problems.

4.5.8 Number of Readmissions

A health outcome often mentioned in literature is the number of readmissions. In our study, a readmission is defined as an admission within 30 days after discharge from the hospital, following a surgery on an infection. In the control group, 15 readmissions were recorded, which gives a readmission percentage of 26%. In the intervention group, 12 readmissions were recorded, giving a decreased readmission percentage of 23%. As these results are based on very few patients, and only a minor decrease is suggested, we cannot conclude whether or not the intervention actually caused a decrease in readmissions.

4.6 Conclusion

In this chapter, we explore the results of our research, delving into the complexities of outpatient care pathways, healthcare professionals, and key performance indicators. These findings provide invaluable insights into the efficiency and effectiveness of the care pathways and the impact of our intervention.

The chapter provides a detailed overview of care pathway X at Isala, both before and after the Connected Care intervention. Notable changes include the timing of antibiotic delivery and communication improvements. Additionally, the bottleneck analysis identifies several critical bottlenecks, some influenced by the intervention, such as alterations in communication and discharge deadlines. Others, not directly impacted by the intervention, include issues related to documentation, incorrect material supplies, ADL or wound care requirements, and communication between patients and the VCC.

We observed that the introduction of a VCC within the care pathways led to notable changes in several key performance indicators. Analysing the Length of Stay KPI, we identify a reduction in hospitalization duration in the intervention group of 1.4 days, with the optimistic scenario showing the largest decrease. However, when we only look at injury type 2 patients, an apparent increase of 0.3 days is found, showcasing the importance of homogeneous patient groups. The analysis of the Duration of OPAT presents a slight increase in duration following the intervention of 0.8 days, suggesting a shift from inpatient to outpatient treatment.

The assessment of the Total Working Time of Healthcare Professionals per patient reveals changes in the allocation of time, particularly with reduced time spent by medical specialists and secretaries. While the data suggests an overall reduction in working time of 25 minutes per patient, the standard deviation remains relatively high. Examining Wage Costs per patient, we identify a reduction in costs, particularly in the optimistic scenario, which shows a €21 per patient decrease compared to the control group, reflecting the benefits of redistributing tasks to the VCC. The overall results do not show significant differences in wage costs per patient between experiments, though they demonstrate the potential for cost savings with the implementation of the VCC.

Lastly, the analysis of Readmissions explores the percentage of patients readmitted within 30 days of discharge. While the intervention group shows a lower readmission percentage of 23%, compared to 26% for the control group, the small sample sizes and large standard deviations prevent significant conclusions. Statistical tests also confirm the lack of significance in the results.

Overall, the data analysis provides valuable insights into the OPAT care pathway's performance and highlights areas where the intervention appears to have an impact. However, it is essential to acknowledge the limitations of small sample sizes and variable data, which prevent drawing statistically significant conclusions in many cases. This suggests the need for further research with larger sample sizes and refined methodologies to better evaluate the intervention's effectiveness.

5 Conclusion & Recommendations

5.1 Conclusion

This study aimed to investigate the main research question: "What effect does the implementation of a virtual care centre in an OPAT care pathway have on the capacity of transmural care organised by Isala?" Our analysis reveals a range of findings that provide valuable insights into care pathway X and the impact of the Connected Care intervention.

While the results of our data analysis suggest an improvement in the care pathway since the intervention, with regards to length of stay, time spent by care professionals, and wage costs, we cannot draw any conclusions with certainty, since the results do not pass our tests for statistical significance. Still, we mention the most important results found from the data analysis in this chapter, as they give us some practical insights.

The data analysis highlights key findings related to the Connected Care intervention in the OPAT setting in department X at Isala. The Length of Stay showed a notable reduction of 1.4 days in the intervention group, slightly below the expected 1.8-day decrease, indicating improved efficiency. However, when only looking at type 2 patients, we see a 0.3-day increase after the intervention. For Duration of OPAT, there was an increase of 0.8 days after the intervention, reflecting a shift from inpatient to outpatient treatment. The analysis of Total Working Time of Healthcare Professionals demonstrated a shift in responsibilities, notably less time spent by medical specialists and secretaries and more by VCC nurses. Wage Costs per patient also decreased following the intervention, particularly in the optimistic future scenario minimizing communication problems. Although the Number of Readmissions decreased in the intervention group from 26% to 23%, small sample sizes and large standard deviations limited the statistical significance of these findings.

However, our research is not limited to just a data analysis, meaning we can also draw conclusions from our analysis of the care pathway before and after the intervention, and our bottleneck analysis. In the conventional pathway, patients with infections undergo hospitalization, a transition to home healthcare and lab tests. The intervention pathway aims to optimise the process, streamlining antibiotic delivery, enhancing discharge flexibility, and implementing a VCC with a directing function for patients post-discharge. Several significant changes have been introduced, including revised discharge deadlines, VCC taking over organisation of blood tests, and altered transfer agency responsibilities. Based on these results, the care pathway after the intervention seems more streamlined, but there also seem to be new problems arising. To draw more in-depth conclusions, we move to the results from the bottleneck analysis.

