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Improving Parenteral Medication Administration at Home pathways

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Management summary

This thesis focuses on improving the efficiency of Parenteral Medication Administration at Home (PMAaH) pathways within the mProve hospitals. This research is part of the Medication@home project, which has three participating hospitals in this pilot study: Isala, Rijnstate, and Máxima Medisch Centrum.

Research objective

The primary goal of this study is to improve the efficiency of the PMAaH pathways by analysing the current processes, identifying significant differences, and suggesting recommendations based on the drawn conclusions. This is crucial as hospitals face capacity challenges due to staff shortages, coupled with a growing demand for care, as the population is aging. PMAaH is a value-based care initiative that focuses on making care more accessible to patients, which improves the quality of healthcare. However, the current PMAaH pathways vary significantly across hospitals, which implies inefficiencies in the process. This research analyses the antibiotics and biologicals PMAaH pathways and provides recommendations for improvements to enhance quality of care and reduce time spent executing PMAaH pathways.

Research questions

This study is divided in sub-research questions to guide towards the research objective:

1. What are the current processes for administering parenteral medication at home in Isala, Rijnstate and Máxima MC?
2. What are the differences between the antibiotics PMAaH pathways and between the biologicals PMAaH pathways in the three hospitals?
3. What are improvements and recommendations for the six PMAaH pathways, based on the differences in process steps and the differences in throughput time of the processes?

Methodology

This research utilized a mixed-methods approach, which involved two perspectives. The qualitative component involved process mapping of PMAaH pathways at each hospital, visualized through swimlane diagrams. These diagrams provided a structured overview of the steps involved in medication administration, categorized into five stages: (1) order processing, (2) medication preparation, (3) delivery-handover, (4) medication transport, and (5) administration.

The quantitative component involved data collection on the throughput times of the process steps using a digital registration tool called the ‘PowerApp’. Data was gathered from healthcare workers measuring their activities in the PMAaH pathways across the three hospitals, focusing on the time taken to complete each process step and the quality of these measurements. The analysis compared throughput times across hospitals to identify significant differences in efficiency.

Results

There are significant differences in the PMAaH pathways across the three hospitals. For instance, Isala and Rijnstate have 8 professions involved in executing the antibiotics PMAaH pathway, compared to Máxima MC having 5 involved professions. This is a consequence of Máxima MC outsourcing their ‘Medication preparation’ to an external company, while Isala and Rijnstate do this in-house.

A notable difference for the biologicals pathways are the number of involved professions, which are ten, five and eight for respectively Rijnstate, Isala and Máxima MC. In Rijnstate most activities are fulfilled by the pharmacist or pharmacist assistants, while in Isala the home care nurse is more involved in these steps of the process. Máxima MC utilises a combination of these approaches.

This research also found notable disparities in the throughput time of process steps across hospitals, especially in the process step ‘Delivery – handover’ for both the antibiotics and the biologicals pathway. The study found a total of three significant differences in the throughput times of a process step across hospitals, which is due to a limited dataset.

Conclusion & recommendations

The conclusion combines the insights obtained from the swimlane diagram analysis and the data analysis. The results suggest a potential positive correlation between the number of professions involved in a process step and an increase in through put time. The objective of the process step is the same in the three hospitals, but the amount of professions involved in achieving this objective is different. Although the data of the hospitals on the throughput time is limited, the analysis does highlight this correlation in both antibiotics and biologicals PMAaH pathways. Therefore, this study advises the hospitals to further research this correlation, as reducing the amount of professions involved in a process step may improve the efficiency of the pathways.

Discussion

There are some complexities and limitations of using the digital registration tool called the ‘PowerApp’ in this pilot study. The varying success of the implementation of this measurement tool led to small datasets from some hospitals, which impacts the internal validity and reliability of the study. The occasional malfunctioning of the app led to manual data entries, which reduced the reliability of the measurements. There were also differences in the number of activities measured per process steps for hospitals, especially in the process step ‘Order processing’, which challenges the internal validity of this research. The small dataset reduced the amount of statistically significant findings, which influences the power of the drawn conclusions. Therefore, a continuation of researching this subject should focus on process mapping to improve the PMAaH pathways, instead of utilizing the ‘PowerApp’. Process mapping in combination with intensive stakeholder engagement could enhance identifying improvements across the mProve hospitals, while reducing the effort needed from healthcare professionals.

Preface

Dear reader,

Before you lies my bachelor thesis, which I have written to conclude my Bachelor of Industrial Engineering & Management at the University of Twente. Over the past months, I have dedicated myself to researching improvements in parenteral medication administration at home pathways. This project has both been challenging and rewarding, providing me with the opportunity to contribute to advancements in healthcare and experience meaningful moments. Although, there were also difficulties researching such a complex topic on my own. Luckily, I overcame these challenges, for which I want to thank everyone that supported me in this process of writing my bachelor thesis.

My graduation assignment was conducted as part of the Medication@home project within the mProve hospitals. My gratitude goes to all the people within the mProve group for granting me the opportunity to work on this project and providing me with the necessary resources and guidance. Especially, Michelle for organising meetings with stakeholders in the pathways and supporting me where necessary. Also Robert for supporting me in the data preparation and analysis. Engaging with a field unfamiliar to me has been a significant learning experience, and I hope my findings will contribute to the hospital's ongoing efforts to enhance patient care.

I would like to give a special thanks to my supervisors. Sebastian, for providing detailed feedback and brainstorming with me about complexities in the writing process of my thesis. Your valuable insights helped me overcome hurdles and greatly contributed to the quality of this work. Jedidja, who not only served as my supervisor on this thesis but also guided me through the process of conducting research at Isala. You were always available for a brainstorming session about difficulties in my research process and your insight made a significant contribution to the outcome of my graduation assignment.

Lastly, I want to thank my friends and family, not only for their support during this bachelor thesis, but throughout my whole study. Your support and encouragement helped me complete my bachelor degree, of which this thesis is the final product.

Mathijs Kremer

Enschede, September 2024

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List of Abbreviations

Abbreviation	Definition
BMS	Behavioural, Management and Social Sciences
CP	Clinical Pharmacy
KPI	Key Performance Indicator
Máxima MC	Máxima Medical Centrum (Máxima Medisch Centrum)
MCB	Medical Coordination Bureau (Medisch Coördinatie Bureau)
PA	Physician Assistant
PMAaH	Parenteral Medication Administration at Home
ZoCo	Care coordinator (Zorgcoördinator)

1 Introduction

This research is part of the Medication@home project of the mProve hospitals. It aims at improving the parenteral medication administration at home (PMAaH) pathways by focusing on the logistics of the process. The mProve hospitals set up a combined research, where the activities of the PMAaH pathways are measured in a digital registration tool. The aim of the research is to identify differences in the PMAaH pathways between the three participating hospitals and provide recommendations for improving the efficiency, as well as evaluating the measurability of the key performance indicators in this process, which are the throughput time and quality registration of activities. The analysis of the data of the digital registration tool and visualised flowcharts of the pathways provide the basis for the conclusions in this research.

Section 1.1 introduces mProve, Isala, Rijnstate and Máxima MC. Subsequently, Section 1.2 presents the research motivation. Followed by the discussion of the research design in Section 1.3. Lastly, Section 1.4 establishes the research scope of this study.

1.1 mProve hospitals

The mProve hospitals are a group of seven hospitals in the Netherlands that collaborate with each other on several aspects. These hospitals are the Albert Schweitzer hospital, Isala, Jeroen Bosch hospital, Noordwest Ziekenhuisgroep, Máxima MC, Rijnstate and Zuyderland Medisch Centrum (mProve, 2020b). They are committed to provide care that is of good quality, accessible and affordable. The collaboration between the hospitals involves sharing knowledge and experiences, to learn from each other and come up with the best approach for giving appropriate care. The data of healthcare improvement processes is also shared and compared to find solutions for optimizing healthcare processes and finding the best treatment and trends in healthcare.

This research concerns a pilot study, in which only three out of the seven hospitals participate. The other four hospitals do participate in the broader study, if the evaluation of the pilot study indicates continuation of the research. The three hospitals participating in this research are described below.

1.1.1 Isala

Isala is an organization of hospitals with five locations. The main location is in Zwolle. It is one of the nation's largest hospitals, serving a wide range of medical specialties and delivering top-tier medical services to patients in the region. The hospital focusses on quality of care and personal involvement to give patients the care that they deserve. They do this under the motto “close if possible, further away if necessary”. Isala has 6,803 employees and 1,206 beds available for patients (Stichting Holding Isala klinieken, 2023). Isala processed 486,018 outpatient clinic visits and 39,148 hospital admissions in 2022 (Stichting Holding Isala klinieken, 2023).

1.1.2 Rijnstate

Another hospital participating in this research is Rijnstate. They provide care for patients from four locations. The main location is in Arnhem, with other locations in Zevenaar and Elst. Rijnstate wants to be an innovator in healthcare and that is why they are constantly working on improving themselves. Rijnstate has 6,584 employees and they have 724 beds available for patients (Rijnstate, 2023). In 2022 they provided care to 304,824 patients (Rijnstate, 2023).

1.1.3 Máxima MC

Máxima Medisch Centrum (Máxima MC) is another top clinical hospital that is participating in this research. They have two locations, one in Eindhoven and one in Veldhoven. The professionals of Máxima MC strive to make patients healthier every day with the patient and their family as main focus. They also focus on research, education and innovation to bring their healthcare to a higher level. Máxima MC has 3,146 employees and provided care to 312,910 patients in 2022 (Máxima Medisch Centrum, 2023).

1.2 Research motivation

One of the biggest challenges in healthcare is the lack of capacity in hospitals. This is not physical capacity, like beds or rooms, but mostly the capacity of the staff. This is caused by a shortage of healthcare workers, while the demand for care increases, because of the aging population in the Netherlands. This is a problem that is expected to increase in the upcoming years, also on a more global scale (Centraal Bureau voor de Statistiek, 2023; KPMG Advisory N.V., 2020). Hospitals in the Netherlands made an agreement in 2018 with the 'Ministry of Health, wellbeing and sports', which is called the 'Outline agreement' (Federatie Medisch Specialisten, 2018).The aim of the agreement is to improve the quality and efficiency in specialist medical care and to guarantee the accessibility and affordability of care in the long term. One of the solutions of this agreement is to create a more hybrid healthcare system (physical and virtual), where the patient is more in control, and where the care is virtual and at home if possible, and physical if needed.

mProve aspires to contribute to a solution for the lack of capacity by focusing on technological innovations that make the work in hospitals easier and less time consuming (mProve, 2020a). The collaboration between these hospitals ensures that the hospitals can work together on these innovations, which makes sure that they spent their time efficiently by not repeating the research of each other.

One of the solutions are value-based care initiatives (Teisberg et al., 2020), that move healthcare provision from a clinical setting to the home situation of patients. These value-based care initiatives put a greater focus on integrated care, where healthcare providers work together to provide the care a patient needs. Parenteral medication administration at home (PMAaH) is a value-based care initiative, that focusses on making care more accessible for patients, which aims to improve the quality of care and the experience of the patient. Various Dutch hospitals have set up these PMAaH pathways individually and in a small time span. This led to many different implementations of these pathways, even within hospitals.

The existence of various PMAaH pathways, leads to the assumption that certain PMAaH pathways are more efficient than others, regardless of the specific situation and infrastructure of the hospital. This means that there is room for improvement in most PMAaH pathways. Previous studies within Isala and Rijnstate on medications administered at the patient's homes concluded that there are still several opportunities to improve the effectiveness and efficiency of these pathways, due to bottlenecks in the processes (De Kunder, 2021). Therefore, we can conclude that the pathways are inefficient with room left for improvements.

The Quadruple aim methodology is chosen by an expert group of mProve to demonstrably achieve a more effective and efficient PMAaH process. The Quadruple aim focusses on improving the experience of the care of the patient, improving the general health of the population, reducing the healthcare cost per capita and improving the experience of the healthcare workers (Bodenheimer & Sinsky, 2014).

The first steps in improving the efficiency of the PMAaH pathways in the mProve hospitals is researching the current situation in the hospitals and measure the efficiency of the current situation. This research focusses on improving the logistics of PMAaH pathways by determining the measurability of key performance indicators in this process, which are the throughput time and quality registration of activities, as well as identifying differences in the PMAaH pathways in between the hospitals. The measuring of the throughput time of the processes aims to get a deeper understanding of the current practices in the three mProve hospitals and to assess the feasibility of this measurement method for a continuation of this research method on a larger scale. This goal is in line with the Quadruple aim methodology, as improving the efficiency leads to reducing the healthcare costs per capita in the first place, but also improves the healthcare for all stakeholders in the long term.

1.3 Research design

The main aim of this study is to identify major differences between the PMAaH pathways of the three hospitals and give a recommendation for improvements related to the efficiency of these pathways. This study also contains an evaluation on the feasibility and usefulness of measuring the throughput time of the pathways by means of a digital registration tool, which is included in the discussion.

The goals of this research are subdivided into sub-research questions, which are defined to guide and reach the research objective.

1. What are the current processes for administering parenteral medication at home in Isala, Rijnstate and Máxima MC?

Identifying differences between processes indicates that processes have to be compared to each other. Comparing processes only works when the format in which the process is displayed is similar to the format of the other process. Therefore, the PMAaH pathways are visualized and analysed based on a standard model; the swimlane diagram, which is a business process modelling method (BPM) that models the steps of a process (Jeyaraj & Sauter, 2014).This method enables us to answer three research questions that give a clear overview of the pathways:

- What are the activities that are executed in every PMAaH pathway?
- Which positions in the hospital execute activities of the PMAaH pathways?
- What is the sequence in which these activities are executed?

This approach provides a basis for the second research question and for the quantitative part of the study. This research looks into two groups of medicine that are administered at home, antibiotics and biologicals. Section 1.5 further elaborates on the specifics of these two medicine groups. These groups that are measured in three hospitals make a total of six different PMAaH pathways and thus six swimlane diagrams.

2. What are the differences between the antibiotics PMAaH pathways and between the biologicals PMAaH pathways in the three hospitals?

This research question uses a mixed-methods approach taking into account two perspectives. One perspective is comparing the swimlane diagrams of the antibiotics pathways to each other and the swimlane diagrams of the biologicals to each other based on the involved professions, sequence of activities and amount of activities. Chapter 2 describes this perspective of the comparison with the swimlane diagrams.

The other perspective is a more quantitative view on the PMAaH pathways. The three participating hospitals (Isala, Rijnstate and Máxima MC) have gathered data on throughput times and the quality of these registrations of various activities and processes within the PMAaH pathways by using a data registration tool. This is a mobile application that is designed specifically for this research. It is called ‘PowerApp’. Healthcare workers registered the throughput times and a quality registration for the activities they executed. The quality registration gives insight into the progress of the measured activity, as healthcare professionals can indicate by using a three point scale of smileys how the activity went compared to the same activity normally.

This perspective includes performing a data analysis on the obtained data from the hospitals. The data analysis includes descriptive statistics, like averages and standard deviations. It also includes patient flow analysis visualizations, like a boxplot. The pathways are compared based on the average throughput times that result from the data analysis, which are expected to give insights into the differences in time spent for a patient by healthcare workers in a PMAaH pathway.

3. What are improvements and recommendations for the six PMAaH pathways, based on the differences in process steps and the differences in throughput time of the processes?

The conclusions of the two perspectives on the identified differences are combined to identify areas for improvement. The activities and processes that have the same objectives are compared for the six pathways, based on the data analysis and the flowcharts. Comparing the sequence and amount of

activities, next to the involved professions in a process step, with the throughput time of the process step between the hospitals gives insight into which approach of which hospital is likely to be more efficient. This can lead to valuable recommendations for certain parts of a pathway in a hospital.

1.4 Research scope

As mentioned in section 1.4, there are three hospitals, and two medicine groups, The antibiotics and the biologicals, in the scope of this research. Antibiotics are medicines that fight infections, which are caused by bacteria (Muteeb et al., 2023) The antibiotics kill the bacteria or stop them in their growth and multiplication. Biologicals are medication that are made with the use of a living organism (Mukhtar et al., 2021). These biologicals can be a variety of medications, like antibodies, interleukins blood components or vaccines (Mukhtar et al., 2021). The biologicals are used to treat conditions such as diabetes, heart attacks, autoimmune disorders and cancer (Mukhtar et al., 2021). The biologicals that are part of this study are used to treat cancer.

These two groups of medicine each have a couple of specific medicine that are included in the study. This are vancomycin, flucloxacillin, benzylpenicillin, ceftriaxone, ceftazidime, and cefazoline for the antibiotics. The biologicals group consists of nivolumab, pembrolizumab, trastuzumab and durvalumab. The logistic processes of the medicine within a group are almost completely similar, which justifies the choice for these medicine.

This is a pilot study, in which researchers of the mProve hospitals have chosen to start with these groups of medicine in three hospitals. The administration of the antibiotics and biologicals are already often transferred to the home situation of the patient (Jawa et al., 2021) (Mukhtar et al., 2021). Therefore it seemed valuable to the researchers to start with obtaining data about the logistic structures of the PMAaH pathways of these medicine groups.

