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LOGISTICS IMPLEMENTATION OF COLON SURGERY IN DAY-CARE AT MEDISCH SPECTRUM TWENTE

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PREFACE

The thesis “logistics implementation of colon surgery in day-care at MST” is the final assignment done to graduate from the Bachelor Industrial Engineering and Management at the University of Twente. The thesis is conducted at Medisch Spectrum Twente. The goal of the thesis is to get insight in the logistics operations changes needed for implementing colon surgery in day-care and to calculate the costs of the implementation for the MST.

Firstly, I would like to thank my first supervisor Derya Demirtas. Her expertism and enthusiasm on healthcare logistics has helped me a lot during meetings and discussions to get the most out of this bachelor thesis. Also, I would like to thank Patricia Rogetzer for being my second supervisor. She gave me extensive feedback that improved the thesis a lot.

Secondly, I want to give a special thanks to my supervisors Annemieke Witteveen and Daan Lips. Both guided me during my research and always helped me in case it was needed. I thoroughly enjoyed working with them. In addition to that, I want to thank all employees of the MST that supported me in this research.

Kind regards,

Lars Lubbers

Enschede, November 2022

MANAGEMENT SUMMARY

The research takes place at the surgery department at the Medisch Spectrum Twente hospital in Enschede, the Netherlands. In the upcoming years, it is expected that there will be more cases of colon surgery in the upcoming years in the Netherlands since colon surgeries are most prevalent with elderly people. Currently, the number of people in this age group is increasing due to the general aging of the Dutch population (CBS, 2022). This leads to more patients being hospitalized. In the current situation, after colon surgery all patients stay for on average 3.7 days in the hospital to recover and monitor complications. This is a comparatively long time as 50-70% of patients do not have any complications. So, they remain at the hospital unnecessarily. This is a disadvantage for both the hospital and patients as more beds are occupied and patients do recover better at home (Hentenaar & Demmer, 2021). A solution for this is implementing day-care for some colon surgery patients (CID). However, currently the logistics operations changes needed to implement CID are still unknown. In this research these logistics operations changes and their associated costs are evaluated.

The aim of this thesis is on providing an overview of logistics implementations needed for performing colon surgery in day-care and subsequent in-home monitoring instead of a three-day hospital recovery and a cost-benefit analysis on the potential results of this implementation. To achieve this the following research question is formulated: *Which logistics operations changes are needed to implement day-care for colon surgery and what does it cost Medisch Spectrum Twente?*

In this study, the first step is to create an overview of the current situation and the desired situation with CID. When comparing these situations, the logistics changes needed to transition to CID are evaluated. Following this, experts assist in choosing the best possible way of implementing these changes. To be able to give an insight into the project set-up costs the logistic changes are then programmed into a Monte Carlo simulation and are also put into a sensitivity analysis. Finally, these results are used to give a conclusion on the viability of CID.

The main result is that the cost of introducing CID is approximately €37,000.00 . This is calculated in the Monte Carlo simulation dashboard. The main cost reduction comes from patients occupying hospital beds for a shorter period after surgery. The main costs involved are the set-up of the monitoring centre, the monitoring equipment, the extra policlinic time slots needed and the slight increase in rehospitalization rate. Furthermore, the sensitivity analysis showed that CID was very susceptible to upscaling as it became significantly more profitable when more patients are using CID. This is mainly due to the fixed costs that are made for the monitoring centre and equipment.

As a conclusion, the logistics changes needed to transition to CID are the set-up of a monitoring centre and finding a suitable supplier for the remote monitoring, hiring, or assigning staff for the monitoring centre and increasing the available timeslots for the policlinic. The choice for a monitoring centre is to have a monitoring centre in the MST itself instead of a regional monitoring centre or nurses checking the monitoring during their regular shifts. The needed remote monitoring is either from Masimo or Luscii. These are two companies that provide remote monitoring for hospital use. Furthermore, to implement CID it is needed to reserve extra timeslots at the policlinic. This can be either one or two extra timeslots per patient. According to the simulation, the cost of introducing everything is approximately €37,000. Due to the potential for upscaling at the monitoring centre, it is recommended to investigate which other surgery types can make use of remote monitoring.

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READER'S GUIDE

In eight chapters, it is explained how the research at Medisch Spectrum Twente is performed. In this reading guide all chapters are introduced briefly.

CHAPTER 1: INTRODUCTION

The first chapter introduces the organization and explains the motivation for the research. Also, in this chapter the research methodology, the research questions, and the scope are described.

CHAPTER 2: CONTEXT ANALYSIS

The second chapter is about the current situation and the desired situation. Firstly, the current situation is discussed. Secondly, the desired situation is discussed. Then, the problems areas of transitioning from the current situation to the desired situation are mentioned. Lastly, the relevance of transitioning to the desired situation are explained.

CHAPTER 3: LITERATURE REVIEW

The third chapter includes the literature review. The literature review consists of three parts. Firstly, the Clavien-Dindo classification for complications is researched. Secondly, the method of determining cost in hospitals is researched. Lastly, it is researched what the best way is to estimate the project set-up costs of CID.

CHAPTER 4: DATA ANALYSIS

The fourth chapter includes the data analysis. The first part of the chapter is about the quantitative data analysis of all relevant data from Medisch Spectrum Twente. The second part of the chapter is about the qualitative data gathered via interviews with experts.

CHAPTER 5: EXPERIMENT DESIGN

The fifth chapter is about the experiment design. The first part of the chapter is about the variables chosen for the model. The second part describes how to build the set-up for the dashboard. The last part explains how the sensitivity analysis is performed.

CHAPTER 6: RESULTS

The sixth chapter visualizes the results. In the first part of the chapter, the results of the dashboard are visualized discussed. The results of the dashboard are based on the values found in the data analysis. In the second part, the results of the sensitivity analysis are visualized and discussed.

CHAPTER 7: CONCLUSION, DISCUSSION, AND RECOMMENDATION

The last chapter evaluates and concludes the research. Furthermore, the study is discussed in this chapter. Lastly, recommendations are provided for Medisch Spectrum Twente.

LIST OF ABBREVIATIONS

Acronym	Description
ASA	American Society of Anesthesiologists
BMI	Body Mass Index
Cc	millilitre
CID	Colon surgery In Day-Care
COPD	Chronic obstructive pulmonary disease
ERAS	Enhanced Recovery After Surgery
EWS	Early Warning System
IT	Information Technology
JBZ	Jeroen Bosch Ziekenhuis
MEDAL-C	CID of JBZ
MST	Medisch Spectrum Twente
POD	Post Operative Day
TM	Technical Medicine
WHO	World Health Organisation

Table 1: Acronyms

GLOSSARY

CID	Colon surgery in day-care is defined as sending patients home to recover the day after surgery instead of recovering at the hospital.
Bed-stops	Bed-stops are the moments in which no more patient can be operated due to reaching the hospital's maximum capacity.
Logistics operations	The definition of logistics operations can be defined as many developments, planning and implementation activities that subsequently facilitate more activities, such as purchasing, inventory management, transport management, the goods and services that form part of the overall medical service provided for the patient (Pengyu et al., 2006). The changes consist of the extra services that need to be implemented or can be removed because of CID.

Table 2: Glossary

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1. INTRODUCTION

In the first chapter, there is an introduction of the MST and a problem description relevant for this research. In Section 1.1, an introduction about the MST can be found. In Section 1.2, the motivation behind this research is described. In Section 1.3, the conclusion of this chapter is given.

1.1 INTRODUCTION OF MST

Medisch Spectrum Twente is a hospital located in Enschede in the Netherlands. It is one of the biggest non-academic hospitals in the Netherlands with a reach of approximately 264,000 civilians. Medisch Spectrum Twente was founded in 1990 as a merger of Ziekenzorg and Sint Joseph Stadsmaten in Enschede, the Sint Bernardius hospital in Losser, the Sint Antonius hospital and Heil der Kranken in Oldenzaal. For a long time, Medisch Spectrum Twente had two locations close to one another connected with a footbridge of a few hundred meters long. From 2016 forward, Medisch Spectrum has one location at the Koningsplein in the centre of Enschede (Westerink, 2019).

The MST has approximately 4000 employees of which 240 specialists. The yearly budget is around 350 million euros. At the MST, a large fraction of the medical specialisations is present as well as all basic facilities. In 2014, in total there were 33,000 hospital admissions at the MST (Westerink, 2019).

1.2 RESEARCH MOTIVATION

The initial problem stated by the MST is the long post-surgery recovery time for colon surgery patients when recovering at the hospital. Due to this, the hospital is reaching its bed capacity for recovering patients often. This results in bed stops, which means no more patients can be operated at a certain department. Currently, all patients stay for on average 3.7 days in the hospital to recover after a colon surgery and to monitor the development of complications. This is a comparatively long time as 50-70% of patients do not experience any complications after colon surgery. So, they remain at the hospital unnecessarily. A solution for this is implementing day-care for some colon surgery patients, which is called colon surgery in day-care (CID). However, currently the logistic operation changes needed to implement CID are still unknown. In this research these logistic operations changes and their associated costs are evaluated.

1.2.1 RESEARCH OBJECTIVE

At the current situation, colon surgery patients stay on average for 3.7 days at the MST for recovery and monitoring. Nowadays, 50-70 % of patients have no complications after surgery. Approximately 15% of these patients can be sent home the same day after surgery with remote monitoring devices. To conclude, the difference between norm and reality is that 15% of patients could be sent home the same day to recover while currently they remain in the hospital for on average 3.7 days, while this could be only 1 day. This results in a reduction of 2.7 days. The desired process for 15% of the patients and a more in-depth version of the new process are found in Chapter 2.

To be able to achieve this goal of transitioning to CID it is necessary to first discover what logistic changes are needed to set-up this project and what costs are associated with the implementation.

This leads to the main goal of our research being: *To give insight in the logistic operations changes and costs required to implement CID.*

The secondary goal of the research is: *To calculate the costs of the logistic operations changes required when implementing the desired system compared to the current system.*

To accomplish this the main knowledge problem that needs to be solved is:

Which logistic operations changes are necessary to implement CID and what are its costs?

CID means colon surgery in day-care. This is defined as sending patients home the same day after receiving colon surgery to recover at home. This is achieved by equipping patients with remote monitoring devices which monitor multiple health variables of every patient. This data is sent to the hospital and evaluated.

The definition of logistic operations can be defined as many developments, planning and implementation activities that subsequently facilitate more activities, such as purchasing, inventory management, transport management, the goods and services that form part of the overall medical service provided for the patient (Pengyu et al., 2006). The changes consist of the extra services that need to be implemented or can be removed because of CID.

The current system is described in Section 2.1. The desired system is described in Section 2.2.

The challenge about the decision to implement CID is that it is one of the first initiatives to transition patients from recovering at the hospital to their home. This means that the effectiveness and the consequences of CID are not exactly known in both medical and logistic terms. Due to CID still being in the pilot phase, no data is available on CID patients. This results in most data needing to be researched qualitatively and via multiple various sources to get a complete view and sufficient data of the current situation. Consequently, assumptions can be made about implementing CID to estimate what logistics operations need to be altered and what the associated costs are for the set-up of this project.

1.2.2 RESEARCH QUESTIONS

To reach the goals and answer the knowledge question, several smaller research questions are formed. These research questions form a guideline throughout the thesis to answer the main knowledge question. In Appendix A, several more detailed knowledge questions can be found that assist in answering the research questions below.

Research question 1: What are the differences between the current and desired process of colon surgery?

This question is answered via flow charts of processes and an explanation of the steps taken in both the current process and the desired process for colon surgery. The information used is qualitative data researched via interviews with experts from multiple expertise's and hospitals. The experts involved are from the MST itself, the Jeroen Bosch Ziekenhuis (JBZ) and the Isala hospital in Zwolle. This research question is answered in Chapter 2. The difference between the two processes is taken from earlier research (Bot, 2022) (Raijmakers, 2021).

Research question 2: *Which complications cause rehospitalization after colon surgery?*

This question is answered via a literature review. It is relevant due to unknown safety of CID and to consider when the associated costs for CID are determined, because a significant increase of rehospitalizations when utilising CID is both dangerous and costly.

Research question 3: *Which cost calculation methods for hospitals do exist?*

This question is answered via a literature review. It is relevant to know this to evaluate the costs shown by the hospital and for set-up the Excel cost calculation dashboard. To set-up the Excel dashboard costs needs to be analysed, it is important to know what these costs consist of as these costs are used for the dashboard afterwards.

Research question 4: How can the project set-up costs for CID be calculated?

This question is answered via a literature review. It is relevant to know, because the method chosen to determine the project set-up costs can influence the outcome of the results. Furthermore, this will determine partly what method will be used to calculate the several logistic operations changes scenarios for CID.

Research question 5: What does the current data of the MST show?

This question is answered through a data analysis of all available data in Section 4.1. This includes all needed patient information and the current costs of colon surgery. The results of the data analysis are then visualized in graphs to make the results of the data-analysis more presentable.

Research question 6: Which logistic operations changes can be implemented and how feasible are they?

Firstly, all changes should be noted to make a list that evaluates all options. From this all the non-feasible changes will be eliminated via qualitative interviews. The second part of this question is answered via a literature review. This is research question is answered in Section 4.2.

Research question 7: What input variables are needed for the Excel cost calculation dashboard?

It is important to know what KPIs are of importance to create the dashboard. In addition to that to calculate most of the KPIs current data from the MST needs to be evaluated. In Chapter 5, the exact input KPIs are determined.

Research question 8: What are the results of the Excel cost calculation dashboard and the sensitivity analysis?

In Chapter 6, the results of the Excel dashboard are discussed and visualized. This is done to show the impact of the logistic operations changes and to be able to get quantifiable data on the effectiveness of the logistic operations changes. In addition to that, it gives an overview of the costs that need to be made to implement CID. Furthermore, a sensitivity analysis is performed to give insight in the

Research question 9: Which logistic operations changes are the most suitable for the MST and what does it cost?

All logistic operations changes are determined via expert opinion. These changes are evaluated via the cost calculations. Based on this evaluation recommendations are given to the MST. The answer to this question is given is in Chapter 7 as the conclusion.

1.2.3 RESEARCH SCOPE

Firstly, the research at the MST can quickly become too extensive due to the amount of data available on the surgery department. For example, the costs made for a patient on the nursing department can become too detailed and complex, because of the overhead costs, such as for the building and cooperating employees that never have direct contact with the patients. For that reason, the overhead costs which are a constant variable in this research will not be considered. Furthermore, the overhead costs are a constant variable, because to calculate the costs of CID the changes to the process are calculated instead of calculating the costs of both processes individually. The reason for this is that in the end, calculating the changes between the two processes is equal to the calculating the two processes and then comparing the two processes. So, this research will strictly be about the implementation of CID for colon surgery and the changes required to transition from traditional care to day-care for the suitable patients.

Secondly, identifying what percentage of patients are suitable for CID is not in the scope of this research. This is done by Technical Medicine students, so that percentage for the model is based on their research (Bot, 2022). Over the years that percentage may rise due to more experience with CID. Therefore, this percentage will be an input variable that is easily adjustable in the Excel cost calculation tool, so that it can be changed when new data is available.

1.3 CONCLUSION

The core problem found in this chapter is the current long post-surgery recovery for colon surgery patients. This can be solved by implementing CID as a separate healthcare track for fit patients. The main goal of this research is to give insight in the logistics operations changes required to implement CID. The secondary goal is to calculate the costs when implementing CID in the hospital. The main knowledge problem is: *Which logistics operations changes are needed to implement colon surgery in day-care?* This main knowledge problem is divided into research questions that will each be answered in a chapter. Lastly, the scope of this research is strictly about the logistics changes needed to transition to CID and its associated costs, as to not make it too extensive.

2. CONTEXT ANALYSIS

In this chapter, there is an analysis of the current situation at the MST. To produce the logistic operations changes needed, a thorough overview of the current process and desired process are needed to determine what needs to be changed. The main research question answered in this chapter is: *What are the differences between the current and desired process of colon surgery?* The current situation will be discussed in Section 2.1. The desired situation will be discussed in Section 2.2. In Section 2.3 the problem areas of the transition to CID will be analysed. Lastly, Section 2.4 is about the conclusion of this chapter.

2.1 CURRENT SITUATION

Firstly, the patient is screened in the hospital to determine whether a colon surgery is necessary. If this is the case, an appointment will be made to perform the colon surgery. After the colon surgery, the patient is put at the nursing department for on average 3.7 days after surgery to recover from the surgery and to check whether complications will occur. During the first day the patient is checked every 2 hours via the Early Warning System (EWS). If no complications have occurred during the first 24 hours after the surgery, then the patient only receives a check by a nurse in the morning and afternoon. If no severe complications have happened during this second period, then the patient is discharged from the hospital to further recovery at home (Bot, 2022). A flow chart of the current process can be seen below. In figure 1, POD stands for the post operative day.

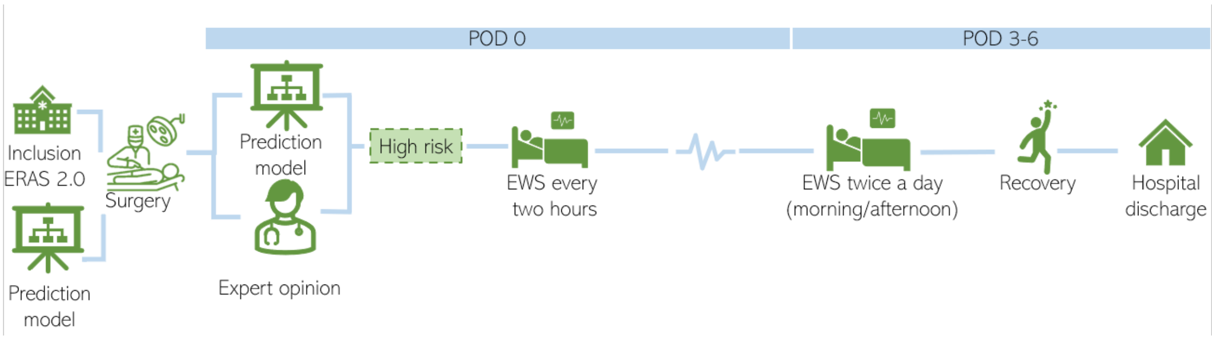

Figure 1: Current process of colon surgery (Bot, 2022)

Colon resection surgery is the removal or partly removal of your colon. This surgery is done when the colon stopped working or if it has an incurable condition that threatens other parts. This is mostly done in case of cancer or precancerous conditions. Another option for requiring a colon resection surgery is when there is large obstruction in your colon which cannot be removed in any other way.

There are multiple types of colon resection. For colon surgery in day-care there are five types of surgeries with different restitutions selected. The five types are: Rectosigmoid, sigmoid left, hemicolectomy, transverse colectomy, right hemicolectomy. These five diagnoses all have several healthcare products from health insurances to determine the appropriate restitution for different treatments used at the hospital.

In the current situation, there are approximately 210 colon resection surgery patients every year. The difference between these surgeries is important, as it might impact the impact of the benefits achieved when transitioning to CID. These include an increase of occurrence of complications for patients at home, the reduction in costs CID offers and the number of patients for which CID is possible.

2.2 DESIRED SITUATION

The desired process for colon surgery is a two-option healthcare track. In this system, there is the regular track for people with a higher chance of experiencing complications.

Secondly, there is a path for people with a lower rate of complications. In this system the chosen option is decided based on a prediction model based on various exclusion criteria and expert opinion from the surgeon. This will result in patients staying on average 2.7 days shorter in the MST, since patients always stay the first day. A list of criteria (Bot, 2022) can be found in Appendix A. After the surgery, monitoring is put on the patient. Currently, for the medical trial at the MST two companies are seen as potential facilitators of the monitoring equipment, Masimo and Luscii. Currently, Masimo's reliability and validity have been tested by Technical Medicine (TM) students in the MST for their bachelor assignment. From Luscii less information is known. The process in which Masimo works is detailed below:

When at home, the patients are continuously monitored via the equipment. This data can be seen by the patient in an app. The MST itself has a monitoring system which gives an alarm if any complications occur. In addition to that, the patients are allowed to call the hospital in case of an emergency. When complications occur, it depends on the severity whether the patient is hospitalized again or that treatment is done by the general practitioner. In Figures 3 and 4, on the next page the entire process can be seen. From the hospital side itself it needs to be determined what is the most efficient way to integrate it and what costs are associated with it. Options for this are the integration of monitoring in the daily routines of patients or facilitating a separate central monitoring station. In this thesis both these options will be evaluated.