The intervention has notably addressed key bottlenecks, leading to positive changes in various aspects of the care pathway. Some bottlenecks that improved include timely availability of culture results, medication pickup, and discharge file completion, which now have a more accommodating deadline of 15:00, compared to the previous 12:00 deadline. However, it is crucial to acknowledge that the intervention introduced a communication bottleneck, which was not present in the conventional pathway. This new communication bottleneck, involving changes in communication processes, requires attention to ensure it does not hinder the overall efficiency and effectiveness of the care pathway. Additionally, challenges unrelated to the intervention, such as documentation issues in home healthcare organisations, occasional supply of incorrect materials, and communication gaps between patients and home healthcare nurses, as well as VCC nurses, also warrant consideration to further optimize the care pathway.

5.2 Recommendations

Based on the findings of our study, we make some recommendations. The first, and most important recommendation is to continue the use of a VCC within care pathway X. We recommend continuing to treat patients with the virtual care pathway introduced by the Connected Care intervention. While our results did not achieve statistical significance, there are clear indicators of positive outcomes, including reduced hospitalization time, cost savings, and fewer readmissions. Further research and data collection are needed to provide more robust evidence of its effectiveness, but the virtual care pathway appears to hold promise for the future of healthcare.

Looking at the experiments in which we tested the implications of a decrease in communication problems, we can see that Isala can benefit from improvement of this bottleneck. The introduction of new communication moments in the care pathway can lead to challenges. It is crucial to focus on mitigating these communication bottlenecks. This extends to improving communication between different stakeholders within the care pathway, including better communication between the VCC and regular nurses, as well as between the hospital and home healthcare nurses. Establishing clear communication channels and protocols can help streamline care and reduce potential misunderstandings.

As Isala hospital is the largest, non-academic hospital in the Netherlands, it wants to focus more on its scientific contributions to healthcare research (Program manager Connected Care, 2023). To achieve this objective, a more systematic approach to project evaluation is needed. While conducting our research we have come across several points of improvement, leading to our final recommendation: the establishment of a structured framework for evaluating project performance, especially following project modifications. Such a structured approach is essential for a scientifically sound evaluation. Firstly, before implementing changes in a care pathway, clear intervention goals must be defined, specifying the aspects of the process to be enhanced, the methods for achieving these improvements, and the measurement criteria. Notably, this is also where the assessment methodology, such as evaluation-based KPI assessment, can be defined. For any methodology that is chosen, the necessary data must be defined. Establishing necessary data allows for exploration of possibilities to start recording data that is not usually recorded. Next, it is important to establish a patient set for the control group, which will serve as the baseline for assessing performance changes. Once all these steps are taken and sufficient patient data is recorded for the control group, the intervention can be implemented. Following the intervention, project leaders should engage in ongoing dialogue with the healthcare personnel involved to ensure that the intended changes are progressing as planned. Over time, as a substantial dataset from the intervention group becomes available, performance can be assessed and compared against the control group using the predefined assessment methodology. This approach yields effective and scientifically-grounded evaluations, enabling project leaders to make informed decisions that maximize the benefits derived from the project improvements.

In conclusion, our research, despite not achieving statistical significance, provides promising insights into the Virtual Care Centre's potential. We can therefore answer our main research question by stating that the implementation of a VCC in an OPAT care pathway seems to have a positive effect on capacity, but more research needs to be done to confirm this. As healthcare organizations continually strive for enhanced capacity and efficiency in care pathways, understanding the limitations of the current research and incorporating the outlined recommendations will be essential for driving progress and achieving meaningful outcomes. The complexity of healthcare management requires constant evaluation and adaptation, making the search for a more efficient and effective healthcare system a continuous effort.

6 Discussion & Future Research

The limitations and complexities of this study need to be considered in the context of interpreting our findings. Firstly, we encountered challenges related to the availability of patient data and the formation of a control group. The absence of a pre-established control group made it challenging to create a rigorous comparative analysis. As a result, this study should primarily be viewed as exploratory, highlighting the need for more comprehensive research in the future.

Comparing our results to literature can make for an interesting addition to our research. From our results it is suggested that a trade-off is made where LOS decreases and OPAT duration increases, which has been mentioned before by Gordon et al. (2011). In the article by Gordon et al., readmission rates are also compared between a control group from 1978 to 1990, and the intervention group in 2014. This shows a decrease from 6% to 1%. In our research we also find a decrease, yet the decrease is much smaller, and the overall readmission rate is much higher (26% and 23%). This could confirm that our readmission rate is not representative for OPAT care pathways. Next, our results show a decrease in wage costs, which is promising. Yet, there are many more cost factors to consider. Furthermore, it is possible that a broader implementation of OPAT care pathways results in larger cost reductions, which could happen when it is implemented in more departments (Peters et al., 2022).