Some hospitals in this research outsource part of the PMAaH pathway to external companies, like home healthcare companies. In this case, the process steps that are outsourced are not included in this research, because there is no available data for these activities. Gathering data for these steps would have been complicated, because there are other parties involved that are not part of mProve. Also implementing improvements would have been difficult. Therefore, this lies outside the scope of this research.

2 Current situation

In this chapter, the current situation of the PMAaH pathways for antibiotics and biologicals is analysed in Isala, Rijnstate and Máxima MC. This analysis is visualized in flowcharts which are the basis for identifying the major differences between the pathways in Chapter 4. The flowcharts of the six pathways are standardized to allow for comparison across each other. In the following subsection, the focus is on the following research questions:

- What are the activities that are executed in every PMAaH pathway?
- Which positions in the hospital execute activities of the PMAaH pathways?
- What is the sequence in which these activities are executed?

Section 2.1 explains the methods used for the analysis of the current process. Subsequently, Section 2.2 gives an overview of the current situation for the antibiotics PMAaH pathways in the three hospitals. Section 2.3 describes the current situation for the biologicals PMAaH pathways. Lastly, Section 2.4 answers the research questions and gives a short summary of the current situation of the six PMAaH pathways.

2.1 Method for process analysis

This research focuses on the PMAaH pathways of the administration of six antibiotics and four biologicals. The exact medicines that are part of this research are mentioned in Section 1.5. The process steps of the various antibiotics are similar, which is the reason for combining the pathways of these medicines into one general antibiotics PMAaH pathway. This reasoning also applies to the biologicals. The antibiotics and biologicals pathways are not similar, which accounts for the distinction between the type of medicines. This approach results in two PMAaH pathways per hospital, which makes it six pathways in total in the three hospitals.

The main aim of this research is to standardize and improve the various PMAaH pathways in the hospitals. One part of this research process is to compare the PMAaH pathways between the hospitals to gain insights into areas that can be improved. Therefore, it is essential to visualize and subsequently analyse the current situation using a standardized method and format. All the activities that are executed in a PMAaH pathway are divided in five steps. These steps are (1) ‘Order processing’, (2) ‘Medication preparation’, (3) ‘Delivery – handover’, (4) ‘Medication transport’ and (5) ‘Administration’. This categorization of the activities in the PMAaH pathways help to structure the various pathways and provides an overview. This structure is also valuable for the data analysis of the pathways, since the obtained data is categorized in the same way.

The data analysis focusses on comparing the data of the antibiotics pathways with each other and the data of the biologicals pathways with each other in the three hospitals. The antibiotics and biologicals pathways are significantly different from each other in objective and activities, which makes a comparison between them ineffective. Therefore, the analysis of the current situation in this chapter is based on one antibiotics pathway and one biologicals pathway of one of the three hospitals, that are compared to the other two pathways administering the same kind of medication. The antibiotics PMAaH pathway of Isala is compared to the antibiotics PMAaH pathways of Rijnstate and Máxima MC, and the biologicals PMAaH pathway of Rijnstate is compared to the biologicals PMAaH pathways of Isala and Máxima MC. The reason for choosing pathways of two different hospitals for the basis of the comparison is to avoid bias towards one of the hospitals. Máxima MC has no data on the second process step, because they outsource the preparation of their medication. As a consequence, a comparison in this process step between the hospitals is only possible for Isala and Rijnstate. For this reason, no pathway of Máxima MC is chosen as the basis for the comparison. The role of Maxima MC in the data analysis of the PMAaH pathways is further discussed in Chapter 3.

The visualization and analysis of the pathways is based on Business Process Modelling Notation (BPMN), which is part of Business Process Modelling (BPM) (Bakar et al., 2020). The swimlane diagram is an example of a flowchart in BPMN. Flowcharts enable you to display a process, by showing the sequence in which the activities or process steps take place. The swimlane diagram additionally enables you to categorize activities of the process in lanes. These lanes categorize the activities based on the position that performs them. Therefore, the swimlane diagram visualizes the sequence of the activities as well as the position that performs the activity in one diagram. This is an

advantage over other types of flowcharts. This also results in enabling the stakeholders to correctly and quickly verify and understand the business process, which means that the swimlane diagram is more efficient compared to non-swimlane diagrams (Jeyaraj & Sauter, 2014). This substantiates the choice of utilizing swimlane diagrams for the analysis of the current situation in the hospitals.

2.2 PMAaH antibiotics

Subsection 2.2.1 explains and visualizes the PMAaH pathway for antibiotics in Isala. This is followed by Subsection 2.2.2, which describes the PMAaH pathway for antibiotics in Rijnstate and the differences with Isala. And lastly, Subsection 2.2.3, which describes the PMAaH pathway for antibiotics in Máxima MC and differences with the other antibiotics pathways.

2.2.1 Isala

Figure 1 shows the swimlane diagram of the antibiotics PMAaH pathway in Isala. The antibiotic Vancomycin is the most common antibiotic in Isala that is administered, according to the data of the pilot study. Therefore, the flowchart is based on the PMAaH pathway of this specific medicine. The PMAaH pathways of the other antibiotics are similar, which means that the few small differences do not have a big impact on the analysis of the current situation of the antibiotics PMAaH pathways. The only notable difference between Vancomycin and the other antibiotics is the determination of the blood levels. This activity is only performed for the antibiotic vancomycin.

The antibiotics pathway of Isala has eight stakeholders that execute activities in this care path. These are the medical coordination bureau (MCB) nurses, the outpatient pharmacist, pharmacy assistant preparations, clinical pharmacy assistant circulation, Aseptic circulation outside pharmacy assistant, clinical pharmacy (CP) pharmacist, clinical pharmacy (CP) pharmacist assistant, external transportation company and a specialist team of nurses from an external company. In the remainder of this section the involvement of these stakeholders in the process is explained.

The antibiotics PMAaH pathway is carried out for patients that were recently admitted to Isala and are being treated with an antibiotic infusion, if the treating physician has decided in consultation with the patient that the treatment can continue at home. The process starts with the step ‘Order processing’, of which registering the patient in HIX for the antibiotics PMAaH pathway is the first activity. Then the recipe is checked in HIX, after which an appointment is scheduled for determining the blood levels. This step is only relevant for the antibiotic vancomycin. Therefore, this activity is skipped for the other antibiotics. Then the specialistic home healthcare is arranged and the medicines are ordered for the patient. The order is sent to the outpatient pharmacy of Isala in Zwolle, if the patient is staying in Isala Zwolle, and it is sent to APPO (external pharmacy), if the patient stays in the smaller hospital in Meppel. After these arrangements the relevant stakeholders are notified and relevant notes are documented. The next activities take place when the patient is scheduled to be discharged. The dischargement of the patient is checked, and the changes in the treatment plan of the patient have to be implemented and documented. These activities are all carried out by the MCB-nurses.

The next activities of the step ‘Order processing’ are executed by the outpatient pharmacist. The blood level check is only carried out if the patient receives vancomycin. Then the outpatient pharmacist creates the planning form of the antibiotic for the patient, and sent this with the medication recipe to the clinical pharmacy. Finally, the pharmacist prepares the envelope with the instructions for the patient and processes possible chances in the treatment plan.

The next step in the process is ‘Medication preparation’. The planning form and medication recipe are received by the clinical pharmacy assistant at the clinical pharmacy, who prints it out and puts it in a folder. In this process the clinical pharmacy is responsible for providing ready to use medication to the patient at home. The pharmacy assistant circulation receives this folder and prepares the necessary stuff with the pharmacy assistant preparer, after which they prepare the medication and place it in quarantine. Then the pharmacy assistant preparer checks the paraph, after which the CP pharmacist releases and delivers the medication to the pharmaceutic patient care. There, the CP pharmacy assistant arranges the transport of the medication to the outpatient pharmacy.

The third step is the ‘delivery – handover’, which is carries out by the outpatient pharmacist. The pharmacist sticks the patient label on the bag with medicines and double checks the medication. Then the pharmacist checks if there are other discharge instructions for the patient and put these together, if

this is the case. The next activities are packing the medication with instructions for home care and there follows a conversation with the patient, partner or nurse. The last step in the process is arranging the medication for the patient in the coming weeks.

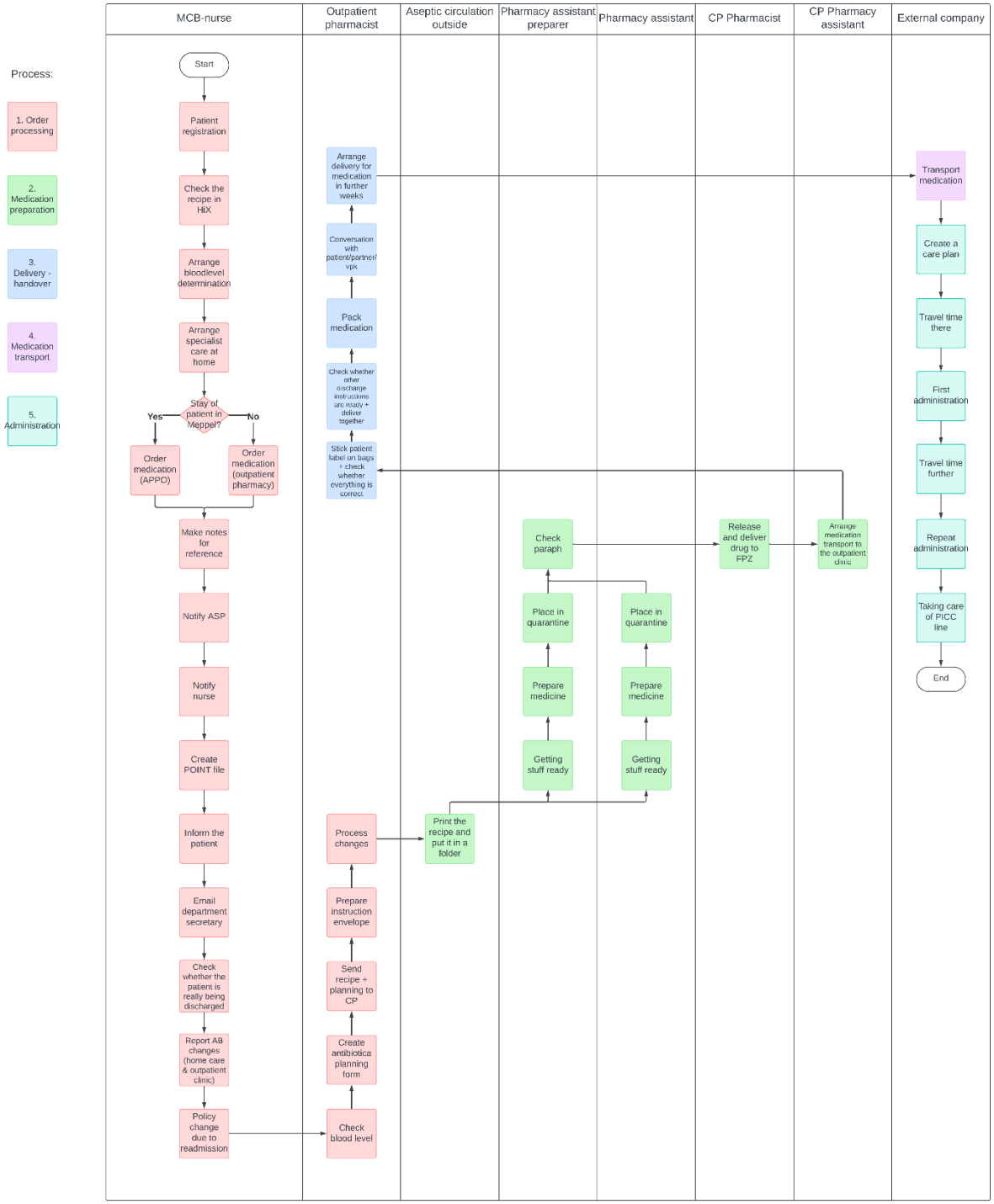

Figure 1: Swimlane diagram antibiotics Isala

The last two steps of the process are described for the completeness of the care path, but are of secondary importance. These process steps are performed by an external company in all three hospitals. Therefore, there is no data of these two process steps, which makes it is less relevant to analyse and compare the process steps between the hospitals. The fourth step is the 'Medication transportation', which is done by an external transportation company. They are responsible for transporting the medication from the outpatient pharmacy to the patient's home. The fifth and last step is the 'administration'. The antibiotics are administered at the patient's home by a specialist nurse of

an external home care company. Activities that these nurses perform are making a planning, driving to the patient's home, administering the antibiotics and taking care of the peripherally inserted central catheter (PICC) line.

The process described above is the ideal process of the antibiotic vancomycin for the first administration at home of the medication. However, when the patient needs the medication for several weeks, this process is partially repeated, as the patient only receives a certain amount of medication at a time. In the case of a recurrent order, several activities in the first step 'order processing' are skipped, like the patient registration.

2.2.2 Rijnstate

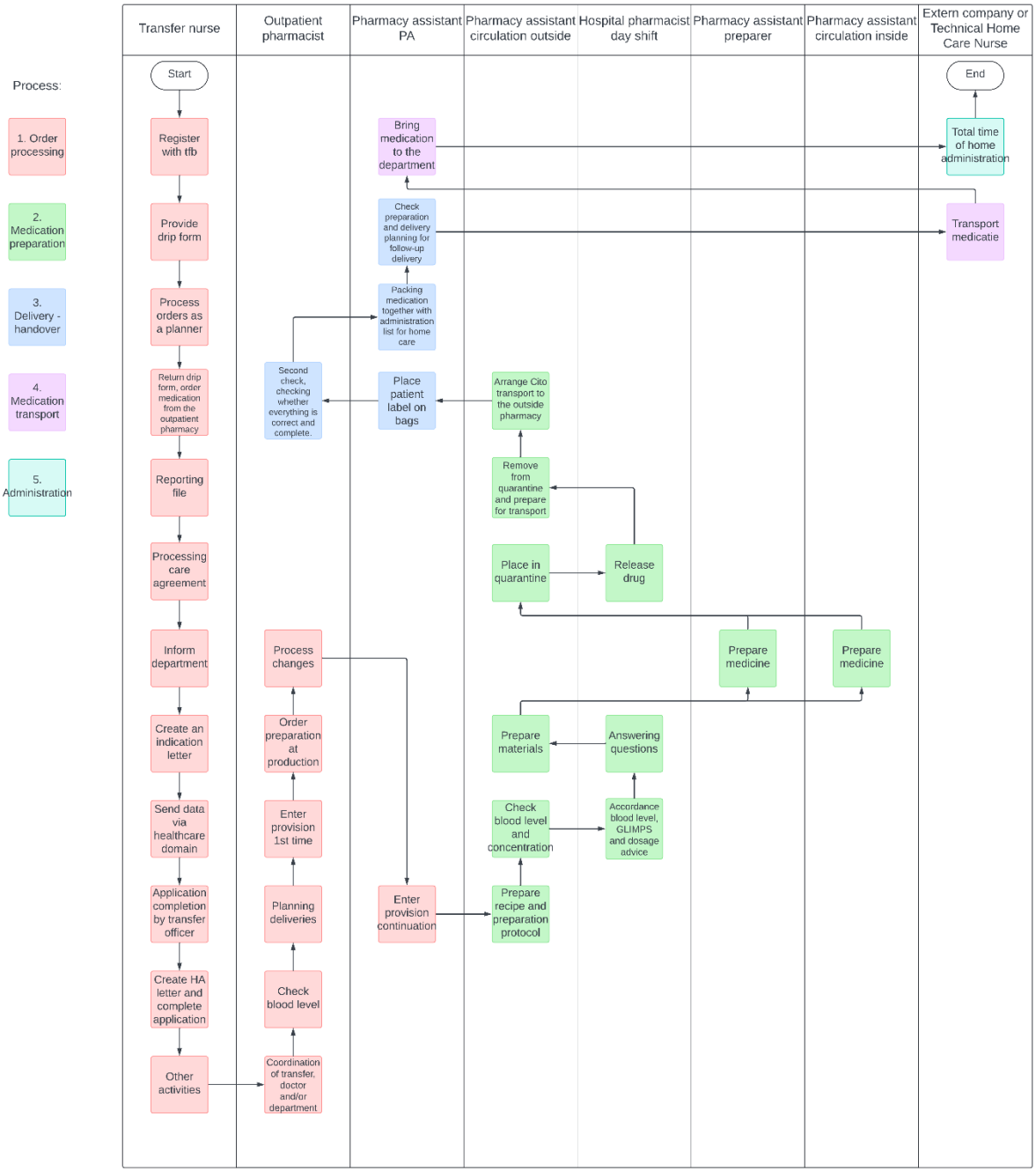

Figure 2: Swimlane diagram antibiotics Rijnstate

Figure 2 visualises the antibiotics pathway at Rijnstate. It only differs on a couple of details with the antibiotics pathway in Isala. This process also has eight stakeholders that execute the activities of this

process, and although the function names are slightly different, the activities they perform are very similar to the activities performed in PMAaH antibiotics pathway in Isala.

The main difference in the first process step of ‘Order processing’ is that in Rijnstate all medication orders are prepared at the outpatient pharmacy, where at Isala patients in Meppel receive medication from APPO. Another difference is that in this process step three stakeholders are involved instead of two at Isala.