Figure 2: Masimo SafetyNet

Source: Masimo (2022)

Compared to the current system a few changes are needed in the distribution of time spent on the patient in the policlinic. It will cost the surgeon 20 minutes extra time during the screening at the outpatient clinic compared to now. The reason behind this is the extra exclusion criteria that need to be checked and explaining the new process to the patient if the patient agrees to participate at CID. In addition to that, it will cost 10 more minutes at the policlinic during the post-surgery recovery screening after a few days to evaluate CID. So, on average it will add 30 minutes in total to the time a surgeon spends on a patient at the policlinic. This may differ slightly due to the process sometimes going slower or faster during a screening. The advantage of CID is that it will cost the nurse 2.3 days less of monitoring and treating the patient at the hospital.

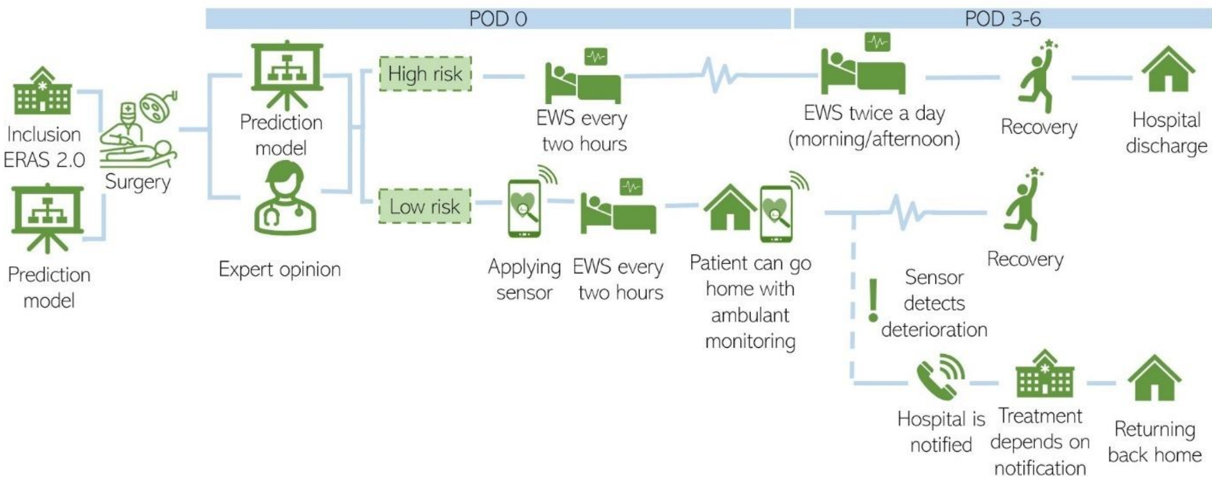

Figure 3: Desired situation (Bot, 2022)

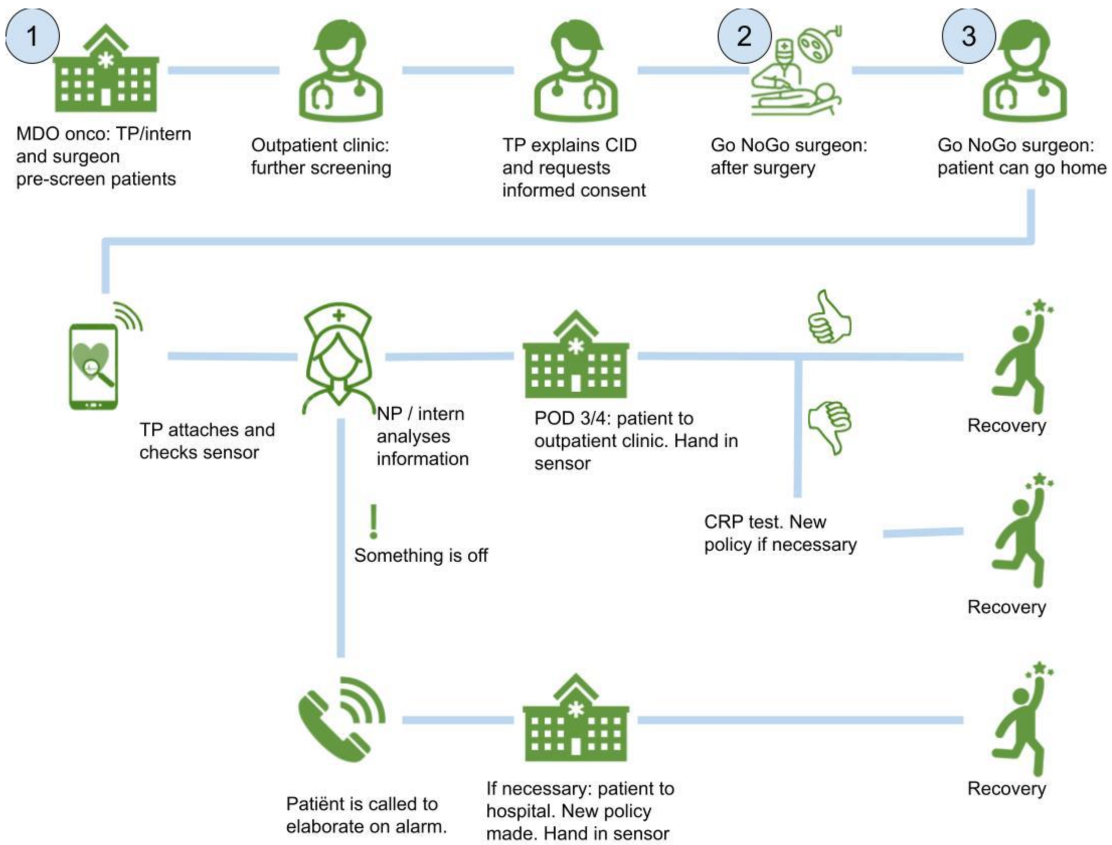

Figure 4: Detailed process desired situation (Bot, 2022)

2.3 PROBLEM AREAS

There are a few problem areas for transitioning from the current situation to the desired situation.

Firstly, at this moment transitioning colon surgery in day-care will impact only thirty-seven patients on average per year using the current exclusion criteria. This can lead to excessive costs for introducing the new healthcare track. For this reason, combining multiple surgery types together when monitoring for this system is beneficial for the costs and the logistics simplicity. The reasoning behind this comes down to that if every surgery type would have its own monitoring programme it would become very chaotic and not very efficient, as multiple patients can easily be monitored by one employee.

Secondly, monitoring at home is currently not well investigated. This means that there are unpredictable factors that need to be considered. These include the reliability and validity of the monitoring equipment and the rate of rehospitalization. Currently, the Masimo equipment has been tested by 3rd year bachelor TM students to see if it meets the requirements of the research done by Marit Bot.

Thirdly, currently the restitutions of healthcare insurances for all operation types are based on patients recovering at the hospital for a certain amount of time, for example 8 days. If these restitutions remain the same when patients are sent home this is beneficial in costs for the hospital. However, over time this might be reduced since health insurances will introduce a different restitution for day-care patients as they cost the hospital significantly less.

2.4 RELEVANCE

During the past few years and the upcoming future, the number of civilians in the Netherlands needing healthcare has significantly increased (Hentenaar & Demmer, 2021). This has led to multiple problems, such as excessive costs and long waiting lists for hospitals. Currently, the number of nurses in hospitals in the Netherlands is not sufficient to handle all healthcare that needs to be performed as fast as demanded. This cannot be changed easily and in a brief period as the number of nurses cannot be expanded quickly. This causes health care institutions and hospitals to search for new initiatives to meet the demand for healthcare. One of these initiatives is to send patients home more frequently after surgery to decrease the workload of the nurses (Hentenaar & Demmer, 2021). The benefits associated are increased patients' satisfaction due to recovering in a trusted environment with as a result better recovery, lower workload for the hospital workers and decreased costs. As a result, hospitals have been looking more frequently to put more surgery interventions in day-care to reduce the workload on their employees and to be able to prevent bed-stops.

2.5 CHAPTER CONCLUSION

In this chapter the first research question is answered: *What are the differences between the current and desired process of colon surgery?* The main difference is that an extra care path is created for patients that have a high chance of a quick recovery with a low chance at complications. The problem areas regarding this extra care path are mostly down to scale and the newness of the innovation. Home monitoring is yet to be researched thoroughly due to the monitoring technology and progress of hospitals in helping patients recover quicker than in the past. The relevance of home monitoring is evident, as it lowers the work pressure in hospitals if applied on large scale and it can help with the upcoming rise of patients due to the elderly population and the insufficient number of nurses currently available.

3. LITERATURE REVIEW

The literature Review is divided in three sections. Section 3.1 answers research question 2: *Which complications cause rehospitalization after colon surgery?* Section 3.2 answers research question 3: *Which cost calculation methods for hospitals do exist?* Section 3.3 answers research question 4: *How can the project set-up costs for CID be calculated?* Section 3.4 gives a conclusion of this chapter.

3.1 CLAVIEN-DINDO CLASSIFICATION OF COMPLICATIONS

Complications are categorised by the Clavien-Dindo classification system consisting of five grades (Berkel et al., 2021) (Zoucas, 2014). Grade 1 complications mean that there is a deviation from the normal post-operative course without needing pharmacological intervention or treatment. Grade 2 complications mean that pharmacological treatment in the form of antibiotics, b-blockers or blood transfusion and total parenteral nutrition is required. There are two types of grades 3 complications: 3a and 3b. Grade 3a complications means that surgical, endoscopic, or radiological intervention without general anaesthesia is required. Grade 3b complications means that intervention under general anaesthesia is required. Clavien-Dindo Grade 4 means that it is a life-threatening complication. Grade 5 consists of the most severe complications which result in death (Zoucas et al., 2014).

A study about elderly people said that the risk for needing a colon surgery became significantly bigger with age. Also, the risks of complications increased significantly with age. Examples of complications seen during the study are mostly of classification types 1, 2 and 3 of which the most were of types 1 or 2 (Menegozzo et al., 2019).

From these complications grade 3 and upwards cause rehospitalization in most cases. From 168 patients evaluated in the London region between April 1st and June 30th in 2021 around 4.2 % of colon surgery patients had complications within 30 days graded 3a or above on the Clavien-Dindo classification. The total amount of patients needing rehospitalization was 1.4 % percent, so one-third of the patients having severe complications needed re-admission. The mortality rate was 0.6% (Carvalho et al., 2021).

Clavien-Dindo grade 1 and grade 2 complications are frequently seen after colon surgery. While Grade 3 and 4 are seen significantly less. All these four Clavien-Dindo classifications increase costs significantly. Since grade 1 and 2 complications are prevalent and are associated with longer hospital recover stays, this must be reduced as much as possible (Louis et al., 2020). This is done via the Enhanced Recovery After Surgery program (ERAS). This has already helped in reducing costs significantly as it decreased the average hospitalization time in the MST around 50% from 5.8 to 3.7 days on average (Bot, 2022).

3.2 METHODS FOR CALCULATING COSTS AT HOSPITALS

In hospitals the costs are often divided in three types: direct costs, indirect costs, and full costs. This is also the case for the MST.

Direct costs are costs that are directly involved with patient care. Examples of these costs are food service, drugs, and rehabilitation. Indirect costs are costs that are not directly involved with patient care. Examples of these costs are ICT costs, human resources, and capital expenses. Full costs are simply put the direct costs plus the indirect costs.

When calculating these costs there are two methods to calculate the costs. These are Micro-Costing (Bottom-Up) and Standard Costing (Top Down) (Pengyu et al., 2006).

Micro-Costing is based on registering all used resources by the patient and calculating costs for them. To do this, extensive knowledge is needed of the treatment and services provided to every individual patient. After that, all costs are counted individually for each patient to come to the full cost per patient. This is the most accurate method of calculating costs. However, it is also the most time-expensive process and therefore often not the most practical manner of calculating the costs (Pengyu et al, 2006).

Standard-Costing is often referred to as average costing because the method uses the total health care expenses and divides it by a measure of total services provided to determine the cost per patient. For Standard-Costing there are two main calculating methods Per Diem Costs and Case Mix Costing (Pengyu et al., 2006).

Per Diem costs are calculated by dividing the total expenditure for the services done by the total number of days of a service given to come to an average cost per day. In general, per diem costing is a poor estimation of hospital costs due to the generalization of individual cases and a difference in provider characteristics (Bogdanovic, B., 2001).

Case Mix Costing is a method which puts patients into clinically meaningful groups that are expected to use similar amounts of hospital resources. The Case Mix method uses a relative weight to patient cases and expects a similar usage of resources for every patient in a group. This is also the method used by health insurance companies in the Netherlands for determining their healthcare products and restitutions (Bogdanovic, B., 2001).

Lastly, in complex organisations such as hospitals often a method called Activity-Based Costing is used to assign indirect costs to the patients (Bogdanovic, B., 2001). This system can be used for the targeted reduction of overhead costs.

The method used in the MST is Case Mix Costing. This is done in collaboration with health insurances as this makes it easier to assign different prices to certain surgeries. Due to the hospitals negotiating about the prices themselves this has resulted in hospitals in the Netherlands having slightly different restitutions for treatments compared to one another. Another reason for the different prices between hospitals are the differences in treatments they offer to patients as some treatments are more expensive.

3.3 HOW TO DETERMINE THE COST OF CID

In the hospital, most of the data concerning costs and complications is stored in Excel. Therefore, the handiest option for them is to also have the cost calculation tool made in Excel. To be able to create this tool information on how to make such a tool is found in literature. In the excel calculation tool two costs are calculated: The total cost reduction and the cost reduction per patient. These two are closely related as cost reduction per patient is equal to the total cost reduction divided by the amount of patients.

The standard formula for total cost is:

$$Total\ cost = total\ fixed\ costs + variable\ costs * number\ of\ patients$$

This formula is used frequently in the model to calculate costs for the different variables needed in the model which will be written down in Chapter 4.

To introduce CID set-up costs, it is needed to make investments into technical equipment such as monitoring centre and monitoring equipment. At the start, these costs for CID are high compared to the current process as it is a big investment to implement the necessary infrastructure in the MST. To offset this amortizing the costs by using the Net Present Value (NPV) formula is necessary to determine the value of the equipment over time and the return that can be measured.

Net present value formula: $NPV = \sum_{t=1}^{n} \frac{Rt}{(1+i)^t}$

In this formula, Rt is the net cash inflows-outflows during a single period t. i is the discount rate that could be earned in alternative investments and t is the number of timer periods.

In the MST, a lot of variables are based on probabilities and unpredictability as we are dealing with patients. To make a prediction of these variables in the future in the new process it is important to be able to account for this variability. This can be done via the Monte Carlo simulation model. A Monte Carlo simulation is also called a multiple probability simulation. It was invented during World War ll to improve decision-making processes under uncertain conditions. It was called after Monaco as gambling with chances is also frequently done in Monaco and chance is the core to the Monte Carlo simulation (Harrison, 2010).

Monte Carlo simulations have been applied to many different real-life situations such as stock-prizing, artificial intelligence, sales forecasting, and project management. The difference to other simulation models is that a Monte Carlo simulation can be used to get a lot of different forecasts of costing. In contrary to other models this is done by using probability distributions variables to calculate those instead of stationary input variables. Then a set number of iterations is running with every time a new set of probabilities within the minimum and maximum limit. This can be repeated countless times to create an as accurate result as wanted. Monte Carlo simulations are also used for long-term predictions due to their high accuracy. When the number of iterations increases the number of forecasts grow which can give an accurate average result over an extended period. When a Monte Carlo simulation is finished, it gives multiple outcomes with each outcome with the present probability of it happening (Harrison, 2010).

Other options similar to the Monte Carlo simulation are Jackknife, Bootstrap and cross-validation. Jackknife and Bootstrap are both cases of resampling methods. Cross-validation means that a model is tested with data that should normally not fit the model. From these methods, the Monte Carlo simulation is the most adequate as it a randomization test over the entire probability distribution. . This gives a more accurate example of the difference between the current situation without CID and the new situation with CID. In contrary, resampling gives the opportunity to learn more about the population itself with the data provided. Since the goal is to estimate the costs of CID with the model, it won't be an accurate method to incorporate the costs. Therefore, Monte Carlo is used as the method to give a cost projection of CID.

In appendix E, more information about the general principles of a Monte Carlo simulation can be found.

3.4 CHAPTER CONCLUSION

In this chapter, research questions 2, 3 and 4 are answered.

For research question 2: *Which complications cause rehospitalization after colon surgery?* the conclusion is that complications graded three or above on the … scale are most likely to cause a rehospitalization. In addition to that, these complications are more likely to occur with elderly patients.

For research question 3: *Which cost calculation methods for hospitals do exist?* The conclusion is that case-mix costing is the most used cost calculation method for hospitals in the Netherlands. Furthermore, this method is also used by the MST in collaboration with health insurances to determine the restitution for all treatments.

For research question 4: *How can the project set-up costs for CID be calculated?* The conclusion for this research question is that the most probable option for calculating the project set-up is to make use of a Monte Carlo simulation. The reasoning for this is that it is the best option to consider the probabilities most variables are bound to.

4. DATA ANALYSIS

In this chapter, all data gathered at the MST and from interviews is evaluated. In Section 4.1, research question 5 is answered: *What does the current data of the MST show?* These include all types of costs and operation data of patients over the last few years. In Section 4.2 research question 6 is answered: *Which logistic operations changes can be implemented and how feasible are they?* This section includes qualitative data from experts from diverse backgrounds that is analysed to come up with possible logistic operations changes.

4.1 QUANTITATIVE DATA

For the quantitative data from the MST several variables are analysed. These can be divided into colon surgery patient data and cost data from the MST in general and colon surgery specific data. Since a Monte Carlo simulation is used for the dashboard in Excel also all standard deviations are analysed.

4.1.1 COLON SURGERY PATIENT DATA

The total number of patients receiving colon surgery in the dataset of the MST is 419 patients from the period between 2-3-2020 till 20-4-2022. From these patients, 128 were treated in 2020, 217 were treated in 2021 and 74 were treated in 2022. 78 would have been able to participate in the CID programme according to the inclusion and exclusion criteria determined by Bot (2022).This is 18.6% of all colon surgery patients. This results on average in 37 patients per year that could be treated via CID. The inclusion and exclusion criteria for patients can be found in Appendix C. The standard deviation over this period is three per year. Furthermore, since the intake of patients has been relatively stable over the past few years a normal distribution is chosen as its most likely distribution type, as the amount of colon surgery patients has been relatively stable.

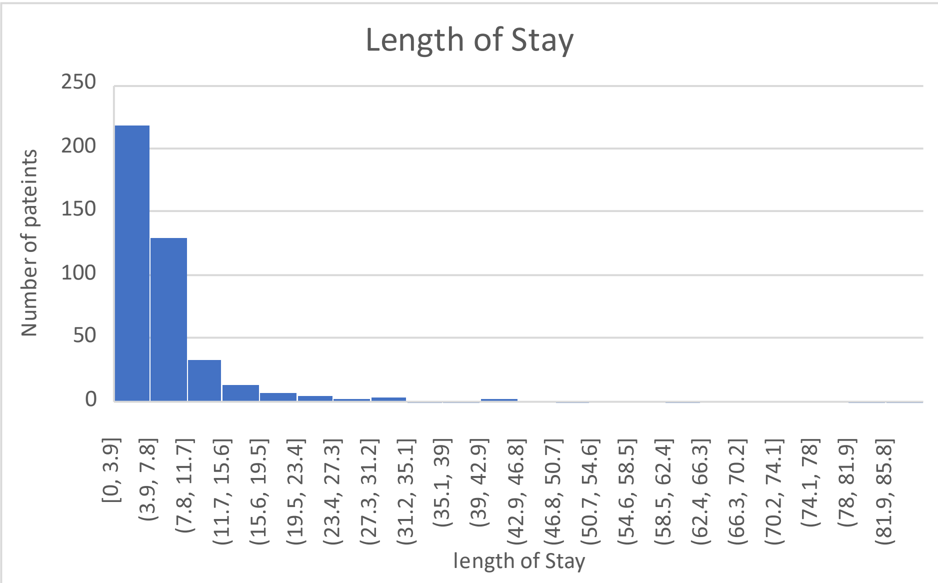

Figure 5: Length of Stay

The average length of stay in the hospital for all patients combined who have undergone a surgery is 5.7 days. For CID patients, the average length of stay is 3.7 days. When sending the CID patients home for recovery, this would give a reduction of the average stay of 2.7 days. The standard deviation for the average stay of CID patients is large as it is 5.67 days. The probability distribution of the average length of stay is a lognormal distribution as can be seen in Figure 5.