The substantial variance in our results is influenced by various factors. The wide range of patient diagnoses, including patients with injuries of type 1 and 2, as well as variations in treatment plans and surgical methods, contributes to data variability. The importance of having a homogeneous patient group is clearly shown in our calculations of LOS for type 2 patients only, as this gave a different indication than patients with type 1 and 2 injuries combined. Additionally, the severity of the infection and the resulting treatment duration significantly affect the outcomes. These inherent variations pose a considerable challenge in achieving statistical significance and underline the necessity for a larger and more homogenized sample in future studies.

Moreover, the inadequacy of our data sample, which did not meet the minimum sample size according to Yamane's Formula for Sample Calculation, is a limitation that should be addressed in future research. Data quality issues, uncertainty regarding patient inclusion, and the lack of comprehensive patient documentation hindered our ability to increase the sample size. Generating additional patients based on the available data could help bridge the gap and enhance the statistical power of our analysis.

Since we use secondary data, another limitation is the quality of this data. To get more insight into capacity, we are using patient data that was originally collected to monitor the patient and make sure they are getting the care they need. This means that the data is collected for a different purpose than for our research. An issue with the use of secondary data is the possibility that some useable data cannot be found due to e.g. spelling errors made by nurses. This might mean that the data does not show up correctly in our data search engine.

A factor that may influence our results is the impact of advances in infection prevention during surgery since the intervention. However, it is unlikely to have a significant influence. While it may have contributed to fewer patients developing an infection, there is limited evidence to suggest that the presentation of infection cases, and therefore the treatment course, has changed significantly.

Addressing the limitations, future research directions are outlined to improve the robustness of investigations in the domain of Virtual Care Centres in OPAT care pathways. Recommendations include increasing the sample size, enhancing data collection to encompass both billable and non-billable activities, predefining a control group, and exploring specialized care pathways for more homogenized research outcomes. By addressing these issues and adopting a value-based healthcare framework, future studies have the potential to provide more accurate and statistically significant insights into the efficacy of Virtual Care Centres and their impact on transmural care.

Furthermore, there are some interesting topics to explore in future research. Investigating the working time of home healthcare nurses is the most important addition, which would give a more complete overview of time allocation throughout transmural care. Next to this, exploring pharmacy options, particularly regarding the choice between different providers and optimal deadlines for completing discharge files, could further improve the care pathway.

In summary, this discussion states the exploratory nature of our study, emphasizing the limitations while also highlighting the practical implications. We have expanded on the need for improved data collection, alternative methodologies, and topics to explore in future research, all of which help in shaping the future of healthcare delivery within the outpatient setting.