It is interesting to notice that there are less stakeholders participating in the second process step ‘Medication preparation’ at Rijnstate, four stakeholders at Rijnstate compared to five at Isala, but the activities that have to be carried out do switch more often between these four stakeholders. In this process step the medication order switches hands seven times, compared to four times at Isala.

In step three ‘Delivery – handover’ the activities are similar to Isala, only executed by the pharmacy assistant PA mostly, instead of the outpatient pharmacist. The transportation and administration of the mediation are in both hospitals performed by an external company, as described in the previous section.

2.2.3 Máxima MC

The process of the PMAaH antibiotics pathway in Máxima MC is shown in Figure 3. The activities in the first step of ‘Order processing’ are quite the same. Máxima MC orders the materials that are needed for the administration of the medication either at Mediq or at a combination of Mediq and a partner home care company. This depends on if the patient lives inside the operating region of the home care company. Another notable difference is that there are four functions involved in this first process step, which is more than at Isala and Rijnstate.

The second step of ‘Medication preparation’ is outsourced to an external company. Máxima MC does not prepare vancomycin themselves. There is also no data available for this process step and for this reason it not in the focus of this research. It is displayed in the diagram in the lane of the external company.

The third process step of ‘Delivery handover’ is completely the same as in Isala, but only when it concerns a first issuance of the medication. A repetition issuance of the medication is directly delivered to the patient by the external company that prepares the medication. Process step four and

five are also executed by an external company, which means that in this pilot study only process step one and three are compared to the antibiotics pathways of the other hospitals.

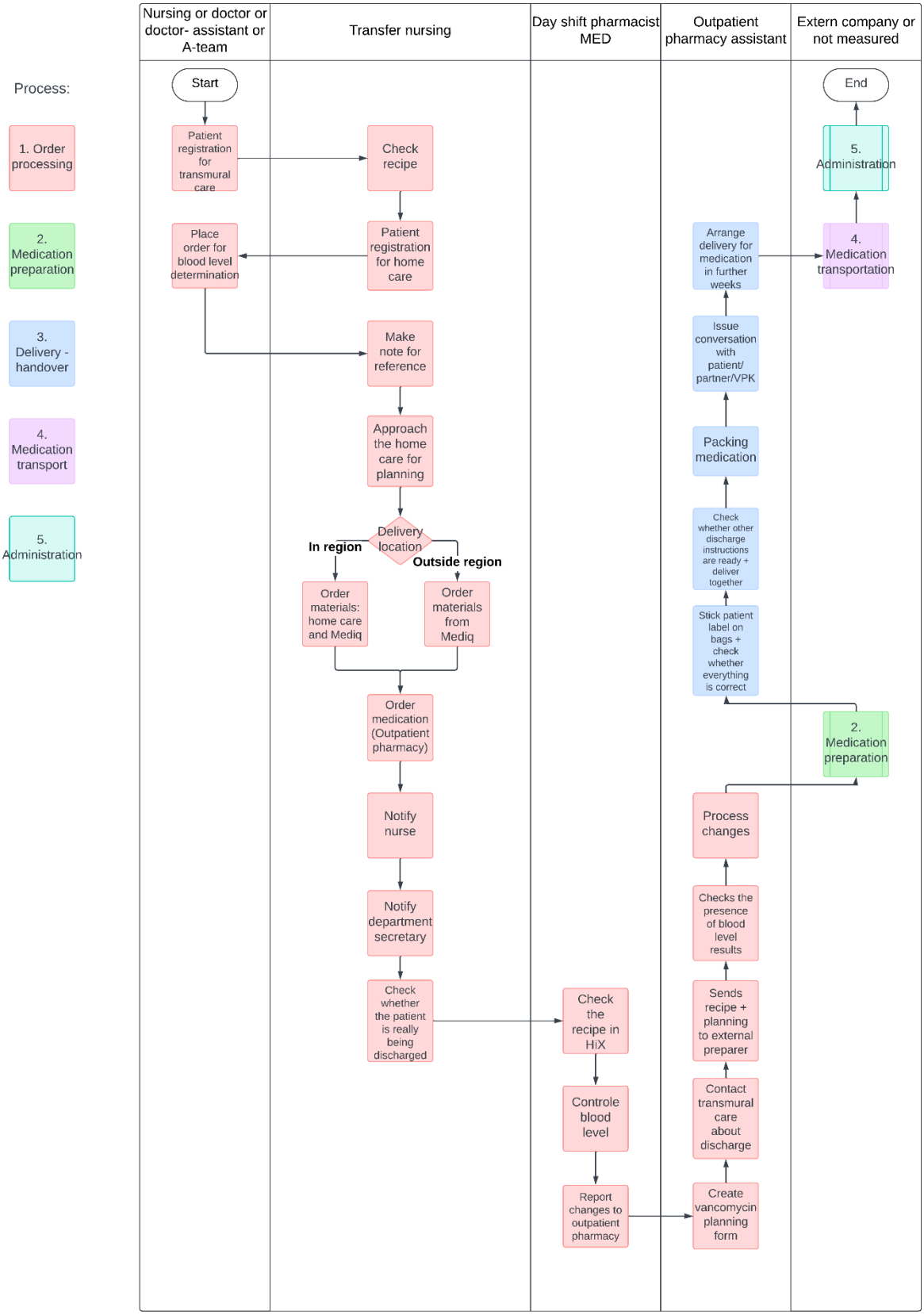

Figure 3: Swimlane diagram antibiotics Máxima MC

2.3 PMAaH biologicals

Subsection 2.3.1 explains and visualizes the PMAaH pathway for biologicals in Rijnstate. This is followed by Subsection 2.3.2, which describes the PMAaH pathway for biologicals in Isala and the differences with Rijnstate. And lastly, Subsection 2.3.3, which describes the PMAaH pathway for biologicals in Máxima MC and differences with the other biologicals pathways.

2.3.1 Rijnstate

Figure 4 shows the PMAaH biologicals pathway of Rijnstate. This pathway is carried out for patients that are treated with biologicals at home. Biologicals are used for immunotherapy of various cancer types (Mellman et al., 2011). Only immunotherapy treatments that have an infusion time of thirty minutes or less are administered at home, if the patient feels comfortable receiving their treatment at home. The first treatment of immunotherapy is always done at the daycare of the hospital to provide a safe environment in case the patient gets side effects. All treatments after this can be administered at home. The swimlane diagram in Figure 4 displays the ideal process for immunotherapy that is administered at home.

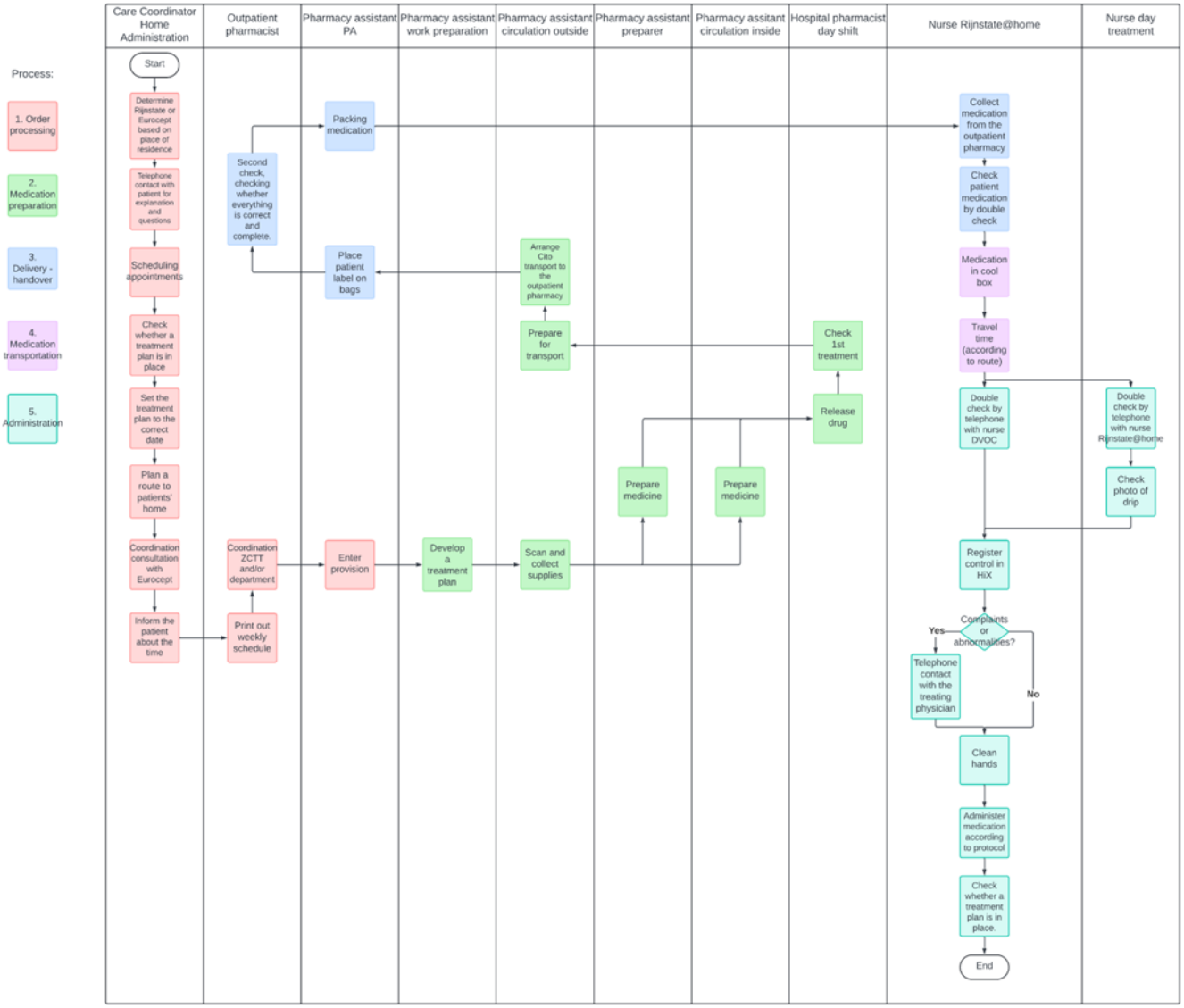

Figure 4: Swimlane diagram biologicals Rijnstate

This pathway has ten stakeholders that execute activities in this care pathway. These are care coordinator home administration, outpatient pharmacist, pharmacy assistant PA, pharmacy assistant work preparation, pharmacy assistant circulation outside, pharmacy assistant preparer, pharmacy assistant circulation inside, hospital pharmacist day shift, nurse Rijnstate@home, and nurse day treatment. In the remainder of this section the role of these stakeholders in the care path is explained.

The process starts with the 'Order processing' step, of which the activities are mostly carried out by the care coordinator home administration. This coordinator determines if the administration of the medication is executed by the team of nurses from Rijnstate@home, or by Eurocept (a homecare provider). This decision is based on the place of residence of the patient. Then the coordinator communicates with the patient to explain the process and plan the treatment dates. The coordinator also checks the treatment plan and coordinates this with the treatment dates. Then the coordinator plans the route for the nurses of Rijnstate@home and communicates the time planning with the patient. If nurses of Eurocept perform the administration the coordinator communicates the treatment plan with them. Lastly, the outpatient pharmacist and pharmacy assistant PA print out the weekly schedule and communicate this with the other involved stakeholders in the system.

The second process step 'Medication preparation' starts with working out the treatment plan further by the pharmacy assistant work preparation. The pharmacy assistant circulation outside receives the treatment plan and scans it and collects materials for the preparation of the medication, which is executed by the pharmacy assistant preparer and the pharmacy assistant circulation inside. After finishing this activity the medication is passed on to the hospital pharmacist day shift, who has to check and release the medication. The next step is for the medication to return to the pharmacy assistant circulation outside, who prepares the medication for transport and arranges this transport to the outpatient pharmacy.

In the third process step 'Delivery – Handover', the pharmacy assistant PA places the patient labels on the bag with medication. After this the outpatient pharmacist performs a second check on the medication, if everything is correct the pharmacy assistant PA packs up the medication. Lastly, a nurse of Rijnstate@home collects the medication and performs another check.

Process step four is the transportation of the medication in a cool box to the patient's home by the nurse of Rijnstate@home. At the patient's home process step five begins, which is administering the medication to the patient. At the patient's home the nurse of Rijnstate@home calls the nurse day treatment in Rijnstate and sends a photo of the drip to double check if the right medication is administered to the patient. This control is registered in HIX, after which in case of abnormalities with the patient the treating physician is called for advice. This activity is rarely necessary. The last steps are for the Rijnstate@home nurse to clean their hands, administer the medication according to protocol and check if there is a future treatment plan in place.

2.3.2 Isala

The biologicals PMAaH pathway of Isala is shown in Figure 5. The patient planner in Isala executes more or less the same activities as the care coordinator home administration in Rijnstate, but it is described in less activities in this diagram. In Isala the home care nurse then checks the prescriptions and corresponding patients for the next day, in Rijnstate this is done for the whole week by the outpatient pharmacist. The big difference with Isala is that the outpatient pharmacy is not involved in this pathway at Isala.

In the process step 'Medication preparation' the activities are the same as in Rijnstate, but the positions that execute them are different as the medication is prepared in the cytostatic pharmacy in Isala. Therefore, the pharmacy assistant cytostatic and the pharmacist production are the only stakeholders involved in this part of the process, compared to Rijnstate, where there are five stakeholders involved.

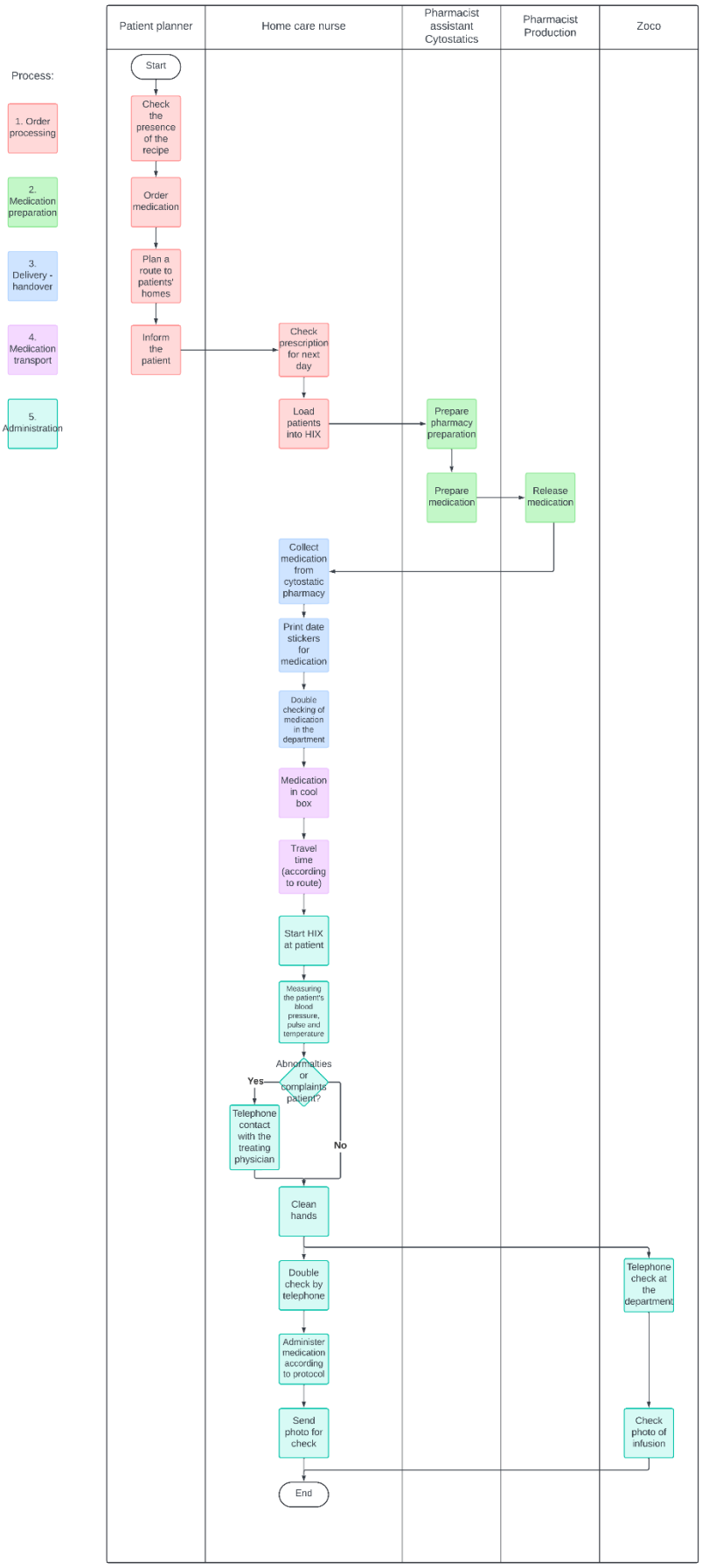

Figure 5: Swimlane diagram biologicals Isala

Process steps three, four and five are all executed by the home care nurse, and two activities in process step five by the nurse day treatment. The main difference with Rijnstate in process step three 'Delivery – handover' is the amount of involved different functions for only a couple of activities. In Rijnstate there are three functions involved in this step, compared to only one at Isala. Process steps four and five don't have any notable differences.