The average complication percentage during primary stay at the hospital for all patients is approximately 18.9%. This percentage includes all complications in the Clavien-Dindo classification system. The primary stay is the period the patients stays at the hospital after surgery, excluding rehospitalization The average complication percentage after leaving the hospital is 14.5%. When excluding patients that experienced complications both in the hospital and at home from these two percentages, about 31% percent of patients experienced complications. This is close to the same numbers found in the research of Bot (2022). From the group of patients having complications, 11 patients experienced complications during both the primary stay and after leaving the hospital.

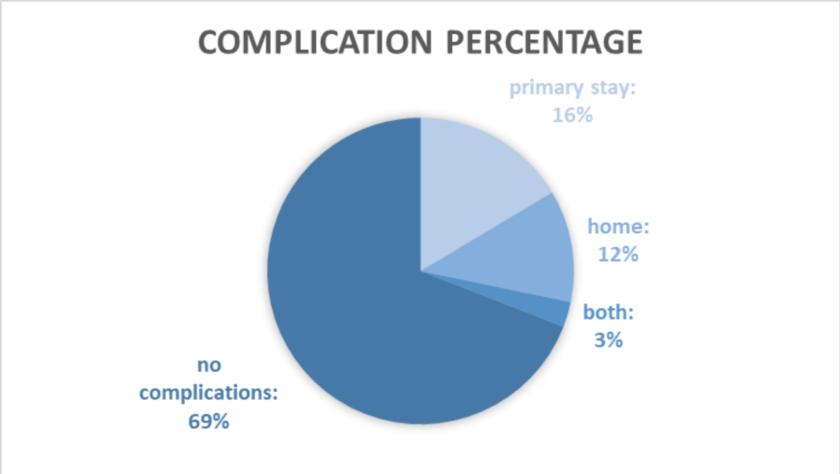

Figure 6: Complication percentage all patients

For patients eligible for CID these values are different. Eight percent of the selected patients has complications during primary stay. In addition to those 7.7% has complications after their primary stay which has often been shorter. This means that CID patients have a significantly lower chance of experiencing a complication. Furthermore, none of the CID patients has complications both at the hospital and at home.

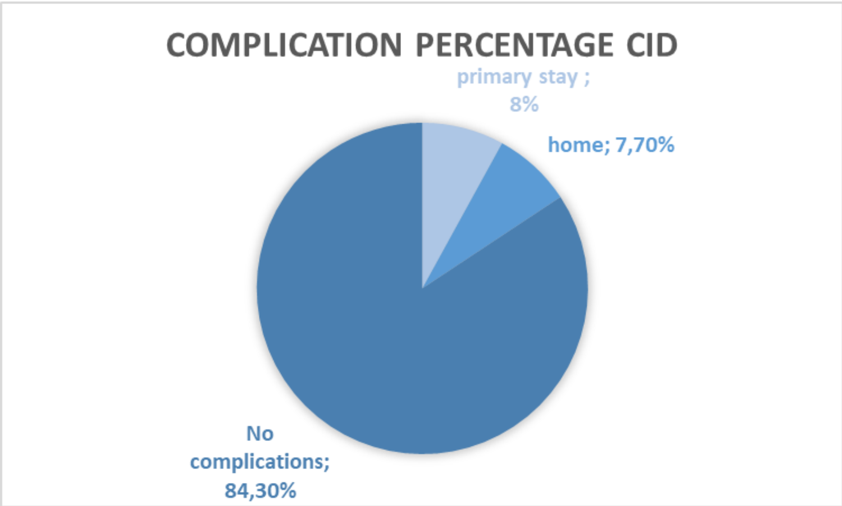

Figure 7: Complication percentage CID patients

When looking at the severity of the complications occurring, most complications are non-serious and fall in grade 1 or 2. This means that a re-operation is not needed. When looking further grade 3 complications also are still quite frequent, this is the first complication that needs a re-operation. Both grade 4 and grade 5 are rare. However, when these are occurring it is extremely dangerous for the patient. In all cases of having complications of grade 3 and above a re-operation is required. From Grade 4, complications are called severe and can be life-threatening. The most frequent severe complications are due to anastomotic leakage, ileus, and wound infection.

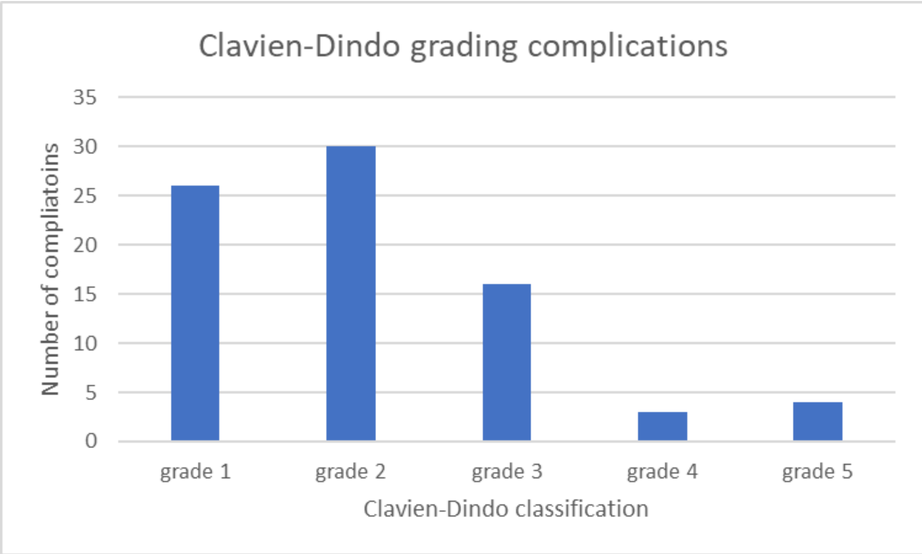

Figure 8: Clavien-Dindo grading complications all patients

For CID patients the distribution of complications is different. Of all seventy-eight selected patients only 8 have complications and all are not severe. It is not viable or needed to calculate the rehospitalization rate for every Clavien-Dindo classification as, grade 4 and grade 5 are rare among patients selected for CID. This can be seen in Figure 9.

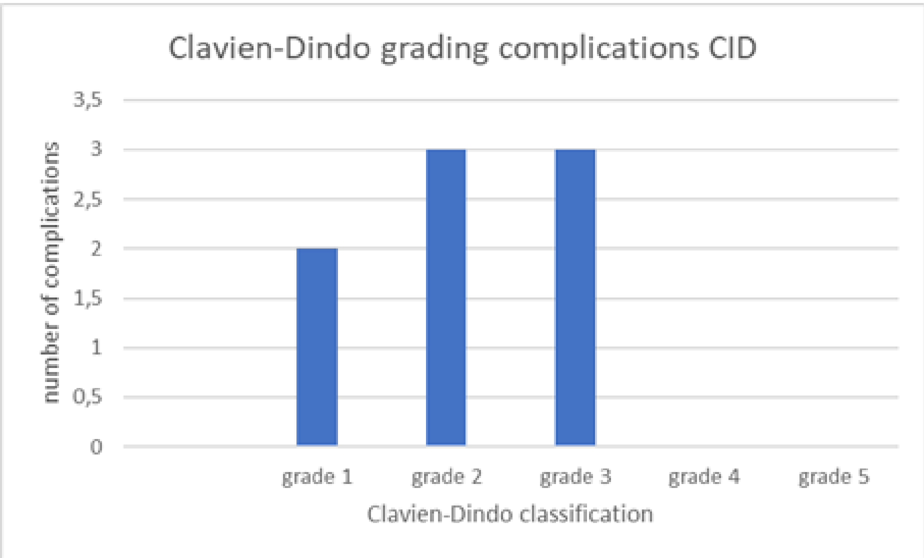

Figure 9: Clavien-Dindo grading complications CID patients

In total, the number of readmissions over the past 2 years was 39 of the 419 patients. As a percentage this is approximately 9,2% among all patients. When considering the CID criteria of Bot (2022), the number of patients needing rehospitalization are 3 out of 78 with the current criteria. This means that only 3,8% of CID patients is predicted to need a readmission. In addition to this, the predicted complication rate is around 15% in total. This means that the goal of the MST project development can be reached, as the aim is to have 85% patients recovering at home experiencing no complications. However, due to patients recovering at home, they might come back to the hospital in case of a complication. The difference between the complications at home and the re-admission rate is around 4 percent, because only grade 3 complications require a re-admission in the current system. To be extra safe during the initial start-up phase of CID, it is recommended to re-admission all patients experiencing complications. This includes patients with grade 1 and 2 complications. For that reason, this is taken as an additional rehospitalization rate in the dashboard. Due to the low number of re-admissions, there is not a clear probability distribution. Therefore, the normal distribution is used as it the most logical.

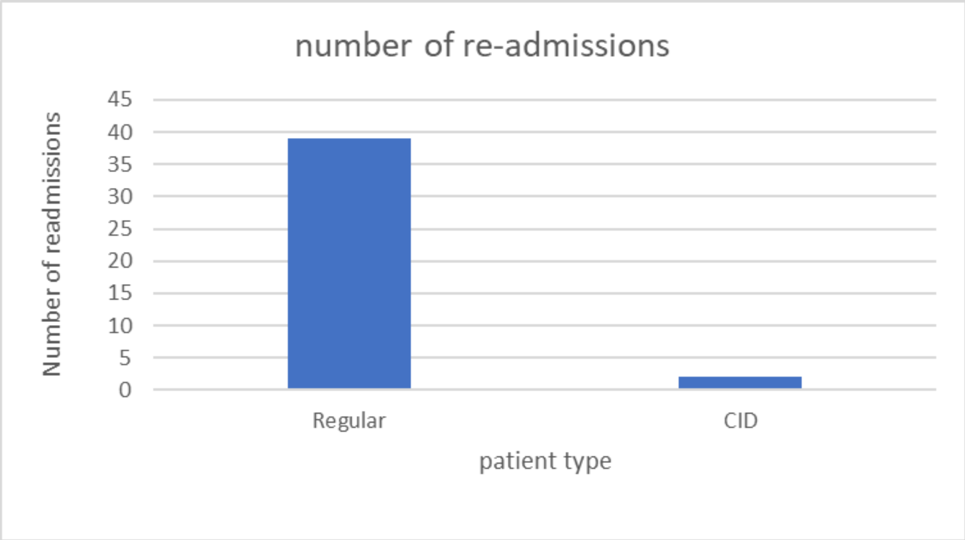

Figure 10: Number of re-admissions

The average stay after re-admission is approximately 7.5 days when considering all patients and 10.7 days for CID patients. It must be said that there is a large variance in re-admission rates at the CID patients due to only having 3 patients in the dataset that have experienced a re-admission. This makes the data quite inaccurate. At the same time, the number of days that the re-admission takes is depended on the severity of the complications. This has been skewed for the CID patients due to an outlier in the data affecting the average re-admission length of stay. However, due to outliers occuring quite often it is not handy to change this. The outliers occur sometimes due to multiple complications occuring at once or in a snowball effect. To compensate for this, in the model a triangular distribution is used with this outlier as the upper bound.

4.1.2 COSTS RELATED TO COLON SURGERY

With the integration of CID as a care path type several costs need to be known to determine the cost difference per patient. In addition to that the restitutions need to be considered to determine the difference compared to the current situation.

The costs of the MST are divided into direct and indirect costs. The ratio between those 2 is 56% for the direct costs and 44 % for the indirect costs (Rozendom, 2022).

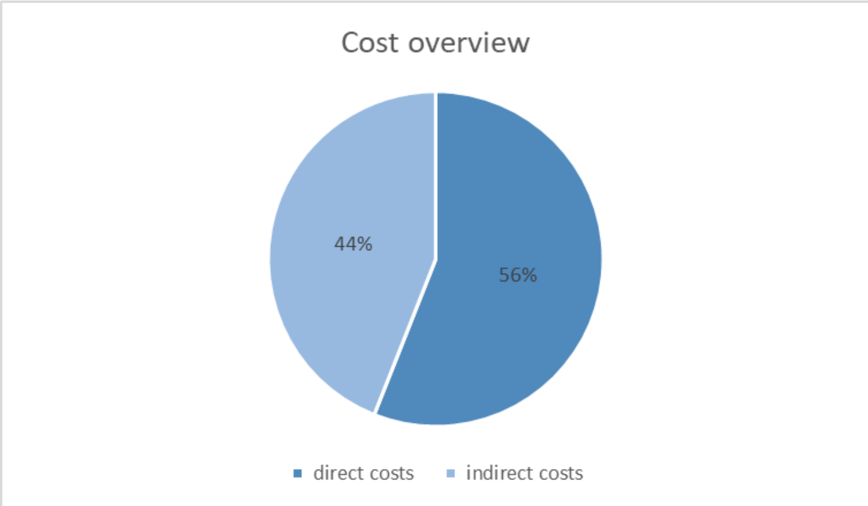

Figure 11: Cost overview

Currently there are several cost variables in the MST per patient. Firstly, according to expert opinion, a nursing day costs around 532 euros in 2021 in the MST in general. The overview of costs in Table 3 is with prices from 2019. These are indexed to 2021 by multiplying the direct costs by 8.15% and the indirect costs by 3.7% as indexation rates. The costs are derived from the following variables.

Type of cost	**Direct or indirect cost**	**Total cost**	**Cost per patient**
General costs	indirect	€1,678,688	€55.11
Pharmacy	direct	€402,481	€13.21
Equipment	direct	€65,795	€2.16
Facility costs	indirect	€1,132,087	€37.16
Buildings	indirect	€1,777,479	€58.35
Materials	direct	€280,052	€9.19
Earnings direct	direct	-€838,432	-€27.52
Patient-bound	indirect	€972,257	€31.92
Employees	direct	€8,625,232	€283.15
Specialist	direct	€1,165,440	€38.26
Food	direct	€9,266	€0,30
Total		€15,270,345	€501.29

Table 3: MST hospital day costs (2019)

This gives a total of € 501.29 per nursing day per patient in the MST in 2019. This comes down to €532.32 per patient per nursing day in the MST in 2021. A regular day-care costs € 230.75 in 2021 in the MST. The cost of staying in the MST is €26.58 per hour in the MST in 2021. However, for CID only the direct costs are of importance due to the indirect costs not changing when introducing CID. For this reason, it is needed to make a division of which costs are direct and which are indirect. According to cost data from the MST approximately 56% of the costs are direct. This means that €297,92 is the direct cost per hospital day per patient. However, due to the high inflation in 2022, all cost variables are put into the Monte Carlo simulation to make a range of possible prices with the inflation rate of August 2022 in the Netherlands, which is 14.5% (CBS, 2022). This is done by using a triangular distribution that has a higher range that is equal to 14.5% extra costs.

There are also specific costs for colon surgery. These are specified into multiple categories. These are:

Types of cost:	**Description**
Clinic	Clinic costs are specified as the costs made at the nursing department where patients lay to recover.
OR	The OR costs are defined as the cost made during the operation itself, these include the cost of using the OR and the employee costs.
Laboratory	The laboratory costs consist of all the costs made in the laboratory, such as blood tests.
Consult	The consult costs are defined as the costs made during regular consult appointments at the policlinic.
Actions	The action costs consist of mostly revalidation costs, such as physiotherapy.
Imaging	The imaging costs consist of the several types of scans done during the treatment.
Materials	The material costs consist of all the materials used, such as blood, implants, and medicine.
Dialysis	The dialysis costs are costs for being attached to a dialysis machine.
Other	The other costs are unspecified.

Table 4:MST types of cost

For CID, a few of these costs are important as most of them do not change when introducing CID. The costs that can be excluded have been checked by the business controller of the MST. Costs that are relevant for CID are the clinic costs, due to the time spent on the nursing department decreasing. Furthermore, the consult costs as those increase due to the extra amount of time needed to explain the CID care path. Action costs may be relevant as people are expected to recover better and faster at home (Hentenaar & Demmer, 2021). Therefore, this cost type might decrease, but this would require more research into this topic, so for this research it is taken as an overhead cost. From the description in can be concluded that the imaging, material and other costs remain the same. However, in addition to that an extra category for monitoring needs to integrate into the cost overview, because this will become part of the costs with the introduction of CID, and it is currently not in the big cost overview.

The average clinic costs are €26,58 per hour as already said above. This is the same across all surgery disciplines. Currently colon surgery patients stay for on average 3.7 days. This comes down to a total cost of €2036.30, - per patient on clinic costs in general in 2019.

The consult costs are currently divided into multiple distinct parts. In Table 5, all influential costs can be seen:

Consult cost types	Cost per patient
First policlinic visit	€212.53
Repeated policlinic visit	€236.12
Multidisciplinary meeting	€307.52
Total	€756.17

Table 5: Policlinic costs

All these meetings consist of two timeslots. To take the price per extra timeslot the first policlinic visits and the repeated policlinic visits were used. This results in a price per timeslot of €112 in 2019. As the current price is not known the inflation was used to make it usable for 2022.

The current monitoring costs of the MST as a package determine on the monitoring options chosen. According to multiple studies, the Masimo equipment has the best specifications to be used in CID. However, because the hospital prefers to use the products of Luscii in all Santeon hospitals, only these costs are available as information as they have made a quotation for the MST. The costs for the monitoring equipment of Luscii consist of three factors: a one-time fixed start-up cost, a variable cost per month and a cost per monitoring device. In the model the correct numbers are used. However, they are disclosed so will not be named in this thesis. The total monitoring costs named in this thesis are included with the correct costs. So, only the individual costs will not be named (MST, 2022).

In addition to that, the Masimo equipment will cost the same. So, this quotation can be used to make an accurate estimation of the costs.

4.2 QUALITATIVE DATA

The goal of this section is to give insight on the current opinion of several experts to get insight on what logistic operations changes are most appropriate to implement.

4.2.1 GENERAL INFORMATION

To keep up with the rising pressure on the healthcare department due to increasing number of patients and the shortage of nurse capacity, innovation is key (Hentenaar & Demmer, 2020). During the Covid-19 crisis, the development of remote monitoring improved significantly. This development together with the improved recovery programs at hospitals such as ERAS at the MST, has resulted in the possibility to send a group of patients home for recovery. This has resulted in several hospitals initiating projects and pilots to investigate sending patients home to recover. Several hospitals in the Netherlands such as the JBZ, Zuiderland and the MST see certain types of colon surgeries as a feasible option to incorporate remote monitoring during recovery. When this proves to be successful for colon surgery patients this procedure can be used as a template for other surgery types. Therefore, the results of this pilot for CID can be the start of a large transition to recover at home instead of at the hospital.

Currently, at the JBZ hospital they have started a pilot with the Masimo SafetyNet monitoring equipment to test its validity and reliability. So far none of the patients sent home had to return to the JBZ due to occurring complications. The selection of patients in the trial was done by exclusion and inclusion criteria to only include the patients with the lowest chance of complications. This resulted in around 20% percent of colon surgery patients being included.

In the JBZ, the monitoring is now done every hour from 9 a.m. till 9 p.m. in the monitoring centre. In the night, the nursing department is responsible for checking in on the patients. This is done at 11 p.m. and at 6 a.m. by the nurse at service. The beds normally occupied by the patients that recover at home are now reserved for them to ensure that all of them can return in case that is needed. Currently, the JBZ monitors 95 different types of patients in their monitoring centre. Most of these are patients with chronic diseases requiring monitoring only once or twice per week, such as people suffering from chronic obstructive pulmonary disease (COPD) . In this manner, already 800 patients are being monitored via this centre. Now, CID is the first programme requiring continuous monitoring in the JBZ. Consequently, this gives more workload and requires additional capacity of the monitoring centre. The long-term goal for the JBZ is to have the monitoring centre up and running 24/7 as more surgery types are found suitable for remote monitoring.

4.2.2 REMOTE MONITORING

When determining how to monitor patients at home there are several options currently being investigated:

The first option is to call recovering patients at home every few hours to check how they are doing. Nowadays, this has already been investigated in France and England (Garcia, 2021). This method is also tried in the Zuiderland hospital in Zeeland as they are participating in the same international pilot. This method outside of trial is not allowed in the Netherlands due to the unsafety of not monitoring the patients.

The second option is to use remote monitoring using technology that is using point measurements such as Luscii. When the monitoring system warns that something is wrong, the patient gets a call from the hospital. This monitoring equipment is preferred over the Masimo equipment by the Santeon hospitals as it can be integrated in the already used IT system.

The third option is to use remote monitoring technology that is using continuous measurements such as Masimo. When the monitoring indicates that it is not going well or something is wrong, the patient will be called. This method is used in the JBZ hospital as it has the best monitoring due to it constantly registering the persons vital measurements.

