Assessing the Impacts of Remote Patient Monitoring on the Capacity and Financial Performance of Isala Hospital

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Preface

I am pleased to present you my bachelor's thesis in this document. The completion of this thesis marks a significant milestone in my academic journey, marking the culmination of my bachelor's degree. This journey has contributed a lot to my academic and personal growth. This work would not have been possible without the guidance, support, and inspiration from various individuals who have played pivotal roles in my academic and professional development.

First and foremost, I would like to extend my heartfelt gratitude to my university supervisors Dr. ir. Gréanne Leeftink, and Dr. Sebastian Rachuba. Your unwavering commitment to academic excellence, insightful feedback, and mentorship have been invaluable throughout this research journey. Assisted by your constructive insights, and guidance I was able to enrich the depth and quality of this thesis. Your encouragement to explore innovative approaches and your patient guidance through complex research challenges have been critical in shaping this work.

I would also like to express my sincere appreciation to my company supervisor, Jedidja Lok-Visser. Your practical wisdom and industry insights have provided a unique perspective to this research project. Your unwavering support, encouragement, and the opportunity to bridge theory and practice in a real-world setting were critical in enhancing the relevance and applicability of this work.

I must also acknowledge the countless hours invested by my colleagues, friends, and family, who have provided encouragement, support, and a nurturing environment for my academic pursuits.

As I reflect upon this journey, I recognize that research is a collaborative effort, and this thesis represents not just my own endeavors but the collective contribution of a supportive academic community.

With gratitude, I present this thesis, hoping that it contributes to the body of knowledge in our field and inspires future explorations. I would like to present this not for myself, but also for everyone who has played a role, no matter how small, in the creation of this thesis.

Omar Abdelmaksoud

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Management Summary

Introduction

Along with other hospitals, Isala Hospital faced capacity problems during the Covid-19 pandemic, due to some factors including the increasing demand for healthcare, shortages in medical professionals, and the ageing population. In response to this, hospitals started looking into more efficient models of care such as remote patient monitoring systems and telehealth solutions. Telehealth solutions are models of care which integrate digital components into healthcare models. The aim of this research is to assess the impacts of transitioning to virtual care pathways on the capacity and financial performance of hospitals. For our research, we take the transition to the virtual care pathway and implementation of the home monitoring programme for the treatment of Covid-19 patients at Isala Hospital as a case study. The home monitoring programme is a treatment method implemented during the Covid-19 pandemic, where patients are discharged earlier from the hospital once they don't need hospital care, and are monitored online by virtual monitoring nurses from their homes. We assess the impacts of transitioning to the virtual care pathway for the treatment of Covid-19 patients, while also comparing its capacity and financial performance with the traditional care pathway used for the treatment of Covid-19 patients. We define our main research question as: **"Is the transition to virtual care pathways beneficial for hospitals from a capacity performance and cost-efficiency perspective?"**. The research question follows from our core problem.

Literature Research

We conduct a systematic literature review for our research, we look into several aspects, such as the concepts of care pathways, and the differences between virtual and traditional care pathways, while also looking into the assessment of capacity and financial performance at hospitals. First, we seek to define the concepts of virtual and traditional care pathways, while looking into their main components, differences, and benefits for both hospitals and patients. Furthermore, we aim to define capacity in the healthcare industry, which is a term that does not have a general definition, as every article defines it in the context of the research conducted. Additionally, we look into the assessment of hospital capacity and financial performance in the literature, by looking into the different assessment methodologies used. During our research, we define four assessment methodologies, and chose the comparison of KPIs to be the main assessment methodology used in our research. Thus, we look into the usage of Key Performance Indicators (KPIs) and find 24 KPIs which are used for the assessment of capacity and financial performance at hospitals. Some of these KPIs include the Length of Stay (LoS) per patient, the average number of appointments per patient, and the treatment costs per patient. These 24 KPIs were found in the literature, and in previous research conducted by the Connected Care Center (CCC) department at Isala Hospital to assess the impacts of transitioning to the virtual care pathway during the Covid-19 pandemic. We make a selection of KPIs from the KPIs found to assess the capacity and financial performance of transitioning to the virtual care pathway for the treatment of Covid-19 patients. We find that most articles use KPIs linked to the general ward of hospitals, such as the bed occupancy rate, and bed turnover rate. Lastly, no articles were found assessing the impacts of transitioning to virtual care pathways on the capacity performance of hospitals.

Context Analysis

In the context analysis chapter we discuss the transition project to the virtual care pathway, and the implementation of the home monitoring programme for the treatment of Covid-19 patients at Isala Hospital. Isala Hospital transitioned to the virtual care pathway on the 20th of November 2020, almost a year after the start of the Covid-19 pandemic. Since the transition took place, Isala Hospital was able to treat 153 Covid-19 patients using the home monitoring programme, until January 2022. The home monitoring programme, and the virtual care pathway implemented at Isala Hospital involve that Covid-19 patients are discharged earlier from the hospital once they no longer need hospital care, to free in patient beds. The early discharged patients are then monitored online from their homes by virtual monitoring nurses, which check some measurements such as the oxygen saturation in the patients' blood, and the oxygen consumption of an oxygen tank which is provided by Isala Hospital. The traditional and virtual care pathways are then defined and introduced with their main components as implemented at Isala Hospital, a flow diagram of both care pathways is provided as well. Finally, some descriptive statistics such as the gender and age distributions are discussed for Covid-19 patients treated using both the virtual and traditional care pathways.

Methods

The case study for our research is the transition to the virtual care pathway, and implementation of the home monitoring programme for the treatment of Covid-19 patients at Isala Hospital. We retrieved our datasets from the Isala Hospital online data repository, where patient records and other data are stored. For our research, no patient records were used, only operational performance data were extracted from the CTCue software. Since we need to assess the capacity and financial performance of the hospital, we look into three focus areas, admissions and appointments for capacity performance, and costs for financial performance. We were able to extract two datasets containing admissions and appointments data for Covid-19 patients treated using the traditional and virtual care pathways, each datasets is representative for one of both care pathways. The dataset for Covid-19 patients treated using the traditional care pathway includes 111 patients, and was extracted using a filter to show only lung patients, treated between the 1st December 2019 until the 20th of November 2020. Additionally, the dataset of Covid-19 patients enrolled in the home monitoring programme after the transition to the virtual care pathway consists of 97 patients. For the extraction of the dataset for Covid-19 patients enrolled in the home monitoring programme we use a filter to show lung patients treated between the 20th of November 2020, the 1st of May 2023. We assume that the Covid-19 pandemic started on the 1st of Dec 2019, and ended on the 1st of May 2023, while the 20th of November 2020 represents the date Isala Hospital transitioned to the virtual care pathway for the treatment of Covid-19 patients. Furthermore, we assume that patients with an LoS of less than a day are not admitted to the hospital and are therefore removed from the datasets. Moreover, we assume that treatment methods of Covid-19 patients were kept the same throughout the pandemic. Lastly, we make the assumption that 453 Covid-19 patients were enrolled in the home monitoring programme after transitioning to the virtual care pathway. In order to assess the capacity performance of the hospital, we decided on two focus points, which are appointments and admissions. For appointments and admissions we obtained the following data fields; Patient Pseudo ID, Appointment Description, Appointment Type, and Appointment Duration. As for admissions we extracted the following data points; Patient Pseudo ID, Length of Stay (LoS), and the Number of Admissions was calculated by counting the number of times Patient Pseudo IDs were repeated. For admissions of Covid-19 patients to Isala Hospital we have two scenarios, the first is for patients treated using the traditional care pathway, and for this scenario we have three generated data samples. The second scenario is for Covid-19 patients enrolled in the home monitoring programme, and for this scenario we have a dataset consisting of 100 patients. We generate data samples for the first scenario because the existing dataset does not contain enough patients for creating a proper assessment, which is why data samples are generated, to create a fair comparison between both scenarios. On the other hand, for the assessment of appointments we compare between six data samples, three for each scenario. All data samples have a sample size of 100 patients, and have been simulated using the synthetic data generation technique. After examining datasets for admissions and appointments of Covid-19 patients treated using the traditional and virtual care pathway, we find that the main attributes such as the LoS at the hospital, Number of Admissions, Total Duration of Appointments, and Number of Appointments follow a gamma distribution in the original datasets extracted from CTCue. Therefore, data samples were simulated based on alterations in the alpha (α) and beta (β) of these parameters.

Results

The final list of KPIs selected in Chapter 2 for the assessment include KPI used to assess the impacts of transitioning to the virtual care pathway for the treatment of Covid-19 patients, on the financial and capacity performance of Isala Hospital. To the assess the capacity performance of the hospital we focus on admissions and appointments, while for assessing the financial performance we focus on costs and profits. For evaluating the impacts of the transition on the capacity performance we look into the KPIs average LoS at the hospital per patient, average number of appointments per patient, and average total duration of appointments per patient. Additionally, for assessing the financial performance of the hospital, we look into the KPIs average total treatment costs per patient, average reimbursement per patient, and average profit generated per patient. Our findings highlight some primary insights between the capacity and financial performance of the virtual and traditional care pathways. Firstly, patients treated using the virtual care pathway and enrolled in the home monitoring programme spend less time admitted to the general ward by 1.9 days on average. Despite the difference in the LoS at the hospital, patients enrolled in the home monitoring programme spend 7 more days to complete their treatment process, due to the time spent at home being monitored by Isala Hospital's nurses. Additionally, Covid-19 patients treated using the virtual care pathway had approximately 5 times the number of appointments, and almost 8 times the total duration of appointments as patients treated using the traditional care pathway on average. As for the results of the cost analysis, we find that appointments of Covid-19 patients treated using the traditional care pathway are 11 times more expensive, and the total appointment costs per patient are 2 times more expensive than patients enrolled in the home monitoring programme on average. We reason the difference in the average appointment costs by examining the percentage of appointments by types for both scenarios. We find that 100% of appointments of the home monitoring programme consist of telephonic consultations, while the traditional care pathway contains outpatient clinic visits with percentages ranging from 12% to 44% for all 3 samples, besides having telephonic consultations as well. Moreover, our findings show that the total treatment costs for Covid-19 patients enrolled in the home monitoring programme are 23% cheaper on average than for Covid-19 patients treated using the traditional care pathway. We use our assumption that 453 patients were enrolled in the home monitoring programme to calculate that Isala Hospital saved around 838 nursing days, resulting in cost savings of € 437,403.44. Furthermore, Covid-19 patients enrolled in the home monitoring programme generates Isala Hospital € 575.57 more as profit per patient, saving Isala Hospital € 260,734.75 in profits gained. Finally, due to the costs of the nursing days saved, as well as the profit gained, we find that Isala Hospital benefits from cost savings of € 698,138.18 from the 20th of November until the 1st of May 2023, due to the transition to the virtual care pathway for the treatment of Covid-19 patients.

Conclusion and Recommendations

We conclude that the virtual care pathway performs better from a capacity and financial perspective for our case study for the treatment of Covid-19 patients at Isala Hospital. The virtual care pathway performs better by reducing the LoS of patients at the hospital, reducing the total treatment costs per patient, and yielding higher profits per patient. Additionally, the virtual care pathway can contribute to a better patient experience, by having more interactions with hospital staff. The reason for the better patient experience is that patients have almost 5 times the appointments as patients treated using the traditional care pathway, while having these appointments online from their homes, without having to go to the hospital, saving patients time, money, and effort. We recommend that Isala Hospital keeps using the virtual care pathway and the home monitoring programme, while limiting the number of telephonic consultations patients have with virtual monitoring nurses. Reducing the average number of appointments per patient by 40% will not only improve the capacity performance, but will contribute to reducing the average total appointment costs per patient by € 66. Our research can be extended by implementing the following; improving the cost analysis by including costs which are not included such as the costs of implementing the sensors. Moreover, the data collection method needs to be improved as to provide data of higher quality and quantity, improving the reliability of data and reducing the reliance on assumptions. Furthermore, more KPIs could be used to assess different aspects of the virtual care pathway such as the patient satisfaction and patient case mix KPIs which were not implemented. Lastly, the research could be extended by carrying out the research on an extended period of time to provide long-term results, while also looking at different patient groups or other hospitals worldwide having a similar transition project. This will help to build a more solid conclusion on the transition to virtual care pathways, and further generalize the results.

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List of Abbreviations

HCPs: Health Care Providers

VCPs: Virtual Care Pathways

TCPs: Traditional Care Pathways

GP: General Practitioner

KPIs: Key Performance Indicators

RPMS: Remote Patient Monitoring Systems

CCC: Connected Care Center

1 Introduction

This chapter introduces this research assignment by providing background information regarding the capacity problem faced by Isala Hospital and other hospitals worldwide during the Covid-19 pandemic, in Section 1.1. We also discuss the research design for this research in Section 1.2.

1.1 Problem Identification

This section provides an overview of Isala Hospital, while also introducing the capacity strain faced during the Covid-19 pandemic, and the interventions taken to resolve this problem, and improve the capacity performance of hospitals. Moreover, we discuss the increasing implementation of telehealth solutions such as Remote Patient Monitoring Systems (RPMS), while introducing the implementation of the home monitoring programme, and the research conducted by Isala Hospital in Sub-section 1.1.1. Then, the problem cluster for this research assignment is visualized, highlighting the core problem and action problem faced by Isala Hospital in Sub-section 1.1.2. Finally, the research objectives are outlined in Sub-section 1.1.3.

1.1.1 Background and Context

Isala Hospital is the largest non-academic general hospital in the Netherlands, known for its commitment and mission to ensure high-quality care and patient involvement in the healthcare delivery process. The hospital's academy ensures the training and education of medical staff, students, and researchers (About Isala, n.d.). Moreover, Isala Hospital constantly conducts scientific research to remain up to date with the innovations in the healthcare industry, contributing to improved care and outcomes.

Isala Hospital, along with other hospitals worldwide, faced significant challenges during the Covid-19 pandemic. Mainly because the healthcare industry faces a capacity crisis, due to some factors such as the ageing and growing population, tightness of the labor market, shortages in medical professionals, resource constraints, and the increasing demand for healthcare services (Boldt-Christmas et al., 2023; Jack & Powers, 2009). Because the increasing demand exceeds the available capacity, hospitals find themselves facing a capacity strain (Humphreys & Spratt, 2022; Schneider, 2020).

The impact of the pandemic on the capacity performance of hospitals has highlighted the need for accessible and cost-effective models of care, which accelerated the adoption of telehealth solutions such as Remote Patient Monitoring Systems (RPMS). Telehealth tools have proved effective to provide high quality and convenient care during the Covid-19 pandemic, allowing the transition from reactive to proactive healthcare models (Boldt-Christmas et al., 2023)

RPMS is one of the most known telehealth solutions, and has already shown potential in improving hospital capacity performance, reducing readmissions rates, and enhancing the overall patient satisfaction. Additionally, the implementation of RPMS can result in cost-savings in the long-term, and optimize resource allocation (Augenstein & Chamberlain, 2019; Enrique & Burches).

In response to the capacity strain faced by the hospital, and the increasing adoption of telehealth solutions, Isala Hospital setup the Connected Care Center (CCC) to develop and implement a home monitoring programme involving the early discharge and home monitoring of Covid-19 patients. The programme aims to optimize capacity management and enhance patient care, through the use of RPMS to monitor patients remotely from their homes.

After implementing the home monitoring programme, the CCC department conducted a research providing insight into the impacts of the implementation at Isala Hospital during the Covid-19 pandemic. The research focused on several aspects such as the effectiveness of the programme in providing quality care, while also reducing the capacity strain faced by the hospital, and making the hospital more cost-efficient. In our research, we aim to minimize assumptions, and if assumptions are made they should be scientific with references to other articles. Moreover, we conduct a comparison between treatment data of Covid-19 patients treated before and after the implementation of the home monitoring programme. Finally, our research looks at a larger portion of Covid-19 patients enrolled in the home monitoring programme, improving the overall reliability of our results.

The main aim of this research is to assess the impacts of the programme on the financial and capacity performance of Isala Hospital, and researching if it satisfied its goal of making Isala Hospital more efficient in terms of costs and capacity.

1.1.2 Problem Cluster

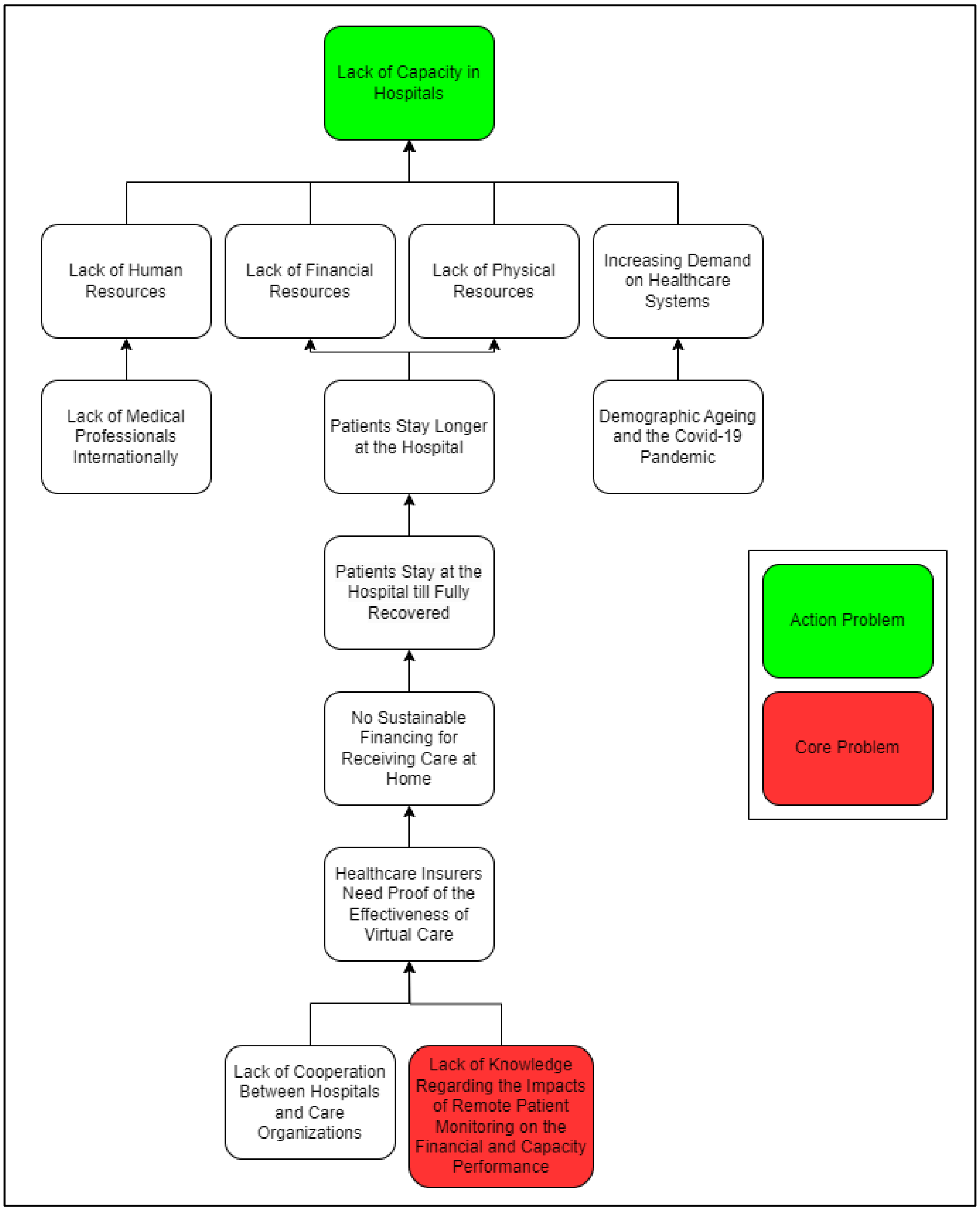

Figure 1 - Problem Cluster

Figure 1 presents the problem cluster, providing a detailed view of the problems faced by hospitals, their relationships, and the root causes for each of the problems mentioned above. The action problem of this research is the lack of capacity in hospitals, which was highlighted due to the Covid-19 pandemic and the capacity strain faced by hospitals during the pandemic. Moreover, the problem cluster includes problems causing capacity shortages, such as the lack of medical professionals globally and the demographic ageing of the population.