2.3.3 Máxima MC

The biologicals PMAaH pathway of Máxima MC is shown in Figure 6. The first process step of 'Order processing' has as main difference that the medication prescription has to be authorized by the day shift pharmacist preparer at least two days prior to the administration of the medication. The other activities are also executed in the pathways of the other hospitals.

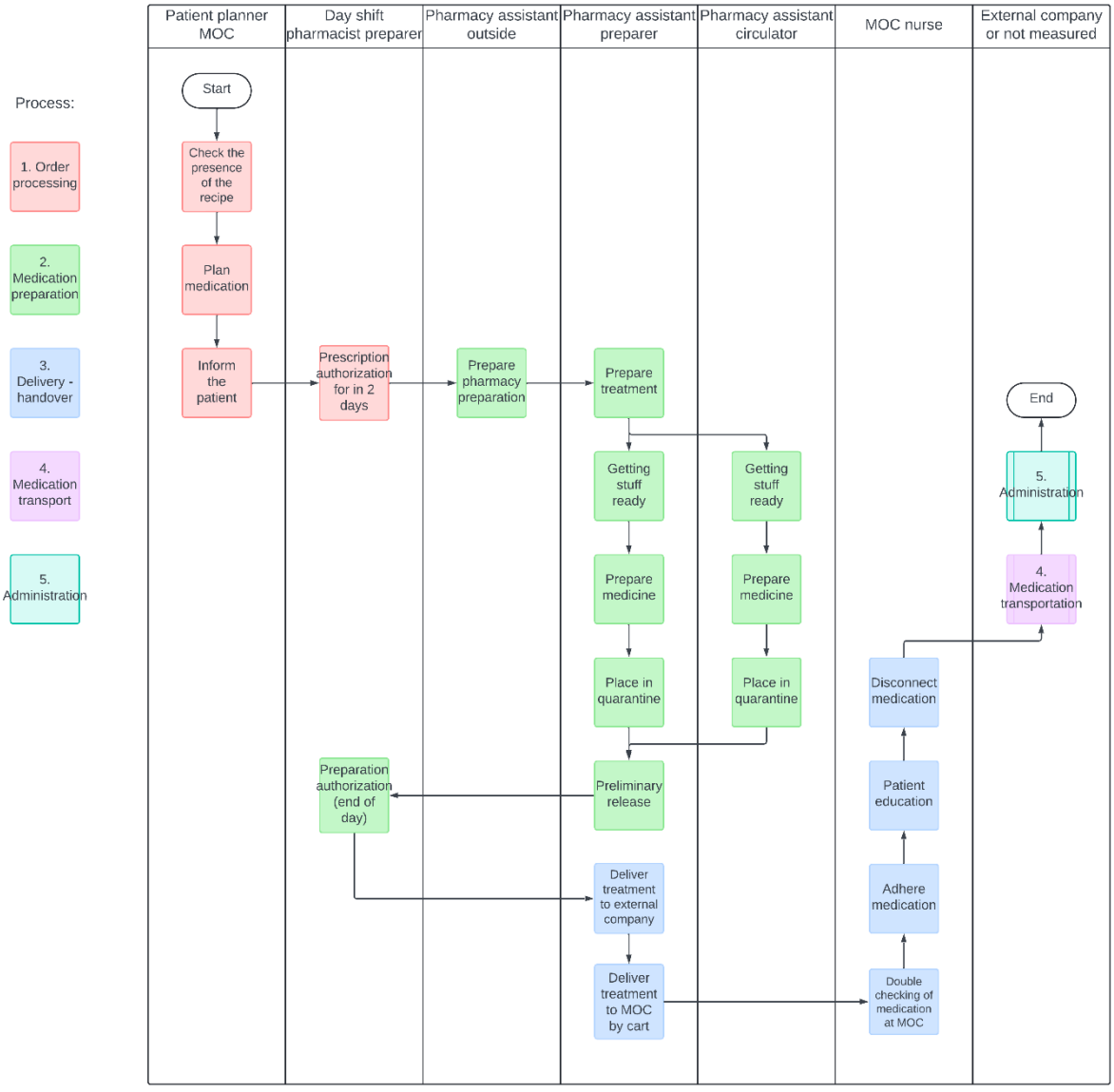

Figure 6: Swimlane diagram biologicals Máxima MC

In the 'Medication preparation' step, the activities that are carried out by the pharmacy assistants preparer and circulation are split into three separate activities, while in the other two diagrams this is shown as one activity. There are four stakeholders involved in this process step, compared to two at Isala and five at Rijnstate.

In the 'Delivery – handover' step of the pathway the medication is delivered to the right department or stakeholder and a double check is performed on the medication corresponding with the patient information in the system. This is similar in all hospitals. The main difference in the biologicals PMAaH

pathway of Máxima MC is that the transportation and administration of the medication are outsourced to home care companies, while in Isala and Rijnstate this is carried out by their own team of nurses.

2.4 Conclusion

In this chapter, the focus lied on analysing the PMAaH pathways in the three hospitals by answering the research questions, which were concentrated on the nature of the activities, the involved positions in the pathways, and the chronological order in which they are carried out. Figures 1 – 6 show the activities that are carried out in the pathways for antibiotics and biologicals in Isala, Rijnstate and Máxima MC, sorted per position.

The antibiotics pathways in Isala and Rijnstate have eight stakeholders involved in the process, compared to five at Máxima MC. The registration of the patient is done by a different function in all three hospitals, but after these activities the pharmacist of the outpatient pharmacy creates the treatment planning and communicates this with the party responsible for preparing the medication, which is the case for all hospitals. Isala and Rijnstate prepare their medication inside the hospital, while Máxima MC outsources it to an external company. The third process step is also carried out by the outpatient pharmacist (assistant) in all hospitals. Lastly, process step four and five are executed by external companies in all three hospitals.

For the biologicals pathways the number of stakeholders are ten, five and eight for respectively Rijnstate, Isala and Máxima MC. In the Rijnstate biologicals pathway a lot of activities are carried out by the pharmacist or pharmacist assistants in process step 1 till 3. In Isala the home care nurse is more involved in these steps of the process, while Máxima MC is somewhere in between. Process steps four and five are carried out by a specialist team of nurses in Rijnstate and Isala, whereas Máxima MC made the choice to outsource this part of the biologicals pathway.

This chapter gave an overview of the antibiotics and biologicals PMAaH pathways in Isala, Rijnstate and Máxima MC. This forms the basis for the research methodology in Chapter 3.

3 Methodology

This chapter discusses the methodological framework that underlies this research. It provides insights into the research design and the methodology used to assess the performance and effectiveness of the care pathways. This methodology is the foundation on which the results and recommendations are based in the upcoming Chapters 4 and 5. Section 3.1 discusses the research design, which includes the KPI's, study population and data gathering methodology. After which Section 3.2 consists of the methodology behind the data analysis.

3.1 Research design

The goal of this research is to provide recommendations for improvements of the PMAaH pathways for antibiotics and biologicals of Isala, Rijnstate and Máxima MC, as well as recommendations about the feasibility of this research design. The data registration tool used in this research design has not been utilized for similar purposes before. Therefore, this research concerns a pilot study, of which lessons should be learned and form the basis for a potential follow-up study, which is evaluated in Chapter 6.

The recommendations for improvements of the PMAaH pathways are based on expected differences in the efficiency of the pathways. The efficiency of the pathways is assessed by measuring performance indicators, which make this part of the research design a quantitative research. Section 3.1.1 discusses the KPI's. Followed by Section 3.1.2, which provides insights into the study population and inclusion and exclusion criteria. Lastly, Section 3.1.3 discusses the data gathering methodology and tool.

3.1.1 Key performance indicators

The PMAaH pathways are compared regarding the efficiency of the logistics of the process. Efficiency is defined as the relationship or ratio between the output factor and the input factor (Van Der Aalst et al., 2003). The output factor is the quality of care in the PMAaH pathways, which includes patient satisfaction, healthcare worker experience and the overall health of the population. The input factor is the resources used to achieve the output, which includes resources like materials and time. The focus of this research is on the input factor time. Experts from the mProve group discussed KPIs that measure this input factor for efficiency and identified throughput time as the best performance indicator, which implies in this setting the time healthcare workers spent on activities of a patient following the PMAaH pathway.

Another KPI that is registered in the digital registration tool is a quality registration of the measured activity. This gives insights into the validity and reliability of the measurement. Further a couple variables are registered, the profession of the healthcare professional, an pseudonymised patient number to link all the measured activities to a patient trajectory, the type of application being either 'new medication' or 'recurrent medication', the type/ name of the medication, and the name of the hospital where the activity is measured are all registered in the PowerApp.

The throughput time is measured as end time of an activity minus the start time of the activity, and registered by using a stopwatch in a PowerApp on the phone or computer of the healthcare professional executing the activity. The quality registration of the measured activity is measured using a three point scale with smiley faces in the PowerApp. Healthcare professionals are also able to provide a note in an open text field next to three point scale with remarks about the measurement of the process step. The use of these KPIs and datatypes are shown in the data analysis methodology in Section 3.2.

3.1.2 Study population

The study population includes patients from the three participating mProve hospitals that qualify for home treatment with the parenteral medication inside the scope of this research as discussed in Section 1.5. For the patients in this study there are also a couple of inclusion and exclusion criteria, which are mentioned in Table 1 below. Most of these criteria are standard and self-explanatory. The reason behind the inclusion criteria regarding the maximum number of prior administration within this study is to reduce bias in the data set.

Table 1: Inclusion and exclusion criteria of the study population

Inclusion criteria	Exclusion criteria
Patient is competent.	Patient is incompetent
Patient is eligible for treatment with parenteral medication at home.	
Patient is receiving the treatment for the first time or as a repeat treatment.	
Patient has had a maximum of one prior administration of the same medication within this study.	
Patient is being treated with a hospital-assigned indicator drug.	
Patient agrees to treatment at home.	
Patient is 18 years or older.	

The sample size is based on the amount of data that is gathered in the hospitals over a period of three months. The hospitals set as goal to measure twenty whole process registrations, which was not based on a formal statistical test, but more on a trade-off between the expected results and the time invested by the healthcare professionals.

3.1.3 Data gathering methodology

The six PMAaH pathways of the mProve hospitals are divided in five process steps. These five process steps are further subdivided into activities that are carried out by healthcare professionals, as shown in the figures in Chapter 2. These activities are different for every PMAaH pathway, but the three hospitals set up a list that includes all the different activities, where similar activities fall under a general description or name. This list can be found in Appendix A, and is also the list of activities of which the healthcare professionals can choose from for measuring the activities of the PMAaH pathways in the PowerApp.

The PowerApp is a tool, which is developed for this specific research project in collaboration with Microsoft, on which the healthcare professionals can register the measured throughput times. The healthcare professionals measures the throughput times by starting a stopwatch on their phone or computer at the start of executing an activity of the PMAaH pathway for a patient in the study. Before this they must select the right patient, after which they select the activity or activities they are performing. Healthcare professionals can choose to time multiple activities they perform in a sequence. They only measure the throughput time once and select the activities that were included in this measurement. At the end of their activity they stop the stopwatch, after which it is optional to change the measured time, if they forgot to either start or stop the stopwatch at the right time. Changing the measured time can only be done in minutes, which has influence on the accuracy of the measured time, if the measured time is modified. The follow-up step in the measuring process is the quality registration. The healthcare professional indicates the quality of the measurement by using the three point scale visualised by smiley faces for bad, medium and good quality of the registered measurement. Lastly, they save the measured time on the PowerApp.

The registrations are saved in a closed IT-environment of the hospital where the measurements are taken. The data of the three hospitals is then exported to a mProve cloud, from where the data is

made available for the data analysis. The data is anonymised before exporting it to the mProve cloud, as there are some confidentially issues regarding working with patient and healthcare professionals data. This is further elaborated on in Appendix B. The ethical aspects of this research design are reviewed by the BMS ethics committee and approved, which can be found in Appendix C.

3.2 Data analysis methodology

This section elaborates on the methodology behind the data analysis. Section 3.2.1 discussed the preparation of the dataset, which is followed by Section 3.2.2 which explains the analysis of the cleaned dataset.

3.2.1 Data preparation

The data analysis starts with cleaning and filtering the data. This is a crucial step to improve the quality of the data for the analysis and results. All major errors and duplicates are removed from the dataset. Outliers are only removed, if the registered throughput time for an activity or activities is completely illogical or wrong. This is the case for time registrations that are zero or longer than eight hours, as this is the normal shift length of a healthcare professional in the hospitals. Also data entries with missing information were deleted, if it was not doable to fill in the data by hand. The dataset was further structured by fixing some layout issues, which helps for the analysis of the data.

The cleaned and filtered data set imported from the mProve cloud consists of measured throughput times of an activity or multiple activities in a process step. The hospitals are interested in a comparison on process step level, as all the activities executed in a certain process step have the same objective in every hospital, and are therefore comparable to each other. The activities in the trajectory of a patient are summed up per process step, which provides an throughput time per process step.

The throughput times of process step 2 of the antibiotics PMAaH pathways, ‘Medication preparation’, are divided by the units produced of a certain medication. Antibiotics are often produced in batches, instead of single units, as is the case with biologicals. The magnitude of these batches can vary strongly, between one and seven, depending on the production decision of the hospital. The throughput time of ‘Medication preparation’ is strongly dependent on the units produced. Therefore, the throughput time is divided by the units produced, instead of comparing the actual throughput time for this process step, which gives a throughput time per unit of medication produced.

The activities that are measured vary a lot per process step and per patient trajectory. Some process steps of a patient’s trajectory include only one measured activity, while others have several activities that are measured. These process steps would not be comparable to each other, as the throughput time is mostly reliant on the amount of measured activities, and does not give a good indication of the actual throughput time of the whole process step. A control table is setup to tackle this problem, which is displayed in Table 2. The control table indicates which activities are minimal required for a whole process step, which means that the sum of the throughput time can include more activities than only the required activities. The minimal required activities are determined by an expert focus group from the three participating hospitals. These experts include the three hospitals pharmacists, who are clinical pharmacists, and members of the mProve workgroup. The minimal required activities are chosen based on the importance and length of the activity within the process step. The average throughput time length had the highest weight in this consideration, as this has a significant influence on the throughput time of the whole process step. Activities that take on average seconds or a few minutes influence the total throughput time less.

In the first process step ‘Order processing’, the expert focus group determined that there are no required activities in this step. This process step has relatively many possible activities, which is due to the variability of activities that are executed in this step among the three hospitals. The measured activities executed per medication type (biologicals or antibiotics) and per type of application (recurrent or new) in the hospitals also vary. Therefore, the focus group determined no minimal required activities, but preferred to focus on and analyse the most frequent compositions of activities in the results in Chapter 4.

Table 2: Control table minimum required activities per process step

	Not required or not measured		biologicals					antibiotics								
	Required		Recurrent	MMC	RIJNS	ISAL	New	MMC	RIJNS	ISAL	Recurrent	MMC	RIJNS	ISAL	New	MMC	RIJNS	ISAL
Process Step	**Activity**	**Number**																
1. Order processing																		
	Patient registration	1.1																
	Check prescription/treatment plan	1.2																
	Contact outpatient pharmacy	1.3																
	Arrange infusion form	1.4																
	Arrange concentration determination	1.5																
	Arrange specialized home care	1.6																
	Order medication & materials	1.7																
	Administration (reference, POINT, care agreement, etc.)	1.8																
	Inform nurse/secretary department	1.9																
	Inform patient	1.10																
	Check if patient is being discharged	1.11																
	Contact transmural care	1.12																
	Process medication changes	1.13																
	Process policy changes	1.14																
	Check concentration	1.15																
	Plan preparations	1.16																
	Send prescription (+ planning) to preparations first time	1.17																
	Send prescription (+ planning) to preparations follow-up	1.18																
	Prepare instructions	1.19																
	Plan route for patient visits	1.20																
	Read patient information	1.21																
2. Medication preparation																		
	Receive prescription and forward to preparations	2.1																
	Develop treatment plan	2.2																
	Check first course	2.3																
	Answer questions	2.4																
	Prepare	2.5																
	Prepare medication	2.6																
	Place in quarantine	2.7																
	Preliminary release preparation	2.8																
	Release preparation	2.9																
	Arrange transport to delivery location	2.10																
3. Delivery - handover																		
	Prepare medication for patient (incl. home instructions)	3.1																
	Delivery conversation	3.2																
	Arrange medication transport	3.3																
	Double check medication	3.4																
	Deliver course	3.5																
	Check preparation and delivery planning for follow-up	3.6																
	Collect medication in outpatient pharmacy	3.7																
4. Medication transport																		
	Transport medication to home	4.1																
	Transport medication to department	4.2																
5. Administration																		
	Check if treatment plan is present	5.1																
	Start-up	5.2																
	Prepare medication for administration	5.3																
	Double check medication	5.4																
	Double check infusion	5.5																
	First administration according to protocol	5.6																
	Repeat administration according to protocol	5.7																
	Administration registration	5.8																
	Care for infusion line	5.9																
	Measure blood pressure, pulse, and temperature in patient	5.10																
	Register control in EHR	5.11																
	Contact treating physician	5.12																

The second step of ‘Medication preparation’ is not measured by Máxima MC, because they outsource most of the preparation of their medication. That is the reason for the columns of Máxima MC being red. The expert group requires activity 2.4, 2.5, and 2.9 as a minimal requirement for a complete process step in Isala, where Rijnstate requires 2.2 as well. In the third process step 3.1 and 3.4 are the minimal required activities for every hospital except Máxima MC, as they did not measure activity 3.4. Process steps four and five are only measured by Isala, which make comparisons between the hospitals for these step impossible. These steps are analysed to give Isala insights in the throughput times of their processes, but not relevant for the goal of this research.