In all cases, patients can call the hospital when they don't feel well or want more information. They are also allowed to always return to the hospital in case of an emergency.

4.2.3 MONITORING AT THE HOSPITAL

The future of remote monitoring is to make use of regional monitoring centres that monitor all patients in a region instead of hospitals doing it individually (Garcia, 2022). However, there are a few disadvantages of regional monitoring centres at this moment. All hospitals belong to assorted brands of hospitals. This means that working together outside of these brands is harder as their procedures are different. In addition to this, the equipment used might be different and require different software programmes. This has resulted in most hospitals opting for their own monitoring centre instead of regional centres, as it takes significantly less time to set-up and requires less policies and communication.

The set-up of a remote monitoring centre has already been done in the Isala hospital in Zwolle. The cost of a monitoring centre depends on a few factors. These factors are the needed space, equipment needed, and employees needed (Peters, 2022). From these factors, the space and equipment are fixed costs. The employee costs are variable based on the number of patients that need monitoring. The needed room is often available and does not result in extra costs due to the MST having it available freely. In addition to that, most hospitals have enough space, but not enough nurses (Oulton, 2006). As a result, the cost for the office itself has no role in determining the cost of remote monitoring as there is no need for extra space.

Secondly, determining the equipment needed for a monitoring centre is simple. A server is needed to store all the data, computers are needed and some desks. Counting all of these up it is in the range of a few thousand euros as a onetime investment. Generally, it depends on the quality of equipment that is invested in. However, most equipment might also already be available at the hospital. Therefore, the cost is estimated on €5,000 with a minimum of €0 and a maximum of €10,000 in consultation with Peters (2022) and the business controller of the MST. This equipment will be replaced every 6-7 years for updates and should be written off over time.

Lastly, the employee costs are the highest cost of the monitoring centre. Considering, that the JBZ has the monitoring centre staffed from 9 to 9 everyday this comes down to 12 hours of work per day. In addition to that, in the night shift the patients should also be checked twice. This will also take time, an hour in total. So, in total monitoring patients costs 13 hours per day. This means that the biggest cost is the costs of the nurses employed at the monitoring centre.

4.3 CHAPTER CONCLUSION

In section 4.1, the answer to research question 5 *What does the current data of the MST show?* is given. From the data analysis can be concluded that patients selected for CID have less risk for complications and experience less severe complications. This is mostly due to them being selected based on the exclusion and inclusion criteria in Appendix C. In addition to this, CID patients also have significantly less re-admissions into the hospital. For the costs of CID, it became clear that a hospital day on average costs €532 per day. The direct costs are responsible for approximately 55% of the costs. Since all data is from earlier years and the inflation this year is exceptionally high, all cost variables in the Monte Carlo simulation are put into the simulation as a triangular distribution with a 14.5% inflation as its maximum value compared to its average.

In section 4.2 research question 6 is answered: *Which logistic operations changes can be implemented and how feasible are they?* According to most experts interviewed, a monitoring centre in the hospital itself is the easiest to implement on a short-term. In addition to this, remote monitoring is a preferred method compared to only calling patients at home to check in. The remote monitoring options for the MST are either Masimo or Luscii. Lastly, the monitoring itself will take up to 13 hours a day, when following the procedure of the JBZ as they are running a fully operational monitoring centre for over 800 patients for multiple disciplines.

5. EXPERIMENTAL DESIGN

The experimental design is divided into four sections. Section 5.1 describes the variables used in the model and why they are used. Section 5.2 reflects on the values used in chapter 5.2 and puts them into a clear overview. Section 5.3 explains the design of the Excel dashboard. Section 5.4 explains how the sensitivity analysis is performed. Finally, Section 5.5 gives a conclusion of this chapter.

5.1 VARIABLES

To calculate the total costs of the project set-up for CID multiple input variables are needed. In Chapter 4, multiple values have been determined. These were either calculated in Excel via quantitative data or determined via qualitative analysis with expert opinions.

Firstly, to determine which variables are necessary, it was researched which costs and profits are relevant for the project set-up of CID. This led to the following main costs and profits being included in the main dashboard:

- CID profit
- Additional complications costs
- Remote monitoring costs
- Additional policlinic slot costs

These variables are all separately explained below in detail.

5.1.1 CID PROFIT

CID profit is the main profit variable in the dashboard. This variable is defined as the costs that can be saved per patient in the MST when following the CID health track. The CID profit variable in the dashboard is calculated via the variables: Incoming patients, cost per day on the nursing department of the MST and the average stay of every patient in the hospital. Then the profit is calculated as follows:

$$\begin{aligned}&\mathit{Incoming\ patients} * \mathit{reduction\ in\ costs\ per\ day\ at\ the\ nursing\ department\ in\ the\ MST} * \\ &\mathit{the\ average\ stay\ of\ a\ patient} = \mathit{Total\ profit\ of\ CID}\end{aligned} \qquad (1)$$

The variables in Equation (1) together are responsible for the total profit of introducing CID. This is only the direct profit of introducing CID. There are indirect benefits that come with the introduction of CID, such as lower nursing workload and a decrease in bed-stops. Bed-stops are the moments in which no more patient can be operated due to reaching the hospitals maximum capacity. This can occur when the maximum number of patients residing in hospital beds is reached. Another example is when the maximum treatment capacity of nurses is reached which means no more patients can be taken care of. As bed-stops are occurring due to the MST itself reaching its capacity and this is only marginally impacted by the reduction in beds caused by the introduction of CID, this is not quantifiable now due to a lack of data in this regard. Therefore, this benefit of CID is not considered for this model, but it will cause a small decrease in the number of bed-stops.

In the MST, the Mixed-Case costing method is used to determine the costs, all costs are in total and specified per patient. In the case of CID, there are multiple reasons to take the costs per patient for the dashboard. Firstly, the cost per patient is easier to scale when patients are added and this needs to be adjusted in the model. Secondly, the use of the cost per patient is more practical as some of the monitoring equipment is also bought per patient. For these reasons, it is easier to work with cost per patient instead of the total costs.

5.1.2 ADDITIONAL COMPLICATIONS COSTS

With the introduction of CID, patients will recover at home when fulfilling the requirements for CID. The intention of the requirements is to select the patients with the highest chance of safely recovering at home without complications. This has multiple advantages. Firstly, the MST wants to guarantee the safety of every single patient that is sent home. Secondly, if patients are selected wrongly the complication rate of CID-patients will be high. This causes more rehospitalizations than with the original healthcare track. In this case, the costs are also significantly higher than in the original approach. So, it is important to have strict requirements for selecting CID patients.

Furthermore, due to the innovative nature of CID some factors are still unknown, for colon surgery specifically. According to expert opinion recovering at home can cause a slightly higher rehospitalization rate due to the following factors: insufficient pain management, anxiety at home due to the fear of getting complications and slightly longer reaction times in case of a complication.

To compensate for this uncertainty in the model, there is an additional complications category that takes the risk of additional complications into account for patients. This is calculated by using the rehospitalization rate of people eligible for CID in the data. In addition to that, the average stay after rehospitalization for CID patients is used. Lastly, the cost per hospital day is used again to determine the average costs per day when hospitalized with a complication.

These three variables together are used together to get the average cost of a rehospitalization for a CID patient. This is calculated with formula (2):

$$Rehospitalization\ rate\ of\ a\ CID\ patient * average\ time\ of\ a\ rehospitalization\ of\ a\ CID\ patient * average\ cost\ of\ a\ hospital\ day = average\ cost\ of\ a\ rehospitalization\ of\ a\ CID\ patient\ per\ day \quad (2)$$

5.1.3 REMOTE MONITORING COSTS

To make CID possible in the Netherlands it is necessary to guarantee a patient's safety at home. A solution for this is using remote monitoring. To be able to use this monitoring certain costs need to be made. These are the costs for the monitoring equipment itself, the monitoring centre and the employees needed to perform the monitoring in the hospital.

As mentioned, in Section 4.2, most experts said that it was most realistic and logical to use a separate monitoring centre per hospital. The reasoning behind is that it is the easiest to implement and it can be easily scalable to the entire hospital or to a specific department. Furthermore, it does not require a lot of set-up time as there are already other monitoring services in the hospital which protocols can be used to create CID protocols.

The other two options are that nurses check upon the patients in between their other tasks or to have a regional monitoring centre that checks the monitoring data from multiple hospitals from the same branch. For example, for the MST this is the Santeon brand.

The first option with the nurses is practical on a small scale such as a pilot. However, due to the time it requires from each individual nurse it is not the most efficient way when there are multiple patients involved. In addition to that, a lot of nurses need to be educated on how the monitoring system works and what needs to be done in each specific situation. For these reasons, this option is not viable long-term and not a desirable choice to implement.

The second option with the regional centre is now not immediately usable as the time to set it up is quite long and a lot of specific procedures need to walkthrough, such as what needs to be done and who needs to contact in case of an emergency. In addition to that, this option is not easily quantifiable in any manner as there is no prior example and the costs to introduce a regional centre are unknown. Therefore, in this research these two options were not evaluated in the model and use the monitoring centre in the MST as the most viable option.

Currently, for the monitoring equipment itself there are two suitable providers of monitoring equipment, Luscii and Masimo. The difference between these two monitoring systems is explained in Section 4.2. Now, the MST is planning to use Luscii on large scale within the hospital as the equipment can be used throughout the entire hospital. Since the proposal of Luscii has already arrived these numbers can be used for the model. The monitoring systems itself both exists out of two products: The monitoring worn by the patient and the server system that receives and displays the data. The costs for both products in the model will be from Luscii.

Lastly, the monitoring centre needs to be staffed. Currently, in the JBZ senior nurses do this. For the model here the same assumption will be made for the cost of staffing the monitoring centre.

These three factors combined lead to the following formula for the total cost of the monitoring:

$$Cost\ monitoring\ centre + cost\ monitoring\ per\ patient + cost\ staff\ monitoring\ centre = total\ cost\ monitoring \quad (3)$$

5.1.4 ADDITIONAL POLICLINIC SLOT COSTS

The implementation of CID is new for specialists and patients. Due to this, in the policlinic more time is needed to explain how CID works and what actions must be performed at home by the patient instead of in the hospital. Furthermore, afterwards, CID patients receive a longer evaluation of their recovery process and their opinion on the use of the monitoring equipment. Both activities will result in extra time being spent at the policlinic.

To calculate the cost Equation 4 is used:

$$Extra\ timeslots\ used\ at\ policlinic\ before\ surgery * cost\ of\ a\ policlinic\ time\ slot = Total\ extra\ cost\ policlinic \quad (4)$$

All variables and formulas used in the model are checked by the business controller from the MST. This is done to guarantee that the values the model produces are based on the correct variables and formulas.

5.2 VALUES

All values used in the model have already been determined in Section 4.1 and Section 4.2. In Table 6, these values are shown as the values that enter the model. Furthermore, their probability distribution types are noted.

Variable	Probability distribution type	Mean (Most Likely)	Std. Deviation	Min	Max
Incoming Patients	Normal	37	3	-	-
Cost hospital day in euros	Triangular	€310	-	€300	€354.95
Average stay in days	Lognormal	2.7	5.67	-	-
Rehospitalization rate in percentage	Normal	6.5%	1%	-	-
Complication Stay in days	Normal	8.3	5.65	-	-
Complication cost per day	Triangular	€310	-	€300	€354.95
Cost monitoring centre	Triangular	Example: €5,000	-	Example: €0	Example: €10,000
Cost monitoring equipment	Uniform	-	-	Example: €50	Example €50
Extra slots used in the policlinic	Discrete	1.5	-	1	2
Cost extra policlinic time	Triangular	€120	-	€112	€137.40
Total days needed for monitoring centre	Normal	99.9	6.41		

Table 6: Input variables

(Remark: the example value used for monitoring are only for demonstration purposes, the actual values are used in the calculations but cannot be displayed)

The values in Table 6 are the standard values used in the model to calculate what the actual costs of CID will be. Furthermore, a sensitivity analysis is performed to test the influence these variables separately have on the total cost.

In the model, the total cost is calculated in the traditional way and via the Monte Carlo simulation. In the traditional way the mean is always used as the variables value instead of using a probability distribution.

Furthermore, the model will be simulated 10000 times per simulation run as that is enough to get a stable and consistent result out of the model (Kroese et al., 2014). This is enough to get a consistent cumulative distribution of the total cost. In addition to that, the mean is the same for every simulation run.

The values used for the variables are checked by comparing the results with the research of Bot (2022). In addition to that, they have been explained to the business controller of the MST and she deemed them reasonable.

5.3 DESIGN DASHBOARD

The dashboard for CID is designed in Excel. This is done to make it easily adjustable and accessible for the MST as most of their data is also in Excel.

5.3.1 DATA TABLES

The first step done to design the dashboard is to determine all variables needed and their probability distributions. After that, all these values need to gather from the data. These values can be seen in Section 5.2. These are then put in a large table as can be seen in Appendix F.

The next step is to determine which formulas are needed to calculate a value for a variable within the probability distribution of said variable. To do this firstly a RAND () function must be used for every variable to constantly take a random point in the distribution per simulation iteration.

Together with the values from the tables the random values are then put into separate lines which can be easily adjustable via the table. The random variables are all independent for every variable. For every probability distribution type, the RAND () function is called Random except for the triangular distribution as the formula for the triangular distribution is quite different compared to the other probability distributions.

All of this can be seen in the Figure 13. Furthermore, in figure 13, all data is shown that is necessary to run a Monte Carlo simulation at each individual variable that is used in the model.

To show the difference between the traditional way of the cost calculation and the Monte Carlo simulation both methods are used to calculate the project set-up costs of CID.

These can be seen in the next Table 7.

Mean	Std. Deviation	Random
37	3	0.417304144

Min	Most Likely	Max
300	310	354.95

Lower Range	Higher Range	Total Range	Cumulative probability
10	44.95	54.95	0.141320217

Scaled mean	Scaled std. Deviatic	Random
0.149127227	1.2993264	0.710041116

Mean	Std. Deviation	Random
0.04	0.01	0.169172581

Min	Most Likely	Max
5	10	17

Lower Range	Higher Range	Total Range	Cumulative proability
5	7	12	0.372654034

Min	Most Likely	Max
300	310	354.95

Lower Range	Higher Range	Total Range	Cumulative probability
10	44.95	54.95	0.301218681

Min	Most Likely	Max
0	5000	10000

Lower Range	Higher Range	Total Range	Cumulative probability
5000	5000	10000	0.821787028

Min	Max	Max-Min	Random
50	50	0	0.666953682

0.5	0.5	Random
1	2	0.57261007

Min	Most Likely	Max
50	55	60

Lower Range	Higher Range	Total Range	Cumulative probability
5	5	10	0.095741937

Min	Most Likely	Max
112	120	137.4

Lower Range	Higher Range	Total Range	Cumulative probability
8	17.4	25.4	0.972634483

Mean	Std. Deviation	Random
99.9	6.414740837	0.145489581

Figure 12: Random probability distribution calculator

Model	Traditional	Monte Carlo
Incoming Patients	37	36.37
Cost per day hospital	-€ 310.00	-€ 308.81
Average Stay	2.7	2.38
Reduction in costs	-€ 30,969.00	-€ 26,766.00
Rehospitalization rate	0.04	0.03
complication stay	5	9.73
complication cost per day	€ 310.00	€ 313.40
Increase in cost	€ 2,294.00	€ 3,374.27
Monitoring Centre	€ 5,000.00	€ 7,014.93
Monitoring Equipment	€ 50.00	€ 50.00
Cost Monitoring employees	€ 55.00	€ 52.19
Total stay of patients in days	99.9	93.12618739
Increase in cost	€ 59,844.50	€ 61,193.67
Extra policlinic time used in slots	1.5	1
policlinic cost per slot	€ 112.00	€ 133.92
Increase in cost	€ 6,216.00	€ 4,871.24
Total cost	€ 37,385.50	€ 42,673.18

Table 7: Example total cost table (numbers used for the monitoring centre are examples due to confidentiality)

In Table 7, two columns are made: one for traditionally calculating the costs and one using the Monte Carlo simulation. The values in the Monte Carlo simulation are for one of the scenarios that could be possible. The traditional method always stays the same. The formulas used for calculating the total cost for both the traditional method and the Monte Carlo simulation are noted below:

$$Total\ cost = Reduction\ in\ cost + rehospitalizaiton\ increase\ in\ cost + monitoring\ increase\ in\ cost + increase\ cost\ of\ policlinic \quad (5)$$

$$Reduction\ in\ costs = Incoming\ patients * savings\ in\ cost\ per\ hospital\ day * average\ stay \quad (6)$$

$$Rehospitalization\ increase\ in\ cost = Rehospitalization\ rate * complication\ stay * complication\ cost\ per\ day \quad (7)$$

$$Monitoring\ increase\ in\ cost = Monitoring\ Centre + fixed\ cost\ Luscii + variable\ cost\ Luscii + Monitoring\ Equipment * Incoming\ Patients + Total\ stay\ of\ patients\ in\ days * cost\ monitoring\ employees * hours\ monitoring\ centre\ is\ operational \quad (8)$$

$$Increase\ cost\ of\ policlinic = extra\ policlinic\ time\ used\ in\ slots * costs\ per\ slots \quad (9)$$

5.3.2. PROBABILITY DISTRIBUTION FORMULAS

As said earlier the value of the variables used in the traditional method is always the mean or most likely value of the variable. To calculate the variables of the Monte Carlo simulation formulas are needed to incorporate the randomness for each probability distribution. The probability distribution types used in this model are the Normal, Discrete, Uniform and Triangular probability distribution.

The Excel formulas used to pick a random point in the distribution of each probability distribution are noted below.

For variables with a normal probability distribution the following Excel formula was used:

$$Variable\ (Normal\ distribution) = Mean + NORM.S.INV\big(RAND(\quad)\big) * Std.Deviation \tag{10}$$

In this formula RAND () is a value between 0 and 1.

For variables with a Discrete probability distribution the following Excel formula was used:

$$Variable\ (Discrete\ distribution) = IF(RAND(\quad) < Upper\ chance; Max\ value; Min\ value) \tag{11}$$

For variables with a Uniform probability distribution the following Excel formula was used:

$$Variable\ (Uniform\ distribution): Min + RAND(\quad) * (Max - Min) \tag{12}$$

For variables with a Triangular distribution the following Excel formula was used:

$$Variable\ (Triangular\ distribution) = Cumulative\ probability(\quad) < \frac{LowerRange}{TotalRange}; Min + SQRT(Cumulative\ probability * Lower\ Range * Higher\ Range; Max - SQRT((1 - Cumulative\ probability) * Higher\ Range * Total\ Range \tag{13}$$

In this formula the Cumulative probability is in practicality the same as the Random function. Therefore, it is a randomized value between 0 and 1. The Lower Range is calculated by the Most Likely value- Min value and the Higher Range is calculated by the Max value – Most Likely value. The total range is then the Lower Range + Higher Range.

Lastly for the variables with a lognormal distribution the following Excel formula is used:

$$Variable\ (lognormal\ distribution) = LogNorm.INV(RAND(\quad), scaled\ mean, scaled\ standard\ deviation) \tag{14}$$

The scaled mean is used to change the standard mean into a lognormal mean. The same is done for the standard deviation.

These are the formula’s used to calculate a random point for each run within each variable’s probability distribution.

5.3.3 SIMULATION RUNS

To run the Monte Carlo simulation in Excel several variables are needed. Firstly, the number of times the simulation is run should be noted in Excel. This done via the Counter variable. Furthermore, to keep track of the number the number of iterations run is noted in case of an error, so it can easily be seen at what point in the run an error has occurred.

Run Simulation		
Counter		10000
Iterations		10000
Average		€ 37,780.11
Probability above		
	€ 0.00	0.8936
	€ 30,000.00	0.7918

Figure 13: Excel simulation run

Since Table 7 only represents one run of the Monte Carlo simulation at a time automatically, the average of all runs together should register separately. To accomplish this, the Average function in Excel is used to keep track of the average across all runs.

Furthermore, as an extra statistic the probability that the project set-up costs are above a certain value is noted. This is done to get insight in the number of times the costs calculated can be expected to be around a certain value.

```
Sub MonteCarloSim()
Dim i As Integer
For i = 1 To Cells(4, 16)
    Cells(11 + i, 16) = Cells(75, 7)
    Cells(11 + i, 15) = i
    Next i
End Sub
```

Figure 14: VBA code for loop

Lastly, to run the simulation itself a VBA button, called Run Simulation, is used to start the simulation. The code in VBA used to loop the Monte Carlo simulation is seen in Figure 15.