Additionally, the core problem highlighted in Figure 1 is the lack of knowledge regarding the financial and capacity performance of implementing virtual care pathways and the usage of RPMS. As mentioned in Sub-Section 1.1.1, the pandemic has accelerated the adoption of telehealth solutions such as Remote Patient Monitoring Systems (RPMS) which was implemented by Isala Hospital during the Covid-19 pandemic as part of their home monitoring programme used for the treatment of Covid-19 patients.

Collecting enough knowledge regarding the impacts of transitioning to the virtual care pathway on the capacity and financial performance of hospitals is essential to conclude whether the implementation contributes to improving efficiency. Moreover, results can contribute to solving the financing problem faced by hospitals, as hospitals do not receive sustainable financing for the treatment of patients using home monitoring.

Finally, through solving our core problem, we aim to solve the action problem, which is the lack of capacity at hospitals as shown in the problem cluster in Figure 1. We see the lack of capacity at hospitals as our action problem because the capacity strain and in-ability to meet demand at hospitals are the reason virtual care pathways are implemented, and thus the reason behind our research.

1.1.3 Research Objectives

This research aims to evaluate the impacts of transitioning to virtual care pathways on the capacity and financial performance of hospitals. We take the transition to the virtual care pathway for the treatment of Covid-19 patients at Isala Hospital as a case study. Our aim is to provide a conclusion on efficiency of virtual care pathways in terms of capacity and financial performance of hospitals, through the analysis of different KPIs.

1.2 Research Design

This section introduces the research questions for this research, including the main research question and sub-research questions we identified for this research. Next, we discuss the deliverables and the scope of this research project, highlighting what is expected in the research and how hospitals can use the outcomes of this research to understand the effect of implementing virtual care pathways. Finally, validity and reliability of the results is discussed, with how we ensure that the results are credible and replicable for future research.

1.2.1 Research Questions

This section discusses the research question identified for this research assignment, while also discussing the sub-research questions we need to answer in order to solve the main research question.

- **Is the transition to virtual care pathways beneficial for hospitals from a capacity performance and cost-efficiency perspective?**

Our main research question was defined following from our research objectives.

For answering the main research question we need to answer four sub-research questions that provide answers for our main research question.

The Sub-Research Questions (SRQs) are as follows:

- **How is capacity defined and how can it be assessed?**
  - **How is capacity defined in the literature?**
  - **Which assessment methodology is applicable to the research?**

  - **Which KPIs can be used to assess the impacts of transitioning to virtual care pathways on the capacity and financial performance of hospitals.**
    - **Which KPIs are used for the assessment of capacity and financial performance at hospitals in the literature?**
    - **Which KPIs did the CCC department use during the research regarding the impacts of implementing the home monitoring programme during the Covid-19 pandemic?**

To assess the impacts of transitioning to the virtual care pathway and implementing the home monitoring programme on the capacity and financial performance of hospitals we need to first define the concept of capacity in the healthcare industry. Moreover, for the assessment we need to identify an assessment methodology applicable to our research. We use the assessment methodology to assess the impacts of transitioning to the virtual care pathway on the capacity and financial performance of Isala Hospital. Therefore, a literature review is conducted to define capacity, find assessment methodologies used for the assessment of the capacity and financial performance of hospitals, and identifying KPIs used in the literature for the same purpose.

The assessment methodology identified for our research is selected based on discussions with the project supervisor at Isala Hospital, what is applicable to our research, and taking the assessment methodology previously used by the CCC department during the research conducted as a reference. Finally, a selection of KPIs is made for the assessment based on the KPIs found in the literature, and the KPIs previously used by the CCC department to assess the impacts of implementing the home monitoring programme during the Covid-19 pandemic.

- **What is the difference between the traditional care pathway system and the virtual care pathway system, and what are the benefits of implementing virtual care pathways for both hospitals and patients?**

To understand how the transition from the traditional care pathway to the virtual care pathway including the home monitoring programme implemented by Isala Hospital impacts the capacity and financial performance of hospitals, we need to identify the components of both care pathways. Additionally, the concept of care pathways is introduced, with benefits of transitioning to the virtual care pathway for hospitals and patients.

- **How can the assessment methodology be implemented?**
  - **Which KPIs are identified and selected for the assessment?**
  - **What data is available?**
  - **How to prepare and structure the available data?**

After the final list of KPIs is identified and selected, the assessment phase of the research commences. The data required for the data analysis is provided by Isala Hospital, and is kept on the hospital's online data repository the CTCue software. Once the data is retrieved, it is cleaned as it was poorly reported during the Covid-19 pandemic. The data is cleaned through the removal of outliers and extracting only the data needed for the data analysis into a new Excel spreadsheet for easier navigation and comparison between the datasets available.

Once the data is ready, it will be analyzed by creating multiple scenarios for the datasets with a small sample size to allow a fair comparison between the datasets, while creating graphs and figures for the different datasets and scenarios to compare between them. Finally, an evaluation of the impacts of transitioning to the virtual care pathway implementing the RPMS system on the capacity and financial performance of hospitals is conducted.

- **Was the transition to the virtual care pathway beneficial in terms of reducing capacity strain and making Isala Hospital more cost-efficient?**

Based on the assessment methodology, and the KPIs identified, a comparison will be formulated based on the different KPIs analyzed. Through the comparison of these KPIs before and after the transition to virtual care pathways, a conclusion will be made as to whether or not the transition was beneficial for Isala Hospital, in terms of financial and capacity performance.

1.2.2 Deliverables

There are two deliverables to this research assignment. The first deliverable is the assessment of the impacts of transitioning to virtual healthcare systems and home monitoring on different KPIs related to the capacity. For the assessment we take the transition to the virtual care pathway and the implementation of the home monitoring programme at Isala Hospital during the Covid-19 pandemic as a case study for our research. The second deliverable is a tool, that can be used by the Connected Care Center (CCC) department at Isala Hospital to monitor the effects of implementing RPMS on the different capacity and financial performance KPIs.

1.2.3 Scope

For the scope of this research, we only focus on our core problem, which is the lack of knowledge regarding the impacts of transitioning to the virtual care pathway on the financial and capacity performance of hospitals. We evaluate if the transition to the virtual care pathway improves the efficiency in terms of capacity performance and costs incurred by hospitals. We aim to solve the core problem while taking the transition to the virtual care pathway for the treatment of Covid-19 patients at Isala Hospital as a case study for our research.

Isala Hospital transitioned to the virtual care pathway for Covid-19 patients on the 20th of November 2020 during the Covid-19 pandemic. Therefore the availability of data for Covid-19 patients treated at Isala Hospital before and after the transition to the virtual care pathway is important for the assessment. The Covid-19 pandemic is an international dilemma which had significant impacts on healthcare systems globally, and affected numerous individuals which suffered because of the pandemic. Moreover, the pandemic pressured hospitals by the sudden increase in demand, and the capacity strain faced by hospitals, and Isala Hospital is one of the hospitals affected by these factors during the pandemic.

On the other hand, some aspects were not included in the scope of this research. The improvement in treatment methods during the Covid-19 pandemic was not taken into account due to the tight timing and inability to implement this in our research. Some KPIs such as the quality of care and the patient case mix in our assessment were not included in the assessment due to the lack of knowledge regarding these subjects. The costs of implementing sensors along with other costs such as license costs, and administrative costs are not included in the assessment of costs due to the complexity of the assessment. The exclusion of these aspects might affect the quality and reliability of the results, however through further research these aspects could be included.

1.2.4 Validity and Reliability

For the assessment methodology to be reliable, the results have to be consistent and replicable when used by another researcher. We ensure that the results are replicable by detailing all the steps in the data collection and data analysis processes, while also ensuring that the methodology used is well defined and presented in detail. Moreover, we provide a flow diagram with the criteria for the data cleaning process, and what data were considered as outliers. Finally, the limitations faced during the research are transparently presented such that they can be anticipated by future researchers.

For our assessment methodology to be valid, it has to accurately answer the main research question of this research. To ensure the validity of our data, we clean it properly through a detailed data cleaning process, which is outlined in a flow diagram in Appendix 1.1. The data needed to be cleaned because it was not reported properly during the Covid-19 pandemic. Additionally, for our results to be reliable they have to be applicable to other hospitals than Isala Hospital. We ensure the applicability of our results by including the Covid-19 pandemic in our research, the pandemic has affected a lot of individuals and hospitals worldwide, including Isala Hospital which struggled during the Covid-19 pandemic with the increasing demands and limited capacity available. Therefore, Isala Hospital transitioned to the virtual care pathway like many hospitals during the Covid-19 pandemic. To ensure the credibility of the research assignment, the results have to be valid and reliable, while being replicated and generalized to other cases and hospitals. Moreover, no falsifications will be done with the data, to make the research as credible as possible. Finally, we aim to compare our results with other results from the literature for hospitals transitioning to virtual care pathways to overcome the capacity strain faced during the Covid-19 pandemic.

2 Literature Research

In our literature research, we focus on three topics, these include care pathway systems, defining capacity in the healthcare industry, and finding an assessment methodology for the assessment of hospital capacity performance. We decide to focus on these three topics in our literature research following from our first Sub-Research Question (SRQ) which aims to define capacity, find a proper assessment methodology, and selecting KPIs for the assessment. Section 2.1 introduces care pathway systems, and provides an overview of the definitions and characteristics of the traditional and virtual care pathways, while emphasizing the differences between both care pathway systems. In Section 2.2, we give a unified definition for the term capacity in the healthcare industry, since there are a lot of definitions for capacity as found in the literature research. Moreover, we identify assessment methodologies used to assess the capacity performance of the hospitals as stated in the literature, as well as some of the KPIs used in the same context in Section 2.3. The table for the literature review including the search terms, articles found, and authors is presented in Appendices 1.3.1 and 1.3.2.

2.1 Care Pathway Systems

This section covers the first sub-research question, discussing the difference between the old traditional care pathway system and the new virtual care pathway system implemented at Isala Hospital during the Covid-19 pandemic. The section discusses how each care pathway is defined in literature, and provides an overview of the baseline standard-of-care situation at the hospital, and the transition to virtual care pathway systems during the Covid-19 pandemic. The elaboration and explanation of both care pathway systems is crucial to understand how the transition affected the capacity performance at Isala Hospital.

2.1.1 Definition of Care Pathways

The concept of care pathways is not only used in the healthcare sector, but in other industries as well, by creating predictable processes and improving the overall operational performance of an organization through the identification of bottlenecks and weaknesses, contributing to the improvement of processes (Smeds, 2019) (Schrijvers, van Hoorn, & Huiskes, 2012).

It is important to note that care pathways vary from one hospital to another, due to the differences in patient characteristics, flow times, and guidelines (Smeds, 2019). An estimation conducted by Sermeus et al. (2002) states that 60% of hospital care can be highlighted in the care pathway.

By planning care pathways ahead for medical processes at the hospital, the hospital amongst others, benefits from a reduction in the capacity demand uncertainty, leading to a more effective and efficient capacity management (Remijn, 2018), reducing unnecessary variations in the healthcare process (Han & Ma, 2022), and improving outcomes while simultaneously reducing costs (Clinician, 2023).

There are three types of care pathways; the traditional analogue care pathway, the hybrid care pathway, and the integrated digital care pathway (Clinician, 2023). The traditional analogue care pathway is a standardized pathway, with no digital components, such as the traditional care pathway implemented by Isala Hospital before the transition. The hybrid care pathway is a hybrid of analogue and digital care pathways, such as the virtual care pathway system and the virtual care pathway implemented by Isala Hospital after the transition. The integrated digital care pathway has only digitalized components, these digital components are integrated to maximize ease and efficiency, and improve the quality of care (Clinician, 2023).

2.1.2 Traditional Care Pathways

A traditional care pathway is a standardized care pathway, without any digital interventions. It is characterized by the sequential and routine processes it has, therefore it is perceived to be repetitive with low variations (Smeds, 2019). Traditional care pathways are also characterized to have a straight-line of thinking, without changing the sequence of processes based on the patient's condition or treatment (de Savigny & Adam, 2009). Finally, the traditional care pathway system falls under the traditional analogue care pathways category, which just includes the traditional patient journey, and has no forms of digitalization (Clinician, 2023).

2.1.3 Virtual Care Pathways

A virtual care pathway is a care pathway that has iterative and non-routine processes, characterized by randomness, high variation, non-predictability, and its high dependence on patients and their diagnosis (Smeds, 2019). Unlike traditional care pathways which have a straight-line of thinking approach, the virtual care pathway employs a loop thinking approach, making it constantly changing and non-linear (de Savigny & Adam, 2009). Virtual care pathways fall under the category of hybrid care pathways, and belong to the direct-to-consumer category of telehealth systems, which includes virtual monitoring and extends care delivery into patients homes (Augenstein & Chamberlain, 2019).

Virtual care pathways employ digital technologies and components to assist patients through their healthcare journey (Clinician, 2023). By analyzing timely data from multiple sources, virtual care pathways provides a more patient-centered approach to healthcare, while simultaneously focusing on patients with severe symptoms (Kamp & Kirkegaard, 2020). The patient-centered approach is a crucial characteristic of virtual care pathways, which consider patient experience to achieve successful patient engagement in the care process (Hall, O'Neill, & McBride, 2023). This highlights the most dominant strength of virtual care pathways, the user-centered design approach, which leads to better patient satisfaction with the healthcare experience (Campbell-Yeo, Dol, Richardson, & McCulloch, 2021).

The transition to virtual care pathways is advancing rapidly due to governments focusing on patient-centered and value-based care instead of traditional healthcare models. Virtual care pathways help Health Care Providers (HCPs) to gather and acknowledge health outcomes that matter to patients, to further understand the health status and concerns of the patients to improve value-based care (Clinician, 2023).

An example of virtual care pathways are the Data-Driven Integrated Care Pathways (DICP) which incorporate a number of different data sources and digital tools to improve patient care experiences and engagement. The patient experience is improved by standardizing patient-centered care, through the utilization of real-time data and advanced technology tools. Moreover, DICP systems give HCPs a personal care plan for each patient (Han & Ma, 2022).

2.1.4 Benefits for Implementing Virtual Care Pathways

This section outlines the benefits of implementing virtual care pathways for both Health Care Providers (HCPs) and patients, the virtual care pathway is the same as the virtual care pathway implemented by Isala Hospital during the Covid-19 pandemic.

First, the use of virtual care pathways allows the expansion of access to medical professionals, ensuring that patients receive the right care, at the right place, and at the right time (Augenstein & Chamberlain, 2019). Second, virtual care pathways contribute to improving the patient experience, by making healthcare more convenient and accessible for patients that live in remote or rural areas through connecting at-home care and internet-based health systems to medical professionals, substituting hospital care, thus, increasing access and continuity of healthcare systems (Han & Ma, 2022). Moreover, the successful integration of virtual care pathways enables patients to be routed to the most appropriate care setting (Hall, O'Neill, & McBride, 2023), saving patients time, money, and energy that would be spent unjustifiably (Clinician, 2023).

For HCPs, the implementation of virtual care pathways yields a lot of benefits that can improve how health care systems and cost models look. The most dominant advantage HCPs gain from implementing virtual care pathways is cost-effectiveness, as virtual care pathways prove to be the most-effective approach to healthcare systems (Hall, O'Neill, & McBride, 2023). Virtual care pathways are able to reduce the costs

HCPs incur for treating patients through incorporating a more efficient system to better monitor and manage patients and medical staff, through reducing unnecessary hospital readmissions, shortening the Length of Stay (LoS) of patients, and ensuring compliance with the care plans (Clinician, 2023).

Moreover, the implementation of virtual care pathways improves the quality of care, through enabling more precise predictions and recommendations for HCPs, based on data analytics and machine learning, as well as the early detection of any worsening in patients' conditions, to give HCPs the opportunity to avoid unnecessary hospitalisation (Clinician, 2023). The improved quality of care leads to improved health outcomes for patients (Hall, O'Neill, & McBride, 2023).

Last but not least, virtual care pathway systems expand the potential patient population and catchment area of HCPs, allowing HCPs to reach more patients. Finally, digitalising components in the care pathway can improve the hospital's capacity, by freeing up inpatient beds due to early discharge and home monitoring, while also saving unnecessary congestion in the waiting rooms by treating patients remotely (Clinician, 2023).

2.2 Defining Capacity

This section answers the second sub-research question aiming to define capacity, based on the different definitions of capacity in the literature. We also identify the different assessment methodologies used to assess the capacity performance of hospitals. Finally, we discuss the different KPIs used in the assessment of hospital capacity performance, and identifying the KPIs previously used by Isala Hospital to assess the impacts of the transition to virtual care pathways on the hospital's capacity performance.