3.2.2 Data analysis

The data analyse provides insights into the differences per hospital in throughput time per process step. It only takes into account the throughput time of the whole process steps in the analysis and is done in SPSS. The whole data analysis approach is shown in Figures 7 & 8 by means of a flowchart diagram. A process step can be further subdivided into groups, like the type of application, either 'new medication' or 'recurrent medication'. This distinction is also mentioned in Chapter 2, where it is discussed that some activities in process steps are skipped when it is an 'recurrent medication' for a patient. Especially, in the first process step 'Order processing', the expert focus group hypothesizes that there is a significant difference in throughput time, but this could also apply to other process steps. For this reason, the first step in the analysis is to perform a statistical test to determine if there is a statistical significant difference in the median and the distribution of the two groups of application types. The hypothesis for this test is that the distribution and the median of the two groups are the same.

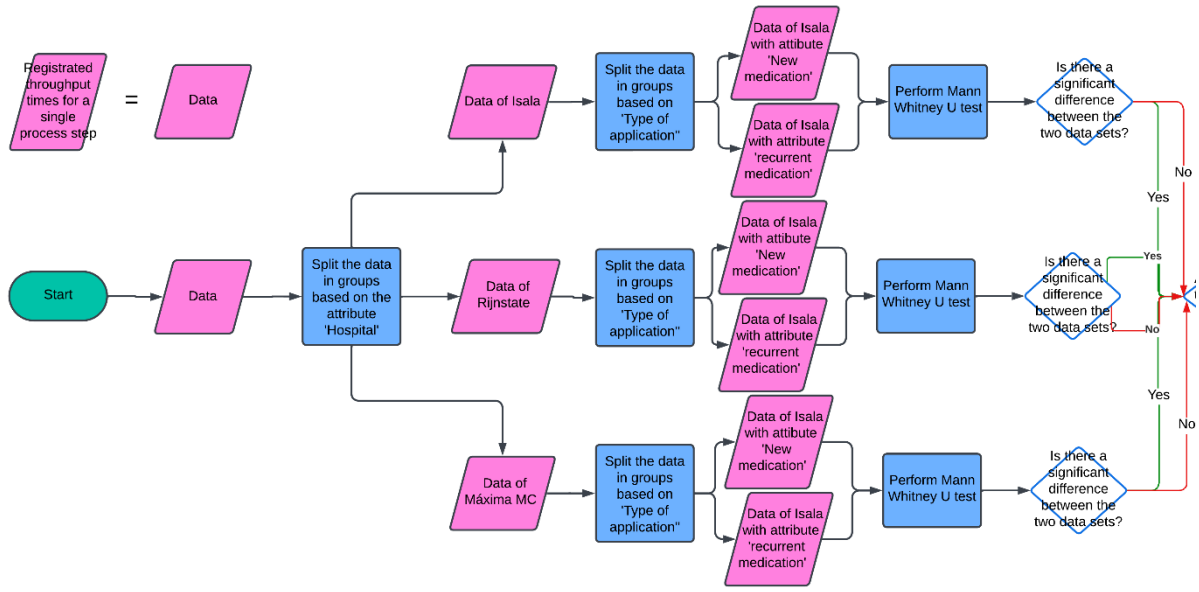

Figure 8: Flowchart of data analysis methodology (1/2)

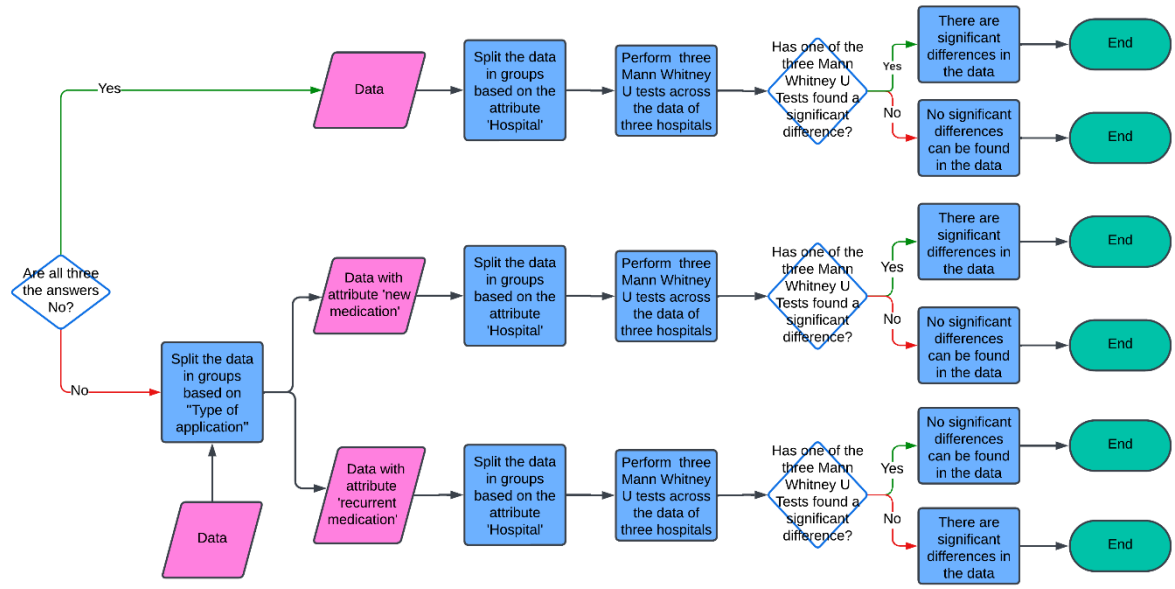

Figure 7: Flowchart of data analysis methodology (2/2)

The independent-samples Mann Whitney U test is used to check this hypothesis. This test forms an alternative for the independent samples t-test. The independent samples t-test assumes that the data is normally distributed, but because the sample sizes are expected to be very small in some of the groups in this research, this would not be valid (Hart, 2001). The dataset is independent, because there is not overlap in patients for identifying the differences in throughput time per process step between the hospitals.

The follow-up step in the analysis is dependent on the results of the Mann Whitney U test for the type of application. The application type is either 'new medication', which is the first administration for a patient with that medication, or 'recurrent medication, which are all the administrations of the medication after the first time. If the null hypothesis, which states that the distribution is the same across the two types of application groups, is rejected for at least one of the three hospitals with a 5% significance level, then a distinction is made for the comparison of the throughput time in this process step. The dataset with all the throughput times for the process step is split into the two groups of application types, 'new medication' and 'recurrent medication'. The reasoning behind this methodology, which splits the dataset if only one of three hypothesis is rejected, is that the distinction cannot be made for only one hospital, as the throughput time of this hospital for a certain application type would be compared to the throughput time of the other hospitals without this distinction. This leads to a skewed comparison. If the null hypothesis is not rejected for all hospitals, then the distinction is not made and the data of the complete process step is compared between the hospitals, without splitting the dataset in 'new medication' and 'recurrent medication'.

The next step is to visualize the data distribution per process step between the hospitals, focusing on the differences in throughput time. This is visualized with boxplots, which immediately shows the median, lower quartile, upper quartile, minimum, maximum, and the outliers. The outliers are identified from the boxplots, and analysed by hand. Only when the outlier is clearly a wrong measurement, it is deleted from the dataset. A professional in the field has to indicate that the measurement is clearly wrong, otherwise it is not deleted. In addition to this the descriptive statistics like the number of complete process steps, mean, median, standard deviation, minimum and maximum (without identified wrong measurements) are also shown in a table. This visualization of the data shows the differences between the hospitals in a clear overview.

The aim of this analysis is to identify significant differences in the efficiency of the process steps between hospitals, because this allows us to indicate one process step of a hospital to be more efficient than the other. This is based on the throughput time, as this represents the time spent on the process step by healthcare workers. The data of the hospitals is subjected to the Mann Whitney U test again to determine if the differences in throughput time per process step per hospital are not due to coincidence. The test has to be executed three times, when there are three groups of data from the three hospitals for a process step, as the test can only reject the hypothesis of two sample groups having the same distribution. The data groups are significantly different, when the test rejects the null hypothesis. The differences in throughput time can also be due to coincidence, if the tests does not reject the null hypothesis.

The last step is to provide a table with the frequency of the activities that were measured in the data of the complete process steps. The frequency of the activities measured can give insights into other factors that influences the identified differences in the data between the hospitals, which is valuable for the conclusion, recommendation and discussion in the following chapters. These frequency tables are displayed in Appendix D, and are discussed in Chapter 6.

4 Results

This chapter provides an overview of the results and insights obtained from analysing the dataset. The structure of the overview in which the results are provided is based on the methodology discussed in Chapter 3, which contributes to a clear understanding of the findings in this research. Section 4.1 focuses on the outcomes of the data preparation, which shows the sample size of the data before and after cleaning of the data. Section 4.2 dives further into the data analysis and displays the findings using boxplots and tables. Lastly, Section 4.3 provides a brief summary of the results of the performed analysis.

4.1 Data preparation

The dataset received from the mProve cloud consists of data entries that measure the throughput time of a single activity or a sequence of activities. Table 3 shows the amount of data entries per group, where the distinction between the groups is based on the hospital, the type of medication and the type of application. This are all the data entries, also the ones that are not part of a complete process step. The colour of the cells of the table already show that there are not many data entries for certain groups, which is even more clear when the complete process steps are counted.

*Table 3: Measured activities per group per hospital. *Red = No data, Orange = Less than 50 data entries, Green = More than 50 data entries.*

Measured activities	Antibiotics NM	Antibiotics RM	Biologicals NM	Biologicals RM
Isala	180	11	18	280
Máxima MC	200	13	-	-
Rijnstate	280	336	41	597

Table 4 displays the amount of complete process steps, per type of medication, per hospital, per type of application. The columns of the table show the small sample size for some comparisons on throughput time. This has implications for the reliability of the research outcomes, as conduction significance testing between groups is complicated for some comparisons. Some comparisons of process steps are only conducted between two hospitals, as the third hospital has no data for a complete process step. The missing data can be due to various reasons, which are elaborated on in the discussion in Chapter 6.

*Table 4: Amount of complete process steps per group, with on the y-axis the six PMAaH pathways, and on the x-axis the process steps with the distinction between 'new medication' and 'recurrent medication'. *Red = No complete process step measured, Orange = Less than 5 complete process steps measured, Green = 5 or more complete process steps measured.*

Process step	1. NM	1. RM	2. NM	2. RM	3.NM	3.RM	4. NM	4. RM	5. NM	5. RM
Isala – antibiotica	16	1	1							
Rijnstate – antibiotica	26	13	2	15	7	29				
MMC – antibiotica	32	3			8	1				
Isala – biologicals	1	13		6	1	7	1	12	1	12
Rijnstate – biologicals	7	85		21	2	37				
MMC – biologicals										

4.2 Data analysis

The results in this section are displayed according to the methodology discussed in Chapter 3. The process steps of the antibiotics PMAaH pathways are analysed in Section 4.2.1, after which the biologicals PMAaH pathways follow in Section 4.2.2..

4.2.1 Antibiotics PMAaH

The results of the first process step of the antibiotics pathway are shown in detail using the steps of the data analysis methodology, after which the focus lies on the average throughput time per process step and if there are significant differences in throughput time between the hospitals. The antibiotics section only discusses the first three process steps, as there is no data for process steps 4 and 5. This is identical for the biologicals section, although there is data for process steps 4 and 5 in Isala, which is shown in Appendix E. This section focuses on comparing the data between the hospital, which makes discussing the data of a single hospital irrelevant.

4.2.1.1 Order processing

There is a significant difference between the group ‘new medication’ and ‘recurrent medication’ in the first process step of Rijnstate. In the other two hospitals the null hypothesis is not rejected, which means that there is no significant difference found between the two groups in these hospitals. This is shown in Figure 9. The distinction between the two groups is still made, as explained in the data analysis methodology. So, the further analysis of the process step ‘Order processing’ is split into the application types ‘new medication’ and ‘recurrent medication’.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
Isala				
1	The medians of TijdsDuur Activiteiten are the same across categories of Herhaling_nieuw.	Independent-Samples Median Test	1,000[c]	Retain the null hypothesis.
2	The distribution of TijdsDuur Activiteiten is the same across categories of Herhaling_nieuw.	Independent-Samples Mann-Whitney U Test	,444[c]	Retain the null hypothesis.
Máxima MC				
1	The medians of TijdsDuur Activiteiten are the same across categories of Herhaling_nieuw.	Independent-Samples Median Test	1,000[c]	Retain the null hypothesis.
2	The distribution of TijdsDuur Activiteiten is the same across categories of Herhaling_nieuw.	Independent-Samples Mann-Whitney U Test	,266[d]	Retain the null hypothesis.
Rijnstate				
1	The medians of TijdsDuur Activiteiten are the same across categories of Herhaling_nieuw.	Independent-Samples Median Test	,001[c]	Reject the null hypothesis.
2	The distribution of TijdsDuur Activiteiten is the same across categories of Herhaling_nieuw.	Independent-Samples Mann-Whitney U Test	<,001	Reject the null hypothesis.

a. The significance level is ,050.
b. Asymptotic significance is displayed.
c. Yates's Continuity Corrected Asymptotic Sig.
d. Exact significance is displayed for this test.

Figure 9: Independent-samples Mann Whitney U test conducted to determine significant differences in application type

New medication

Figures 10 & 11 show the box plots and descriptive statistics for the ‘new medication’ application type in the ‘Order processing’ step of the antibiotics PMAaH pathway. The medians of the throughput time

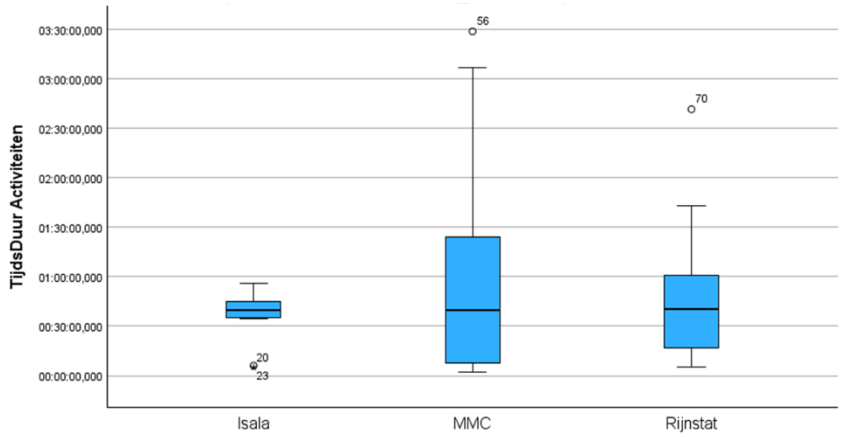

Figure 11: Boxplot antibiotics 1. NM

Throughput time:		Isala	MMC	Rijnstate
N	Valid	16	32	26
	Missing	0	0	0
Mean		0:36:57,88	0:52:10,28	0:43:47,42
Median		0:39:37,50	0:39:49,50	0:40:10,00
Std. Deviation		0:13:26,40	0:53:11,15	0:34:51,36
Minimum		0:05:06,00	0:02:00,00	0:05:27,00
Maximum		0:55:41,00	3:28:50,99	2:41:35,99

Figure 10: Descriptive statistics antibiotics 1. NM

are very similar to each other, although the means and standard deviations differ substantially between the three hospitals. The outliers in the dataset of the hospitals are shown in the boxplots and were identified in the dataset. These measurements of several activities were not clearly a wrong or illogical measurement by the logic provided in the previous chapter, and therefore they are not deleted from the dataset.

The average throughput time at Isala for the 'Order processing' of patients with the 'new medication' application type is 37 minutes, with a sample group of 16 patients. For Máxima MC this is 52 minutes on average, with a sample group of 32 patients. Rijnstate measured an average throughput time of 44 minutes, with a sample size of 26 patients.

The median and distribution of the data of the three hospitals are tested for significant differences between them, but for all three tests, this is not the case (see Figure 12).This implies that the differences in the average throughput time observed between the hospitals could be due to random variability, instead of actual causes, which means that there is no basis to make claims about one hospital's pathway being more efficient than the others in this process step. Therefore, more data would need to be gathered and analysed.