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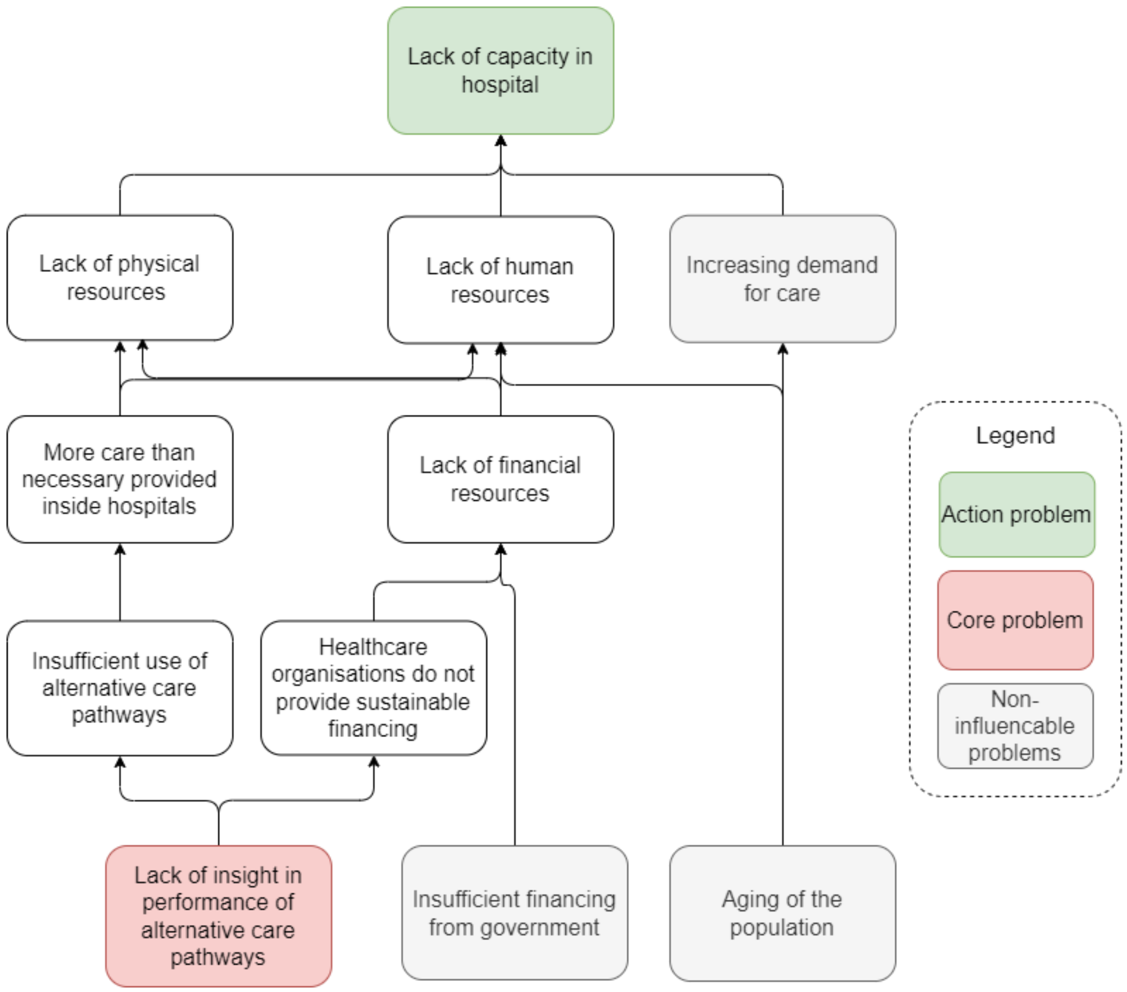
Appendices

A. Problem cluster



B. Ethics Approval

a. Ethics Committee University of Twente

Req…	Title	Researcher	Application	Appr.superv.	Status
230570	Assessing the effect of medication@home on healthcare capacity	Agaart, M.J.J.	13-04-2023	21-04-2023	Approved by commission

b. Lokale Haalbaarheidscommissie Isala

20230604	Capacity effects virtual care center	Niet WMO	Marijke Agaart	Goedgekeurd Lokale Haalbaarheid NWMO	2 dagen

C. Search Log

Database	Date	Search String	Number of Results	Notes
Scopus	10/06/2023	(TITLE-ABS-KEY (capacity) AND TITLE-ABS-KEY (healthcare OR health OR care OR hospital OR "home care") AND TITLE-ABS-KEY (	67.390	Little focus on capacity. Often it is only mentioned in the abstract once. In order to focus more on capacity we will change the

		kpi* OR "key performance indicator*" OR "performance indicator*" OR indicate* OR variable* OR measur*)) AND (LIMIT-TO (LANGUAGE , "English"))		search string to only show articles with capacity in the title .
Scopus	10/06/2023	(TITLE (capacity) AND TITLE-ABS-KEY (healthcare OR health OR care OR hospital OR "home care") AND TITLE-ABS-KEY (kpi* OR "key performance indicator*" OR "performance indicator*" OR indicate* OR variable* OR measur*)) AND (LIMIT-TO (LANGUAGE , "English"))	5.792	More focus on capacity, yet mostly in the sense of mental or intrinsic ability, which is not what we are looking for.
Scopus	11/06/2023	(TITLE (capacity) AND TITLE (hospital OR healthcare OR "health care") AND TITLE-ABS-KEY (kpi* OR "key performance indicator*" OR "performance indicator*" OR indicator*)) AND (LIMIT-TO (LANGUAGE , "English"))	56	We want to find articles that mention something about performance indicators specifically. Therefore we removed some of the terms related to KPI's, in order to get more specific results. This seems to be giving better results.
PubMed	11-06-23	(TITLE (capacity) AND TITLE (hospital OR healthcare OR "health care") AND TITLE-ABS-KEY (kpi* OR "key performance indicator*" OR "performance indicator*" OR indicator*)) AND (LIMIT-TO (LANGUAGE , "English"))	30	In the more specialized database more articles seem to fit the research question better.
Scopus & PubMed		Many articles were found by snowballing, using articles found with above mentioned search strings as a starting point.		When useful articles are found we can dig deeper into the areas of interest using this search strategy.

Table 5: Search Log, describing Search Strings used for Literature Review

D. Hourly Wages

Category	Hourly Wage
Medical Specialist	€ 33.14
Secretary	€ 18.67
Transfer Agency	€ 25.99
VCC	€ 29.53

Table 6: Hourly wage per Employee type, multiplied by a random factor