2.2.1 Capacity in the Healthcare Industry

In the healthcare industry, the term capacity has a lot of definitions, through conducting a literature review we found a number of different definitions for capacity, with some having the same definition and others having contradicting definitions, applied to the specific case study of the research conducted. Table 1 presents the different definitions for capacity as derived from literature. Capacity is defined in different terms, some articles define capacity in terms of productivity and utilization, some in terms of output and patient numbers, and some in terms of the handling and availability of resources. From the definitions found in the literature, we derive our own definition of capacity in the healthcare industry. Our definition of capacity covers the areas we want to address for the assessment of the capacity performance of Isala Hospital. We define capacity as *the availability and utilization of hospital resources, particularly hospital beds, and the ability to efficiently and effectively handle patient flow and provide healthcare services.*

Table 1 - Capacity Definitions from Literature Research

Capacity Definition	Reference
Hospital capacity is defined as an upper bound that describes the best possible performance of the hospital in terms of productivity, output, or number of patients treated	(Humphreys & Spratt, 2022)
Capacity is defined as the ability of a hospital to effectively handle patient flow and deliver services	(Rechel & Mckee, 2010)
Capacity is the ability of the hospital to provide healthcare services and the availability of resources to meet the demand for healthcare	(Zhang, Lu, & Shi, 2022)
Capacity refers to the availability and utilization of hospital resources, specifically hospital beds and ICU units, to accommodate patients requiring medical care	(Bhowmik & Eluru, 2021)
Capacity is defined as the number of nurses or healthcare professionals required to meet the demand and ensure optimal care	(Kokangul, Akcan , & Narli, 2016)
Capacity refers to the utilization or productivity of hospital beds	(Masoompour, Farhadi, & Petramfar, 2015)

Capacity refers to the resources and capabilities of a hospital to provide healthcare services efficiently and effectively	(Burdett & Kozan, A Multi-Criteria Approach for Hospital Capacity Analysis, 2016)

The definition of capacity by Humphreys & Spratt (2022) describes capacity as the best performance of the hospital, in terms of productivity, output, or the number of patients. Humphreys & Spratt (2022) defined capacity different to other articles such as Zhang et al. (2022), which define capacity as the ability to provide healthcare services, and the availability of resources at the hospital. Our definition of capacity covers the most repeated areas, the availability of resources, and the ability to provide healthcare services to meet the demands.

2.2.2 Assessment Methodologies

During our literature research, we looked for methodologies used for the assessment of hospital capacity performance, we found two articles which discussing the different assessment methodologies. The two methodologies found are the Pabon Lasso (PL) model, and the comparison of KPIs for the assessment of hospital capacity performance.

The Pabon Lasso (PL) model was developed by Dr.Pabon in 1986, and modified by Dr.Lasso in 1996. The Pabon Lasso (PL) model is a simple and widely used model for evaluating the hospital performance based on capacity utilization measures. It employs three indicators, namely bed turnover rate, average Length of Stay (LoS), and occupancy rate, in order to assess the efficiency of a hospital. Based on these three indicators, the PL model categorizes hospitals into four quadrants, namely efficient, inefficient with excess capacity, inefficient with inadequate capacity, and very inefficient. Hospitals lying in the efficient quadrant are considered to be using their resources optimally, while those in other quadrants have room for improvement (Masoompour, Farhadi, & Petramfar, 2015).

The PL model is useful for identifying areas where hospitals can improve their performance and allocate resources more effectively. However, it has some limitations, as it does not take into account the quality of services provided by hospitals, or other factors that may affect their capacity performance (Masoompour, Farhadi, & Petramfar, 2015).

Finally, the comparison of KPIs is considered to be a very widely used assessment methodology for the assessment of hospital capacity performance. A study reviewed compared different capacity KPIs such as travel time, waiting time, service costs, and so on, which provides valuable insight into the differences in the capacity performance of different management strategies. Enabling healthcare organizations to make informed capacity management decisions, regarding the utilization of different management strategies or models (Khairat, Lin, & Liu, 2021). When compared to the Pabon Lasso (PL) model, the comparison of KPIs is the simpler option, as it does not include complex mathematical calculations. Furthermore, the PL model only addresses the three indicators bed turnover rate, average LoS, and occupancy rate, while the comparison of KPIs allows the inclusion of more factors such as the waiting times of patients, and the satisfaction rates.

Concluding, in this research we use the comparison of KPIs as an assessment methodology. We find this assessment methodology to be the most applicable to our research because we need to assess the financial and capacity performance of Isala Hospital after transitioning to virtual care pathways, and this methodology allows the inclusion of multiple KPIs, which can be used to assess different aspects of the transition to virtual care pathways for this research.

2.2.3 KPIs from Literature

Key Performance Indicators (KPIs) are a well-defined performance measurement metric that is used to monitor, analyse, and optimize all relevant healthcare processes to increase patient satisfaction. KPIs are very helpful for Health Care Providers (HCPs), as they help ensure the efficient utilization of resources, while providing effective healthcare services for patients (Healthcare Industry KPI Examples, n.d.). A number of different KPIs exist for assessing the capacity performance of hospitals. A literature research was conducted, as represented in Appendices 1.3.1 and 1.3.2. From our literature research, we found a list of KPIs, which will be discussed in this sub-section.

After analysing the literature found, we conclude that KPIs were used to assess hospital capacity for seven purposes. These purposes were determined through reading the literature, and the main reason KPIs were used to calculate hospital capacity.

1. Assessing the logistical performance of hospital wards
2. Assessing hospital capacity through the number of inpatient beds
3. Assessing hospital capacity performance
4. Measuring hospital capacity
5. Assessing hospital capacity performance using a multi-objective optimization approach
6. Measuring productivity efficiency
7. Assigning patients to hospital wards

Table 2 presents the different KPIs found in the literature, the number of mentions, the purpose of using these KPIs, and the sources that mentioned the usage of these KPIs.

Table 2 - KPIs Mentioned in Literature, and their Purposes

KPI	No. of Mentions	Sources	Purpose
Throughput	*2*	(Schneider, 2020) (Brandeau, Sainfort, & Pierskalla, 2005)	*1, 2*
Blocking Probability	*1*	(Schneider, 2020)	*1*
Bed Occupancy Rate	*4*	(Schneider, 2020) (Brandeau, Sainfort, & Pierskalla, 2005) (Kokangul, Akcan , & Narli, 2016) (Masoompour, Farhadi, & Petramfar, 2015)	*1, 2, 3, 4*
No. Free Inpatient Beds	*1*	(Brandeau, Sainfort, & Pierskalla, 2005)	*2*
Waiting Time	*1*	(Schneider, 2020)	*2*
Length of Stay (LoS)	*2*	(Augenstein & Chamberlain, 2019) (Masoompour, Farhadi, & Petramfar, 2015)	*3, 4*
No. Admissions	*1*	(Kokangul, Akcan , & Narli, 2016)	*3*
Satisfaction Rate	*1*	(Kokangul, Akcan , & Narli, 2016)	*3*
No. Readmissions	*1*	(Augenstein & Chamberlain, 2019)	*3*
Bed Turnover Rate	*1*	(Masoompour, Farhadi, & Petramfar, 2015)	*4*
Patient Case Mix	*1*	(Burdett & Kozan, A Multi-Criteria Approach for Hospital Capacity Analysis, 2016)	*5*
No. Patient Discharges	*1*	(Thornton, Bonzo, Khan, & Souza, 2022)	*3*
Percentage Patient Discharges	*1*	(Thornton, Bonzo, Khan, & Souza, 2022)	*3*
Patient Costs per day	*1*	(Li & Benton, 1995)	*6*
Nurse-to-Patient Ratio	*1*	(Brandeau, Sainfort, & Pierskalla, 2005)	*7*

Table 3 displays the different KPIs found from the literature research conducted, and their definitions according to the literature using them.

Table 3 - KPIs acquired through Literature Research and their Definition

KPI	Definition	Source
Throughput	The number of admissions or discharges per unit time	(Schneider, 2020)
Blocking Probability	The percentage of patients who request a bed in the ward at a moment when there are no available beds	(Schneider, 2020)
Bed Occupancy Rate	Percentage of beds occupied by patients in a specified period of time	(Masoompour, Farhadi, & Petramfar, 2015)
No. Free Inpatient Beds	The number of inpatient beds that are not occupied	(Brandeau, Sainfort, & Pierskalla, 2005)
Waiting Time	Time patients spend while being untreated (Treatment begins when patients are put into a bed)	(Schneider, 2020)
Average Length of Stay (LoS)	Average number of days a patient is admitted in a hospital	(Masoompour, Farhadi, & Petramfar, 2015)
No. Admissions	No. patients admitted to the hospital in a specific period of time	(Kokangul, Akcan , & Narli, 2016)
Satisfaction Rate	Level of patient satisfaction or dislike expressed by patients treated	(Kokangul, Akcan , & Narli, 2016)
No. Readmissions	No. patients who were readmitted to the hospital after discharge (If their condition deteriorates after discharge for instance)	(Augenstein & Chamberlain, 2019)
Bed Turnover Rate	Number of patients treated per bed in a specified period of time	(Masoompour, Farhadi, & Petramfar, 2015)
Patient Case Mix	Groups statistically related patients (Considering variables such as severity of illness, intensity of care required, and demographic characteristics such as age and gender)	(Case Mix, n.d.)
No. Patient Discharges	No. of patients who have been discharged from the hospital in a specific period of time	(Thornton, Bonzo, Khan, & Souza, 2022)
Percentage Patient Discharges	Percentage of patients who have been discharged from the hospital	(Thornton, Bonzo, Khan, & Souza, 2022)
Patient Costs Per Day	The costs spent on the treatment of patients per day	(Li & Benton, 1995)
Nurse-to-Patient Ratio	Represents the number of patients assigned to each nurse	(Brandeau, Sainfort, & Pierskalla, 2005)

From the literature research results, we deduce that Throughput, Bed Occupancy Rate, and Length of Stay (LoS) are the three most used KPIs for the assessment of hospital capacity performance. The KPIs number of patient discharges and percentage of patient discharges, were only used once, and their usage was not argued properly. We found many KPIs that can be used to assess the capacity performance of the hospital, some consider the treatment process, and the total time spent, while some KPIs focus on patient satisfaction, the quality of treatment, and the hospital's nurses.

2.2.4 KPIs Previously Used by Isala Hospital

As mentioned, the Connected Care Center (CCC) department at Isala Hospital assessed the impacts of transitioning to the virtual care pathway and implementing the home monitoring programme including RPMS in the treatment of Covid-19 patients. Table 4 presents the KPIs used for the assessment of the impacts of transitioning to the virtual care pathway for the treatment of Covid-19 patients.

Table 4 - KPIs used by the CCC Department for Previous Research from (CCC, 2022) (Maring, Patijn, Faber, Merkx, & Leenen, 2022)

KPIs	Definition
Patient Experience	Measures patient satisfaction with the healthcare services by combining factors such as surveys and questionnaires (Healthcare KPIs, n.d.)
Staff Experience	Measures staff satisfaction while providing healthcare services by combining factors such as surveys and questionnaires (Healthcare KPIs, n.d.)
Cost of Care	The costs spent for the treatment of patients (Li & Benton, 1995)
Clinical Admission Days	Number of days a patient is admitted in a hospital (Masoompour, Farhadi, & Petramfar, 2015)
No. Readmissions	No. patients who were readmitted to the hospital after discharge (If their condition deteriorates after discharge for instance) (Augenstein & Chamberlain, 2019)
Nurse Shifts	The number of nurse shifts needed for the treatment of the available patients
Bed Day Revenues	Average revenue realized per patient bed per day
Total Costs	Total costs spent by a hospital including treatment costs, electricity, staff …etc.
Patient Case Mix	Groups statistically related patients (Considering variables such as severity of illness, intensity of care required, and demographic characteristics such as age and gender) (Case Mix, n.d.)
No. ICU Admissions	Number of patient admissions to the ICU Unit
Length of Stay	Number of days a patient is admitted in a hospital (Masoompour, Farhadi, & Petramfar, 2015)

For the collection of some qualitative KPIs such as the patient experience and the staff experience, two satisfaction surveys were issued, the first for patients and the other for hospital staff and employees. The patient satisfaction survey included variables such as user-friendliness, acceptance, and compliance, which were filled out by patients involved in the home monitoring programme upon completion.

2.2.5 Selection of KPIs

After collecting a list of KPIs from literature, and the research conducted by the CCC department, a list of KPIs was selected based on research and practice. We select these KPIs for the assessment of the impacts of transitioning to the virtual care pathway on the capacity and financial performance of Isala Hospital. For the assessment, there are two focus areas, capacity performance and costs. For the assessment of capacity performance we focus on admissions and appointments, the two most important hospital activities, and affect capacity performance significantly. Moreover, we need to assess the impacts of transitioning to virtual care pathways on the costs incurred by Isala Hospital, to find out if the transition achieved the goal of improving the hospital's cost-efficiency.

To satisfy the goal of this research, the following KPIs were used for the assessment:

- **Average Length of Stay (LoS) at the hospital per Patient (In Days)**

This KPI is the same as the KPI Length of Stay (LoS) found in the literature, and used by Isala Hospital during the research conducted. We use it to measure the number of days the patient was admitted to the hospital, to compare between the capacity performance of Isala Hospital before and after the transition to virtual care pathways.

- **Average Length of Stay (LoS) at home per Patient (In Days)**

This KPI is specifically for patients treated using the home monitoring programme after the transition to the virtual care pathway. The KPI represents the number of days spent by patients at home while being enrolled to the home monitoring programme, having appointments consisting of Telephonic Consultations (TC) with virtual monitoring nurses from Isala Hospital.

- **Variance and Standard Deviation of the Length of Stay (LoS) of patients at the hospital**

The variance and standard deviation are used to look into the variation of the number of days patients spend admitted to the hospital around the average LoS value of the dataset, both at the hospital and monitored from home through the home monitoring programme. The KPI is used for both datasets of patients treated before and after the transition to the virtual care pathway.

- **Average Appointment Duration**

This KPI is used because we want to assess the impacts of the transition to the virtual care pathway on the capacity performance of Isala Hospital, in this case the KPI focuses on appointments, and measures the time patients spend in each appointment on average. The purpose of the KPI is to see if the transition to the virtual care pathway reduced the average appointment duration spent by patients, which improves patient satisfaction by saving time, and reduces the number of staff needed.

- **Average Total Duration of Appointments per Patient**

The KPI is also related to the assessment of appointments, as it measures the total time spent by patients on all their appointments on average.

- **Average Number of Appointments per Patient**

The KPI measures the average number of appointments per patient, to assess whether the transition to the virtual care pathway increased or reduced the number of appointments patients have, ultimately affecting Isala Hospital's capacity performance.

- **Appointment Type**

We look at the appointment types for patients to see the difference between the distribution of appointment types for Covid-19 patients treated using the traditional and the virtual care pathways.

- **Average Total Treatment Costs per Patient**

The cost KPIs are derived from the KPIs Cost of Care and Total Costs used by Isala Hospital during the past research conducted. The KPI assesses the average costs for treating patients at the hospital, and is calculated based on the Length of Stay (LoS) of patients, and the costs for one nursing day provided by Isala Hospital.

- **Average Admission Costs per Patient**

This KPI is derived from the KPIs costs of care, and patient costs per day. Using this KPI, we calculate the average cost incurred by Isala Hospital for the hospitalization of a patient in the general ward. We use this KPI to calculated the KPI average total costs per patient, and conduct the cost analysis.

- **Average Appointment Costs**

The KPI is calculated from the care activity costs for each appointment type, which are provided to us by Isala Hospital in order to make a proper cost comparison.

- **Average Total Appointment Costs per Patient**

This KPI calculates the total appointment costs incurred by Isala Hospital for the appointments of Covid-19 patients. We calculate this KPI by multiplying the average appointment costs by the average number of appointments per patient.

- **Average Reimbursement per Patient**

The KPI average reimbursement per patient is used to calculate the gain or loss in the reimbursement received by Isala Hospital for treating Covid-19 patients. The hospital received reimbursement from the government for the treatment of Covid-19 patients, and due to the transition and early discharge of patients the reimbursement received could be reduced, thus the KPI is used to test whether this hypothesis is true or not, while also calculating the earnings lost by Isala Hospital due to the transition to the virtual care pathway during the Covid-19 pandemic.

- **Average Profit per Patient**

We investigate the KPI profit per patient to see the difference in the profit generated by Isala Hospital when implementing the traditional care pathway compared to the virtual care pathway.

2.3 Conclusion

Concluding, the final list of KPIs selected for the assessment of the transition to the virtual care pathway covers the most important aspects of the assessment, as it covers the capacity performance of Isala Hospital, as well as the costs incurred due to the transition, leading to a conclusion on whether the transition improved the capacity performance of Isala Hospital and made it more efficient in terms of capacity performance and costs or not.

3 Context Analysis

This chapter provides some insight into the transition project deployed by Isala Hospital during the Covid-19 pandemic in Section 2.1. Then the details of the traditional care pathway deployed at Isala Hospital before the transition, and the virtual care pathway implemented after the transition are introduced in sections 2.2 and 2.3 respectively. We conclude this chapter with a short discussion of both care pathways, and display some results of the transition project, from the outcomes of the research by the CCC.

3.1 Traditional Care Pathway

The Traditional Care Pathway (TCP) does not include digitalized components throughout the healthcare delivery process. Figure 2 shows a visualization of the traditional care pathway used by Isala Hospital during the Covid-19 pandemic before transitioning to the virtual care pathway. To come up with the diagram of the traditional care pathway, discussions were held with the project supervisor working on the Covid-19 pandemic case in the CCC department, where the main activities of the care pathway were discussed.

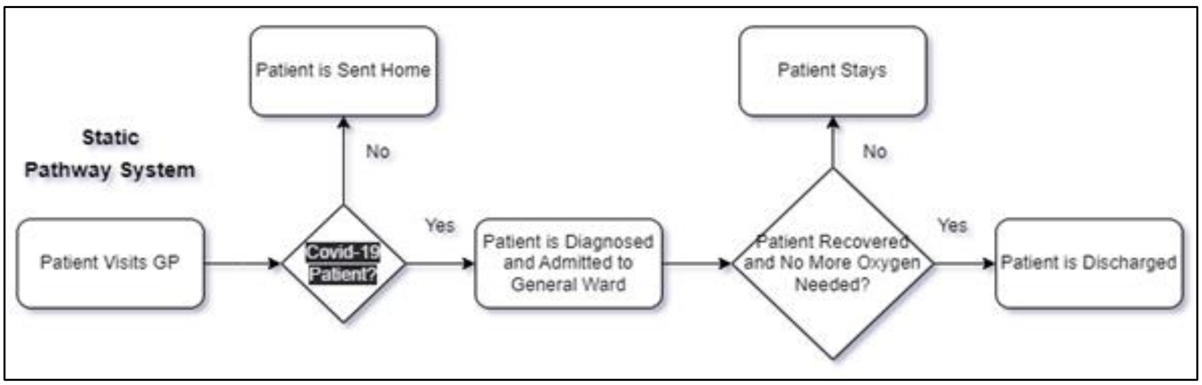

Figure 2 - Traditional Care Pathway Workflow Model

The patient is admitted to the hospital's general ward if he/she has Covid-19, as diagnosed by his General Practitioner (GP). The patient is inspected by Isala Hospital's medical staff upon admission to the general ward to further understand the patient's condition. Patients are treated at the hospital until their condition stabilizes and no more oxygen is needed. The patient completes his/her treatment and is discharged from the general ward once he/she passes the threshold criteria set by the hospital for discharge.