Isala - MMC

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The medians of TijdsDuur Activiteiten are the same across categories of Ziekenhuis.	Independent-Samples Median Test	1,000[c]	Retain the null hypothesis.
2	The distribution of TijdsDuur Activiteiten is the same across categories of Ziekenhuis.	Independent-Samples Mann-Whitney U Test	,743	Retain the null hypothesis.

Isala - Rijnstate

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The medians of TijdsDuur Activiteiten are the same across categories of Ziekenhuis.	Independent-Samples Median Test	1,000[c]	Retain the null hypothesis.
2	The distribution of TijdsDuur Activiteiten is the same across categories of Ziekenhuis.	Independent-Samples Mann-Whitney U Test	,820	Retain the null hypothesis.

MMC - Rijnstate

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The medians of TijdsDuur Activiteiten are the same across categories of Ziekenhuis.	Independent-Samples Median Test	1,000[c]	Retain the null hypothesis.
2	The distribution of TijdsDuur Activiteiten is the same across categories of Ziekenhuis.	Independent-Samples Mann-Whitney U Test	,977	Retain the null hypothesis.

a. The significance level is ,050.
b. Asymptotic significance is displayed.
c. Yates's Continuity Corrected Asymptotic Sig.

Figure 12: Statistical test for differences in median and distribution across hospitals

Recurrent medication

The boxplot and descriptive statistics for the comparison of the recurrent medication for process step 1 are shown in Figures 13 & 14. There are less complete process step measurements in this group, which is seen in the sample size for Isala, Máxima MC and Rijnstate, with respectively 1, 3 and 13 as sample sizes. This results in a mean of 30 minutes for Isala, 12 minutes for Máxima MC and 7 minutes for Rijnstate, although these differences are not significant due to the small sample size.

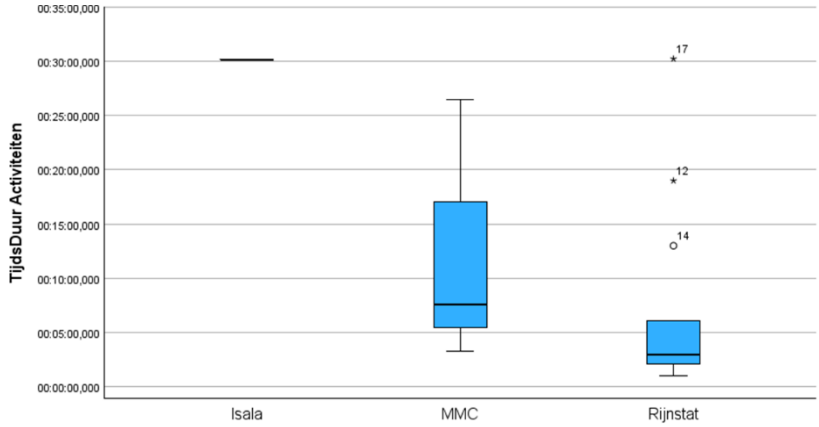

Figure 14: Boxplot antibiotics 1. RM

Throughput time:		Isala	MMC	Rijnstate
N	Valid	1	3	13
	Missing	0	0	0
Mean		0:30:11,00	0:12:27,00	0:06:54,77
Median		0:30:11,00	0:07:37,00	0:03:00,00
Std. Deviation			0:12:19,93	0:08:45,32
Minimum		0:30:11,00	0:03:16,00	0:01:01,99
Maximum		0:30:11,00	0:26:28,00	0:30:14,00

Figure 13: Descriptive statistics antibiotics 1. RM

4.2.1.2 Medication preparation

There is no significant difference between the 'new medication' and 'recurrent medication' groups for the second process step of the antibiotics pathways, according to the Mann Whitney U test. Figures 15 & 16 show the boxplots and descriptive statistics for this process step. The average throughput

time is in this process step defined as the time it takes to prepare one unit of antibiotics for a patient, as this type of medication is made in batches. Máxima MC outsources most of the preparation of their antibiotics, and therefore has no available data on this process step. Isala has only 1 completely measured process step, and Rijnstate has 17. The average time it takes to prepare one unit of antibiotics is 15 minutes for Isala and 13 minutes for Rijnstate. These differences in throughput time are not significant.

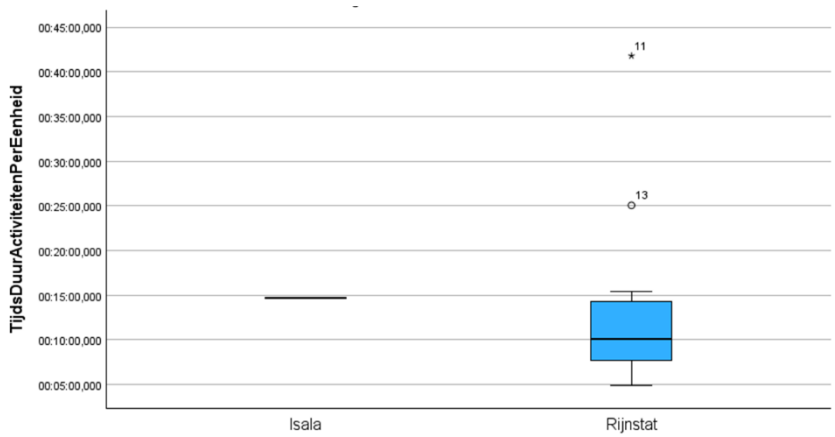

Figure 16: Boxplot antibiotics 2

Throughput time: **Isala** **Rijnstate**

N	Valid	1	17
	Missing	0	0
Mean		0:14:43,43	0:12:45,19
Median		0:14:43,43	0:10:09,00
Std. Deviation			0:08:55,01
Minimum		0:14:43,43	0:04:55,86
Maximum		0:14:43,43	0:41:47,29

Figure 15: Descriptive statistics antibiotics 2

4.2.1.3 Delivery – Handover

There is no data of Isala for the third process step of antibiotics, as Isala did not manage to measure enough activities to have complete process steps. There is a significant difference in the 'new medication' and 'recurrent medication' groups for Rijnstate, and therefore the analysis of this process step is divided into two parts.

New medication

Figures 17 & 18 display the boxplots and descriptive statistics of the third process step for 'new medication'. The average throughput time of this process step is 12 minutes for Máxima MC, with a sample size of 8 patients, and 25 minutes for Rijnstate, with a sample size of 7 patients. Conducting the Mann Whitney U test results in a significant difference in the distribution of these two data samples, which means that this difference in throughput time is not due to coincidence. Although, this difference can also be caused by other factors. A factor that has an influence on the throughput time is the amount of measured activities, which differs substantially across these two hospitals. This is can be found in Appendix D and is further discussed in Chapter 6.

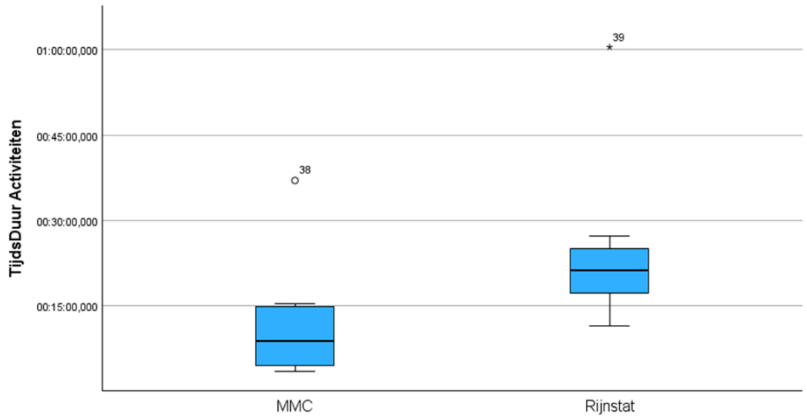

Figure 18: Boxplot antibiotics 3. NM

Throughput time: **MMC** **Rijnstate**

N	Valid	8	7
	Missing	0	0
Mean		0:12:09,25	0:25:27,00
Median		0:08:50,50	0:21:14,00
Std. Deviation		0:11:01,33	0:16:16,59
Minimum		0:03:30,00	0:11:28,00
Maximum		0:37:03,00	1:00:29,00

Figure 17: Descriptive statistics antibiotics 3. NM

Recurrent medication

The boxplots and descriptive statistics of the 'recurrent medication' group for the 'Delivery – Handover' process step are visualized in Figures 19 & 20. The average throughput time is 7 minutes for Máxima MC, with sample size 1, and 13 minutes for Rijnstate, with sample size 29. There is not a significant difference found between the distribution of these two groups.

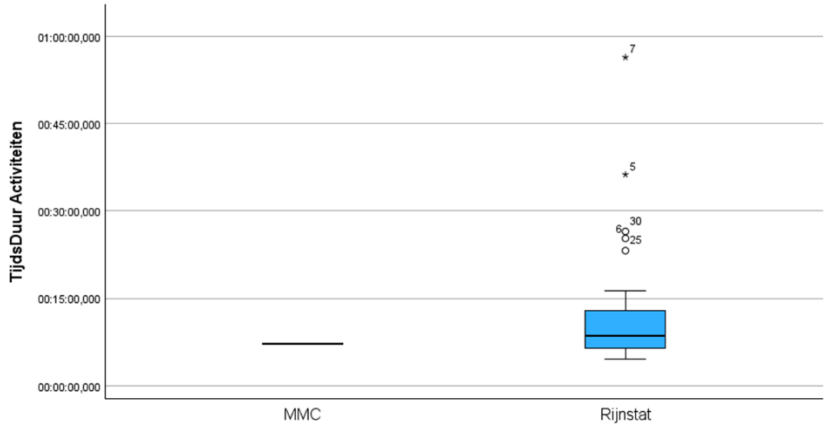

Figure 20: Boxplot antibiotics 3. RM

Throughput time: **MMC**		**Rijnstate**
N Valid	1	29
Missing	0	0
Mean	0:07:14,00	0:12:53,48
Median	0:07:14,00	0:08:38,00
Std. Deviation		0:11:13,47
Minimum	0:07:14,00	0:04:33,00
Maximum	0:07:14,00	0:56:20,00

Figure 19: Descriptive statistics antibiotics 3. RM

4.2.2 Biologicals PMAaH

The results of the process steps of the biologicals pathways are shown in a similar matter as the previous section, where the focus lies on the measured throughput time and if there are significant differences in throughput time for the various process steps of the pathways. This section only compares the process steps between Isala and Rijnstate, because Máxima MC did not measure the throughput time of the activities of the biologicals pathway. The biologicals section also only discusses the first three process steps, as process steps 4 and 5 only have data available from Isala. Therefore, it is not possible to compare these results with the other hospitals. The results of process step 4 and 5 for Isala can be found in Appendix E.

4.2.2.1 Order processing

There is a significant difference between the group ‘new medication’ and ‘recurrent medication’ in the first process step of Rijnstate. Therefore, the data for this process step is divided into these two groups.

New medication

The boxplots and descriptive statistics of the first process step for ‘new medication’ are shown in Figures 21 & 22. The average throughput time for Isala is 4 minutes, with a sample size of 1, and 17 minutes for Rijnstate, with a sample size of 7. The test cannot indicate a significant difference due to the small sample sizes, despite seeing a substantial difference in average throughput time between the two hospitals.

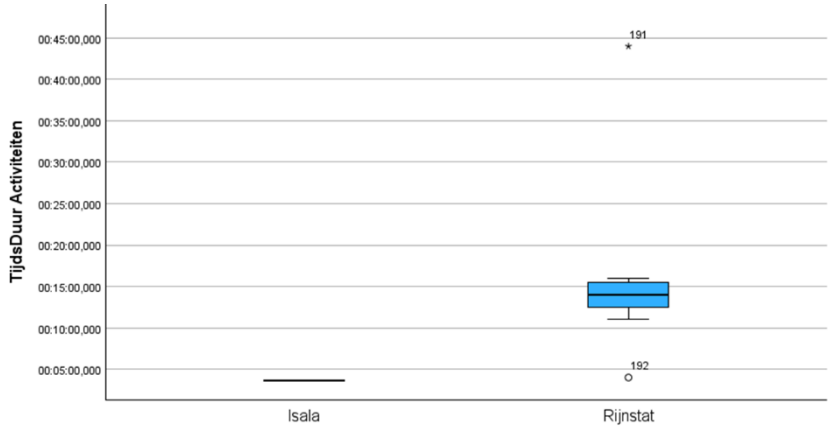

Figure 22: Boxplot biologicals 1. NM

Throughput time: **Isala**		**Rijnstate**
N Valid	1	7
Missing	0	0
Mean	0:03:41,00	0:16:51,43
Median	0:03:41,00	0:14:00,00
Std. Deviation		0:12:37,70
Minimum	0:03:41,00	0:04:00,00
Maximum	0:03:41,00	0:44:00,00

Figure 21: Descriptive statistics 1. NM

Recurrent medication

The boxplot and descriptive statistics for the comparison of the recurrent medication for process step 1 are shown in Figures 23 & 24. There are more complete process step measurements in this group, which is seen in the sample size for Isala and Rijnstate, which are 13 and 85. This results in a mean of 2 minutes for Isala and 11 minutes for Rijnstate. This is a significant difference in average throughput

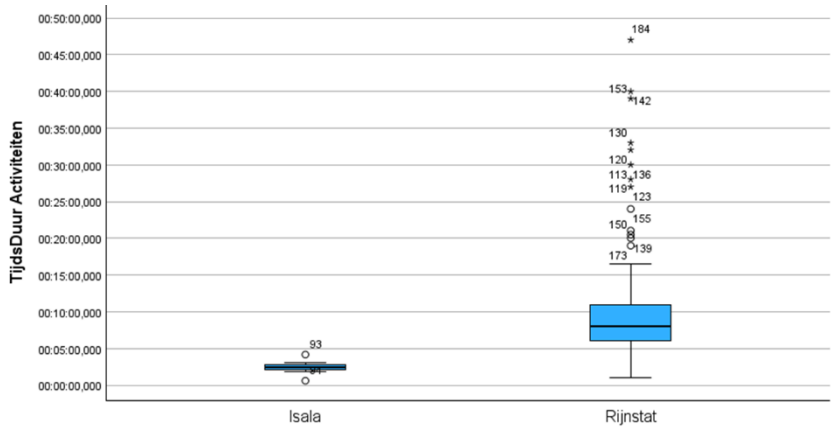

Figure 23: Boxplot biologicals 1. NM

Throughput time:		Isala	Rijnstate
N	Valid	13	85
	Missing	0	0
Mean		0:02:26,62	0:10:43,84
Median		0:02:27,00	0:08:00,00
Std. Deviation		0:00:49,23	0:09:08,49
Minimum		0:00:36,00	0:01:00,00
Maximum		0:04:10,00	0:47:01,00

Figure 24: Descriptive statistics 1. NM

time between the two hospitals, according to the Mann Whitney U test. This difference is partly due to the amount of activities measured in the process step between the hospitals, which is explained in the discussion in Chapter 6.

4.2.2.2 Medication preparation

There is no data available on the throughput time of this second process step for the group 'new medication'. Therefore, the analysis of the 'Medication preparation' step only consists of the group 'recurrent medication'.

Recurrent medication

The boxplots and descriptive statistics of the 'recurrent medication' group for the 'Medication preparation' process step are visualized in Figures 25 & 26. The average throughput time is 13 minutes for Isala, with sample size 6, and 11 minutes for Rijnstate, with sample size 21. There is not a significant difference found between the distribution of these two groups.

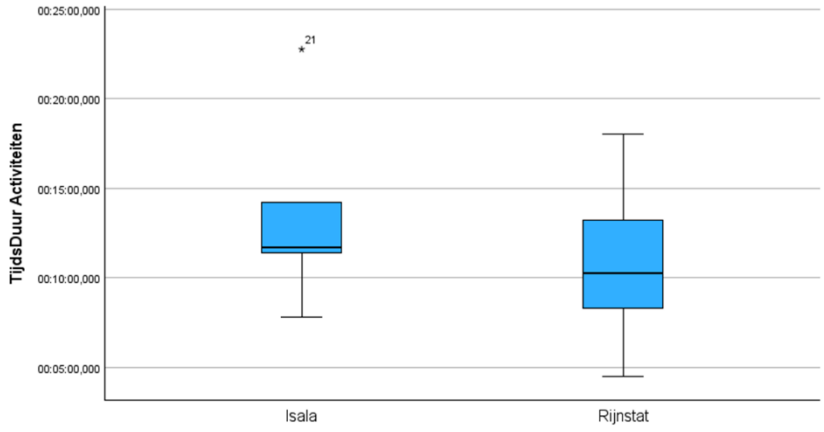

Figure 26: Boxplot biologicals 2

Throughput time:		Isala	Rijnstate
N	Valid	6	21
	Missing	0	0
Mean		0:13:16,67	0:10:34,57
Median		0:11:43,00	0:10:16,99
Std. Deviation		0:05:04,79	0:03:48,51
Minimum		0:07:50,00	0:04:29,00
Maximum		0:22:46,00	0:18:01,00

Figure 25: Descriptive statistics 2

4.2.2.3 Delivery – Handover

There is no significant difference between the 'new medication' and 'recurrent medication' groups for the third process step of the biologicals pathways. Therefore, this distinction is not made in the analysis of this process step. Figures 27 & 28 show the boxplots and descriptive statistics for this process step. The average throughput time for Isala in this third process step is 4 minutes, with a sample size of 8, for Rijnstate this is 6 minutes, with a sample size of 39. These differences in

throughput time are significant and the amount of activities measured in the complete process steps are similar.