Iteration	Total cost
1	-€ 23,354.47
2	€ 67,195.85
3	€ 27,390.95
4	€ 59,854.82
5	€ 62,827.18
6	€ 18,765.78
7	€ 16,364.35
8	€ 29,362.43

Table 8: Loop result example

The explanation for the VBA code is:

A loop is made for i = 1 till the value of the Counter variable. Then the value of the Monte Carlo simulation should be registered in a table in Excel. An example of this table is seen in Table 8. This is done by setting the value of each consecutive cell in Table 7 equal to the value in the table. Then the number of the iteration is written down in the cell beside the registered value keep track to of each individual run. When this is done the iteration counter goes up by one and the next run of the Monte Carlo simulation starts. This happens till the max value of the Counter variable is reached.

An entire figure of the dashboard input can be seen in Appendix F.

5.4 SENSITIVITY ANALYSIS

Due to the skewedness of the data seen in Chapter 4, the model is responsive to changing the variables as the standard deviations for most variables are high and the quantity quite low. This results in some variables having a significant impact on the outcome. To get an understanding of this, a local sensitivity analysis is performed on the variables that have the highest sensitivity in the model. This is done because the Monte Carlo simulation itself functions as a global sensitivity analysis.

The sensitivity analysis is performed on all independent variables in the model with a high standard deviation. These are: Incoming patients, rehospitalization rate, the average stay in days, cost monitoring staff and the cost of a hospital day. All other variables are quite stable or do not have a big standard deviation.

For these four variables, separate tables are made with the changes in each value and the outcomes. The tables are used to create graphs of every variable to increase the understanding of all variables.

The values of each variable are each multiplied by the following percentages of the original value: 0%, 25%, 50%, 100%, 200%, 400%, 800%.

Each of these values is then run throughout the entire simulation run to evaluate the influence the effect of each tested variable. Then the results are compared to the standard values, and it is determined how sensitive it is

5.5 CHAPTER CONCLUSION

In Chapter 5, the experiment design is explained. In Sections 5.1 and 5.2, research question 7*: What input variables are needed for the Excel cost calculation dashboard?* is answered. The variables needed for the dashboard are divided into four categories: the cost reduction by CID, the possible increase in re-admissions, the cost of the remote monitoring and the extra needed policlinic time slots. These four categories together make up for the total project set-up costs for CID. The values of all the variables are explained in Section 5.2 and can be seen in Table 6. In Section 5.3, the entire building of the Excel dashboard is explained. This was done via the use of a Monte Carlo simulation over every variable. Every simulation run consists of ten thousand iterations. Then all outcomes of the four main variables were gathered and summed up together for the total cost. These can also be compared to the traditional cost calculation method in the MST. Lastly, in Section 5.4 the sensitivity analysis for certain variables is explained. Due to some of the input variables of the model having low population samples, standard deviations tend to be large. To investigate how large the impact of these variables is, a sensitivity analysis is performed. The sensitivity analysis is performed for the variables: Incoming patients, cost of a hospital day, average stay and rehospitalization rate. The results will be published in a table as seen in Table 7.

6. RESULTS

In this chapter, the answer to research question 8: *What are the results of the Excel cost calculation dashboard and the sensitivity analysis?* are discussed. In Section 6.1, the general outcome of the Monte Carlo simulation with the standard values is discussed for the KPIs reduction cost CID, increase cost rehospitalization, increase cost monitoring, increase cost policlinic and the total cost. In Section 6.2, the outcome of the sensitivity analysis for the four input variables is discussed. In Section 6.3, a conclusion of the chapter is given by answering research question 8.

6.1 RESULTS OF STANDARD VALUES

In this section, the results of the 5 KPIs are shown: reduction cost CID, increase cost rehospitalization, increase cost monitoring, increase cost policlinic and the total cost. This is done via visualizations of the averages of most values. In addition to that, the standard deviations of all variables are shown.

6.1.1 REDUCTION OF COST CID

The main cost reduction for introducing CID is made by sending patients home earlier compared to the regular colon surgery care path. In Figure 16 and 17, the profit of CID is calculated. In the traditional method, the reduction in cost by CID is € 30,969.00. In the Monte Carlo simulation, the reduction in cost is € 32,023.82. The standard deviation over these ten runs is €602.71. To test the mean a 95% confidence interval has been performed. The result of it is €343.97. This gives a 95% chance that the average in this range is from € 31,650.00 till €32,397.00.

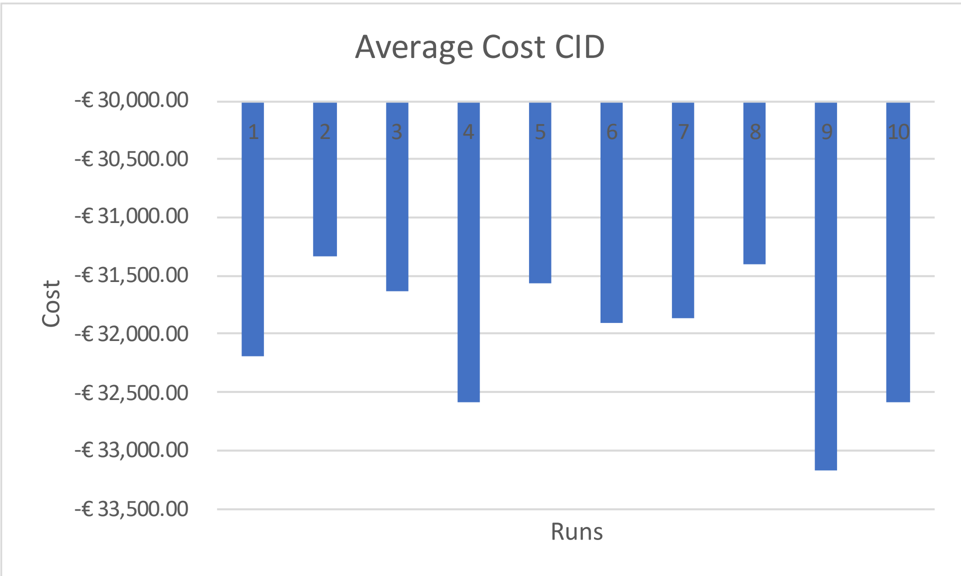

Figure 15: Average cost CID

As can be seen in Figure 17, there is a large discrepancy between the average iteration in a run and the outliers. This is due to the lognormal formula used as a probability distribution for the average stay of a patient. On average this probability distribution is correct. However, the outliers from the graph will not happen in the MST, because the lognormal distribution has an exceedingly slight change of giving an incredibly long average stay per patient value. This leads to abnormal cost reductions in the millions that do not happen. Luckily, these also do not interfere with the average of the run that much due to their scarcity.

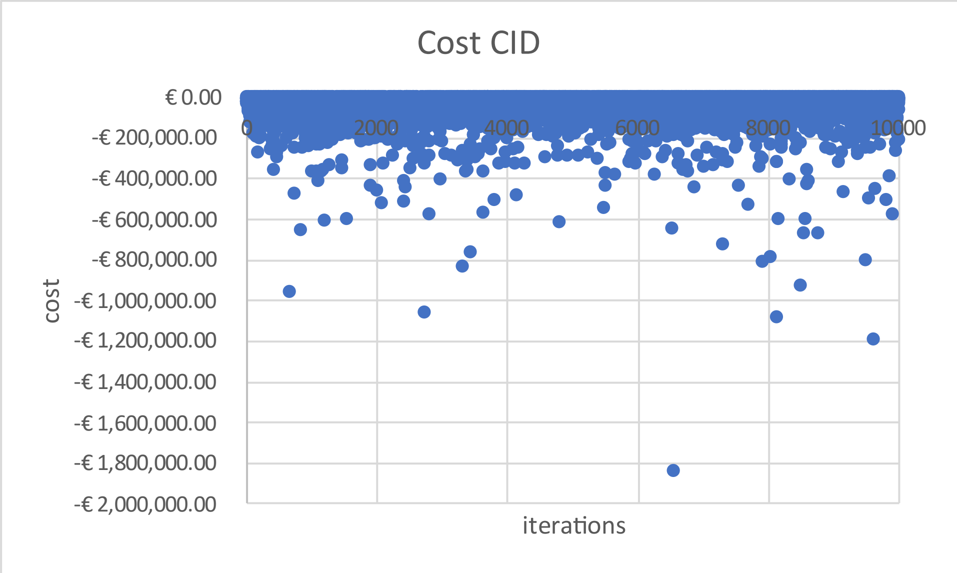

Figure 16: Separate iterations of 1 simulation run

6.1.2 INCREASE COST FOR RE-ADMISSIONS

The impact of re-admissions is quite low due to the pre-selection of CID patients. The traditional method cost for re-admissions is €2,294.00. The average value over ten runs in the Monte Carlo simulation is €3,684.68. In addition to that the standard deviation over ten runs is € 10.44 and the 95-confidence interval is €6.47. As a result, this gives a 95% chance that the average is in this range.

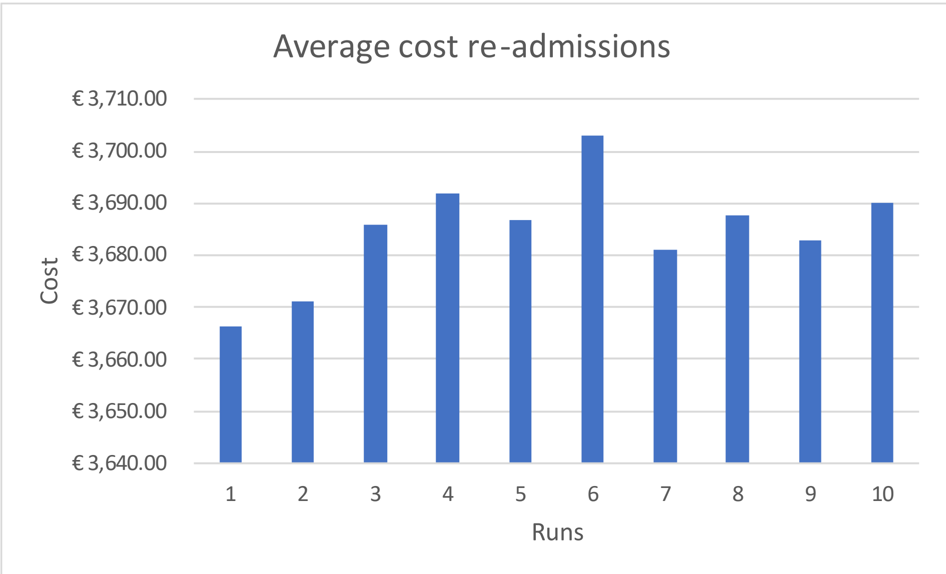

Figure 17: Average cost re-admissions

As can be seen in Figure 19, the spread is centred around the average of the cost. The outliers are not skewed far apart. Therefore, the cost for re-admissions is quite centred around its average. As can be seen the costs might be a bit higher than predicted in some cases. This could be the case due to the scarcity of only having three cases of re-admission under CID patients. This causes the length of stay after a re-admission to be quite unknown and different per patient.

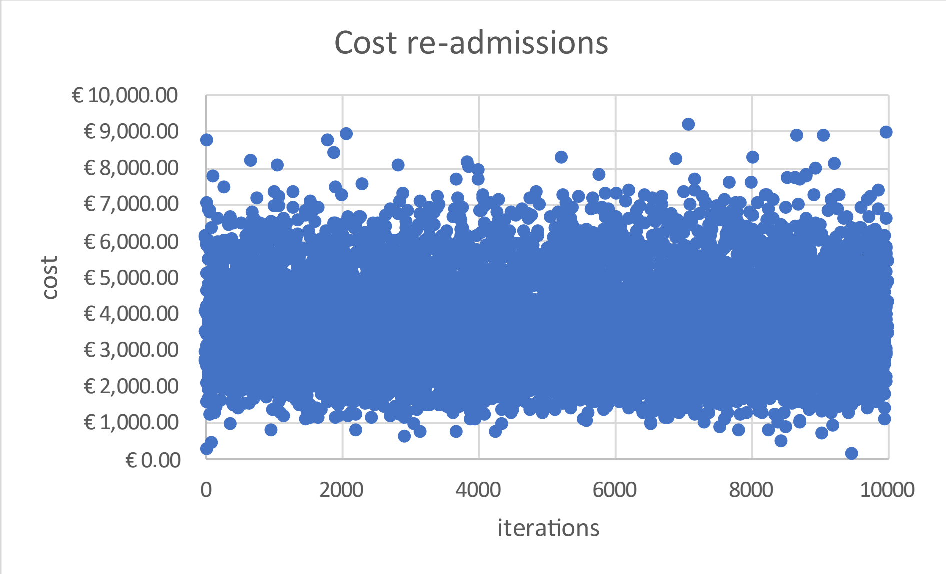

Figure 18: One run of cost re-admissions

6.1.3 COST FOR MONITORING

The monitoring costs are quite stable due a large percentage costs coming from repeated sources, such as the one-time investment and the monthly payment. This results in the variable costs for treating patients being only dependent on the cost of the monitoring equipment and the amount of time the monitoring centre is staffed. According to the traditional method, the cost of the monitoring will be € 59,104.50, while the Monte Carlo simulation gives a cost of € 59,108.00. The standard deviation over ten runs is €14.66. The 95% confidence interval range is €9.09. This results in the average being in around 59,108.00 in 95% of the cases.

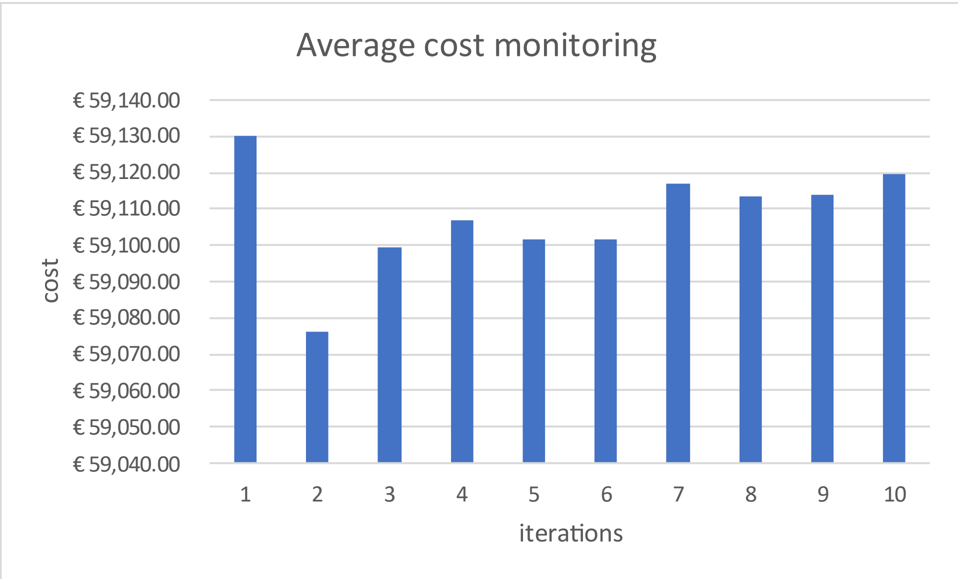

Figure 19: Average cost monitoring

As can be seen in Figure 21, the spread of the cost monitoring is limited. This is because the large part of the monitoring is a fixed cost. Therefore, the estimation of the monitoring is likely to be close to that value when initially setting-up CID. This is since all other costs are made later in the process while the monitoring infrastructure needs to be ready at the start.

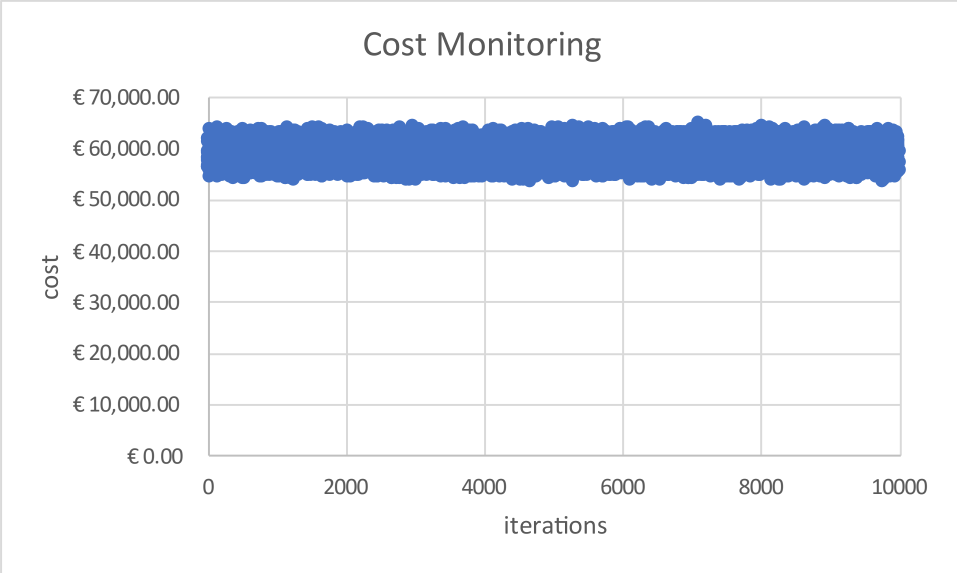

Figure 20: One simulation cost monitoring

6.1.4 INCREASE POLICLINIC COST

The average increase in cost for the policlinic when introducing CID is based on whether 1 or 2 extra timeslots are needed to explain how CID works and to evaluate CID afterwards. According to the traditional method, the increase in costs is €6,223.22. The Monte Carlo simulation gives € 6,834.60 as an average extra cost. The standard deviation over ten runs in the simulation is €16.16. It can also be seen in Figure 22 that the cost is very stable when comparing different runs. The 95% confidence interval is €10.02. This means that the cost for extra policlinic slots is 95% confident to be ±€10.02 around € 6,834.60.

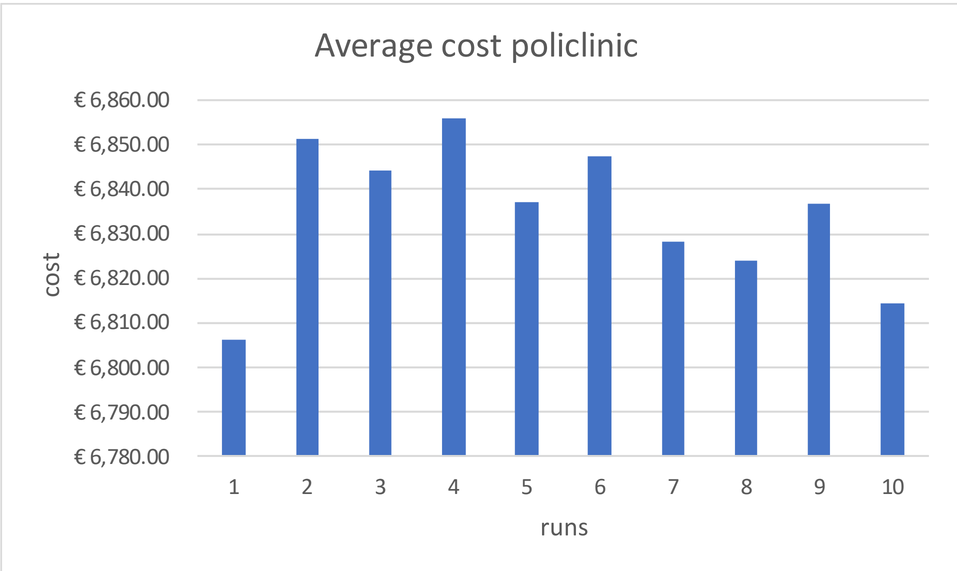

Figure 21: Average cost policlinic

In Figure 23, there is a large spread visible between one and two extra timeslots. The average cost is approximately in the middle of these two colons of dots, because the chance of needing one or two additional time slots is exactly half for choosing one or two timeslots per patient in the model. Also, the outliers in the upper colon are further away from the average than the outliers in the lower colon of points. This is most likely due to a high policlinic cost used twice instead of only once. This is then multiplied by having two timeslots instead of having one, which causes the standard deviation to be twice as big for two additional timeslots compared to needing one additional timeslot per patient.