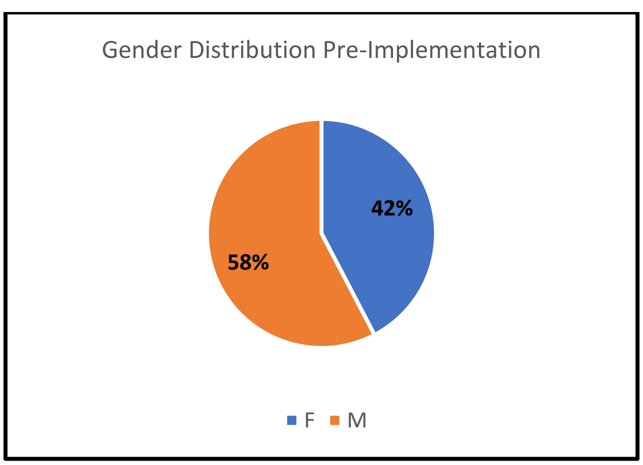

Figure 3 - Gender Distribution TCP Dec 2019 – Nov 2020 Dataset (N=111) from HIX

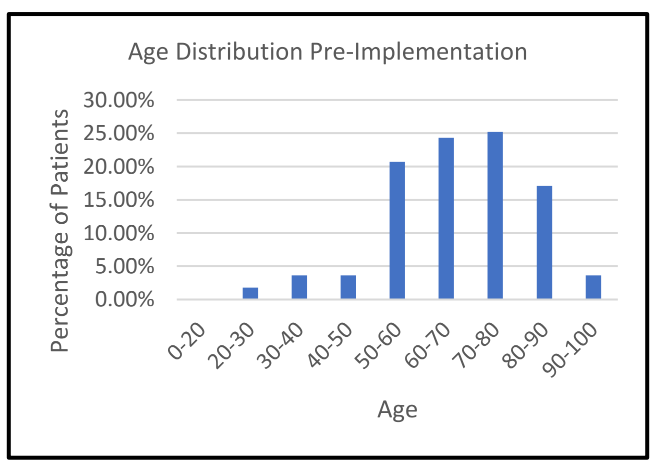

Figure 4 – Age Distribution TCP Dec 2019 – Nov 2020 Dataset (N=111) from HIX

We acquired a dataset with 111 Covid-19 patients treated at Isala Hospital using the traditional care pathway, patients included had an average of 68.2 years, and consist of 58% males, while patient ages lie between 60 and 90 years old the most.

3.2 Transition Project and Home Monitoring Programme

As mentioned, hospitals are facing a capacity crisis, due to some factors such as the ageing and growing population, limited resources, shortages in medical professionals globally, and the increasing demand for healthcare (Boldt-Christmas et al., 2023; Jack & Powers, 2009). Moreover, due to the Covid-19 pandemic, the demand for healthcare systems further increased, and the number of admissions rapidly increased, placing hospitals in a situation where the demand exceeds the available capacity, leading to a capacity strain (Humphreys & Spratt, 2022; Schneider, 2020).

Hospitals were looking for solutions to relieve the capacity strain faced, while also making healthcare more accessible, and cost-efficient, which accelerated the adoption of telehealth solutions such as Remote Patient Monitoring Systems (RPMS). RPMS is one of the most known telehealth solutions, and has shown potential in improving capacity performance, reducing readmissions rates, and making hospitals more cost-efficient (Augenstein & Chamberlain, 2019; Enrique & Burches).

In response to the challenges faced during the Covid-19 pandemic, Isala Hospital transitioned from its traditional care pathway to a virtual care pathway implementing a home monitoring programme and RPMS. The home monitoring programme allowed Isala Hospital to discharge patients earlier from the general ward freeing up beds for other patients, while also providing the discharged patients with care through the RPMS, for all patients enrolled in the home monitoring programme. The most important goals of the transition to the virtual care pathway was to reduce the capacity strain faced by Isala Hospital, and making the hospital more cost-efficient. Moreover, the transition had other goals such as improving the quality of care and services, improving the patient experience, relieving the emergency department and general ward, and achieving a timely healthcare delivery process.

Isala Hospital transitioned to the virtual care pathway and implemented the home monitoring programme in November 2020, almost a year after the start of the Covid-19 pandemic. Since the transition to the virtual care pathway until January 2022, a total of 153 Covid-19 patients have been treated using the home monitoring programme. Once patients are discharged earlier from the hospital they are remotely monitored by Isala Hospital, through the home monitoring programme managed by the CCC department, and the medical coordination office. The patient is provided with an oxygen blood saturation sensor, to measure the oxygen saturation in the patient's blood, and an oxygen tank, which is used by the medical coordination office to maintain the oxygen therapy provided at the hospital in the patient's home.

The home monitoring programme achieved some of the objectives set by the CCC and Isala Hospital before the transition to the virtual care pathway. These objectives included providing care with the same level it is provided at Isala Hospital, but remotely from patients homes, and reducing the average Length of Stay (LoS) in the general ward, for patients who are oxygen dependent. According to research conducted by the CCC department, both objectives were achieved. The first objective was achieved by providing patients with services such as oxygen administration, monitoring oxygen saturation levels, and guiding patients in reducing their oxygen supplement by evaluating the saturation levels provided by the patients. As for the second objective, it has been found that the deployment of the home monitoring programme and the transition to virtual care pathways, allowed patients to be discharged from the hospital five days earlier on average (CCC, 2022; Maring et al., 2022).

3.3 Virtual Care Pathway

The Virtual Care Pathway (VCP) implemented by Isala Hospital after the transition contains digital and telehealth components, which are not included in the traditional care pathway. The VCP allows the early discharge of Covid-19 patients who do not need hospital care, earlier than in the TCP. Patients are instead monitored through sensors and other digital tools at home, due to the implementation of RPMS and the home monitoring programme. Figure 3 visualizes the virtual care pathway implemented by Isala Hospital during the Covid-19 pandemic.

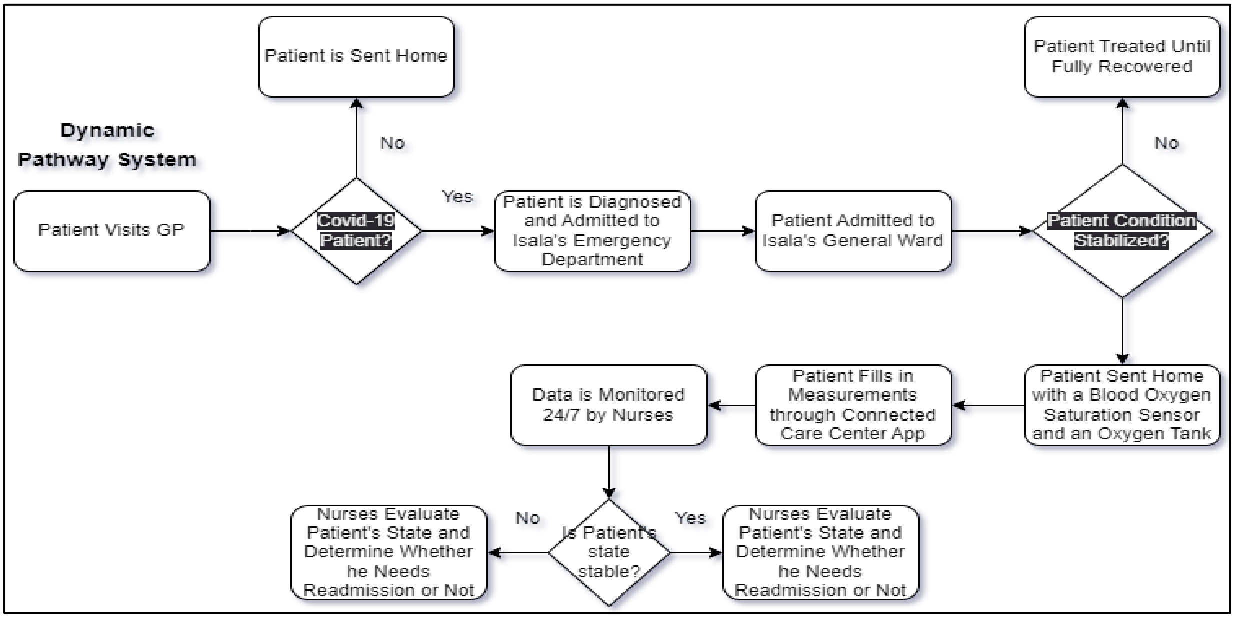

Figure 5 – Virtual Care Pathway Workflow Model

To come up with the workflow of the virtual care pathway displayed in Figure 5, discussions were held with the project supervisor working on the Covid-19 pandemic case in the CCC department, where the main activities taken by the patient were discussed in order to visualize the care pathway.

The patient stays admitted to Isala Hospital's general ward until an inspection is conducted by nurses to evaluate the patient's condition. If the patient's condition is stabilized, and the threshold conditions for early discharge set by Isala Hospital are met, he is discharged earlier from the hospital. The patient is then sent home with an oxygen tank, and a blood oxygen saturation sensor. A medical team from Isala Hospital is then sent home with the patient to setup the sensors and the monitoring station in the patient's house.

Once the patient starts the home monitoring programme, he is provided with a personal care plan, indicating what should be done at each oxygen saturation level, for the patients to feel more safety during the healthcare process. Additionally, patients are provided with an oxygen reduction schedule, which is personalized based on each patient's condition and the measurements reported by the patient. The goal of the oxygen reduction schedule is for patients to reduce their oxygen supplement intake themselves at home, under the hospital's supervision.

The patient uses the sensors to measure the oxygen saturation level in his blood, and other measurements which he then puts into the CCC mobile application, three times a day, specifically at 9:00 am, 3:00 pm, and 9:00 pm. The frequency of measurements is increased if the patient experiences any complaints, such as shortness of breath or severe fatigue. Moreover, the patient has to fill in a daily health questionnaire, in which he gives the hospital a written update of his condition, and expresses any complaints or health questions that might arise. The patient can also contact the monitoring nurse by phone if necessary for the patient's recovery.

The measurements data entered into the CCC app by the patient is monitored 24/7 by nurses from the medical coordination office, who have access to a dashboard displaying the patient's data and charts showing the progress made by the patient. If the patient's oxygen saturation level is lower than the threshold he is contacted by the monitoring nurses, who are notified immediately in case of abnormality in the measurements provided by the patient based on predefined values.

After the patient spends sometime in the home monitoring programme, his condition is evaluated by the monitoring centre based on the measurements provided and the dashboard displayed in Isala Hospital's environment. The evaluation yields a conclusion on whether the patient has completed the home monitoring programme, which usually lasts from 5 days to 2 weeks. If the patient's condition is stabilized, and no more oxygen is needed, the patient has completed the home monitoring programme. However, if the measurements provided by the patient show no progress, and the patient's condition lean towards deterioration, he stays admitted to the home monitoring programme, and is considered for readmission.

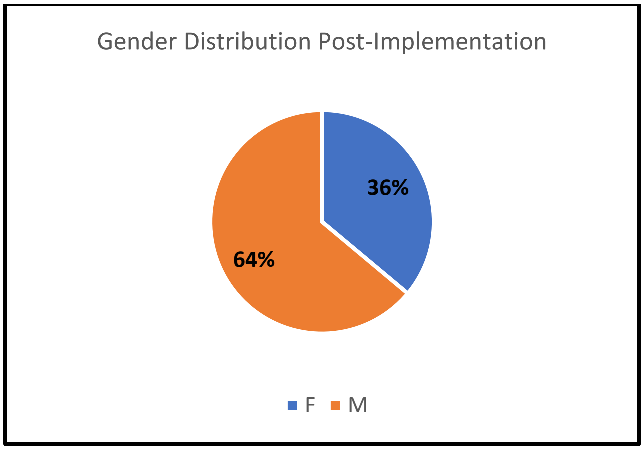

Figure 6 - Gender Distribution VCP Nov 2022 – May 2023 Dataset (N=97) from HIX

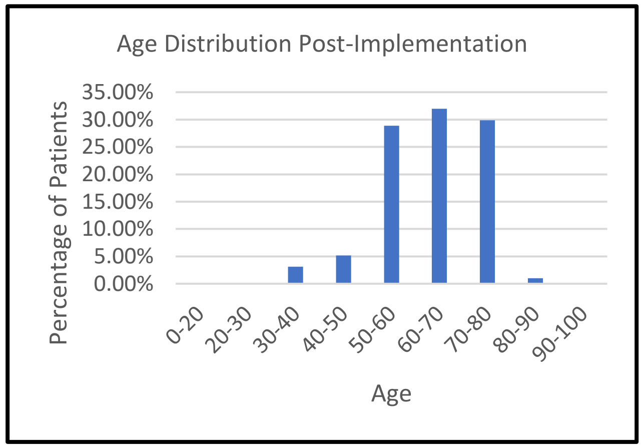

Figure 7 - Age Distribution VCP Nov 2022 – May 2023 Dataset (N=97) from HIX

We acquired a patient dataset of 97 patients, all patients are Covid-19 patients treated at Isala Hospital after the implementation of the virtual care pathway. The average age of the patient population is 64.3 years, with the sample consisting of 64% males, while ages lie between 60 and 80 years old.

3.4 Conclusion

We conclude the context analysis chapter with the a few discussion points. First, we conclude that in their current state, the traditional and virtual care pathways are different to each other, in a number of ways. The most significant difference between the traditional and virtual care pathways is the inclusion of digital components, which have proved to be beneficial to hospitals, according to literature found. Furthermore, we see that the transition to the virtual care pathway at Isala Hospital during the Covid-19 pandemic was beneficial for the hospital. The research suggests that the transition to the virtual care pathway aids the hospital in reducing the capacity strain faced by the hospital, through the reduction of the LoS of patients by five days on average (CCC, 2022; Maring et al., 2022). Finally, the virtual care pathway and the home monitoring programme implemented by Isala Hospital, allow patients to have more contact moments with nurses from the hospital, and have their data monitored 24/7.

4 Methods

This chapter introduces the data and methodology used during the data analysis process. In Section 4.1, we discuss the data retrieval and data cleaning process for the data used. After that, we discuss the assumptions made for this research in Section 4.2. We then introduce the different datasets and data samples used for the data analysis in Section 4.3. Finally, the choice for the test of significance is discussed in detail in Section 4.4.

4.1 Data

As mentioned, our case study is the transition to the virtual care pathway and the implementation of the home monitoring programme for the treatment of Covid-19 patients at Isala Hospital. We were able to extract operational patient data for Covid-19 patients treated using both the virtual and traditional care pathways. Furthermore, since patients are from the same patient group, and have similar characteristics, we conclude that we have proper conditions to assess the impacts of transitioning to the virtual care pathway on the capacity and financial performance of Isala Hospital, and compare them with the traditional care pathway.

4.1.1 Data Retrieval

For retrieving the data, filters were created on the CTCue software of the hospital, to get the data fields needed. The CTCue software is an online data repository, including all patient data stored by the hospital. We only looked at process data for patients, not medical data, or personal information. To retrieve the data of Covid-19 patients treated at Isala Hospital before the transition to the virtual care pathway we filtered patient data based on lung patients treated at Isala Hospital from December 2019, the pandemic's start date, until the 20th of November 2020 when the transition to the virtual care pathway took place at Isala Hospital. For the first scenario of Covid-19 patients treated at Isala Hospital using the traditional care pathway, we were able to retrieve 25 data entries for admissions, and 56 data entries for appointments. On the other hand, for the retrieval of data for Covid-19 patients treated after the transition we filtered the data to get only lung patients treated at Isala Hospital after the 20th of November 2020 until the 1st of May 2023 when the pandemic was officially declared finished by the World Health Organization (WHO) (Covid-19 Pandemic, 2023). For the second scenario of Covid-19 patients enrolled in the home monitoring programme after the transition to the virtual care pathway, we retrieved 92 data entries for admissions, and 143 data entries for appointments.

To create a fair comparison between both care pathways in all areas of the assessment, we applied the same filters to appointments and admissions, to include the impacts of the transition to the virtual care pathway on the capacity and financial performance of the hospital. We chose admissions and appointments to assess the capacity performance of the hospital. For appointments, we selected the KPIs Average Appointment Duration per Patient, Average Total Duration of Appointments per Patient, Average Number of Appointments per Patient, Average Appointment Costs, Average Total Appointment Costs per Patient, and Appointment Type. Therefore, we collected the following data fields, Patient Pseudo ID, Appointment Description, Appointment Type, and Appointment Duration. If the Patient Pseudo ID is listed more than once, this means that the patient with the corresponding Pseudo ID has more than one appointment. Moreover, the data field Appointment Type was collected to calculate the KPI Appointment Type and present the difference in the percentages of the different appointment types for all samples compared. Lastly, the data field Appointment Duration is used to calculate the KPIs Average Appointment Duration per Patient, and Average Total Duration of Appointments per Patient. Lastly, we extracted the care activity codes for all appointment types, to find the exact costs for each appointment type, we used these costs to calculate the KPIs Average Appointment Costs, and Average Total Appointment Costs per Patient.

Besides, we selected the following KPIs for the assessment of admissions; Average LoS at the Hospital per Patient, Average LoS at Home per Patient, Average Admission Costs per Patient, and Average

Reimbursement Costs per Patient. Moreover, we choose the following data fields for admissions; Patient Pseudo ID, Length of Stay at the Hospital. Firstly, the KPI Average LoS at Home per Patient was calculated from a dataset for patients enrolled in the home monitoring. The dataset included only the data fields Patient Pseudo ID, and LoS at Home, therefore we calculated the KPI Average LoS at Home per Patient from this dataset. For the KPI Average Admission Costs per Patient, we multiplied the LoS at the Hospital of the patient by the costs of one nursing day at Isala Hospital, which was provided to us by Isala Hospital. Finally, to calculate the KPI Average Reimbursement per Patient we were provided with the amount of reimbursement received by Isala Hospital depending on the LoS at the Hospital of the Patient, this data was also provided to us by the hospital. As the LoS at the Hospital of the Patient increases, Isala Hospital receives more reimbursement, and vice versa.

4.1.2 Filtering the Data

After retrieving the data, it needed to be filtered, to clean the data and improve the quality of the datasets available. The datasets we retrieved included all lung patients treated at Isala Hospital, therefore patient data was filtered to include Covid-19 patients only, in order to remove other patients of the lung department. The dataset of appointments for Covid-19 patients before the transition to the virtual care pathway was filtered to include only Covid-19 patients treated between the 1st of Dec 2019, and the 20th of November 2020. Additionally, for Covid-19 patients treated at Isala Hospital after the transition to the virtual care pathway, a date filter was added to include only Covid-19 patients treated after the 20th of November till the start of May 2023, when the pandemic was declared done by the World Health Organization (WHO).