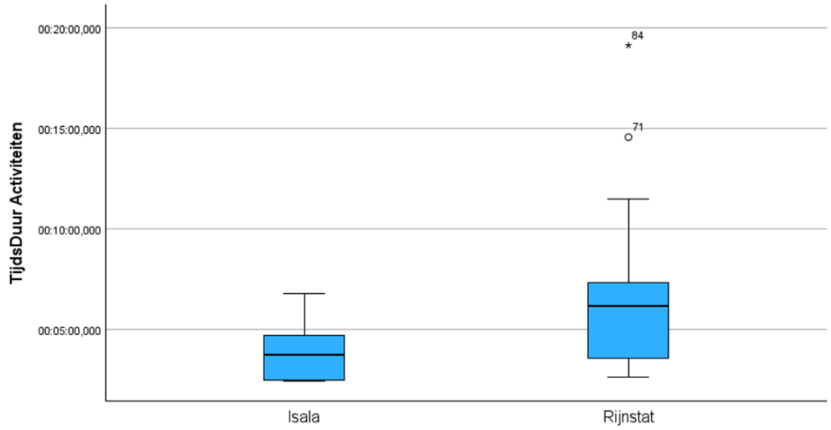

Figure 28: Boxplot biologicals 3

Throughput time: **Isala** **Rijnstate**

N	Valid	8	39
	Missing	0	0
Mean		0:03:53,37	0:06:16,21
Median		0:03:45,50	0:06:08,99
Std. Deviation		0:01:31,52	0:03:19,51
Minimum		0:02:25,00	0:02:36,00
Maximum		0:06:46,00	0:19:08,00

Figure 27: Descriptive statistics 3

4.3 Conclusion

This chapter discusses the data analysis by comparing every process step and application type separately. The data is visualized using boxplots and tables, to give a clear view of the gathered data. These findings provide valuable insights into the time spent per process step by healthcare workers for a PMAaH pathway.

An observation of the results shows a lack of data from certain hospitals in specific process steps and/or application types. As a consequence, it is often not possible to compare the process steps across all three hospitals, which was the goal of this quantitative part of the research. This was already known beforehand for some cases, as Máxima MC does not prepare their own antibiotics medication, for example. It was not known that Máxima MC did not gather any data for their biologicals PMAaH pathway and the amount of completely measured process steps is lower than expected for some groups.

This reflects on the results that are found in the data, as in only three comparisons of the average throughput time a significant difference was found. It is visualized in Table 5 in blue, where the average throughput times are also displayed. These significant differences have an underlying influencing factor, which is the frequency of the measured activities in the process step. This is discussed in Chapter 6.

*Table 5: The average throughput time per process step per application type displayed in u:mm:ss. *Red = No complete process step measured, Orange = Less than 5 complete process steps measured, Green = 5 or more complete process steps measured, Blue marked = significant difference in throughput time for a 5% significance level.*

Process step	1. NM	1. RM	2. NM	2. RM	3.NM	3.RM	4		5	
Isala – antibiotics	0:36:58	0:30:11	0:14:43							
Rijnstate – antibiotics	0:43:47	0:06:54	0:12:45		0:25:27	0:12:53				
MMC – antibiotics	0:52:10	0:12:27			0:12:09	0:07:14				
Isala – biologicals	0:03:41	0:02:27		0:13:17	0:03:53		0:22:09		1:07:21	
Rijnstate – biologicals	0:16:51	0:10:44		0:10:35	0:06:16					
MMC – biologicals										

The found differences in throughput time still give an indication of the time spent per process step, although most differences are not significant. This provides valuable insights for comparing the efficiency of the pathways across the three hospitals in Chapter 5. However, it is essential to acknowledge the limitations of the dataset and the lack of statistically significant conclusions that can be drawn.

5 Conclusion & recommendations

This chapter summarises the results of this study by combining the conclusions of the analysis of the swimlane diagrams and the data analysis. This is described in Section 5.1, after which Section 5.2 gives a recommendation about the continuation of this research.

5.1 Conclusion on PMAaH pathways

The main goal of this study was identifying major differences between the PMAaH pathways of the three hospitals and give recommendations for improvements related to the efficiency of these pathways. Identifying major differences and providing recommendations on the PMAaH pathways is based on two underlying research perspectives. One perspective is comparing the swimlane diagrams of the antibiotics pathways to each other and the swimlane diagrams of the biologicals to each other based on the involved professions, sequence of activities and amount of activities. The other perspective is a more quantitative view on the PMAaH pathways, in which the throughput time of process steps in the logistic process of the PMAaH pathways is compared between the three hospitals. This resulted in comparable quantitative data of the working hours spent by healthcare professionals per patient per process step.

This section takes both perspectives into account and derives conclusions and recommendations based on possible causal relations between the two data types. It is important to note that in most cases the throughput time of process steps in the hospitals did not result in significant differences between the hospitals, mostly due to the small data set of some hospitals. Therefore, it is not possible to draw conclusions with certainty, but the conclusions and recommendations in this section still provide practical insights into the differences in the PMAaH pathways between the hospitals. Section 5.1.1 discusses the conclusions for the antibiotics PMAaH pathways per process step, after which Section 5.1.2 provides these insights for the biologicals PMAaH pathways. Lastly, Section 5.1.3 discusses the recommendations that follow from the drawn conclusions.

5.1.1 Antibiotics PMAaH

The process step ‘Order processing’ for ‘new medication’ has an average throughput time of 37 minutes for Isala, 44 minutes for Rijnstate, and 52 minutes for Máxima MC, although these differences cannot be labelled significant. The amount of professions that are involved in this process step is 2 in Isala, 3 in Rijnstate, and 4 in Máxima MC. The data indicates a possible relation between the amount of involved professions and the average throughput time in a process step, which is in this case that less involved professions reduce the average throughput time. This is a correlation that could be beneficial for the hospital to research further. The amount of activities in this process step is similar for the three hospitals, which does not indicate a relation. There are also no relations identified in the group ‘recurrent medication’, as the data on throughput time is very minimal.

The analysis of the second process step ‘Medication preparation’ is only applicable to Isala and Rijnstate, as Máxima MC outsources this step. Isala has an average throughput time of 15 minutes and Rijnstate has 13 minutes, while in Isala 5 professions are involved in this process step and in Rijnstate 4. This again indicates a potential correlation between the number of involved professions and the average throughput time of a process step.

The third process step ‘Delivery – Handover’ again indicates a correlation between number of involved professions and the average throughput time in the ‘new medication’ and in the ‘recurrent medication’ group. Rijnstate has two involved professions in this step, whereas Máxima MC only has 1. In the ‘new medication group the average throughput time is 25 minutes for Rijnstate compared to 12 minutes for Máxima MC. This differences was confirmed as a significant difference. In the ‘recurrent medication’ group the throughput time is 13 minutes for Rijnstate and 7 minutes for Máxima MC.

5.1.2 Biologicals PMAaH

The biologicals pathways in this section are only compared for Isala and Rijnstate, as Máxima MC does not have data on the throughput time of its process steps, and only comparing the swimlane diagrams does not yield interesting insights, as the differences in the diagrams of the hospitals are minimal. There are differences in the diagrams, like the number of professions involved and the amount of activities per process step, but the latter is largely due to the level of detail of information that the hospitals provided about their biologicals PMAaH pathways. The first three process steps of

Isala include only 12 activities compared to 23 in Rijnstate and 17 in Máxima MC, but the expert focus group of mProve did not asses this as a relevant difference.

The throughput time in the step ‘Order processing’ is 4 minutes for Isala and 17 minutes for Rijnstate in the group ‘new medication’. For ‘recurrent medication’ there was a significant difference in the throughput time between the hospitals with an average of 2 minutes for Isala and 11 minutes for Rijnstate. A factor influencing these differences in throughput time is highlighted in the discussion in Chapter 6. Therefore, the conclusions drawn in this section are not hard conclusions, as mentioned earlier. There are 3 involved professions in this process step for Rijnstate, while there are 2 for Isala. This indicates the positive correlation between the amount of professions involved and the length of the average throughput time in a process step, similar to the correlation mentioned for the antibiotics pathways.

The measured average throughput times for the ‘Medication preparation’ step in the ‘recurrent medication’ group are 13 minutes for Isala and 11 minutes for Rijnstate. This are similar numbers, but the amount of professions involved are different. In Isala there are 2 professions involved compared to 5 at Rijnstate. There are no correlations identified for this process step.

The step ‘Delivery – Handover’ indicates the existence of the positive correlation between involved professions and length of average throughput time again. The average throughput time is 4 minutes for Isala, with only 1 profession involved. Compare this to Rijnstate, where the throughput time is 6 minutes with 3 professions involved. The difference in throughput time is not due to coincidence, as was confirmed by a statistical test.

5.2 Recommendations

The returning common denominator of the previous sections is the identified possible positive correlation between the length of the average throughput time and the number of profession involved in a process step. Involving multiple professions in the PMAaH pathway could lead to delays in the total processing time, as the number of handoffs is increased (Tasi et al., 2021). A handoff means in this context the transfer of patient information and/or knowledge (Tasi et al., 2021). The recommendation for the mProve hospitals is to further research this correlation to improve the efficiency of the PMAaH pathways.

6 Discussion

This chapter discusses the complexities and limitations of this research. This research is a pilot study, which utilized a measuring tool that was specifically developed for this study. This digital registration tool called 'PowerApp' had to be implemented across the three participating hospitals, which was more successful in the one than in the other. As a consequence, the datasets that the hospitals provided was of varying quality, which resulted in limitations and complexities for the results and recommendations in this study. Therefore, this study should be seen as an exploratory research, which should shape the further continuation of researching the efficiency of the PMAaH pathways in the mProve hospitals. Section 6.1 discusses the reliability and validity of the dataset, after which Section 6.2 provides insights into the implications of the small dataset. Lastly, Section 6.3 delves into ideas and recommendations for further research, based on the complications mentioned before.

6.1 Reliability and validity

An instrument is reliable when it supplies consistent results (Cooper & Schindler, 2014). This implies that reliable research would get the same results over and over again, when the same methodology is used again. An observed factor that influences this consistency is the completion of a measurement quite some time after carrying out the activity by a healthcare worker, based on their estimation of the time spent on the activity. This was due to the 'PowerApp' malfunctioning occasionally, which would delete or stop the measured time, which resulted in the healthcare worker filling in the time manually in the app, based on memory. The filling in of the time manually also happened due to healthcare workers being busy, as it was more convenient for them to fill it in later. This influences the reliability of the measurements negatively, because in estimating durations people are influenced by many physical, cognitive and contextual factors (Castellotti et al., 2022). This situation only occurred occasionally, and therefore the influence on the reliability of the results is limited.

The internal validity is the extent to which results represent the truth in the research population (Cooper & Schindler, 2014). The goal of measuring the throughput time of the activities in the PMAaH pathways was to get insights into the total time spent by healthcare workers on the logistics of the process. The hospitals had different procedures for their PMAaH pathways, but a structure consisting of five process steps was created to be able to measure different parts of the process. These process steps were subdivided into activities, which are hospital specific, but activities with the same objective fall under a general activity name in the subdivision of the process steps. This list of general activities per process step can be found in Appendix A.

The data analysis methodology in Chapter 3 describes the minimum required measured activities per process step for a complete process step measurement. The minimum required activities for the 'Medication preparation' and 'Delivery – Handover' process step were determined by an expert group of the mProve hospitals, like the other process steps, based on the importance of the activity in the process step. There were no minimum required activities in the first process step 'Order processing', as the expert group determined that there was not one activity that was of significant more importance than the others. This approach for determining a completely measured process step has complications for the validity of the research, as this results in variance in the amount of activities measured per completed process step, which results in a larger variance in the measured throughput times for a process step.

This treat to internal validity is predominantly observed in the 'Order processing step' of the biologicals PMAaH pathway. The differences in average throughput time are relatively large between Isala and Rijnstate for this process step in the 'new medication' group, as well as in the 'recurrent medication' group. The difference in throughput time in the 'recurrent medication' group is even significantly different. The relatively low throughput time of this process step in Isala can be due to Isala having a more efficient process, but there are also other factors that influence this measured time. Table 13 in Appendix D shows the frequency of a specific activity occurring in a complete process step for 'Order processing' in the 'recurrent medication' group. A notable difference is that Isala only measured activity 1.21 in this process step, for all 13 of their complete process steps, while Rijnstate measured more activities on average for a complete process step. Isala implemented the digital registration tool not in all departments that had a role in the 'Order processing' step, and therefore only measured activity 1.21, which resulted in the measurement of this activity being the total throughput time for the completed process steps. The impact of this underlying problem in the data analysis approach is

severe, which challenges the internal validity of the research for this process step. The other tables in Appendix D display the frequency tables of the other process steps and groups. This treat to internal validity is also observed in other process step, but less severe and notable.

6.2 Size of the dataset

A severe limitation in this research was the small size of the dataset that was utilized for the quantitative part of this study. For some groups there were even no complete process steps available, which made it impossible to compare the PMAaH pathways across all three hospitals for some process steps. In some cases this was known beforehand, like the missing data on the biologicals PMAaH pathway of Máxima MC. It was not known that Isala had no complete data on the third process step 'Delivery – Handover'. Isala had measured activities in this process step, but it missed certain activities that were labelled as a minimal requirement, which meant that all measured process steps were incomplete. A substantial amount of data on process steps was lost also in other process steps, as a result of missing activities that were labelled as minimal requirement. This was necessary to be able to compare the throughput times of process steps, as the comparison would otherwise not be valid, because then the throughput time of a process step would primarily depend on the amount of activities measured.

Another limitation of a small dataset is showing that populations are significantly different from each other (Cao et al., 2024). This was also a consequence of the small sample size in this research, as in only three cases a statistically significant difference could be found between populations. This can be seen in Table 5 of Chapter 4. A bigger sample size would have increased the power of the statistical test and would be likely to have found more significant differences between populations. The result of the small sample size is that some conclusions drawn in this research have no statistical underlying basis, while this would likely be the case with a bigger sample size.

The cause for this small sample size is due to the implementation of the 'Power App' in the hospitals, which went better in the one hospital compared to the other. There were complications with registering the measurements, as there are a lot of different departments and employees involved in the PMAaH pathways. This hampered registering throughput times for all activities across the whole process, especially in Isala and Máxima MC. As a result of complications in the implementation of the digital registration tool, some departments did not participate, which led to missing activities. The implementation in Rijnstate went quite well, which resulted in a substantial higher amount of measured activities for this hospital compared to Isala and Máxima MC, as can be seen in Table 3 in Chapter 4.

6.3 Future research

The evaluation of this study by the expert group concluded that the results of the PowerApp did not weigh up against the effort that needs to be put into the implementation of the tool. Therefore, the study should not be continued across all seven mProve hospitals using this methodology, which would have been the next step in the case of a positive evaluation. A continuation of research into the efficiency of PMAaH pathways should focus on using process mapping as methodology for improving PMAaH pathways. Process mapping is a methodology to identify improvement opportunities in healthcare processes (Antonacci et al., 2018). This builds on the BPM part of this research, by mapping out the processes in the PMAaH pathways in detail and discussing these with stakeholders to get an accurate view of the PMAaH pathways. These process maps are then discussed in focus groups with other representatives of the mProve hospitals, to discuss the advantages and disadvantages of their approaches and learn from each other. This methodology reduces the effort that needs to be made by healthcare professionals in the hospitals, while the results of this research could significantly improve the efficiency of the PMAaH pathways across the mProve hospitals.

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8 Appendix

8.1 Appendix A

Table 6: List of activities and numbers per process step as listed in 'PowerApp'

Process Step	Activity	Number
1. Order processing	Patient registration	1.1
	Check prescription/treatment plan	1.2
	Contact outpatient pharmacy	1.3
	Arrange infusion form	1.4
	Arrange concentration determination	1.5
	Arrange specialized home care	1.6
	Order medication & materials	1.7
	Administration (reference, POINT, care agreement, etc.)	1.8
	Inform nurse/secretary department	1.9
	Inform patient	1.10
	Check if patient is being discharged	1.11
	Contact transmural care	1.12
	Process medication changes	1.13
	Process policy changes	1.14
	Check concentration	1.15
	Plan preparations	1.16
	Send prescription (+ planning) to preparations first time	1.17

	Send prescription (+ planning) to preparations follow-up	1.18
	Prepare instructions	1.19
	Plan route for patient visits	1.20
	Read patient information	1.21
2. Medication preparation	Receive prescription and forward to preparations	2.1
	Develop treatment plan	2.2
	Check first course	2.3
	Answer questions	2.4
	Prepare	2.5
	Prepare medication	2.6
	Place in quarantine	2.7
	Preliminary release preparation	2.8
	Release preparation	2.9
	Arrange transport to delivery location	2.10
3. Delivery - handover	Prepare medication for patient (incl. home instructions)	3.1
	Delivery conversation	3.2
	Arrange medication transport	3.3
	Double check medication	3.4
	Deliver course	3.5
	Check preparation and delivery planning for follow-up	3.6

	Collect medication in outpatient pharmacy	3.7
4. Medication transport	Transport medication to home	4.1
	Transport medication to department	4.2
5. Administration	Check if treatment plan is present	5.1
	Start-up	5.2
	Prepare medication for administration	5.3
	Double check medication	5.4
	Double check infusion	5.5
	First administration according to protocol	5.6
	Repeat administration according to protocol	5.7
	Administration registration	5.8
	Care for infusion line	5.9
	Measure blood pressure, pulse, and temperature in patient	5.10
	Register control in EHR	5.11

8.2 Appendix B

My research requires to obtain data about the PMAaH pathways of antibiotics and biologicals. The healthcare workers register the throughput time and quality registration of the process in the data registration tool. These variables are registered for every subprocess that is executed by a hospital worker. The hospital workers register the data based on the patient that they are executing the subprocess for. Patient data as well as data of the healthcare worker executing the subprocess is stored. This causes confidentiality issues, because the data of the participants of the research has to be anonymous for the researchers, but the data also has to be made public available and be described as transparent as possible. This concerns codes 3.11, 3.23 and 3.26 of the “Netherlands Code of Conduct for Research Integrity” (Netherlands Code of Conduct for Research Integrity, 2018).