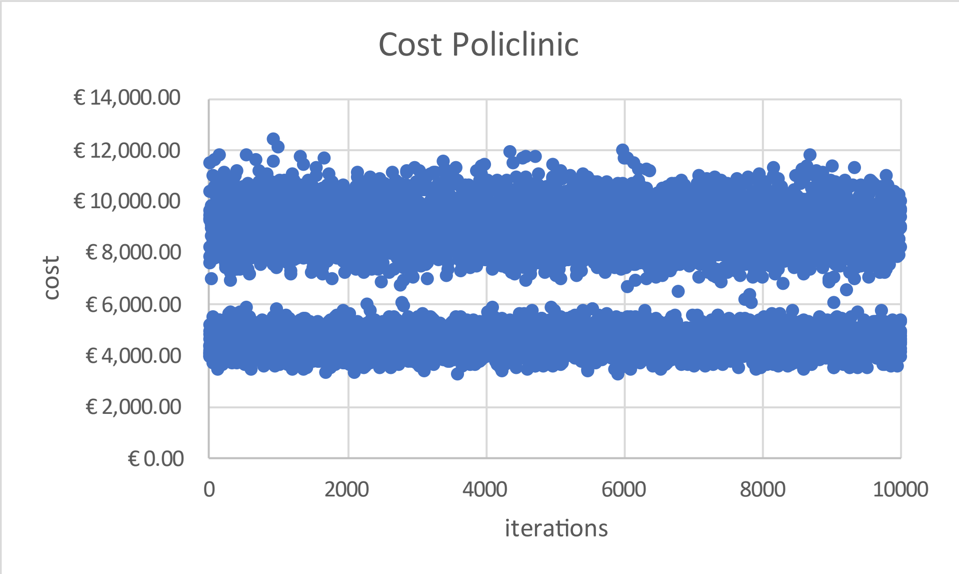

Figure 22: One run cost policlinic

6.1.5 TOTAL COST

The total cost is calculated in the dashboard in two ways: the traditional and the Monte Carlo simulation. The total cost in the Monte Carlo simulation tries to give an accurate estimate of what the project set-up costs of CID would cost while considering the variability of some variables due to them having high standard deviations. The traditional method gives € 36,652.72 as the total cost. The Monte Carlo simulation gives a cost of € 37,257.66 on average with a standard deviation €554.98 over 10 runs of 10000 iterations. When using the 95% confidence interval, the range is €343.971. For that reason, it is 95% certain that the total cost is on average approximately between €36,950.00 and €37,550.00 . This was done to test the consistency of the model over multiple runs. As can be seen in Figure 24, the Monte Carlo simulation is relatively consistent. The difference between these two methods is caused by the fact that the traditional method is only using the means of all variables while the Monte Carlo simulation is using the probability distributions of each variable as well.

Figure 23: Average total cost

As can be seen in Figure 25, the total cost differs a lot per iteration within one simulation run. This is due to the outliers that are caused using the lognormal distribution for the average stay in the hospital. This is completely normal as in the Monte Carlo simulation a global sensitivity is effectively performed. So, with the values out of the datasets of the MST the total cost for CID is approximately €37000 according to the simulation and €48000 according to the traditional method.

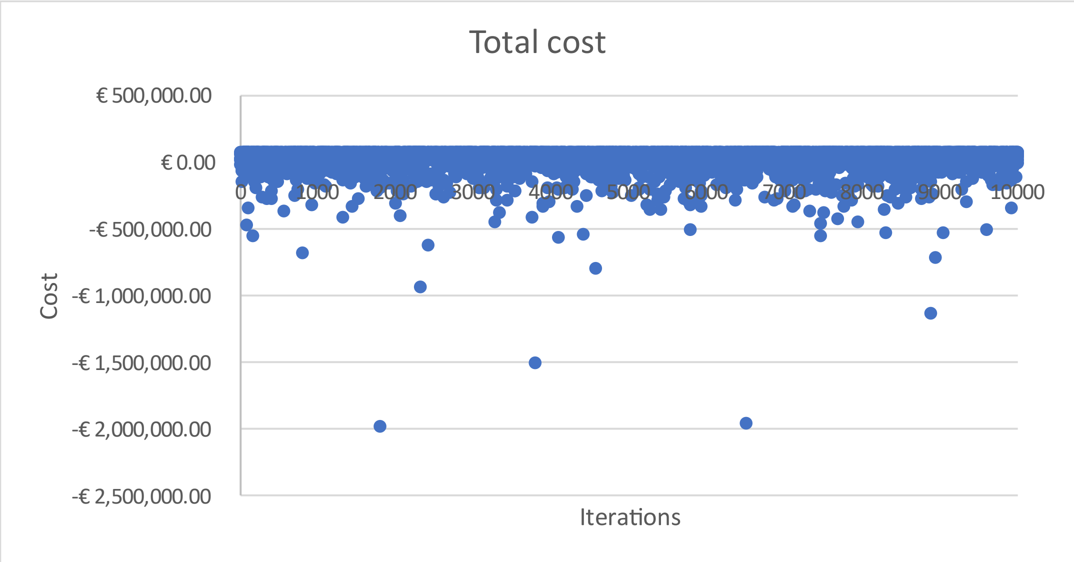

Figure 24: One run total cost

6.2 RESULT OF SENSITIVITY ANALYSIS

To get more insight into the model and its results, a local sensitivity analysis has been performed. The results of this analysis are shown in tables per input variable that is tested. Based on these tables, assumptions can be made on the impact on the total cost of certain input variables. The tables and graphs only show the KPIs that are influenced by the input variables.

6.2.1 INCOMING PATIENTS

The values used for the incoming patients can be seen in Table 9. When looking at the influence of altering the incoming patient's variable it shows that it has a large effect on all costs except for the cost of the monitoring at lower values. This is because the monitoring is the only cost with a substantial amount of fixed costs. In addition to that, between 74 incoming patients and 148 patients there is a crossover point for the total cost where CID becomes a profitable investment.

Incoming patients	Total Cost	Cost CID	Cost re-admission	Cost monitoring	cost policlinic
0	€ 52,492.37	€ 77.40	-€ 10.08	€ 52,504.14	€ 8.79
9.25	€ 48,804.15	-€ 7,912.85	€ 922.17	€ 54,141.68	€ 1,703.19
18.5	€ 44,740.48	-€ 17,052.23	€ 1,840.72	€ 55,772.29	€ 3,422.65
37	€ 37,257.66	-€ 32,023.82	€ 3,684.68	€ 59,108.01	€ 6,834.60
74	€ 21,993.06	-€ 64,744.84	€ 7,422.38	€ 65,693.28	€ 13,668.43
148	-€ 9,234.09	-€ 125,031.43	€ 14,735.94	€ 78,882.24	€ 27,392.55
296	-€ 68,345.17	-€ 251,373.55	€ 29,480.17	€ 105,315.04	€ 54,575.09

Table 9: Incoming patients sensitivity analysis

In Figure 26, it becomes clear that the cost reduction caused by CID becomes more eminent at larger values of patients. This has been made clear in Figure 26 as both the cost reduction of CID and the total cost face a downward trend once more patients are allowed to participate in CID. Furthermore, the cost increase at larger numbers of incoming patients is smaller than the cost decrease caused by CID. This means that the further CID is scaled up, the more attractive it becomes as an option to save money. Optically, it seems from the graph that the decrease becomes more severe with more incoming patients. However, due to the horizontal axis doubling with every value it is actually a linear decrease, since every patient causes the same reduction in cost on average compared to the normal situation. This effect is based on every patient in comparison to the hospital. There is a ceiling for this effect. It is reached when the number of staff in the hospital is sufficient to cover all incoming patients and waiting lists are noticeably short compared to now. If this is reached the cost difference between CID and recovering in the hospital are quite minimal.

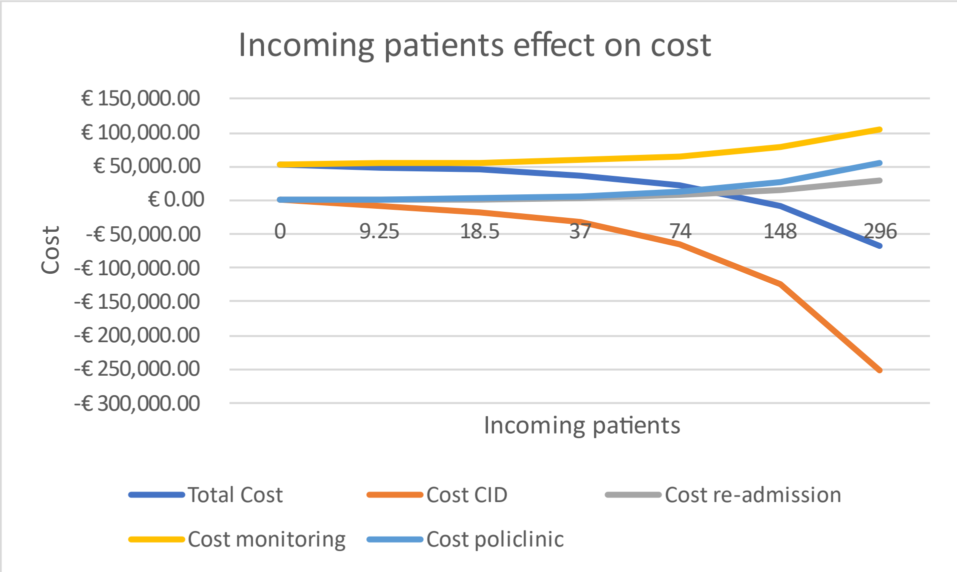

Figure 25: The effect of the incoming patient’s variable on different costs

6.2.2 REHOSPITALIZATION RATE

In Table 10, the results of the sensitivity analysis on the rehospitalization rate can be seen. As can be seen the increase in money from the rehospitalization rate is directly proportional. However, the effect of the cost of re-admissions is not directly proportional to the increase in total cost. It goes up by the same as the re-admission’s costs, but in total it makes a smaller difference.

Rehospitalization rate (percent)	Total cost	Cost re-admissions
0	€ 33,212.82	-€ 12.28
0.01	€ 35,815.82	€ 928.44
0.02	€ 36,004.81	€ 1,846.63
0.04	€ 37,079.62	€ 3,683.21
0.08	€ 42,246.71	€ 7,384.94
0.16	€ 49,710.60	€ 14,806.74
0.32	€ 64,042.41	€ 29,465.20

Table 10: Rehospitalization rate sensitivity analysis

However, at some point (see Figure 27) it can be seen that the rehospitalization rate causes a serious increase in costs. For example, if one in three patients returns it will approximately already cost €30,000,- with a sample of 37 patients. Furthermore, in case of these percentages being true, CID is not only costly, but also not very effective. In addition to that, re-admissions result in patients staying at the hospital for longer which is the opposite of what the MST is trying to achieve. However, due to the real complication percentages not being nearly as high this is a hypothetical scenario that should only be taken into consideration when this percentage turns out to be higher in the CID pilot.

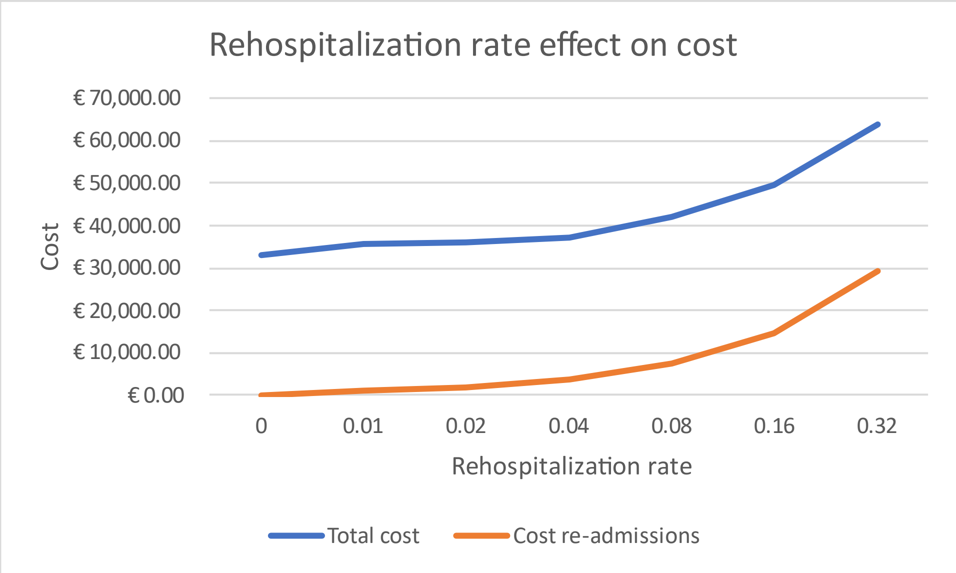

Figure 26: The effect of changing the rehospitalization rate on the different costs

6.2.3 AVERAGE STAY

The initial average stay of patients in the hospital is a large factor in determining whether CID is worth it, due to patients remaining at the hospital shorter has not only a substantial impact on cost, but also on the pressure on the nurses. In Table 11, the results of the sensitivity analysis are noted for the average stay variable.

Average stay (days)	Total cost	Cost CID	Cost monitoring
0.01	€ 64,025.31	-€ 63.15	€ 53,602.84
0.675	€ 56,853.05	-€ 7,848.41	€ 55,000.43
1.35	€ 50,946.48	-€ 16,066.84	€ 56,385.88
2.7	€ 36,877.28	-€ 32,474.13	€ 59,115.91
5.4	€ 10,890.55	-€ 64,249.51	€ 64,673.92
10.8	-€ 42,519.95	-€ 129,353.47	€ 75,586.35
21.6	-€ 147,828.39	-€ 257,496.21	€ 97,562.70

Table 11: Average stay sensitivity analysis

In Figure 28, we see that the longer the average stay in days is the better it is to implement CID and let patients recover at home. In the real world, this is not entirely true as while in terms of cost it is better to send a patient home, but this will not be very safe as a longer average stay often corresponds with a higher complication percentage (Chiu et al., 2017). This would in return lead to a higher re-admission percentage and higher costs. So, it is disputable if the selection of colon cancer patients with a longer average stay in the real world would be more beneficial for CID. However, for other specialisms that have a longer recovery time at the MST combined with a low complication percentage, it might be handy to consider remote monitoring. This is significantly lower in cost as can be seen in both Table 11 and Figure 28.

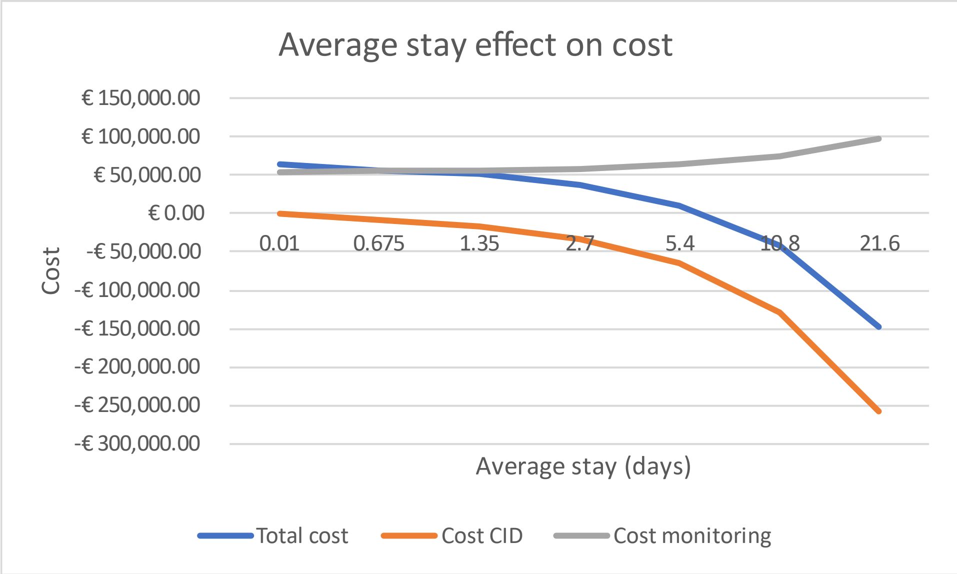

Figure 27: The effect of the average stay variable on the costs

6.2.4 COST OF A HOSPITAL DAY

In Table 12, the results of the sensitivity analysis for the input variable cost of a hospital day are noted. As can be seen in Table 12, both the cost of a hospital day is directly proportional to the cost for CID and the cost for re-admissions. Furthermore, the total cost decrease is the difference caused by the decrease of CID and the increase of re-admissions. It must be noted that the lower and upper costs for this variable are not realistic. This analysis is more so done to provide insight into the sensitivity of the model on this variable

Cost of a hospital day	Total cost	Cost CID	cost re-admissions
€ 0.01	€ 65,884.96	-€ 0.69	€ 0.08
€ 77.50	€ 61,171.59	-€ 5,506.98	€ 633.37
€ 155.00	€ 56,207.39	-€ 10,853.48	€ 1,273.74
€ 310.00	€ 36,306.03	-€ 33,341.64	€ 3,694.56
€ 620.00	€ 8,216.83	-€ 64,126.39	€ 7,381.10
€ 1,240.00	-€ 44,824.04	-€ 130,589.71	€ 14,826.34
€ 2,480.00	-€ 159,488.21	-€ 257,886.85	€ 29,752.20

Table 12: Results of sensitivity analysis for cost of a hospital day

As was previously noticed, in both the incoming patients input variable and the average stay variable as well as the cost of a hospital day variable in Figure 29, the reduction in CID costs variable is impacted most by these changes. This is caused by the fact that CID counts for all involved patients while for example re-admissions is only influenced by 4% of all incoming patients. This is the same for the cost per hospital day variable reaches large values. As can be seen in Table 12, the CID cost reduction is always larger than the increase in re-admissions costs which means that the total costs decrease.

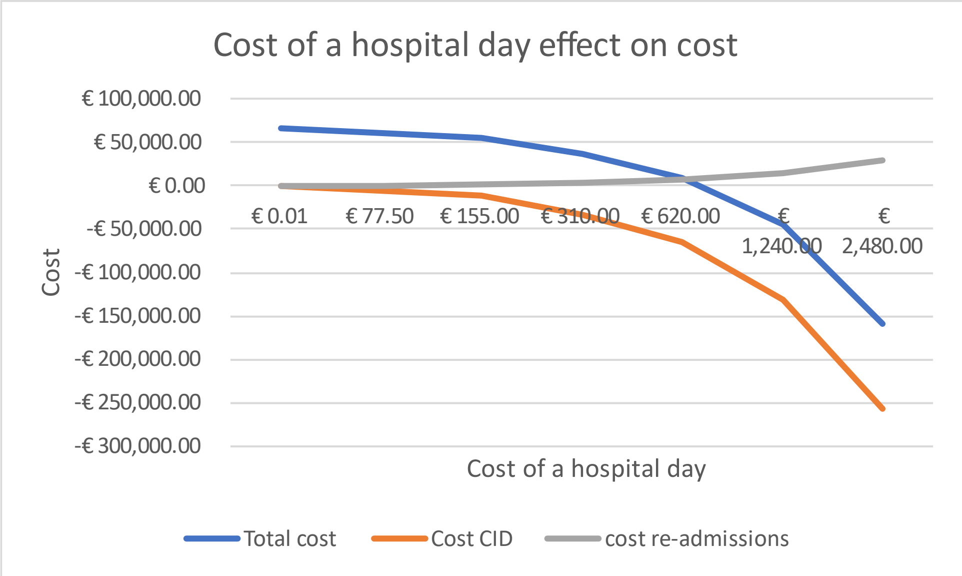

Figure 28: The effect of the average hospital variable on the cost

6.2.5 COST MONITORING STAFF

Currently, there is still debate over what kind of staff should be at the monitoring centre. This varies from nurses to specialists for monitoring equipment. As is logical, these all bring different costs with them. To give insight in the effect of this cost. A sensitivity analysis was performed for the costs of monitoring staff to determine the impact of staff on the total costs and the monitoring costs. As can be seen in Table 13, the costs range from €0 to €440 euros. For example, interns will cost the MST €0, while a surgeon will cost closer to €440 per hour.

cost monitoring employees	Total cost	Cost monitoring
€ 0.00	€ 31,151.52	€ 53,610.34
€ 13.75	€ 32,524.73	€ 54,983.62
€ 27.50	€ 33,898.46	€ 56,357.25
€ 55.00	€ 36,645.50	€ 59,104.50
€ 110.00	€ 42,140.76	€ 65,599.98
€ 220.00	€ 54,234.68	€ 75,588.76
€ 440.00	€ 74,987.65	€ 97,566.43

Table 13: Results sensitivity analysis for cost monitoring staff

As can be seen from the Figure 30, from €0 to €55, there is a relatively minor increase of the costs. From then on, the costs of the monitoring centre start to increase rapidly, when using more expensive staff. Therefore, it would be recommended to choose the staff that is adequately trained but is not too expensive, such as a specialist.