Additionally, throughout the data analysis process, and the calculation of KPIs, we removed some outliers from the datasets available, to ensure the proper distribution of data. First, we removed patients admitted to the hospital for less than a day, from both datasets of Covid-19 patients treated before and after the transition to the virtual care pathway, for this reason 316 data points were removed from the datasets. These patients were removed because they either did not visit the GP before being admitted to the waiting room at Isala Hospital, or because after admission it was found out that they do not have Covid-19, and were admitted to the hospital due to their panic from the pandemic, and were discharged by doctors. This was discussed with the project manager at the CCC department of Isala Hospital. Furthermore, patients admitted to the hospital for more than 30 days were also removed from the datasets, which resulted in the removal of 143 data points, these patients were removed due to their long hospital stay, which may cause unreliable results, and affect our assessment process. Moreover, patients with at least 30 appointments were removed from the dataset of Covid-19 patients treated using the home monitoring programme, which resulted in the removal of 9 data points. Patients enrolled in the home monitoring programme are discharged earlier from the general ward and then monitored at home, thus patients with more than 20 days, or less than 1 day of being admitted to the home monitoring programme after being discharged earlier from Isala Hospital, were also removed from the dataset. Outliers were determined according to a box plot graph formulated for both datasets of admissions and appointments of Covid-19 patients treated using the virtual and traditional care pathways. The flow diagram for the data cleaning process is presented in Appendix 1.1. After outliers were removed from the datasets more patient data was generated, such that all datasets have a sample size of 100 patients, leading to a more proper and fair comparison.

4.2 Assumptions

The following assumptions were made:

- The Covid-19 pandemic started in late December 2019 and ended in the start of May 2023, as stated on Wikipedia, and according to the WHO (Covid-19 Pandemic, 2023)
- We assume that treatment methods were kept the same throughout the Covid-19 pandemic
- Because the available data is limited, and does not include all patients enrolled in the home monitoring programme, we assume that 453 patients were enrolled in the home monitoring programme, based on the assumption made by the CCC that 153 patients were enrolled in the home

monitoring programme from the 20th of November 2020 until the start of January 2022, and the following argumentation.

  - On the 20th of November 2020, there were 479,260 Covid-19 cases in the Netherlands, while at the start of January 2022 there were 3,165,793 Covid-19 cases in the Netherlands. Additionally, at the start of May 2023 cases increased to 8,610,372 in the Netherlands as per (Corona Virus in the Netherlands, 2023)
  - Since the increase in cases between the 20th of November 2020 and the start of January 2022 was 2,668,533, and the increase in cases between the start of January 2022 and the start of May 2023 was 5,444,479, we assume that approximately double the patients treated between the 20th of November and the start of January 2022 have been treated between the start of January 2022 and the start of May 2023
  - Since the pandemic has hit another peak after January 2022, and ended in May 2023, an assumption was made that another 300 patients were treated using the home monitoring programme, making the total of patients treated after the transition to the virtual care pathway 453 patients

- Patients admitted to the hospital for less than a day were not admitted to the general ward at Isala Hospital and are therefore removed from the dataset

4.3 Datasets and Samples

In this sub-section, we introduce the different datasets used for the analysis of admissions and appointments, including the details of these datasets, such as the patients included and the sample size. Moreover, we discuss the generated data samples and datasets for each scenario, highlighting the methods used for the generation. The dataset including admissions data for Covid-19 patients treated using the traditional care pathway, has a sample size of 14 patients who have a combined 16 admissions to the hospital. We consider this dataset the control group for admissions of Covid-19 patients treated using the traditional care pathway, and label it as Adm Pre 2020. For this scenario we generate 3 data samples and label them as S1 Pre, S2 Pre, and S3 Pre, they will be discussed in more detail further. These data samples are generated because the dataset labelled as Adm Pre 2020, does not have a sufficient sample size for creating a proper assessment for the transition, which could lead to unreliable results. On the other hand, the dataset used for the assessment of admissions of Covid-19 patients treated using the virtual care pathway is labelled as Adm Post, and has a sample size of 83 patients having a combined 91 admissions. Because the dataset Adm Post has a sufficient sample size we don't generate data samples out of it. Additionally, an extra dataset was obtained to calculate the length of stay of patients at home during their enrolment in the home monitoring programme. The dataset includes the data fields Patient Pseudo ID, and LoS at Home, and was provided by the project supervisor from Isala Hospital. We calculate the KPI Average LoS at Home per Patient from this dataset. The dataset is only relevant for Covid-19 patients treated using the virtual care pathway. Upon their early discharge from the hospital, patients treated using the virtual care pathway are admitted to the home monitoring programme. The dataset includes a total of 93 patients. Furthermore, we were provided with the reimbursement data for the treatment of Covid-19 patients, based on the LoS of patients at the hospital by Isala Hospital as well. Table 5 displays the amount of reimbursement received by Isala Hospital according to the LoS of patients at the hospital.

Table 5 - Reimbursement based on the LoS of patients at the hospital

LoS of patients at the Hospital	Reimbursement
Short admission (max. 5 days)	€ 3959
Middle (max. 28)	€ 9233
Long (>28)	€ 31565

For the assessment of appointments of Covid-19 patients treated using the traditional care pathway, we have the dataset labelled as Appointments Pre 2020, consisting of 35 patients. On the other hand, for the appointments of Covid-19 patients enrolled in the home monitoring programme, the available dataset is labelled as Appointments HM and has a sample size of 12 patients. The three datasets labelled as Admissions Pre 2020, Appointments Pre 2020, and Appointments HM, have a small sample size, therefore we decided to generate three data samples out of each dataset, while considering these three datasets as the control groups for their three generated data samples.

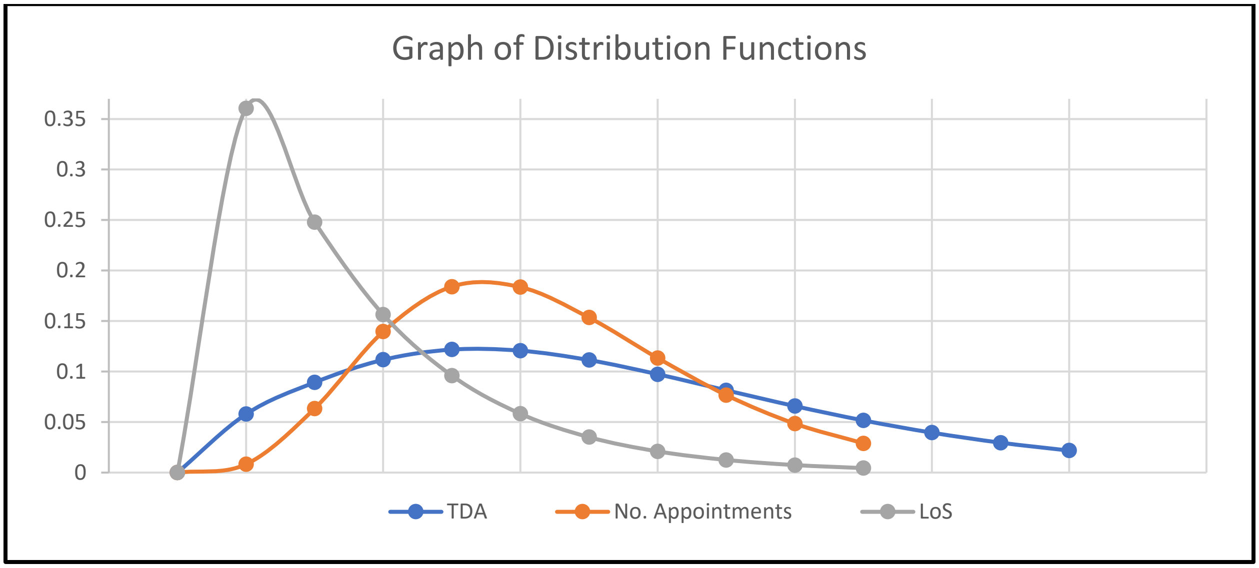

Figure 8 - Probability Distribution of TDA, No. Appointments, and LoS

For generating the data samples, we decided to use the synthetic data generation technique, because we want to simulate patient data derived from the control groups available. The generated data will have similar characteristics to the control groups, with some alterations to each data sample, to make data samples different than each other. We need to generate the following parameters; Number of Appointments, Total Duration of Appointments, and the Length of Stay (LoS) at the hospital. After examining these attributes in the original datasets extracted, we find that they almost follow a gamma distribution, as seen from their probability distributions displayed in Figure 8. For getting the probability distributions of these attributes we use the TDA from the dataset Appointments Pre 2020, the No. Appointments from the dataset Appointments HM, and the LoS from the dataset Adm Post. Since the attributes we want to generate follow a gamma distribution, we calculate the alpha (α) and beta (β) parameters for each of these attributes.

To explain, the gamma distribution, has two parameters, the shape parameter alpha (α), and the rate parameter beta (β). The alpha (α) parameter determines the shape of the probability distribution function, and whether it is more peaked or flattened. As the alpha (α) gets larger, the probability distribution function would be more peaked and less distributed, while lower values result in a flatter and more spread-out distribution. The beta (β) parameter controls the scale of the gamma distribution, and represents the average number of events that happen per unit of measurement. Higher beta (β) values indicate a faster rate of occurrence, while lower values correspond to a slower rate. We first calculate the beta (β) by dividing the variance over the mean, then we calculate the alpha (α) by dividing the mean by the beta (β). The values of the alpha (α) and beta (β) parameters for all generated attributes are displayed in Table 6.

Table 6 - Alpha and Beta Parameters for Attributes Generated

	Alpha	Beta
Number of Appointments HM	5.34	2.06
TDA HM	4.70	35.87
Number of Appointments Pre	4.52	0.35
TDA Pre	4.35	4.77
LoS Pre	1.07	8.82

Since the parameters we want to generate all follow a similar probability distribution to the gamma distribution, we use the GAMMA.INV function in Excel to generate three scenarios for each control group of patient data as defined above. We simulate scenarios by making alterations in the alpha (α) and the beta (β) parameters, and create a sample size of 100 patients for each scenario. The first scenario is conducted using the same alpha and beta as the control groups, the second scenario is simulated using the alpha and beta of the control group multiplied by a factor of 1.1, while the third and last scenario is simulated using the alpha and beta of the control group multiplied by a factor of 0.9. These factors were chosen to assess how variations in the alpha (α) and beta (β) parameters would affect the results. The factor of 0.9 represents a slightly worse than average scenario, the factor of 1 represents a control scenario where no adjustments are made to the alpha (α) and beta (β) parameters, while the factor of 1.1 represents a slightly better than average scenario.

```
Sub GenerateMultipleDatasetsOriginal()
    Dim Seed As Integer
    Dim Alpha As Double
    Dim Beta As Double
    Dim NumberOfSamples As Integer
    Dim Row As Integer
    Dim Column As Integer
    Dim ws As Worksheet
    Set ws = Worksheets("S2 Pre App")

    NumberOfSamples = 10

    Alpha = 5.33
    Beta = 2.06

    For Column = 1 To NumberOfSamples
        Seed = Rnd() * 10000
        Randomize Seed
        For Row = 1 To 130
            ws.Cells(Row, Column + 1).Value = WorksheetFunction.Gamma_Inv(Rnd(), Alpha, Beta)
        Next Row
    Next Column
End Sub
```

Figure 9 - VBA Code used to Generate Datasets

For the data samples we generate, we generate 10 datasets for each attribute, each dataset consists of 100 data points. To simplify, from the dataset Adm Pre 2020, we create three datasets and label them as S1 Pre, S2 Pre, and S3 Pre, to calculate the average LoS at the hospital per patient, we generate 10 datasets consisting of 100 data points of LoS at the hospital values. After the 10 datasets are generated, we calculate the average LoS at the hospital for each dataset, and then calculate the average of all 10 LoS at the hospital averages, to provide us with the average LoS at the hospital per patient for the whole scenario labelled as S1 Pre for example. In order to generate a lot of datasets without consuming a lot of time, we wrote a VBA code to help us with this process, the VBA code is displayed in Figure 9. To break down the code, the values of Alpha and Beta are dependent on the value calculated from the original dataset for each attribute, and the variable NumberOfSamples stands for the desired number of datasets we want to generate, in our case that is equal to 10, and each dataset has 130 data points. We chose to have 130 data points such that when outliers are removed from the datasets, we are left with more than 100 data points, from which the first 100 are taken as one dataset, in order to ensure that all datasets have an equal sample size. The datasets are generated based on the alpha and beta of the attribute in question implemented into the GAMMA.INV function, along with a random seed, which created by multiplying the Rnd function by 1000, in order to ensure that the values of the random seed are different for each dataset. This code ensures that all datasets are generated using a different random seed, which ensures the independence of the generated data, and producing more reliable results.

When sampling the appointment types, the probabilities of occurrence for each appointment type, and the probability of occurrence for the appointment duration of each appointment type were calculated for simulating the appointment type and appointment duration. We then wrote a VBA code that chooses the appointment type and appointment duration based on a random probability which is compared to the probability of occurrence for the appointment type and appointment duration. If the random probability generated is greater than the probability of occurrence for an appointment type or appointment duration it is assigned to it. The VBA code used is displayed in Appendix 1.6. The table below presents the probability of occurrence and costs per appointment type.

Table 7 - The Probability of Occurrence and Costs per Appointment Type

	TC	CPOPNCOR	NPCOR	NPTC
Probability of Occurrence	0.58	0.18	0.02	0.22
Costs	€ 96.52	€ 149.49	€ 96.52	€ 272.97

4.3.1 Study Settings

We calculate the demographics for both datasets extracted for Covid-19 patients treated using the virtual and traditional care pathways. For the dataset of Covid-19 patients treated using the traditional care pathway, 111 patients were extracted from CTCue. As shown in Figures 3 and 4, the dataset consists of 58% males, having an average age of 68.2 years. Additionally, the ages of these patients tend to lie between 60 and 90 years. On the other hand, the dataset for Covid-19 patients treated using the home monitoring programme after the transition to the virtual care pathway, 97 patients were acquired. Figures 6 and 7 present the gender and age distributions of these patients, and show that the dataset consists of 64% males, whose ages tend to lie between 60 and 80 years. Moreover, patients in this dataset have an average age of 64.3 years.

4.3.2 Data Samples Pre-Transition to the Virtual Care Pathway

This sub-section introduces the different data samples for the admissions and appointments of Covid-19 patients treated at Isala Hospital before the transition to the virtual care pathway. As mentioned, these samples are created from the control groups of admissions and appointments using the synthetic data generation technique.

For admissions of Covid-19 patients treated using the traditional care pathway, the first sample is labelled as S1 Pre. Sample S1 Pre includes sampled patient data using the same alpha and beta as the control group of admissions for Covid-19 patients admitted to the hospital before the transition to the virtual care pathway, and has a sample size of 100 patients. The second sample labelled as S2 Pre, is generted using the alpha and beta of the control group multiplied by a factor of 1.1, and has a sample size of 100 patients. Finally, the last data sample contains generated patients using the alpha and beta of the control group multiplied by a factor of 0.9, and contains 100 patients, it is labelled as S3 Pre.

Besides, for the appointments of Covid-19 patients treated using the traditional care pathway, three samples were created using the alpha and beta of the control group. The first scenario labelled as S1 Pre, is generated using the same alpha and beta as the control group, and contains 100 patients. The second data sample labelled as S2 Pre includes generated patient data using the alpha and beta of the control group multiplied by a factor of 1.1, and has a sample size of 100 patients. Finally, the third sample is labelled as S3 Pre, and is generated using the alpha and beta of the control group multiplied by a factor of 0.9, and has a sample size of 100 patients.

4.3.3 Data Samples Post-Transition to the Virtual Care Pathway

For the appointments of Covid-19 patients enrolled in the home monitoring programme, three samples were created based on the control group labelled as Appointments HM. The first data sample of home monitoring appointments is labelled as S1 HM, and is generated using the same alpha and beta as the control group, the sample has a size of 100 patients. The data sample S1 HM, consists of simulated patient data, combined to patient data of the 12 patients included in the control group Appointments HM. The second sample for home monitoring appointments is labelled as S2 HM and is generated using the alpha and beta of the control group multiplied by a factor of 0.9, the dataset has a sample size of 100 patients. The third and last generated sample is labelled as S3 HM. The scenario labelled as S3 HM is generated using the alpha and beta multiplied by a factor of 1.1, and includes 100 patients.

4.4 Test of Significance

This section presents the test of significance conducted between the samples of Covid-19 patients treated using the traditional and virtual care pathways. We conduct a test of significance to ensure the difference between the attributes is not caused by randomness. Moreover, we need the test of significance to examine the statistical difference between the distribution of different data samples. Additionally, the results of the test of significance can help reason findings regarding the different attributes involved in the test. We compare between the Length of Stay (LoS) at the hospital, the Number of Appointments, the Total Duration of Appointments (TDA), and the Total Costs of Appointments for all scenarios. We decided on these parameters due to their relevance for our research, also because of the importance of comparing these parameters between the traditional and virtual care pathways to reach a conclusion that is not affected by the randomness of data.

We decided on the Mann-Whitney U-test because the test works for all probability distributions, which is optimal since our datasets follow a gamma distribution. Moreover, the test uses the median as a measure of central tendency, thus it provides a better measure than the mean because the gamma distribution is skewed and is not necessarily symmetric (Statology, 2020). Finally, we use a significance level of 0.05. For using the Mann-Whitney U-test we need to set up the test steps to interpret the results of the test and determine whether we can reject the null hypothesis stating that there is no statistical difference between both datasets. First of all, we place the data for the attribute we want to compare in two columns, the first containing data for Covid-19 patients treated before the transition, while the second includes data for Covid-19 patients treated after the transition to the virtual care pathway.

Next, the ranks for all entries of both datasets need to be computed. When computing the ranks, the smallest number in both datasets gets a rank of 1, and the largest number gets a rank of N, where N is the sum of the number of entries in both samples (Interpreting Results: Mann-Whitney Test, 2023). After computing the ranks, we calculate the sum of the ranks for both samples, and use them to determine the U-test statistic for each sample using the following formulas in Figure 9, where n_1 and R_1 are the number of entries and the sum of ranks for the first sample respectively, and the same goes for n_2 and R_2 with the second sample. Below, are the equations for parameters U_1 and U_2.

$$U_1 = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - R_2$$

After both U_1 and U_2 values are calculated, we use the minimum of both test statistics as our U-test statistic, and use it to determine the Z-score and the P-value using Excel formulas. The computation of the Mann-Whitney U-test and the formulas used to determine the values used for the comparison are displayed in Appendix 1.2.