The solution for tackling this confidentiality and transparency problem is anonymizing the obtained data. The data is registered per hospital in a closed IT-environment. The name of the healthcare workers and their function are stored and for the patient only the street number, First name, and age. Based on this data the healthcare workers are able to register the throughput time and quality registration for the right patient, but the people with access to the IT-environment don’t know the identity of the patient. In this IT-environment the data is further anonymized by giving all the patients a random number, instead of the patient’s data, and by removing the names of the healthcare workers. The encrypted results of this are exported to a mProve cloud, from where the data is provided to me as the researcher. This research design allows me as a researcher to keep the data of the participants confidential, while also being able to publish the data used in my research.

8.3 Appendix C

240447 REQUEST FOR ETHICAL REVIEW

FACULTY BMS

Request nr: 240447

Researcher: Kremer, M.H.F. Supervisor: Rachuba, S. Reviewer: Rogetzer, P.B.

Status: Approved by commission

Version: 2

The BMS ethical committee / Domain Humanities & Social Sciences has assessed the ethical aspects of your research project. On the basis of the information you provided, the committee does not have any ethical concerns regarding this research project. It is your responsibility to ensure that the research is carried out in line with the information provided in the application you submitted for ethical review. If you make changes to the proposal that affect the approach to research on humans, you must resubmit the changed project or grant agreement to the ethical committee with these changes highlighted.

Moreover, novel ethical issues may emerge while carrying out your research. It is important that you re- consider and discuss the ethical aspects and implications of your research regularly, and that you proceed as a responsible scientist.

Finally, your research is subject to regulations such as the EU General Data Protection Regulation (GDPR), the Code of Conduct for the use of personal data in Scientific Research by VSNU (the Association of Universities in the Netherlands), further codes of conduct that are applicable in your field, and the obligation to report a security incident (data breach or otherwise) at the UT.

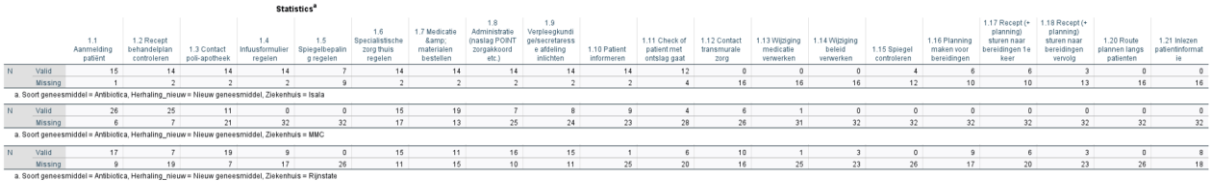
8.4 Appendix D

8.4.1 Antibiotics

8.4.1.1 Order processing

New medication

Table 7: Frequency table measured activities in antibiotics 1. NM

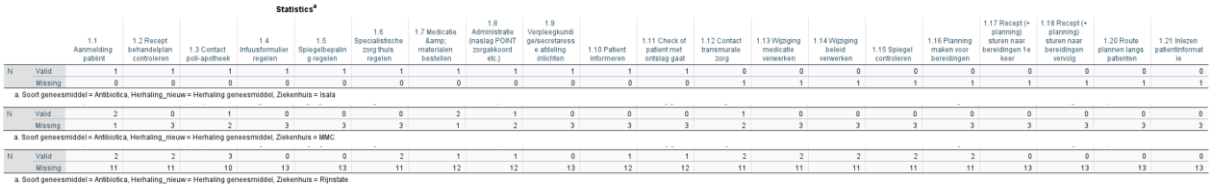


Statistics[a]

		1.1 Aanmelding patiënt	1.2 Recept behandelplan controleren	1.3 Contact poli-apotheek	1.4 Infuusformulier regelen	1.5 Spiegelbepaling regelen	1.6 Specialistische zorg thuis regelen	1.7 Medicatie & materialen bestellen	1.8 Administratie (naslag POINT zorgakkoord etc.)	1.9 Verpleegkundi ge/secretaress e afdeling inlichten	1.10 Patient informeren	1.11 Check of patient met ontslag gaat	1.12 Contact transmurale zorg	1.13 Wijziging medicatie verwerken	1.14 Wijziging beleid verwerken	1.15 Spiegel controleren	1.16 Planning maken voor bereidingen	1.17 Recept (+ planning) sturen naar bereidingen 1e keer	1.18 Recept (+ planning) sturen naar bereidingen vervolg	1.20 Route plannen langs patiënten	1.21 Inlezen patientinformatie
N	Valid	15	14	14	14	7	14	14	14	14	14	12	0	0	0	4	6	6	3	0	0
	Missing	1	2	2	2	9	2	2	2	2	2	4	16	16	16	12	10	10	13	16	16
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = Isala																					
N	Valid	26	25	11	0	0	15	19	7	8	9	4	6	1	0	0	0	0	0	0	0
	Missing	6	7	21	32	32	17	13	25	24	23	28	26	31	32	32	32	32	32	32	32
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = MMC																					
N	Valid	17	7	19	9	0	15	11	16	15	1	6	10	1	3	0	9	6	3	0	8
	Missing	9	19	7	17	26	11	15	10	11	25	20	16	25	23	26	17	20	23	26	18
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = Rijnstate																					

Recurrent medication

Table 8: Frequency table measured activities in antibiotics 1. RM



Statistics[a]

		1.1 Aanmelding patiënt	1.2 Recept behandelplan controleren	1.3 Contact poli-apotheek	1.4 Infuusformulier regelen	1.5 Spiegelbepaling regelen	1.6 Specialistische zorg thuis regelen	1.7 Medicatie & materialen bestellen	1.8 Administratie (naslag POINT zorgakkoord etc.)	1.9 Verpleegkundi ge/secretaress e afdeling inlichten	1.10 Patient informeren	1.11 Check of patient met ontslag gaat	1.12 Contact transmurale zorg	1.13 Wijziging medicatie verwerken	1.14 Wijziging beleid verwerken	1.15 Spiegel controleren	1.16 Planning maken voor bereidingen	1.17 Recept (+ planning) sturen naar bereidingen 1e keer	1.18 Recept (+ planning) sturen naar bereidingen vervolg	1.20 Route plannen langs patiënten	1.21 Inlezen patientinformatie
N	Valid	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
	Missing	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = Isala																					
N	Valid	2	0	1	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0
	Missing	1	3	2	3	3	3	1	2	3	3	3	2	3	3	3	3	3	3	3	3
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = MMC																					
N	Valid	2	2	3	0	0	2	1	1	0	1	1	2	2	2	2	2	0	0	0	0
	Missing	11	11	10	13	13	11	12	12	13	12	12	11	11	11	11	11	13	13	13	13
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = Rijnstate																					

8.4.1.2 Medication preparation

Table 9: Frequency table measured activities in antibiotics 2

Statistics[a]

		2.1 Recept ontvangen en doorsturen naar bereidingen	2.2 Uitwerken behandelplan	2.4 Vragen beantwoorden	2.5 Voorbereiden	2.6 Medicatie bereiden	2.7 In quarantaine plaatsen	2.8 Bereiding voorlopige vrijgifte	2.9 Bereiding vrijgeven	2.10 Regel transport naar afleverlocatie
N	Valid	0	0	0	1	1	0	0	1	0
	Missing	1	1	1	0	0	1	1	0	1
a. Soort geneesmiddel = Antibiotica, Ziekenhuis = Isala										
N	Valid	0	0	1	15	15	10	0	15	0
	Missing	15	15	14	0	0	5	15	0	15
a. Soort geneesmiddel = Antibiotica, Ziekenhuis = Rijnstate										

8.4.1.3 Delivery – Handover

New medication

Table 10: Frequency table measured activities in antibiotics 3. NM

Statistics[a]

		3.1 Medicatie klaarmaken voor patient (incl. instructie voor thuis)	3.2 Uitgifte gesprek	3.3 Medicatie transport regelen	3.4 Dubbele controle medicatie	3.5 Kuur afleveren	3.6 Controleer planning bereiding en bezorging vervolglevering	3.7 Ophalen medicatie in poli-apotheek
N	Valid	8	0	0	0	3	2	3
	Missing	0	8	8	8	5	6	5
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = MMC								
N	Valid	7	0	1	7	4	4	0
	Missing	0	7	6	0	3	3	7
a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = Rijnstate								

Recurrent medication

Table 11: Frequency table measured activities in antibiotics 3. RM

Statistics[a]

		3.1 Medicatie klaarmaken voor patient (incl. instructie voor thuis)	3.2 Uitgifte gesprek	3.3 Medicatie transport regelen	3.4 Dubbele controle medicatie	3.5 Kuur afleveren	3.6 Controleer planning bereiding en bezorging vervolglevering	3.7 Ophalen medicatie in poli-apotheek
N	Valid	1	1	0	0	0	1	0
	Missing	0	0	1	1	1	0	1

a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = MMC

N	Valid	29	0	0	29	12	17	0
	Missing	0	29	29	0	17	12	29

a. Soort geneesmiddel = Antibiotica, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = Rijnstate

8.4.2 Biologicals

8.4.2.1 Order processing

New medication

Table 12: Frequency table measured activities in biologicals 1. NM

Statistics[a]

		1.1 Aanmelding patiënt	1.2 Recept behandelplan controleren	1.3 Contact poli-apotheek	1.4 Intuusformulier regelen	1.5 Spiegelbepaling regelen	1.6 Specialistische zorg thuis regelen	1.7 Medicatie & materialen bestellen	1.8 Administratie (naslag POINT zorgakkoord etc.)	1.9 Verpleegkundige/secretaresse afdeling inlichten	1.10 Patient informeren	1.11 Check of patient met ontslag gaat	1.12 Contact transmurale zorg	1.13 Wijziging medicatie verwerken	1.14 Wijziging beleid verwerken	1.15 Spiegel controleren	1.16 Planning maken voor bereidingen	1.17 Recept (+ planning) sturen naar bereidingen 1e keer	1.18 Recept (+ planning) sturen naar bereidingen vervolg	1.20 Route plannen langs patiënten	1.21 Inlezen patiëntinformatie
N	Valid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Missing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0

a. Soort geneesmiddel = Biological, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = Isala

N	Valid	7	1	0	0	0	0	0	0	0	5	0	0	0	1	0	1	0	0	3	0
	Missing	0	6	7	7	7	7	7	7	7	2	7	7	7	6	7	6	7	7	4	7

a. Soort geneesmiddel = Biological, Herhaling_nieuw = Nieuw geneesmiddel, Ziekenhuis = Rijnstate

Recurrent medication

Table 13: Frequency table measured activities in biologicals 1. RM

Statistics[a]

		1.1 Aanmelding patiënt	1.2 Recept behandelplan controleren	1.3 Contact poli-apotheek	1.4 Intuusformulier regelen	1.5 Spiegelbepaling regelen	1.6 Specialistische zorg thuis regelen	1.7 Medicatie & materialen bestellen	1.8 Administratie (naslag POINT zorgakkoord etc.)	1.9 Verpleegkundige/secretaresse afdeling inlichten	1.10 Patient informeren	1.11 Check of patient met ontslag gaat	1.12 Contact transmurale zorg	1.13 Wijziging medicatie verwerken	1.14 Wijziging beleid verwerken	1.15 Spiegel controleren	1.16 Planning maken voor bereidingen	1.17 Recept (+ planning) sturen naar bereidingen 1e keer	1.18 Recept (+ planning) sturen naar bereidingen vervolg	1.20 Route plannen langs patiënten	1.21 Inlezen patiëntinformatie
N	Valid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
	Missing	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	0

a. Soort geneesmiddel = Biological, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = Isala

N	Valid	23	15	0	0	0	2	0	11	0	45	0	0	1	5	0	40	0	9	43	0
	Missing	62	70	85	85	85	83	85	74	85	40	85	85	84	80	85	45	85	76	42	85

a. Soort geneesmiddel = Biological, Herhaling_nieuw = Herhaling geneesmiddel, Ziekenhuis = Rijnstate

8.4.2.2 Medication preparation

Recurrent medication

Table 14: Frequency table measured activities in biologicals 2. RM

Statistics[a]

		2.1 Recept ontvangen en doorsturen naar bereidingen	2.2 Uitwerken behandelplan	2.4 Vragen beantwoorden	2.5 Voorbereiden	2.6 Medicatie bereiden	2.7 In quarantaine plaatsen	2.8 Bereiding voorlopige vrijgifte	2.9 Bereiding vrijgeven	2.10 Regel transport naar afleverlocatie
N	Valid	0	0	0	6	6	3	3	6	0
	Missing	6	6	6	0	0	3	3	0	6

a. Soort geneesmiddel = Biological, Ziekenhuis = Isala

N	Valid	0	21	0	21	21	7	0	21	5
	Missing	21	0	21	0	0	14	21	0	16

a. Soort geneesmiddel = Biological, Ziekenhuis = Rijnstate

8.4.2.3 Delivery – Handover

Table 15: Frequency table measured activities in biologicals 3

Statistics[a]

		3.1 Medicatie klaarmaken voor patient (incl. instructie voor thuis)	3.2 Uitgifte gesprek	3.3 Medicatie transport regelen	3.4 Dubbele controle medicatie	3.5 Kuur afleveren	3.6 Controleer planning bereiding en bezorging vervolglevering	3.7 Ophalen medicatie in poli-apotheek
N	Valid	8	0	2	8	2	6	8
	Missing	0	8	6	0	6	2	0

a. Soort geneesmiddel = Biological, Ziekenhuis = Isala

N	Valid	39	0	0	39	13	6	0
	Missing	0	39	39	0	26	33	39

a. Soort geneesmiddel = Biological, Ziekenhuis = Rijnstate

8.5 Appendix E

8.5.1 Medication transport

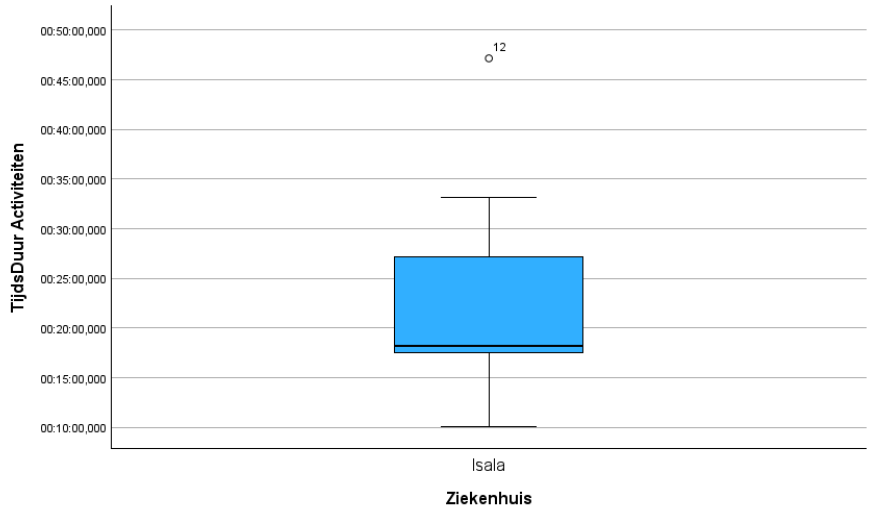


Figure 29: Boxplot biologicals 4

Throughput time: **Isala**

N	Valid	13
	Missing	0
Mean		0:22:09,46
Median		0:18:14,00
Std. Deviation		0:10:15,81
Minimum		0:10:04,99
Maximum		0:47:08,00

Figure 30: Descriptive statistics 4

8.5.2 Administration

Figure 32: Boxplot biologicals 5

Throughput time: **Isala**

N	Valid	13
	Missing	0
Mean		1:07:21,38
Median		1:06:31,00
Std. Deviation		0:06:33,65
Minimum		0:57:21,00
Maximum		1:21:06,99

Figure 31: Descriptive statistics 5