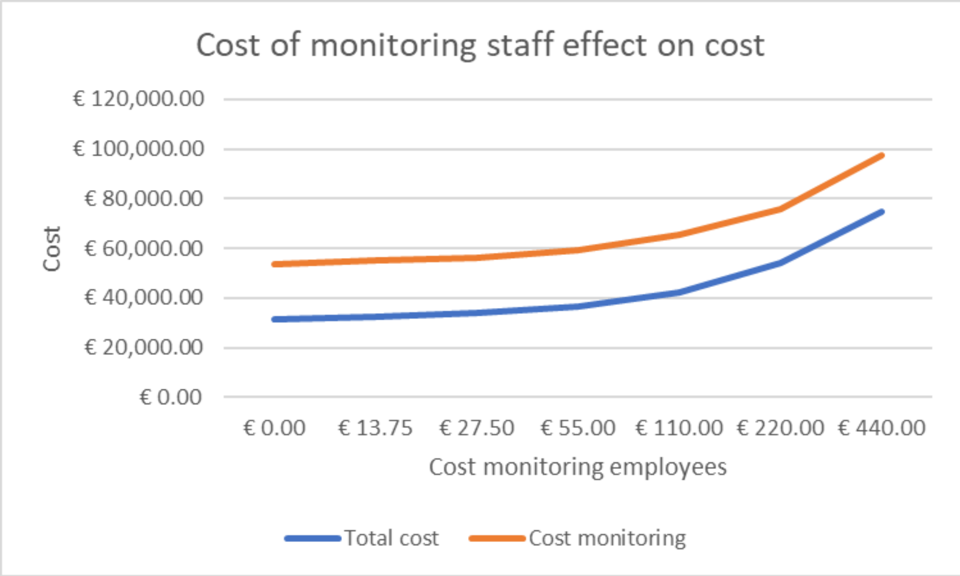

Figure 29: The effect of the cost monitoring staff variable on the cost

6.3 CHAPTER CONCLUSION

In this chapter, the results of both the standard Excel dashboard as well as the sensitivity analysis were discussed and an answer to research question 8 is researched: *What are the results of the Excel cost calculation dashboard and the sensitivity analysis?* The main answer to this question is that the total cost for the project set-up for CID with a monitoring centre in the MST costs approximately €37,000.00. This is the case for both the traditional method as well as the Monte Carlo simulation. This includes the entire monitoring centre itself as well, which can also be used for other departments. Furthermore, the sensitivity analysis showed that an increase in incoming patients, average stay of colon surgery patients and cost of a hospital day all make CID a more attractive option for cost reduction. In addition to that, this also proves the viability of multiple disciplines using remote monitoring as the benefits of remote monitoring become larger when used on a bigger scale.

7. CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

In this report, all research questions stated in the research design are answered. In Section 7.1, a conclusion is given to the main research question of this thesis. In Section 7.2, there is a discussion about the limitations and the validity and reliability of this thesis. In Section 7.3, recommendations are made for the MST on what further can be done with the research. In Section 7.4, there is an elaboration on further research that can be done on this topic. In Section 7.5, there is an analysis of the practical and theoretical contribution of this thesis.

7.1 CONCLUSION

The main goal of this thesis is to give insight in the logistics operations changes required to implement CID. The secondary goal of the research is to calculates the costs of the logistic operations changes required when implementing the desired system compared to the current system.

To accomplish this, the main knowledge problem that was solved in this thesis was:

Which logistic operations changes are necessary to implement CID and what does it cost?

The necessary logistic operations changes to transition to CID are the set-up of a monitoring centre and finding a suitable supplier for the remote monitoring, hiring, or assigning staff for the monitoring centre and increasing the available timeslots for the policlinic.

Firstly, there are three options for the monitoring centre: a regular check by the assigned nurse for every individual CID patient, the set-up of a monitoring centre in the MST itself and a regional centre. According to expert opinion in Section 4.2, the best option for the pilot is to use the nurses, for the short to mid-term the monitoring centre in the MST is most viable and for the long-term the regional monitoring centre is an option. At this moment, the best option for the MST is to set-up a monitoring centre by itself as it gives them the fastest transition to remote monitoring and gives them the ability to increase their capacity quickly.

Secondly, for the equipment either Masimo or Luscii can be used as supplier. The benefit of Masimo is that its monitoring has continuous measurements. The benefit of Luscii is that it can be used both in a lot of different departments in the MST and can be integrated in the IT systems of the MST. As the prizes of Luscii are known these are implemented in the Excel dashboard.

Lastly, due to the extra information that is given to the CID patient before the surgery and the extra evaluation afterwards extra time is needed at the outpatient clinic. To achieve this, an extra timeslot needs to be reserved.

After determining these three logistics changes, the costs were determined via a Monte Carlo simulation in Excel. According to the model, the total cost to set-up CID as an additional care path will cost approximately €37,000, - in the first year. Furthermore, via the sensitivity analysis several insights regarding CID were researched. The main outcome is that CID reacts well to upscaling the variables that are patient related, the average stay and the cost of a hospital day. Therefore, it is beneficial to upscale CID as quickly as possible once introduced. This is also applicable to other surgery types as the monitoring centre can be used multidisciplinary.

To conclude, the necessary logistic operations necessary are the set-up of the monitoring centre in the MST, finding a suitable supplier for the remote monitoring and the increase of timeslots reserved at the policlinic for CID. The expected cost of this project set-up for CID is €37000, -.

7.2 DISCUSSION

In the discussion the limitations, the validity and reliability of this research are analysed. This is done to determine the quality of this research.

LIMITATIONS

Firstly, the quality of the data. The data was gathered from multiple sources and combined. This means that data ranging from the years 2019 until 2022 was used. Furthermore, due to this time frame some data might have become slightly inaccurate when using it in 2022. This is partly due to the high inflation that is impacting some of the costs. On the other hand, surgery and recovery procedures are constantly improving which means that for example, length of stay could have already been reduced for most patients when this research is published. In addition to that, due to the innovative nature of CID there is no previous data on the topic. That means that assumptions were used for some variables in the model.

Secondly, due to CID being a new method, not many people have experience with it. Therefore, the expert opinion is also partly based on assumptions. These are probably correct as all are experts in their profession. However, there is a small chance that something unexpected turns out to be the case, which was not known during this study.

Thirdly, certain requirements need to fulfil to make CID worthwhile. The first one is that the rehospitalization rate should not be a lot higher than the assumption of 4% extra compared to the standard situation as from the sensitivity analysis it showed that the cost will rise rapidly per patient that needs a re-admission. Secondly, in the model it is now assumed that there nurses will staff the monitoring centre. If more specialised staff is needed to manage the monitoring centre it might also become more costly which would mean that CID would less likely be profitable. Furthermore, to implement CID it is required for the MST to scale it up as quickly as possible to reduce the cost of the project set-up. If the MST does not intend to do this, CID is not very cost-effective compared to the standard health track.

Lastly, the information and state of CID at the MST changed continuously throughout the research. This means that information about CID is in a constant state of change. Due to this fact, after this research is being conducted some information might have changed. It has been tried to prevent it from happening by making the Monte Carlo simulation easily adjustable so that it can be updated frequently.

VALIDITY

For the internal validity, the sensitivity analysis has been performed to check for mismatches in the model. This is done by using extreme values as input values to determine if the model is behaving as is supposed with the design. Except for one, all variables performed as expected in the model. The mismatch can be found in the incoming patients variable. As this variable is based on a lognormal distribution, sometimes a remarkably high number can come out of the model. However, since the outliers are quite uncommon this does not have a significant impact on the model, according to the confidence interval tests done. Furthermore all data in the MST are real-world results. From these results the average and standard deviation have been used to properly present the real situation. These input variables have also been shown to the business controller of the MST to confirm if the input variables are correct. The formulas in the model itself has been checked by my first supervisor.

For the external validity, two factors are of importance. The first factor is whether the model also is applicable for other hospitals. In general, the model is applicable for other hospitals if the same variables need to be changed while introducing CID. The input variables itself can easily be altered, so it does not matter if other input variables are needed for another hospital. If this is not case, the model is not correct and variables need to be change. This can be done but requires a lot of effort by manually adding all variables and adapting all coding and most formulas. The second factor is if the model will perform equal to the real costs that the MST has. For this specific situation, the model is quite precise in the predicted costs as all real values have been used to determine the costs that need to be made. These are also both validated in the model by using both the traditional cost calculation method and the Monte Carlo simulation to determine the costs. On average the results are very similar in terms of costs, so it is most likely that the model gives quite accurate results. However, since CID has not actually been introduced, it cannot truly be validated till it is implemented.

For the construct validity, it is about the concepts that are used in this thesis. For the construct validity it is important to reflect on whether they have been operationalized correctly. In most cases, the concepts and variables used have been based on scientific research in the literature study or are determined by experts from the MST. In addition to that, all choices for variables and concepts have been thoroughly explained.

RELIABILITY

In this section, the reliability of this thesis is discussed. The reliability is measured to control the stability of the thesis. This means that when following the steps conducted in this research the results should be the same for a fellow researcher. When using the model, this is the case when the same input variables are used as in this thesis. So, when these stay the same the outcome of the results also remain the same. For the sensitivity analysis, it is the same situation. It must be noted that reliability only takes into account the stability of the research and not if the methods used in the thesis have been the best.

7.3 RECOMMENDATIONS

In this section, recommendations are done on several parts of the research.

Firstly, my main recommendation is to start the pilot on CID as quickly as possible. CID has multiple benefits for both the MST and colon surgery patients that fall within the criteria of CID in Appendix C. The benefits for the hospital are a lower workload for nurses resulting in fewer bed-stops. In addition to that, when using the monitoring centre effectively it is beneficial for the MST cost-wise. This means that the monitoring should be scaled up for CID as quickly as possible and be combined with other types of patients that can recover at home. This combination of factors can have a big impact on the costs for the MST. For the patients there are multiple benefits when recovering at home instead of at the hospital, such as improved rehabilitation (Hentenaar & Demmer, 2021). However, most of these benefits are still somewhat theoretical and not confirmed in practice at the MST. Therefore, my recommendation is to start a pilot on CID as soon as possible. If the pilot has positive results, the next step is to scale up the monitoring centre as quickly as possible to reduce the costs.

Secondly, the dashboard can be extended in case it turns out that more logistic changes need to be made. It is also advisable to update it regularly and to test how accurate it is once CID is introduced. In addition to that, if this is the case it is recommended to also use the dashboard to calculate the costs for other surgery types changing to CID to make a projection of the costs. it is also handy to update the dashboard to the actual values of 2022 as in this research predictions of these values are used.

The following recommendation is to have a good look at what the JBZ is currently doing with CID or to cooperate with them as they are a step further in introducing it. Furthermore, they also already have a monitoring centre in which eight hundred patients are monitored. So, for that reason, it also good to see how they set that up exactly.

The last recommendation is about the available data. Currently, the data is all stored in the systems of the MST without a proper dashboard for all of it. It might be a step forward to make a dashboard in PowerBI to always have a quick overview of the most recent data.

7.4 FURTHER RESEARCH

For further logistic and financial research into CID several recommendations can be made based on this research. Firstly, a further data analysis can be done because some of the data at the MST is currently lacking in terms of quantity to make valid assumptions based on the data. For example, for CID patients there are only three cases of rehospitalization. This is good for CID, since it makes the occurrence of a rehospitalization very low in theory. However, due to only using the inclusion and exclusion criteria from Appendix C, which is based on theory, it is not it a very reliable source for measuring the average stay after a re-admission of a patient. So, further research can be done on the medical data of colon surgery to make it clearer and more extensive. This could also be supported by using quantitative data on CID from other hospitals with comparable procedures. Furthermore, further research can be done to find out the exact costs the colon surgery department has, as now sometimes several different values come out of the dataset.

As seen from the conclusion, to make the monitoring centre financially efficient it is crucial to involve other disciplines in the hospital. So, a viable research option as an extension to this thesis, could be to focus on what other disciplines benefit from the monitoring centre. In addition to this, it can be evaluated if all these disciplines are able to make use of the same monitoring and infrastructure to keep the procedures in the monitoring centre as easy as possible.

From the medical discipline, it is important to check if releasing patients from the hospital to recover at home is as effective as it is currently hypothesised. For example, if the re-admission rate of CID patients is higher than expected, a change in exclusion and inclusion criteria might be needed to guarantee that the patients can safely recover at home.

7.5 CONTRIBUTION

This research is conducted for Medisch Spectrum Twente. They want to transition healthcare from the hospital to homes to reduce the work pressure on their staff. A first step in this direction is to transition aftercare of colon surgery patients to day-care at home. Currently, the JBZ hospital and the Zuiderland hospital are also working on realising this. However, all research done on CID until today has all been medical research. Therefore, this report is the first to elaborate on the logistic and financial changes that follow transitioning to CID. Moreover, it gives insight in the precise logistics operations changes needed. These are all very general so can be used in most of the Netherlands in case it is needed.

The MST can use the insights on the logistical changes needed to implement CID on a large scale. Also, the dashboard is made in Excel so it can easily be used in the MST by business controllers or project developers. It can give accurate assumptions on costs that need to be made for the implementation of CID and is easy to adjust in case of future changes. This can be used to further analyse CID. In addition to that, the dashboard is generic this means that it is possible to also use it for all other surgery types that want to transition to remote monitoring. This dashboard can also be used in other hospitals if they have the same procedural changes for CID or other surgery types.

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APPENDICES

In the Appendix all additional information of this thesis can be found. In Appendix A, an extensive problem definition can be found. In Appendix B, the knowledge questions used at the start of this research are noted. In Appendix C, the inclusion and exclusion criteria used for the selection of CID patients are shown. In Appendix D, the interviews done are transcribed. In Appendix E, the Monte Carlo simulation and the available probability distributions. In Appendix F, the entire dashboard is shown.

APPENDIX A PROBLEM DEFINITION

The problem is defined via two stages. Firstly, all problems are evaluated, after which they are placed into a problem cluster to find the core problem. This will be done in section 1.3.1. In section 1.3.2, the core problem is then analysed and defined.

PROBLEM CLUSTER

To further analyse the problem, a problem cluster is made to create a clear overview of related problems and their connections (Heerkens & Winden, 2017). The problems in the problem cluster have been verified by my supervisors and some are logically induced. The problems are all labelled via the colour coding in the problem cluster.

It is expected that there will be more cases of colon surgery in the upcoming years since colon surgeries are most expected in elderly people. This leads to more patients being hospitalized. Now, after colon surgery all patients stay for on average 2.3 days in the hospital to recover and monitor complications. This is a comparatively long time as 50-70% of patients do not have any complications. So, they remain at the hospital unnecessarily. This is labelled as long post-surgery recovery at the hospital. Furthermore, there is only a limited capacity of post-surgery recovery beds available for all patients. These two problems combined cause a high occupation of the available beds.

This causes a plethora of problems. The available staff is already not sufficient to handle the increased demand, as could be seen during the covid-19 crisis. In combination with the high workload, there is an increase in the sick leave. The higher sick leave and limited capacity of staff lead to another increase of the workload which all together cause another reduction in capacity of staff.

The higher occupation of recovery beds also leads to potentially not having enough beds available for emergency procedures. This bottleneck will lead to patients having to wait longer for their surgery.

The limited capacity of both post-surgery beds and operation rooms (OR'-s) cause a limited capacity of the available machine resources. The longer waiting times, the reduced capacity of staff and the limited capacity of machine resources combined cause a slow throughput of patients. The slow throughput of patients at the post-surgery recovery department causes a non-efficient use of the OR's which in return causes longer waiting times and longer waiting lists.

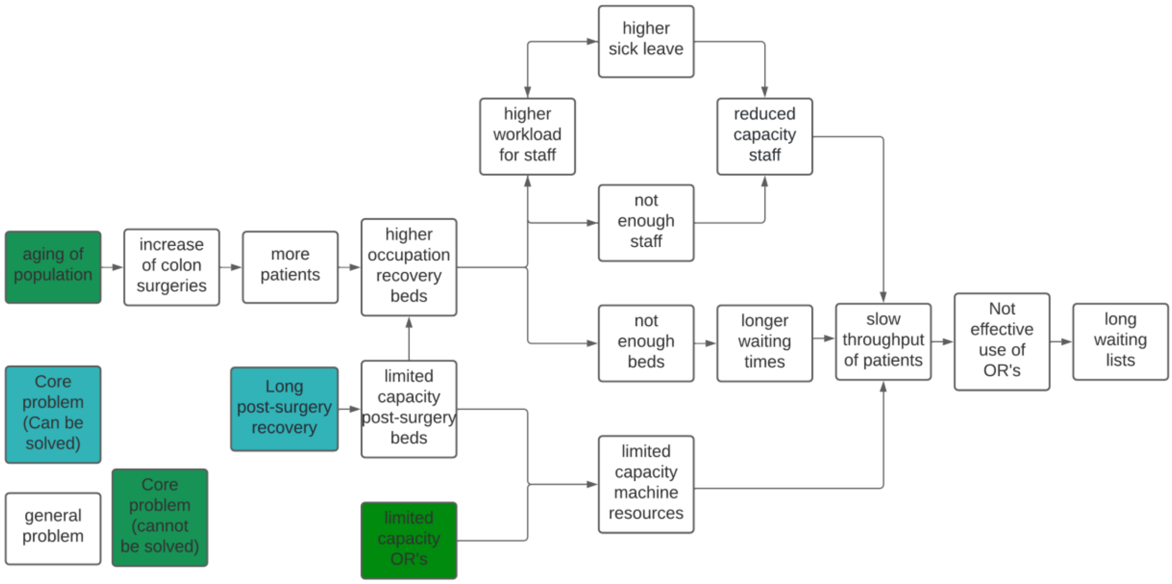

Figure 30: Problem cluster

CORE PROBLEM

According to Heerkens & Winden (2017) core problems are issues that are not influenced by other variables in the problem cluster. In the cluster, three core problems are identified. These are aging of the population, long post-surgery recovery and the limited capacity of OR's. The core problem is always a problem that can be modified. (Heerkens & Winden, 2017). The aging of population remains constant because it is a natural occurrence. Increasing the capacity of the OR's is too expensive to increase and not the most prevalent bottleneck according to the MST. Thus, this cannot be qualified for the core problem. Therefore, the core problem long-post surgery recovery is chosen for this research. In addition to that, it is selected because the MST sees the opportunity to lower the patients coming into post-surgery beds by sending them home to recover which reduces the long post-surgery recovery at the MST. This causes the limited capacity of post-surgery beds to be higher leading to lower occupation and improvements all throughout the system.

APPENDIX B KNOWLEDGE QUESTIONS

1. Defining the problem

The first step of the MPSM is defining the problem. In this step, the research problem is analysed and defined. Furthermore, a flowchart is made of the current situation to get a better understanding of the process. To be able to do that, past research on the topic is analysed and interviews are conducted. The flowchart is then validated by my company supervisors. These research questions are researched within this phase:

1) *What are the current process and desired process for colon surgery?*
2) *Which KPI's are used to measure performance in the process?*
3) *Which stakeholders are involved?*

2. Formulating the approach

In this step, the objectives of possible logistic implementations and solutions are studied. This step discusses the research intended deliverables, the impact of the research, and what is needed to successfully come to the deliverables promised.

3. Analysing the problem

In this phase current data of the process are gathered and analysed in combination with interviews with experts. All variables of the core problem, such as average laying time, nurse hours and costs, are evaluated and an overview will be made. This is all done in Excel. Furthermore, interviews with experts will be done to put the analysed data in perspective and to evaluate what should be the KPI's for the new situation. The research questions in this step are:

4) *What is the status of the required KPI's, for example post-surgery recovery time and nursing hours required?*
5) *What additional KPI's should be chosen to compare the old and new process logistics if needed?*
6) *What do stakeholders see as points of attention regarding changes in the logistic operations?*

4. Formulating alternative solutions

In this step, viable solutions are evaluated. The solutions thought of will be based on a literature study based on earlier implementations of colon surgery in other hospitals in combination with expert opinion, such as a colon surgeon to ensure realistically viable solutions in this specific case. The research questions in this step are:

7) *What methods are other hospitals using to implement CID?*
8) *Are there already other hospitals that have CID?*
9) *Are there new methods that can be used to implement CID?*

5. Choosing a solution

In the thesis several scenarios will be made when calculating the benefits. These scenarios involve predicted percentages of patients returning to the hospital after home-recovery complications require them to return to the hospital to recover, reduction in laying time and needed nursing hours.

10) *What weight should the KPI's have to choose the appropriate logistic operation change?*
11) *Which logistic operations are most feasible to implement at this point?*
12) *To what extent should the margin of error for the VBA tool be considered?*

6. Implementing the solution

There is a pilot upcoming in which the results of this research can be used as a first standard to see if it works in practicality and what improvements are necessary based on this first research.