4.5 Conclusion

Concluding, in this chapter, we presented the methods used for the data analysis of this research. We create six data samples for appointments, and four samples for admissions, all generated using the synthetic data generation technique, by altering in the alpha and beta of the control groups. Then, we conduct a test of significance using the Mann-Whitney U-test to test whether the samples have the same distributions and are statistically indifferent. Finally, the results of the data analysis process will be displayed in Chapter 5.

5 Results

This chapter includes the results of the data analysis process for the comparison between data samples of Covid-19 patients treated using the traditional and virtual care pathways. We start the chapter with discussing the values of the admissions KPIs for the different samples compared in Section 5.1. The comparison of KPIs for appointments then follows in Section 5.2. Furthermore, we discuss the results of the cost analysis, with the impacts of the transition to the virtual care pathway on the financial performance of Isala Hospital in Section 5.3. Lastly, we formulate a conclusion based on the findings and insights investigated from the data analysis in Section 5.4. All costs used have been multiplied by a factor of X to comply with the data confidentiality regulations at Isala Hospital.

5.1 Admissions

For the comparison of admissions data for Covid-19 patients we have two scenarios. The first scenario is for Covid-19 patients treated using the traditional care pathway, and for that we have three data samples labelled as S1 Pre, S2 Pre, and S3 Pre. The second scenario includes Covid-19 patients treated using the virtual care pathway and enrolled in the home monitoring programme. For the second scenario we have two datasets the first is used to calculate the average LoS of patients at the hospital and is labelled as Adm Post, while the second dataset is to calculate the average LoS of patients at home.

5.1.1 Average Length of Stay (LoS) at the Hospital per Patient

To understand how the transition to the virtual care pathway and affected the capacity performance of admissions at Isala Hospital, we examine the KPI average LoS at the hospital per patient, and plot the standard deviation of all datasets to comment on the variability in the LoS of patients at the hospital.

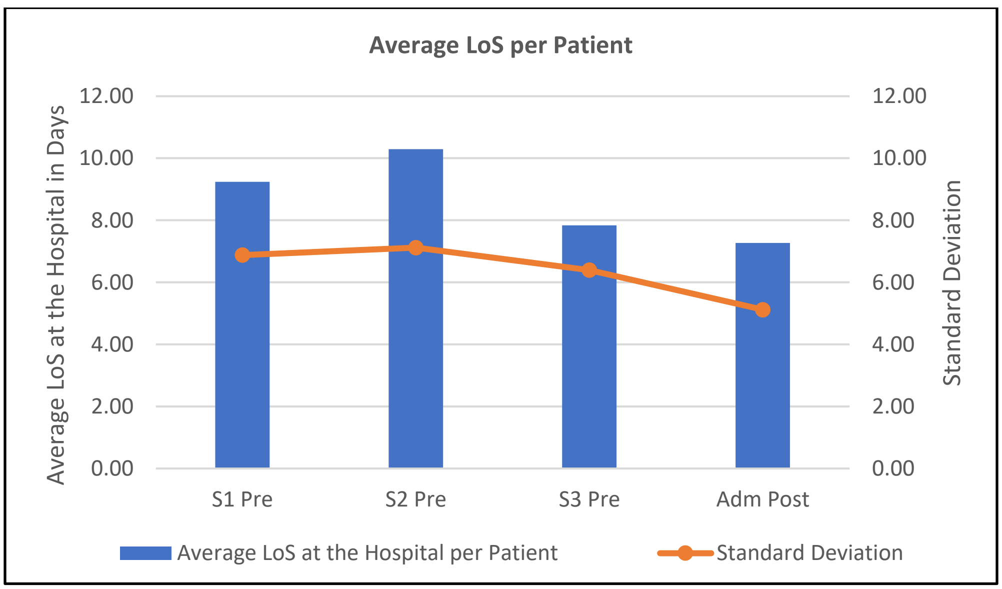

Figure 10 - Average LoS at the Hospital plotted against the Standard Deviation of the Generated Datasets

Figure 10 shows a comparison of the average LoS of patients at the hospital between datasets of Covid-19 patients treated before and after the transition to the virtual care pathway. The KPI average LoS at the hospital presents the average duration spent by patients at the hospital where they are admitted to the general ward of Isala Hospital. From Figure 10, we see that patients enrolled in the home monitoring programme have a lower LoS at the hospital than all three datasets of patients treated using the traditional care pathway. Furthermore, we deduce that the second data set of Covid-19 patients treated using the traditional care pathway labelled as S2 Pre, has the highest average LoS at the hospital per patient. Moreover, we see that the second dataset labelled as S2 Pre has the highest standard deviation out of all datasets, suggesting a greater variability in the LoS values. On the other hand, the dataset Adm Post has the lowest standard deviation, meaning that the LoS values of patients have the least variability than all datasets. As the variability of LoS values increases, more patients might have significantly different LoS values than the average, and vice versa.

Additionally, Table 8 shows the values of the KPIs used for the assessment of admissions, and compares them for all datasets involved in the data analysis process. The KPI average LoS at home per patient represents the average duration a patient stays enrolled in the home monitoring programme. Moreover, we can calculate that patients from samples S1 Pre, S2 Pre, and S3 Pre, have an average LoS at the hospital of 9.12 days, which is almost 1.9 days more than the dataset Adm Post containing patients treated after the transition to the virtual care pathway. However, patients enrolled in the home monitoring programme spend almost 9.4 days at home enrolled in the home monitoring programme. Thus, patients spend almost 16.7 days for their treatment process, almost 7 days more than patients treated using the traditional care pathway at Isala Hospital. We conclude that patients treated using the home monitoring programme spend less time admitted to the hospital, but spend longer to complete their treatment process than patients treated using the traditional care pathway. We also calculate the average standard deviation of the LoS at the hospital for all datasets of Covid-19 patients admitted to the hospital both before and after transitioning to the virtual care pathway. As mentioned, we conduct a test of significance for the LoS at the hospital of patients treated using the virtual and traditional care pathways. According to the results of the test, we can not reject our null hypothesis, and have no sufficient evidence to say that there is a significant difference in the distributions of data samples. Furthermore, the differences between the means of ranks for the data samples are not significant, suggesting that the samples follow a similar distribution.

Table 8 - Admissions KPIs Comparison

	S1 Pre	S2 Pre	S3 Pre	Adm Post
Average LoS at the hospital per Patient	9.24	10.29	7.84	7.27
Average LoS at Home per Patient	0	0	0	9.37
Standard Deviation of LoS of patients at the hospital	6.88	7.12	6.39	5.12

5.2 Appointments

For appointments, we want to compare between two scenarios, the first scenario is for appointments of Covid-19 patients treated using the traditional care pathway, with appointments at the hospital. The second scenario is for Covid-19 patients treated after the transition to the virtual care pathway using the home monitoring programme, with appointments from their homes. For the first scenario, we have three data samples labelled as S1 Pre, S2 Pre, and S3 Pre. On the other hand, data samples for the second scenario are labelled as S1 HM, S2 HM, and S3 HM.

5.2.1 Percentage of Appointments by Type

The first KPI we want to assess for appointments is the percentage of appointments by type. Figure 11 shows the percentage of appointments by type for all six samples of Covid-19 patients treated before and after the transition to the virtual care pathway.

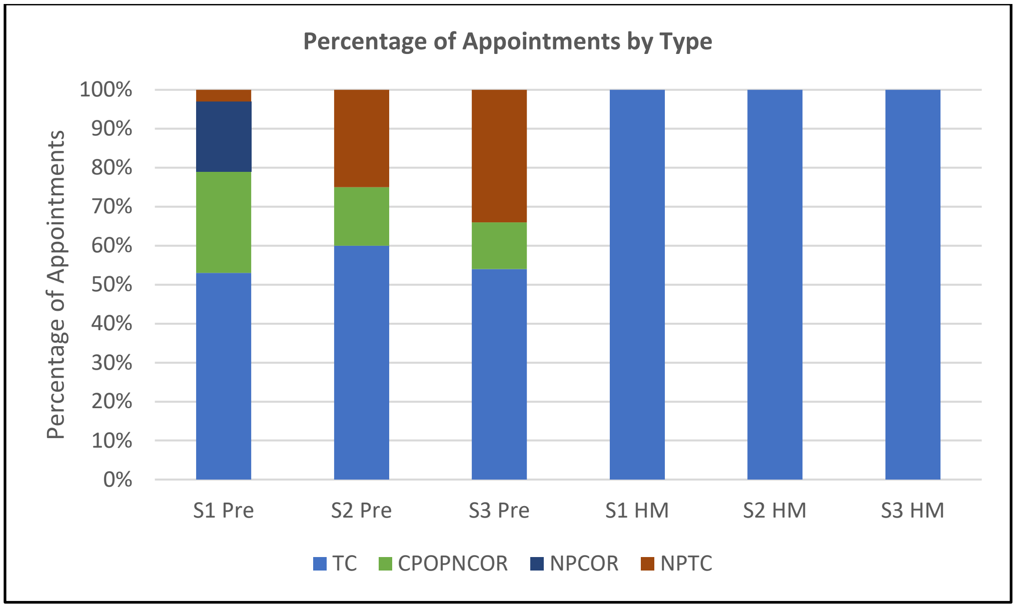

Figure 11 - Percentage of Appointments by Type

Figure 11 presents the breakdown of appointments for Covid-19 patients for each sample by the appointment type. We observe that for the samples of Covid-19 patients treated using the traditional care pathway, the distribution of appointment types is greater than appointments of patients treated using the home monitoring programme. Moreover, the three samples for patients treated using the traditional care pathway have a high percentage of telephonic consultation appointments with appointment types "TC" and "NPTC", with more than 50% of appointments for all three samples. Additionally, sample S1 Pre has the highest percentage of non-telephonic appointments, with almost 45% of the appointments consisting of outpatient visits, opposing to samples S2 Pre and S3 Pre which have 15% and 12% of non-telephonic appointments.

On the other hand, for the samples of Covid-19 patients treated using the home monitoring programme, all appointments are of type "TC" which is the appointment code for telephonic consultations with the virtual monitoring nurses at Isala Hospital. The home monitoring programme aimed at reducing outpatient clinic visits through substituting them with telephonic consultations. Overall, Figure 11 shows that the outpatient clinic visits have been excluded, and replaced with telephonic consultations, which reduces the costs incurred by Isala Hospital. The table in Appendix 1.4 presents the different appointment types, description, and their costs.

5.2.2 Average Number of Appointments and TDA per Patient

To investigate the difference in the number of contact instances patients have with nurses from Isala Hospital and the time they spend on them, we look into the KPIs average number of appointments and average total duration of appointments per patient.

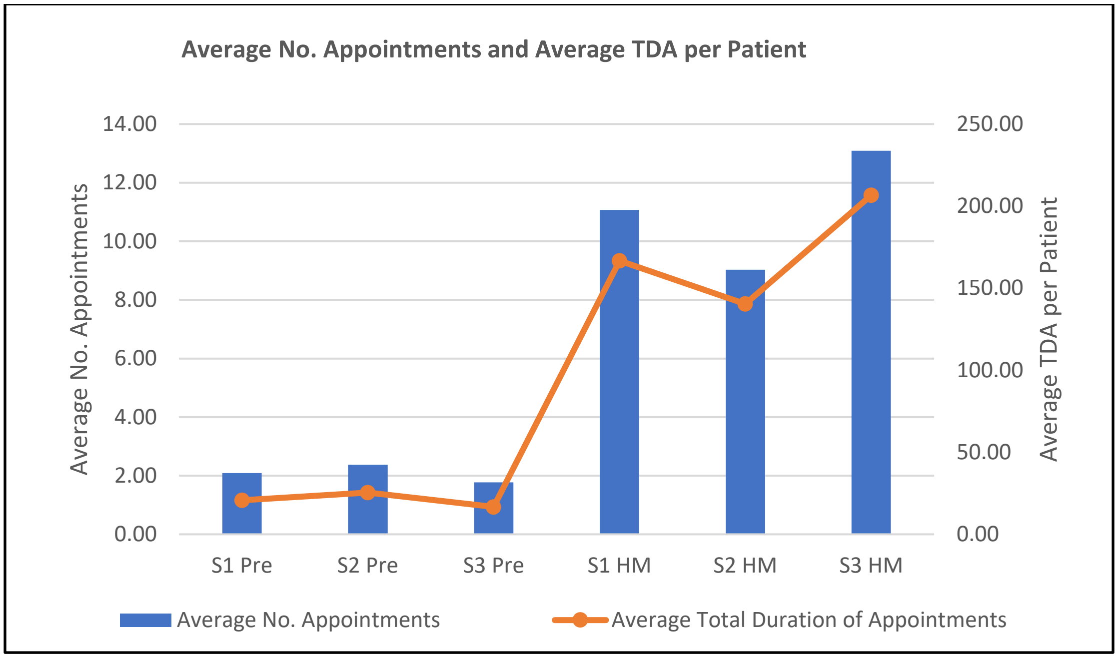

Figure 12 - Average No. Appointments and Total Duration of Appointments per Patient

Figure 12 displays the average number of appointments per patient, and the average total duration of appointments per patient for all samples. The average number of appointments per patient ranges from 1.8 to 13.1, with sample S3 HM showing the most and sample S3 Pre the least average number of appointments per patient. From the data analysis, we calculated that patients treated using the home monitoring programme have approximately 5 times the number of appointments as patients treated using the traditional care pathway on average. Moreover, the average total duration of appointments for patients in samples S1 Pre, S2 Pre, and S3 Pre ranges between 16.7 and 25.4 minutes. On the other hand, the average total duration of appointments for patients treated using the home monitoring programme ranges from 140.3 and 206.6 minutes. We conclude that patients enrolled in the home monitoring programme have approximately 5 times the number and 8 times the total duration of appointments on average as patients treated using the traditional care pathway. According to the Mann-Whitney U-test conducted we reject the null hypothesis, and find that the samples for the average number of appointments follow a different distribution. The significant differences in the mean ranks suggest that samples do not follow the same distribution, suggesting that there are significant statistical differences between the datasets.

5.2.3 Average Number of Appointments per Patient and Average Appointment Costs

In this sub-section we examine the KPIs average number of appointments per patient, and average appointment costs. These KPIs are examined to gain insight into the impacts of transitioning to the virtual care pathway and implementing the home monitoring programme at Isala Hospital on the costs of appointments.

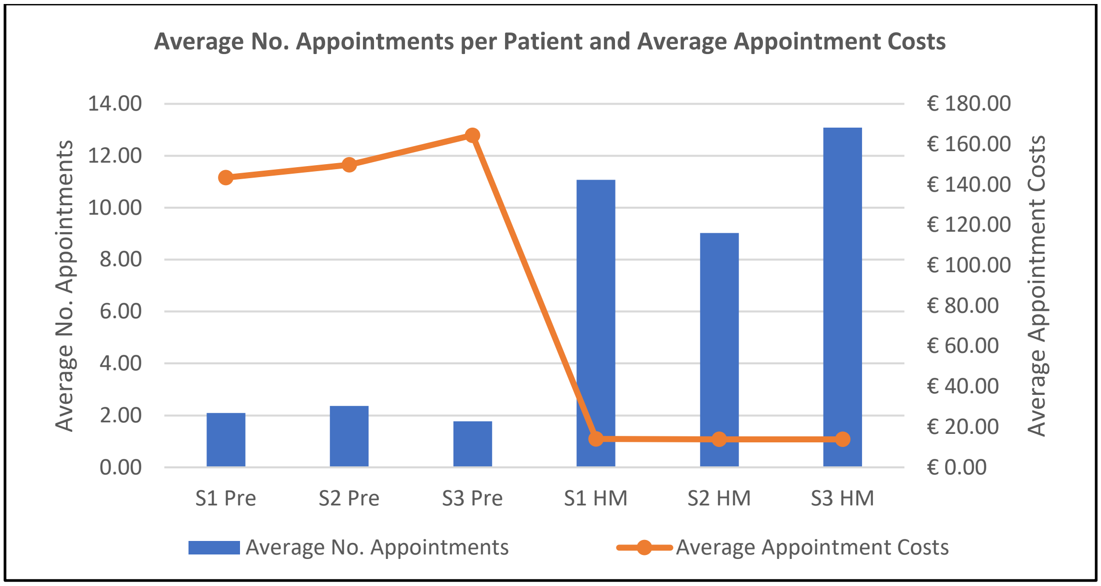

Figure 13 - Average Number of Appointments and Average Appointment Costs

Figure 13 displays the average number of appointments per patient plotted against the average appointment costs for all samples. As mentioned, patients enrolled in the home monitoring programme have approximately 5 times the number of appointments as patients treated using the traditional care pathway. However, appointments for patients treated using the traditional care pathway are almost 11 times the appointment costs for patients enrolled in the home monitoring programme. From Figure 13, we see that sample S3 Pre has the lowest average number of appointments per patient out of all samples, however, it has the highest average appointment costs. On the other hand, sample S3 HM has the least average appointment costs, while having the highest average number of appointments per patient. We conclude that patients enrolled in the home monitoring programme have approximately 5 times the number of appointments as patients treated using the traditional care pathway. However, appointments of patients treated using the traditional care pathway are almost 11 times more expensive than appointments of Covid-19 patients enrolled in the home monitoring programme.

5.2.4 Comparison of Appointments KPIs

In this section we compare between the KPIs used for the assessment of appointments for all data samples. As mentioned, the first three samples labelled as S1 Pre, S2 Pre, and S3 Pre are for Covid-19 patients treated using the traditional care pathway. Additionally, the data samples labelled as S1 HM, S2 HM, and S3 HM are for Covid-19 patients treated using the home monitoring programme after the transition to the virtual care pathway, and enrolled in the home monitoring programme.

Table 9 shows the KPIs used for the assessment of appointments, and the outcomes of the data analysis process for all samples. From Table 9 we can see that on average Covid-19 patients treated using the home monitoring programme have approximately 5 times the number of appointments as Covid-19 patients treated using the traditional care pathway. Moreover, Covid-19 patients enrolled in the home monitoring programme spend approximately 8 times the duration of appointments as Covid-19 patients treated using the traditional care pathway, however, the average appointment costs for Covid-19 patients treated using the traditional care pathway are approximately 11 times more expensive. According to the results of the test of significance conducted, we proved that the total duration of appointments for samples of patients treated using the traditional and virtual care pathways are statistically different and have different distributions, Therefore, we reason the difference in the average total appointment duration per patient by the statistically different samples and distributions.

Table 9 - Appointments KPIs Comparison

	S1 Pre	S2 Pre	S3 Pre	S1 HM	S2 HM	S3 HM
Average Appointment Duration	13.77	12.96	12.87	15.25	15.00	15.00
Average Total Duration of Appointments per Patient	20.68	25.44	16.71	166.71	140.32	206.62
Average Number of Appointments per Patient	2.09	2.37	1.77	11.07	9.03	13.09
Average Appointment Costs	€ 143.41	€ 149.80	€ 164.49	€ 14.09	€ 13.86	€ 13.86

5.3 Cost Analysis

5.3.1 Average Admission Costs and Reimbursement per Patient

In this sub-section, we look into the KPIs average admission costs and reimbursement per patient, to assess the impacts of the transition to the virtual care pathway on the financial performance of Isala Hospital in terms of admissions. The admission costs are calculated by multiplying the LoS at the hospital per patient by € 730.7, which are the costs for one nursing day.

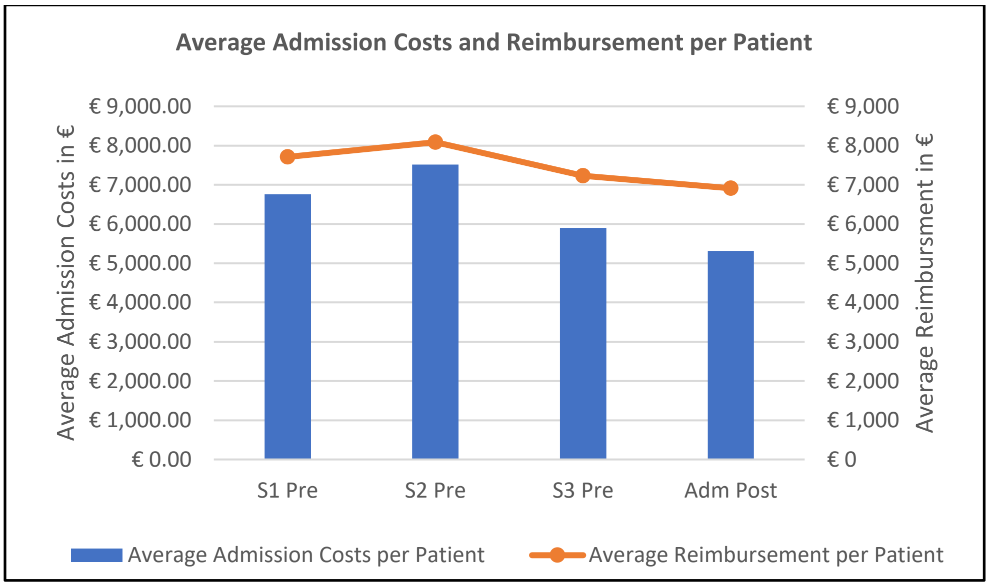

Figure 14 - Average Admission Costs and Reimbursement per Patient

Figure 14 displays the average admission costs and the average reimbursement per patients for all samples compared. From the figure we see that the second data sample S2 Pre has the highest average admission costs and reimbursement per patient, while the dataset Adm Post scores the least of both KPIs. From Figure 14 we deduce that as the average admission costs per patient increases, the average reimbursement per patient increases as well. Table 10 presents the average admission costs and average reimbursement per patient for all data samples compared. From the table, we see that the admission costs for Covid-19 patients treated using the traditional care pathway is almost 26% more expensive than for Covid-19 patients enrolled in the home monitoring programme. Furthermore, Isala Hospital receives 10% less reimbursement per patient if they choose to transition to the virtual care pathway for the treatment of Covid-19 patients.

Table 10 - KPIs Average Admission Costs and Reimbursement per Patient Comparison

	S1 Pre	S2 Pre	S3 Pre	Adm Post
Average Admission Costs per Patient	€ 6,755.13	€ 7,519.89	€ 5,906.33	€ 5,315.59
Average Reimbursement per Patient	€ 7,709	€ 8,087	€ 7,230	€ 6,913

5.3.2 Average Appointment Costs and Average Total Appointment Costs per Patient

In this sub-section we look into the costs KPIs for appointments. The costs KPIs analysed for appointments are average appointment costs and average total appointment costs per patient. The average total appointment costs per patient were calculated by multiplying the average appointment costs by the average number of appointments per patient for samples S1 Pre, S2 Pre, and S3 Pre. On the other hand, for samples S1 HM, S2 HM, and S3 HM, the average total appointment costs per patient were calculated by multiplying the average total duration of appointments per patient by € 55.44, which are the costs per hour of virtual monitoring nurses.

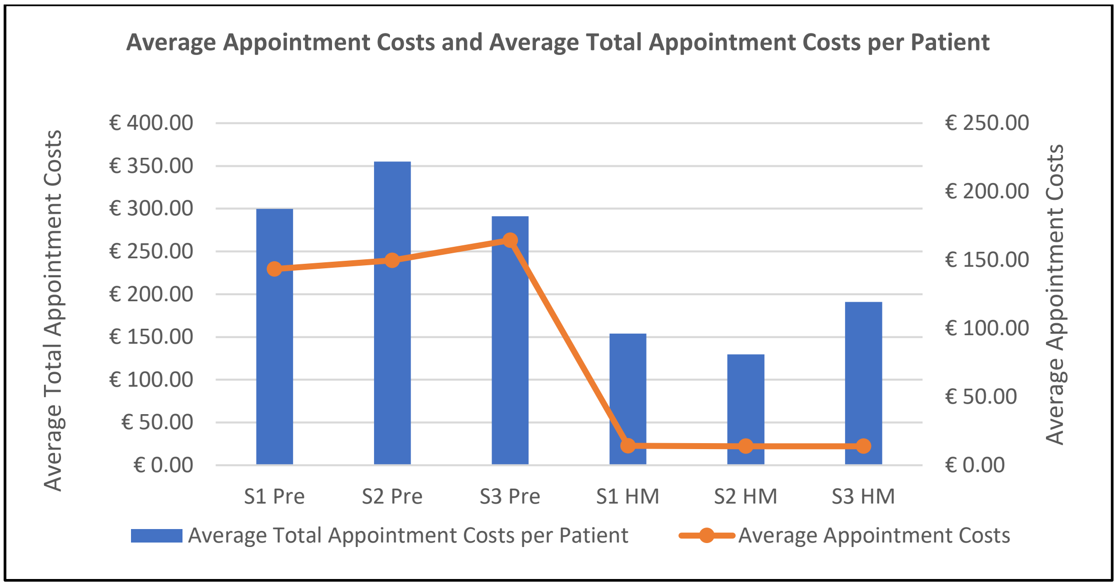

Figure 15 - Average Appointment Costs and Average Total Appointment Costs per Patients

Figure 15 shows the average appointment costs and the average total appointment costs per patient plotted for all samples of appointments. From the graph we see that samples S2 Pre and S2 HM have the highest and lowest average total appointment costs respectively. Moreover, the appointment of samples S1 HM, S2 HM, and S3 HM, are significantly less expensive than appointments of samples S1 Pre, S2 Pre, and S3 Pre. However, the difference in the average total appointment costs per patient is not as significant as the difference in the average appointment costs. Furthermore, the results of the test of significance conducted indicate that samples follow a different distribution for the average total appointment costs, reasoning the difference between the averages of this KPI for the different samples.

Table 11 presents the values of the KPIs average appointment costs and average total appointment costs per patient for all data samples. As mentioned, the average appointment costs for Covid-19 patients treated using the traditional care pathway are almost 11 times more expensive than the average appointment costs for Covid-19 patients enrolled in the home monitoring programme. On the other hand, the average total appointment costs for Covid-19 patients treated using the traditional care pathway is only 2 times the average total appointment costs for Covid-19 patients enrolled in the home monitoring programme.

Table 11 - KPIs Average Appointment Costs and Total Appointment Costs per Patient Comparison

	S1 Pre	S2 Pre	S3 Pre	S1 HM	S2 HM	S3 HM
Average Appointment Costs	€ 143.41	€ 149.80	€ 164.49	€ 14.09	€ 13.86	€ 13.86
Average Total Appointment Costs per Patient	€ 299.72	€ 355.03	€ 291.14	€ 154.04	€ 129.65	€ 190.92

5.3.3 Total Costs Comparison

In this sub-section we discuss the total costs comparison of samples compared to gain insight into the impacts of transitioning to the virtual care pathway on costs for the treatment of Covid-19 patients.

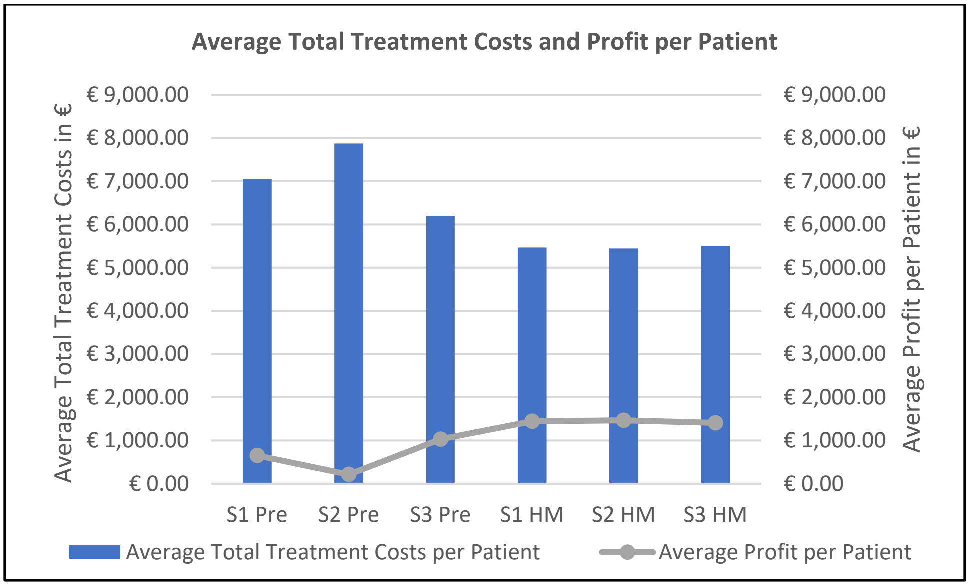

Figure 16 - Average Total Treatment Costs, Reimbursement, and Profit per Patient for all samples

Figure 16 displays the average total treatment costs plotted against the average profit generated per patient. As can be seen from Figure 16, Covid-19 patients enrolled in the home monitoring programme have lower total treatment costs, and generate more profits for Isala Hospital on average. We see that the sample S2 Pre has the least average profit generated per patient, which is mainly due to the very high average total treatment costs of the sample as calculated in the data analysis. Furthermore, Table 12 was created to present the values of the KPIs used for the assessment of costs. The KPI average total treatment costs per patient was calculated by adding the average admission costs per patient to the average total appointment costs per patient. Finally, we calculate the average profit generated per patient as the difference between the average total treatment costs and the average reimbursement per patient.

Table 13 displays the difference between the averages of the costs KPIs for samples of Covid-19 patients treated using both the traditional and virtual care pathways. Our findings show that the total treatment costs for Covid-19 patients enrolled in the home monitoring programme are almost 23% cheaper on average than patients treated using the traditional care pathway. However, Isala Hospital receives more reimbursement by 10% for the treatment of Covid-19 patients using the traditional care pathway. Lastly, we see that Isala Hospital makes more profit by € 805.80 for treating Covid-19 patients using the home monitoring programme. We conclude that the treatment of Covid-19 patients using the home monitoring programme costs Isala Hospital less treatment costs, brings in less reimbursement, and generates more profit than the treatment of Covid-19 patients using the traditional care pathway.

Table 12 - Costs KPIs for Total costs Comparison between all Samples

	Average Total Treatment Costs per Patient	**Average Reimbursement per Patient**	**Average Profit per Patient**
S1 Pre	€ 7,054.85	€ 7,709.21	€ 654.36
S2 Pre	€ 7,874.92	€ 8,087.30	€ 212.38
S3 Pre	€ 6,197.48	€ 7,229.54	€ 1,032.07
S1 HM	€ 5,469.63	€ 6,912.53	€ 1,442.90
S2 HM	€ 5,445.24	€ 6,912.53	€ 1,467.29
S3 HM	€ 5,506.50	€ 6,912.53	€ 1,406.02

Table 13 - Difference between Averages for Costs KPIs

KPI	Difference Between Averages
Total Treatment Costs (Pre is Higher)	€ 1,568.53
Reimbursement (Pre is Higher)	€ 762.82
Profit (HM is Higher)	€ 805.80

As mentioned, Covid-19 patients enrolled in the home monitoring programme are discharged from the hospital approximately 1.9 days earlier on average than Covid-19 patients treated using the traditional care pathway. We use our assumption that 453 Covid-19 patients were enrolled in the home monitoring programme since its implementation till the end of the pandemic to assume that 838 nursing days were saved. We come to the nursing days saved by multiplying the difference in the LoS of patients at the hospital by the number of patients enrolled in the home monitoring programme. By saving approximately 838 nursing days, Isala Hospital saved € 612,364.81 in terms of nursing day costs by transitioning to the virtual care pathway and implementing the home monitoring programme for the treatment of Covid-19 patients. The costs saved were calculated by multiplying the number of nursing days saved by € 730.7, which is the cost of one nursing day.

The treatment of Covid-19 patients using the home monitoring programme generated Isala Hospital € 805.80 in profits. Thus, we multiply the profit gained per patient by 453, the number of patients enrolled in the home monitoring programme, and get that Isala Hospital gained € 365,028.64 in profits due to the transition to the virtual care pathway. We conclude that the transition to the virtual care pathway and implementation of the home monitoring programme for the treatment of Covid-19 patients results in costs savings of € 977,393.46 for Isala Hospital during the observation period, between the 20th of November 2020 and the 1st of May 2023.

5.4 Conclusion

In this chapter we presented the results of the data analysis process, and discussed the KPIs analyzed for all samples of both scenarios regarding admissions, appointments, and costs. We find that Covid-19 patients enrolled in the home monitoring programme are admitted to the hospital approximately 1.9 days less on average, compared to patients treated using the traditional care pathway. However, Covid-19 patients enrolled in the home monitoring programme spend 7.5 more days one average to complete their treatment process, due to the home monitoring process by nurses from Isala Hospital. Additionally, Covid-19 patients enrolled in the home monitoring programme had approximately 5 times the number of appointments and almost 8 times the total duration of appointments as patients treated using the traditional care pathway on average. The difference between the impacts of transitioning to the virtual care pathway on appointments and admissions is reasoned by the early discharge of patients. When patients are discharged from Isala Hospital earlier, they are sent home to be monitored by the virtual monitoring nurses. During the monitoring process patients have a set schedule of appointments, and are called by the virtual monitoring nurses if the patient's situation deteriorates. Therefore, it is expected that patients enrolled in the home monitoring programme would have more appointments, as they are discharged earlier from the hospital, and spend approximately 9 days at home being monitored by nurses. On the other hand, once patients treated using the traditional care pathway are discharged from the hospital, they do not need to have more appointments unless their condition deteriorates.

We conduct a cost analysis to gain insights into the financial performance of the virtual care pathway, and the difference in costs with the traditional care pathway. We find that appointments of Covid-19 patients treated using the traditional care pathway are 11 times more expensive, and the total appointment costs per patient are 2 times more expensive than patients enrolled in the home monitoring programme on average. We reason the difference in the average appointment costs by examining the percentage of appointments by types for both scenarios. We find that 100% of appointments of the home monitoring programme consist of telephonic consultations, while the traditional care pathway contains outpatient clinic visits with percentages ranging from 12% to 44% for all 3 samples, besides having telephonic consultations as well. Furthermore, our cost analysis shows that the total treatment costs for Covid-19 patients enrolled in the home monitoring programme is 23% cheaper on average, compared to patients of the traditional care pathway.

Our findings indicate that the virtual care pathway is more beneficial than the traditional care pathway for the capacity performance of hospitals. The transition to the virtual care pathway reduces the LoS of patients at the hospital by 1.9 days on average. Additionally, we use our assumption that 453 Covid-19 patients were enrolled in the home monitoring programme to calculate that the transition to the virtual care pathway for the treatment of Covid-19 patients saved Isala Hospital approximately 838 nursing days. Additionally, through saving 838 nursing days, Isala Hospital saved € 612,364.81, the costs of 838 nursing days. Furthermore, the treatment of Covid-19 patients using the home monitoring programme was more profitable for Isala Hospital, which made more profit per patient by € 805.80. The increase in the profit per patient resulted in profits earnings of € 365,028.64 for the 453 Covid-19 patients enrolled in the home monitoring programme. Finally, by saving costs of 838 nursing days, and increasing the profit per patient by € 805.80, the transition to the virtual care pathway saved Isala Hospital € 977,393.46 in costs between the 20th of November 2020 and the 1st of May 2023.

6 Conclusion and Recommendations

This chapter concludes our research regarding the impacts of the virtual care pathway on the financial and capacity performance of hospitals. The research is concluded with the results of the data analysis and cost analysis in Section 6.1. Then, we state our recommendations to Isala Hospital for the transition to the virtual care pathway according to our findings, in Section 6.2. Lastly, the discussion, research design, future research directions, and other insights are presented in Section 6.3.

6.1 Conclusion

We conclude that the virtual care pathway performs better than the traditional care pathway from a capacity and financial performance perspective. We take the transition to the virtual care pathway for the treatment of Covid-19 patients as a case study for our research. Our findings show that patients that average LoS at the hospital per patient enrolled in the home monitoring programme, is 1.9 days less compared to patients treated using the traditional care pathway. However, patients enrolled in the home monitoring programme spend approximately 7.5 more days on average to complete their treatment process. We use the assumption that 453 Covid-19 patients were treated using the home monitoring programme, to calculate that Isala Hospital saved approximately 838 nursing days due to the transition to the virtual care pathway. To get more insights into the time spent by patients for appointments, we look into the KPIs average number of appointments, and average total duration of appointments per patient. The data analysis shows that patients enrolled in the home monitoring programme have approximately 5 times the number of appointments as patients treated using the traditional care pathway on average. Additionally, patients enrolled in the home monitoring programme had almost 8 times the average total duration of appointments of patients treated using the traditional care pathway.

Additionally, we conducted a cost analysis for the different samples of both scenarios. Findings suggest that appointments of the traditional care pathway are on average 11 times more expensive than appointments of the home monitoring programme. On the other hand, the average total appointment costs per patient for patients treated using the traditional care pathway are approximately 2 times more expensive than patients enrolled in the home monitoring programme. We reason the difference in the average appointment costs by examining the percentage of appointments by types for both scenarios. We find that 100% of appointments of the home monitoring programme consist of telephonic consultations, while the traditional care pathway contains outpatient clinic visits with percentages ranging from 12% to 44% for all 3 samples, besides having telephonic consultations as well. The difference between the average total appointment costs per patient is not as significant as the average appointment costs due to home monitoring patients having almost 5 times the number of appointments as the traditional care pathway patients.

Lastly, we compared between the average total treatment costs, average reimbursement, and average profit per patient for the virtual and traditional care pathways. From the data analysis we see that the average total treatment costs for patients enrolled in the home monitoring programme is 23% cheaper than the average total treatment costs patients treated using the traditional care pathway. Furthermore, Isala Hospital receives 10% more reimbursement for the treatment of Covid-19 patients using the traditional care pathway rather than the home monitoring programme. Finally, patients enrolled in the home monitoring programme generate more profits for Isala Hospital by an average of € 805.80 more profit per patient treated. We use the assumption that 453 patients were enrolled in the home monitoring programme to calculate the profits earned by Isala Hospital, which come to a total of € 365,028.64 in profits earned. Additionally, Isala Hospital has saved approximately 838 nursing days, which cost € 730.7 each, resulting in cost savings of € 612,364.81. We see that the transition to the virtual care pathway and implementing the home monitoring programme for the treatment of Covid-19 patients at Isala Hospital resulted in cost savings of € 977,393.46, due to the costs of nursing days saved, and the profits earned.

To conclude, we can answer our main research question “**Is the implementation of Remote Patient Monitoring Systems (RPMS) for monitoring patients at home beneficial for hospitals from a capacity performance and cost-efficiency perspective?”.** Our findings show that the transition to the virtual care pathway for the treatment of Covid-19 patients was beneficial for Isala Hospital in terms of capacity and financial performance. For the capacity performance of Isala Hospital, the transition to the virtual care pathway has resulted in a reduction in the average LoS of patients at the hospital by 1.9 days on average, which has led to saving Isala Hospital 838 nursing days, achieving the goal of reducing the strain faced by the hospital and relieving the general ward at Isala Hospital. As for financial performance, the transition to the virtual care pathway has resulted in a reduction in the total treatment costs per patient, as well as an increase in the average profit generated per patient, leading to overall cost savings of € 977,393.46. Thus, we conclude that the transition to the virtual care pathway and the implementation of the home monitoring programme has improved the capacity performance and cost-efficiency of Isala Hospital. Furthermore, we can also assume an improve in patient satisfaction and the quality of care, due to the increased interactions with nurses for Covid-19 patients enrolled in the home monitoring programme. The improvement in the patient satisfaction is because patients enrolled in the home monitoring programme have almost 5 times the appointments as patients treated using the traditional care pathway, while staying at their homes and not having to go to the hospital, thus saving themselves time, money, and effort.

6.2 Recommendations

To improve the capacity performance of the home monitoring programme in terms of appointments Isala Hospital needs to limit the number of telephonic consultations per patient. Our findings show that Covid-19 patients enrolled in the home monitoring programme have almost 5 times the average number of appointments, and spend almost 8 times the average total duration of appointments as Covid-19 patients treated using the traditional care pathway. For the home monitoring programme to perform the same as the traditional care pathway in terms of capacity for appointments of Covid-19 patients, Isala Hospital would have to reduce the number of appointments by 85% or reduce the appointment duration by almost 90% on average. Both options don’t seem reasonable, therefore we recommend that Isala Hospital reduces the average number of appointments per patient by 40% to improve the capacity performance of the home monitoring programme, and reduce the load placed on virtual monitoring nurses, while simultaneously reducing treatment costs. Moreover, the reduction of the average number of appointments per patient by 40%, would reduce the average total appointment costs per patient for the home monitoring programme by approximately € 66.

6.3 Discussion and Recommendations for Future Research

Our research aimed to give a conclusion on the efficiency of the virtual care pathway on the capacity and financial performance while taking the treatment of Covid-19 patients at Isala Hospital as a case study. We assessed the impacts of the transition to the virtual care pathway for the treatment of Covid-19 patients from a capacity and financial perspective. There are several points that limit the results of our research. Firstly, we extracted the data from the CTCue software, which is the online data repository of Isala Hospital. Patient data was not reported properly during the Covid-19 pandemic, which highly affected the quality of data. Secondly, when extracting data from the CTCue software we could not filter by Covid-19 patients, only by lung patients, due to the un-availability of a large dataset of data for Covid-19 patients. Additionally, data samples are not of a very big size, because dealing with huge amounts of simulated data can result in unreliable results. Therefore, data samples were generated to create a proper assessment. Regarding costs, the cost analysis did not include all costs incurred by Isala Hospital due to the transition to the virtual care pathway for the treatment of Covid-19 patients. For instance, the costs of implementing the sensors, and the costs lost due to the complexity of the assessment. Furthermore, we assumed that the removal of appointments will eliminate all appointment costs, which is not entirely true, as facility costs are still incurred and cannot be eliminated. Lastly, the timeframe for the research is not enough to entirely cover the assessment and include all aspects of the virtual care pathway.

The virtual care pathway for the treatment of Covid-19 patients was implemented with the objectives to reduce the strain faced by Isala Hospital, while making the hospital more cost-efficient. Our findings indicate that the virtual care pathway performs better than the traditional care pathway in terms of capacity and financial performance. The improvement in capacity and financial performance is reasoned by the reduction in the average LoS of patients at the hospital, saving nursing days, and the cost savings brought by the transition to the virtual care pathway. Moreover, the findings of (Peters et al., 2022) indicate that the transition to virtual care pathways reduces the average LoS of patients at the hospital by 3 days, which is similar to our finding of the 1.9 days reduction in the average LoS at the hospital of patients. Furthermore, the research by (Mantena & Keshavjee, 2021) shows that the transition to the virtual care pathway and implementation of RPMS for the treatment of Covid-19 patients has resulted in significant reduction in costs. Our findings align with those of (Mantena & Keshavjee, 2021), as we conclude that the transition to the virtual care pathway for the treatment of Covid-19 patients, has saved € 612,364.81 in costs of nursing days saved. Additionally, the average total treatment costs per patient is 23% cheaper for the virtual care pathway compared to the traditional care pathway. Finally, we compare between the demographics of datasets used in the literature for assessing the impacts of transitioning to virtual care pathways with our datasets. The article by (Khairat et al., 2021) uses two datasets, the first datasets for the virtual care pathway includes 1262 patients, of which 16.5% are males, and 83.5% are females. The dataset for the traditional care pathway includes 14734 patients, consisting of 30% males, and 70% females. On the other hand, the dataset we use for the virtual care pathway includes 97 patients, including 64% males, and 36% females. Additionally, the dataset we use for the traditional care pathway consists of 111 patients, of which 58% are males, and 42% are females.

The research design adopted successfully achieved its objective of assessing the capacity and financial performance of the transition to the virtual care pathway for the treatment of Covid-19 patients. However, the research design can be improved using several factors. Firstly, the cost analysis could be improved, by including the un-included costs such as the costs of implementing the sensors, improving the cost analysis. Additionally, the data collection method needs to be improved, to improve the quality and quantity of data. If the datasets extracted are larger, this will lead to a better assessment, improving the overall validity of results, and reducing the reliance on assumptions.

The Covid-19 pandemic left hospitals dealing with a capacity strain due to the increasing demands for healthcare services, while also struggling to maintain financial sustainability in a rapidly changing environment (Humphreys & Spratt, 2022). Therefore, telehealth solutions and virtual care systems emerged as potential solutions to reducing the capacity strain faced by hospitals, while also providing high quality care (Boldt-Christmas et al., 2023). Our research investigates the impacts of transitioning to virtual care pathways on the capacity and financial performance of hospitals, while taking the treatment of Covid-19 patients using the home monitoring programme at Isala Hospital as a case study. Findings highlight important insights which can help hospitals in making informed decisions if they transitioned or want to transition to the virtual care pathway. Furthermore, we identify potential benefits and challenges of transitioning to the virtual care pathway, while taking a real-life case study at Isala Hospital.

Moreover, our findings regarding the impacts of transitioning to virtual care pathways on the capacity and financial performance of hospitals could be extended through future research. Extending our research would further contribute to the developments in the healthcare industry. Firstly, more KPIs could be used to assess different aspects of the impacts of transitioning to virtual care pathways. For instance, KPIs such as patient satisfaction, and patient case mix could be examined to look into the effects of the transition on the patient experience of the healthcare process. Moreover, conducting this research over an extended time period would improve the outcomes. Through examining the effects of the transition to the virtual care pathway over extended periods of time, which would result into better conclusions. Lastly, carrying out the research on different patient groups would be beneficial, as to look into the effects of the virtual care pathway after it was fully implemented by Isala Hospital, leading to better outcomes and increased generalizability.

Appendix

Appendix 1.1

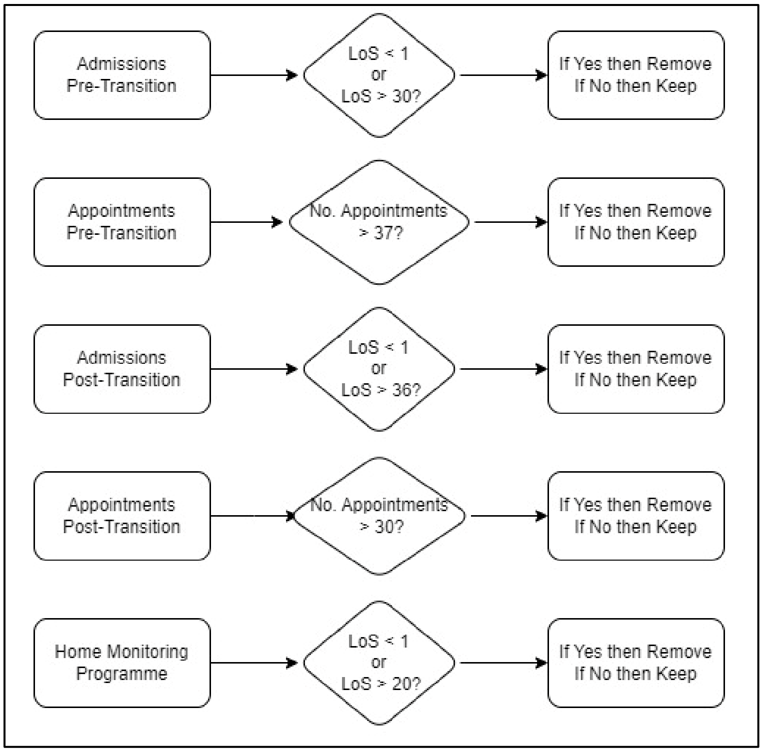

Figure 17 - Flow Diagram of the Data Cleaning Process

Appendix 1.2

TDA Pre	TDA Post	*TDA Pre (Ranks)*	*TDA Post (Ranks)*			
22.35	105.00	65	119	Sum of Ranks TDA Pre	4851	"=SUM(E3:E100)"
10.57	285.00	13	197	Sum of Ranks TDA Post	15049	"=SUM(F3:F103)"
15.44	165.00	34	148			
26.78	165.00	77	148	"TDA Pre" N	98	"=COUNT(B3:B100)"
24.99	90.00	72	110.5	"TDA Post" N	101	"=COUNT(C3:C103)"
14.87	135.00	32	133			
7.93	75.00	7	103	U-test statistic "TDA Pre"	9898	"=I6*I7+I6*(I6+1)/2-I3"
14.27	195.00	28	167.5	U-test statistic "TDA Post"	0	"=I6*I7+I7*(I7+1)/2-I4"
15.87	195.00	36	167.5			
26.93	165.00	78	148	Min U-test statistic	0	"=MIN(I9:I10)"
14.84	90.00	31	110.5			
29.87	180.00	84	160	Z-score	-12.1848266	"=(I12-I6*I7/2)/SQRT(I6*I7*(I6+I7+1)/12)"
5.86	253.95	4	189	P-value	0.00	"=NORM.DIST(I14,0,1,TRUE)*2"
16.06	102.44	38	114			
8.95	166.48	9	150	Significance Level	0.05	
22.63	104.78	67	118			

Figure 18 - Mann-Whitney U-Test used as a Test of Significance

Appendix 1.3.1

Date	Database	Search Terms	Results	Article Name	Author(s)
25-May-23	Scopus	TITLE (Hospital AND Capacity AND Planning)	127	Capacity Planning in Health Care: A Review of the International Experience	Stefanie Ettelt, Ellen Nolte, Nicholas Barron Mays, & Sarah Thomson
		(TITLE (Hospital AND Capacity AND Management) OR TITLE-ABS-KEY(Capacity AND Management))	32	Efficacy, Effectiveness and Efficiency in the Health Care: The Need for an Agreement to Clarify its Meaning	Burches Enrique & Marta Burches
				A review and synthesis of demand management, capacity management, and performance in healthcare services	Eric P. Jack & Thomas L. Powers
		TITLE (Hospital OR Healthcare AND Operations AND Management OR Planning)	115	Operations Research and Health Care: A Handbook of Methods and Applications	Margaret L. Bradeau, Francois Sainfort, & William P.
				What is Value in Healthcare?	Michael E. Porter
		(TITLE (Remote AND Patient AND Monitoring) OR TITLE-ABS-KEY(Remote AND Patient AND Monitoring))	54	Strengthening Healthcare Delivery with Remote Patient Monitoring in the Time of Covid-19	Sreekar Mantena & Salmaan Keshavjee
				Effectiveness of a Mobile Health and Self-Management App for High-Risk Patients With Chronic Obstructive Pulmonary Disease in Daily Clinical Practice: Mixed Methods Evaluation Study	Wim van Harten & Laura Kooij
		TITLE (Virtual OR Dynamic OR Digitalized AND Care AND Pathways)	45	Data-Driven Integrated Care Pathways: Standardization of Delivering Patient-Centred Care	Shasha Han & Libing Ma
				Budget impact analysis of providing hospital inpatient care at home virtually, starting with two specific surgical patient groups	Guido M. Peters, Carine J.M. Doggen, & Wim H. van Harten
				A co-design of clinical virtual care pathways to engage and support families requiring neonatal intensive care in response to the COVID-19 pandemic	Marsha Campbell-Yeo, Justine Dol, Brainna Ricardson, & Holly McCulloch
27-May-23	Essay.Utwente	Searching for similar thesis titles		Capacity Management in Healthcare	Ivan Remijn

Figure 19 - Systematic Literature Review Table for articles found (Part 1)

Appendix 1.3.2

4-Jun-23	Other	These articles were found through different articles read		An Overview of Hospital Capacity Planning and Optimisation	Peter Humphreys & Belinda Spratt
				Integral Capacity Management and Planning in Hospitals	Thomas Schneider
				The care pathway: concepts and theories	Guus Schrijvers, Arjan van Hoorn, & Nicolette Huiskes
				Performance Measurement Criteria in Health Care Organizations: Review and Future Research Directions	L.X. Li & W.C. Benton
				Managing Care Pathways for Patients with Complex Care Needs	Magdalena Smeds
				Virtual Care Pathways: Maximizing the Benefit of Telehealth	Nancy Kamp & Margaret Kirkegaard
				Telehealth A Path to Virtual Integrated Care	Jared Augenstein & Grant Chamberlain
				An Introduction to Digital Care Pathways	The Clinician
				How Virtual and In-person Care Merge for a Healthier and More Sustainable Future	Rachel Hall, Kenny O'Neill, & Aloha McBride
				Virtual Hospital Could Offer Respite to Overwhelmed Health Systems	Oscar Boldt-Christmas, Rebecca Kannourakis, Madeline Maud, & Drew Ungerman
				Evaluation of Patient Experience During Virtual and In-Person Urgent Care Visits: Time and Cost Analysis	Saif Khairat, Xi Lin, & Songzi Liu

Figure 20 - Systematic Literature Review Table for articles found (Part 2)

Appendix 1.4

Table 14 - Appointment Types with Costs and Description

Appointment Type	Costs	Description
TC	€ 96.52	The appointment consists of a telephonic consultation between the patient and a healthcare professional from Isala Hospital.
CPOPNCOR	€ 149.49	An outpatient clinic visit with one of the specialized nurses at Isala Hospital.
NPCOR	€ 272.97	The appointment is an outpatient clinic visit with a specialized nurse, but for new Isala Hospital patients, therefore, it is more expensive due to the administrative costs.
NPTC	€ 96.52	This appointment type stands for the telephonic consultations of new Isala Hospital patients.

Appendix 1.6.1

```
Option Explicit
Dim i As Long

Sub AppointmentType()
    Dim i As Long
    Dim ws As Worksheet
    Set ws = Worksheets("S3 Pre (SS 100) App")

    For i = 1 To 100
        If ws.Cells(i, 3) <= 0.58 Then
            ws.Cells(i, 4) = "TC"
        ElseIf ws.Cells(i, 3) <= 0.76 Then
            ws.Cells(i, 4) = "CPOPNCOR"
        ElseIf ws.Cells(i, 3) <= 0.78 Then
            ws.Cells(i, 4) = "NPTC"
        Else
            ws.Cells(i, 4) = "NPCOR"
        End If
    Next i
End Sub
```

Figure 21 - VBA Code for Simulating Appointment (Part 1)

Appendix 1.6.2

```
    Dim i As Long
    For i = 1 To 100
        Dim randomValue As Double
        randomValue = Rnd()

        Select Case ws.Cells(i, 4).Value
            Case "TC"
                If randomValue <= 0.94 Then
                    ws.Cells(i, 5).Value = 10
                ElseIf randomValue <= 0.97 Then
                    ws.Cells(i, 5).Value = 15
                Else
                    ws.Cells(i, 5).Value = 20
                End If
            Case "CPOPNCOR"
                If randomValue <= 0 Then
                    ws.Cells(i, 5).Value = 10
                ElseIf randomValue <= 0.2 Then
                    ws.Cells(i, 5).Value = 15
                Else
                    ws.Cells(i, 5).Value = 20
                End If
            Case "NPCOR"
                If randomValue <= 0 Then
                    ws.Cells(i, 5).Value = 10
                Else
                    ws.Cells(i, 5).Value = 15
                End If
            Case "NPTC"
                If randomValue <= 0 Then
                    ws.Cells(i, 5).Value = 10
                ElseIf randomValue <= 0 Then
                    ws.Cells(i, 5).Value = 15
                Else
                    ws.Cells(i, 5).Value = 20
                End If
```

Figure 22 - VBA Code for Simulating Appointment (Part 2)

Appendix 1.6.3

```
Sub AppointmentCosts()

    Dim ws As Worksheet
    Set ws = Worksheets("S3 Pre (SS 100) App")

    Dim i As Long
    For i = 1 To 100
        If ws.Cells(i, 4) = "TC" Then
            ws.Cells(i, 6) = 68.94
        ElseIf ws.Cells(i, 4) = "CPOPNCOR" Then
            ws.Cells(i, 6) = 106.78
        ElseIf ws.Cells(i, 4) = "NPTC" Then
            ws.Cells(i, 6) = 68.94
        Else
            ws.Cells(i, 6) = 194.98
        End If
    Next i

End Sub
```

Figure 23 - VBA Code for Simulating Appointment (Part 3)

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