13) *Are all stakeholders satisfied with the changes in logistic operations recommended?*
14) *Do the results of the pilot line up with the KPI's calculated in the VBA application?*
15) *Is the result in line with the requirements of the MST?*

7. Evaluating the solution

In this step, the chosen scenarios and the research get evaluated on if it has achieved its purpose and what might need improvement. The hypothesises set at the begin of the study are compared with the outcome of the model. Based on this comparison, a conclusion and discussion are made, and recommendations are given.

16) *What conclusions and recommendations can be made based on the research done at MST?*
17) *What further research into the topic can be done?*

APPENDIX C INCLUSION AND EXCLUSION CRITERIA PATIENTS

The used inclusion criteria used for determining patients suitable for CID are determined with the help of multiple surgeons in the study of Bot (2022). The named selection criteria are all determined pre-surgery.

Inclusion criteria	**Exclusion criteria**
ASA class 1 or 2	Large T4 tumors
Preoperative WHO performance score 0 or 1	Patient will receive a stoma
BMI < 30	Multiple anastomes will be made
Competent adult present for the first 24 hours after discharge	Multiple colonic leasions
	Emergency procedure
Resection type:	Severe malnutrition
Rectosigmoid	Insulin-dependent diabetes
Sigmoid	Nervous depression
Left hemicolectomy	Curative anticoagulant treatment
Transverse colectomy	Immunosuppresive
Right hemicolectomy	Poor social conditions

Table 14: Inclusion & exclusion criteria

After the surgery is complete there is an extra go-no go moment with the surgeons consisting of a checklist. If any of the conditions on the checklist is confirmed, the patient will not follow the CID care path, but will follow the traditional care path instead. The conditions that will lead to exclusion after operation can be seen in table 15.

Patient received a stoma
Blood loss > 300cc
Length of surgery > 150 minutes
Complicated surgery
Multiple anastomoses
Negative expert opinion surgeon.

Table 15: Exclusion criteria after surgery

APPENDIX D INTERVIEWS

MINUTES INTERVIEW ROBERTO GARCIA

In the interview with Roberto Garcia the home monitoring of their CID pilot at the JBZ was discussed. Roberto Garcia is an IMEC researcher into chips. Currently the protocol for CID is not yet a standard intervention, which means that it still falls under the standard restitution. However, over the years this might change as health insurances will want to renegotiate their terms if patients do not stay in the hospital anymore at all for the interventions that CID include, because the hospital will claim money for 5 days while the patient only resides in the hospital for 1 or 2 days. Currently at the JBZ they already have a monitoring centre for patients with chronic diseases such as COPD. This is done via point measurements. Since February also continuous monitoring is included at the monitoring centre. Right now, there are working 2 or 3 nurses full time to control all eight hundred patients that need to be monitored. Every hour patients with CID are checked during the day shift which is counted from 9:00 from 21:00h. In the night, the nursing department is responsible for the monitoring. They check it at 11 and 6 in the morning. Currently it is working as planned although some changes can be made to the frequency of the notifications. In case CID patients are worried about something, they can call the monitoring centre who will help them. The plan is to have the 24/7 monitoring in the centre when continuous monitoring is extended to multiple interventions.

Another plan Roberto is currently looking into is making use of regional monitoring centres instead of a separate monitoring centre per hospital. However, this is juristically difficult due to all the different systems hospitals are working with and the enormity of people involved in this process. In addition to that, it might be possible to increase the number of interventions done based on the time reduction CID gives, but this is also difficult due to the maximum number of interventions hospitals are allowed to perform each year. Due to this fact, the benefit of having extra time available might not be used appropriately. Currently the beds left empty by sending patients home for CID are used as a safety net for when a patient has complications. This number of beds left empty might be reduced in the future when more data on the rehospitalization rate is known. Older nurses might be interested in working in the monitoring centre due to the lower physical workload during the day. The patients selected for the CID programme are selected based on exclusion and inclusion criteria. In the Zuiderland hospital patients are send home and are called instead of actively monitored. The Masimo monitoring set costs around 180 euros per patient for full on service. The chip used for the Masimo monitoring is reusable. It costs around 100 euros so that can be subtracted from the total for every patient that uses such a chip. Putting the sensors on costs around 10 minutes to properly put on the patient and to instruct them to do it their selves. The training for the monitoring is done by Masimo itself.

MINUTES INTERVIEW GUIDO PETERS PHD CANDIDATE

For his phd, he has done research into continuous monitoring at the Isala hospital in Zwolle. In this regard, they have set-up a monitoring centre there. The main goal of this interview was used in how it was set-up to determine the costs needed to implement a monitoring centre. What Guido said is that the standard cost for the monitoring centre is quite low, as it just involves a place, computer, monitors, and a server. The determining factor is based on the variable cost of the employees to see what is determined.

MINUTES JBZ VISIT

Questions to JBZ:

How did you arrive at the thresholds that are used in the decision tree to call patients back to hospital?

Are you familiar with Halo ION, the algorithm that combines the trend data of the various vital parameters into a single continuous score?

This allows a score to be made with certain weightings per parameter. One deviating parameter says nothing. You choose to use two deviating parameters or a combination with the open questions. Is this deliberate or do you also see advantages in the score?

Do you see disadvantages and advantages of the two separate ways?

Who receives all the alarms? Is this also the patient or only the staff?

From experience, how correct are the thresholds you use now?

Have you also thought about personalising the thresholds/alarms?

Do you have any experience with this?

Patients' activities vary during the day. They will be more active during the day than at night. Have you thought about adaptive threshold methods? An example is to have certain thresholds higher during the day than at night.

Have you done any data analyses, or do you just rely on the thresholds and the decision tree?

What is the nurses' attitude towards CID, trust?

What are the experiences so far of the patients and caregivers?

Have there already been complications in the home situation, if so, what was the course of action?

Is the complication rate in the home comparable to that in the ward?

How has the pilot project progressed so far?

What is the situation with data loss? Is there enough data to monitor the patient?

How is it now distributed among the nurses in terms of monitoring? And what is the plan for a monitoring centre in the event of upscaling, e.g., when different interventions are combined?

Is there any further insight into the costs of monitoring?

Answers in full text:

There are currently ninety-five programmes in the JBZ. It concerns home monitoring, but also continuous monitoring in the hospital. It is also for the entire region. In the monitoring centre, all staff members have the knowledge to work with all different monitoring systems. There is monitoring from 9 am to 9 pm. During the night there will be an occasional check but no steady checks. At some point, the monitoring can be done from points that do it for different hospitals. In the end, the software does not matter. It is all about the experiences. JBZ would eventually like to have one partner, but that is not yet possible. That is why they have several partners. Luscii is not for continuous monitoring, only for point measurements. In the JBZ there have also been problems from above. Roberto also described the vision of monitoring. What do you want to monitor and how do you approach this throughout the hospital? This is not yet final. It contains everything about algorithms and frequencies.

Because the monitoring in the studies in England and France was different, they cannot simply adopt it in the JBZ. There it went with telephony.

Study design JBZ: sixty patients, after surgery sensors are connected and patients receive an explanation. Afterwards there is a daily evaluation whether patients can go home. This is to practise the new working method. In addition, people are already going home on POD 2, but it is being investigated whether slightly less vital people can go home as well. Then they will be monitored remotely. The monitors are checked every hour. If something is wrong, the nurse responsible for the patient comes. He then calls the patient and decides what is needed. In the evening and at night, a nurse does this twice (23:00 and 6:00). After 3 days (current protocol for extra check and blood test) the patient comes back. It was considered to let people take blood samples at home, but it was still nice to see the patient physically. If there is a data gap of half an hour, you receive a notification. The same goes for failing to complete a questionnaire twice. Gradations with different notifications? The nurse takes about the same time. If there are a lot of deviations, it is more convenient if a patient returns. Then the nurse does not have to keep calling and the patient can be monitored visually.

Now, the bed remains reserved. If it turns out that only an x% of patients return, fewer beds can be reserved. Then it can also be said that people get their shots elsewhere. Now the patients go on leave and the doctor is responsible. In the future, the GP must become the main practitioner. This must also be clearly agreed with the patient. The patient may now return to the hospital at any time. If the patients come back, they must stay in the hospital.

Connected to the wearables on the day of the operation, going home the next day. To check the functioning and allergies of the wearables.

The thresholds in the JBZ come from consultation and from tests in the department. Also, from the EWS. Respiration frequency is now 22 bpm, so that there are not too many false alarms. We would prefer to get rid of EWS with AI, but that is not yet possible. Personal thresholds are also something for the future. In the JBZ, there is still too little data for proper analysis to be able to make more predictions.

Consultation in the event of one deviating answer or one deviating parameter.

Return to JBZ with two deviating parameters, two deviating answers or one of each. If there is anything, the nurse decides whether the patient should return. If there is any doubt, it is discussed with the doctor. Nurses find it difficult to let go of the clinical view, but questions have been drawn up for use when calling. With the right questions, a good picture can be obtained. Breathing, for example, is only accurate after sitting still for 90 seconds. This can therefore be the cause of 'false' reports.

Two years ago, there was little enthusiasm for CID in the nursing department. They finally started with three nurses. This is becoming more widespread. The nurses are gaining more confidence in the technique through exercises. Carrying it themselves has also helped. There are two or three nurses a month who join the group who can and want to use the technology. It helps nurses are part of the project team as they are easily approachable. A colon surgeon is willing to cooperate with the MST on MEDAL-C (CID of JBZ). A multicentre study always makes the study better. A delegation with employees from MST who are focused on innovation may visit again.

The choice for Masimo was made because of the lower price. Masimo is a company that has a monitoring service combined with specific monitoring equipment. Now the more expensive companies come back and say that the JBZ can try it for free. One of the steps Roberto is still talking about is measuring mobilisation.

The way home medication works now is that patients are given 48 hours of medication. This is allowed because of the leave. If it becomes standard care, things will have to change from an insurance point of view. This must be done in cooperation with the pharmacy.

Now, seven people have gone home with monitoring. Eighteen people were included. Fourteen people have been connected. Of these, a small number kept having pain. They did not dare. The people who went home liked it very much. One person had the feeling that she was being watched better. Also, because she was called all the time. Nobody was readmitted. The ERAS programme of MST does not include a lab, but the one of JBZ does. JHA measures on day three, MST wants to measure on day four.

In the case of pulmonary trauma, a project with continuous monitoring in the department will start in September. There is now a kind of domino effect in the JHA.

The MSs that are not mobilising have a reason for this. So, you get this with the other values and questions.

In HiX, call moments are registered. The questions from the monitors are also recorded. A text that can be filled in is used to fill in who contacted the patient and why. There is also a summary and whether the patient will return to the hospital.

The study was carried out free of charge. Whether it is profitable is not yet known.

At present, people are informed about the study by the doctor. Then they are given a leaflet. A week later, a nurse calls to ask whether the patient wants to participate and meets the criteria. So now it takes much more time, but later the JBZ does not know yet.

The information leaflet for the patient and the informed consent are sent to Daan Lips, the head colon surgeon at the MST.

MINUTES INTERVIEW BEATKA HASSELBEKE

According to Beatka Hasselbeke, All Santeon hospitals desire to use the same monitoring equipment. The reasoning for this is to have a uniform monitoring centre with all other Santeon hospitals. The Santeon hospitals would like to achieve this by using the same monitoring equipment from the brand Luciid to integrate it perfectly within the infrastructure of all Santeon hospitals. This is called by Beatka: Seamlessly intrigued experience for patient and caregiver.

APPENDIX E MONTE CARLO SIMULATION

For every Monte Carlo simulation there are three needed steps that always should be taken:

1. Set-up of the predictive model, identifying the dependent variable that is calculated and the independent variables that will drive the predictive model.

2. Specify the probability distributions of the independent variables. For this the historical data can be used or it can be based on expert opinion.

3. Run simulation repeatedly to generate forecasts, this is done till a good average result can be taken from the forecasts.

The number of simulations needed to determine the costs accurately is determined using this formula: Using these steps a result can be found. With this result the probability of certain results occurring can be determined and these can help to determine an outcome for the results of these tables.

These probability distributions fall under the Bayesian statistics. Bayesian statistics is a theorem interpreting that the probability of something expresses the degree of belief in an event. Bayesian statistical methods use Bayes theorem to calculate the next event based on a current event that already happened. This is called a conditional probability with the formula:

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

To run a Monte Carlo simulation the data used for the input variables should fulfil certain requirements. For every input variable there should be a probability distribution. There are several probability distributions that are commonly used. These are divided in continuous and discrete distributions. Common discrete distributions are the uniform distribution, the binomial distribution, Bernoulli distribution and the Poisson distribution. Some of these falls under the general beta distribution. On the other hand, there are the continuous distributions. These are the normal distribution in all its forms, the t-distribution, and the Chi-square distribution. The difference between these types of distributions is important to know to complete the Monte Carlo simulation.

In this thesis some of these distributions are explained as they are needed for this specific Monte Carlo simulation. These are all continuous distributions as discrete distributions are not suitable for the costs at hand.

NORMAL DISTRIBUTION

The normal distribution is one of the most used probability distributions due to it being of use in many natural occurrences. The distribution consists of a mean with a standard deviation. The μ stands for the mean. This is the most value to appear from there the probabilities of values occurring depends on how far away they are from the mean on both sides. The formula for the normal distribution is:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

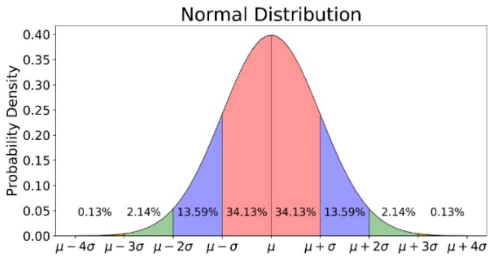

Figure 31: Normal distribution

BETA DISTRIBUTION

The beta distribution is the standard distribution for a lot of different distributions. The distributions originating are the binomial, negative binomial, Bernoulli, and geometric distributions. Beta distributions are used when there is a limited range such as 0 to 10. These can be used for example for the duration of activities. The probability density function of the beta distribution is different based on which type needs to be used.

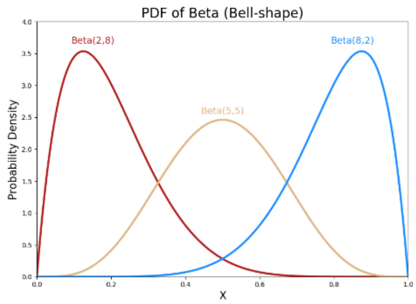

Figure 32: Beta distribution

BETA PERT DISTRIBUTION

The Beta Pert distribution can be used when there is not enough available data for a beta distribution. Only the highest lowest and the value are needed to use this distribution. This might come in handy preparing variables for the Monte Carlo simulation.

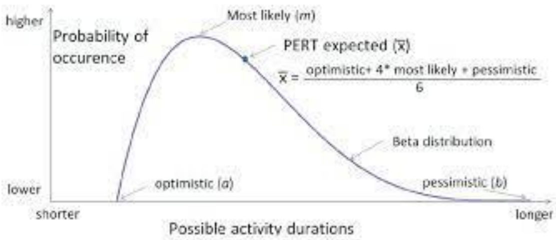

Figure 33: Beta pert distribution

LOGNORMAL DISTRIBUTION

The lognormal distribution is mostly used in situations where the mean is close to the lowest possible value, often negative values are impossible. It is called the lognormal distribution due to the logarithm being a normal distribution. It uses the mean and standard deviation to be calculated. These can also be in logarithmic form.

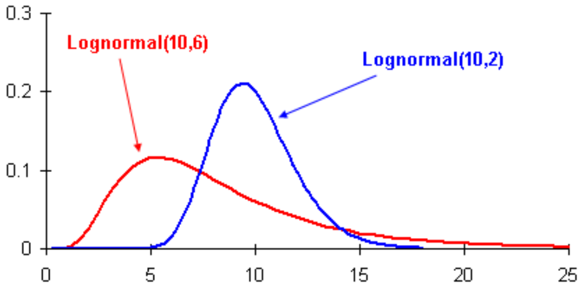

Figure 34: Lognormal distribution

TRIANGULAR DISTRIBUTION

The triangular distribution is often used in the same situations as the Beta Pert distribution. The difference is that the triangular distribution gives a normal average via the formula used for its probability density while the Beta distribution gives a weighted average, favouring the value over the less likely values.

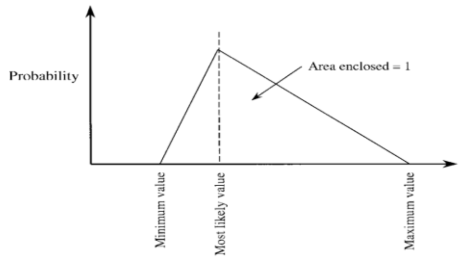

Figure 35: Triangular distribution

WEIBULL DISTRIBUTION

The Weibull distribution is often chosen to deal with reliability issues. It can take many forms as a graph due to it consisting of three variables: the location, the scale, and the shape. By changing these parameters accordingly, a lot of other probability density functions can be replicated. Therefore, there is no typical graph of this probability distribution.

APPENDIX F DASHBOARD

Monte Carlo Simulation

MST CID

Variables			Distribution
Incoming Patients (per year)	Mean	37	Normal
	Std. Deviation	3	
Cost Hospital Day (euros)	Min	300	Triangular
	Most Likely	310	
	Max	354.95	
Average Stay (in days)	Mean	2.7	Lognormal
	Std. Deviation	5.67	
Rehospitalization Rate (percent)	Mean	4.00%	Normal
	Std. Deviation	1.00%	
Complication Stay (in days)	Min	5	Triangular
	Most Likely	10	
	Max	17	
Re-admission cost (per day)	Min	300	Triangular
	Most Likely	310	
	Max	354.95	
Cost Monitoring Centre (Euros)	Min	0	Triangular
	Most Likely	5000	
	Max	10000	
Cost Monitoring Equipment (Euros)	Min	50	Uniform
	Max	50	
extra slots used policlinic (slots)	0.5	1	Discrete
	0.5	2	
Cost monitoring employees (euros)	Min	50	Triangular
	Most Likely	55	
	Max	60	
cost extra policlinic time (euros)	Min	112	Triangular
	Most Likely	120	
	Max	137.4	
total stay of patients (Time)	Mean	99.9	Normal
	Std. Deviation	6.414741	

Mean	Std. Deviation	Random
37	3	0.913669403

Min	Most Likely	Max
300	310	354.95

Lower Range	Higher Range	Total Range	Cumulative proability
10	44.95	54.95	0.27264319

Scaled mean	Scaled std. Deviatic	Random
0.149127227	1.2993264	0.466398816

Mean	Std. Deviation	Random
0.04	0.01	0.525144134

Min	Most Likely	Max
5	10	17

Lower Range	Higher Range	Total Range	Cumulative proability
5	7	12	0.254028942

Min	Most Likely	Max
300	310	354.95

Lower Range	Higher Range	Total Range	Cumulative proability
10	44.95	54.95	0.058161226

Min	Most Likely	Max
0	5000	10000

Lower Range	Higher Range	Total Range	Cumulative proability
5000	5000	10000	0.653161827

Min	Max	Max-Min	Random
50	50	0	0.310166693

0.5	0.5	Random
1	2	0.593705039

Min	Most Likely	Max
50	55	60

Lower Range	Higher Range	Total Range	Cumulative proability
5	5	10	0.098663944

Min	Most Likely	Max
112	120	137.4

Lower Range	Higher Range	Total Range	Cumulative proability
8	17.4	25.4	0.591322095

Mean	Std. Deviation	Random
99.9	6.414740837	0.723292027

Model	Traditional	Monte Carlo	Comments
Incoming Patients	37	41.09	
Cost per day hospital	-€ 310.00	-€ 312.56	
Average Stay	2.7	1.04	
Reduction in costs	-€ 30,969.00	-€ 13,361.89	
Rehospitalization rate	0.04	0.04	
complication stay	5	8.90	
complication cost per day	€ 310.00	€ 305.65	
Increase in cost	€ 2,294.00	€ 4,543.80	
Monitoring Centre	€ 5,000.00	€ 5,835.64	
Monitoring Equipment	€ 50.00	€ 50.00	
Cost Monitoring employees	€ 55.00	€ 52.22	
Total stay of patients in days	99.9	103.701691	
Increase in cost	€ 59,844.50	€ 60,805.61	
Extra policlinic time used in slots	1.5	1	
policlinic cost per slot	€ 112.00	€ 123.96	
Increase in cost	€ 6,216.00	€ 5,093.68	
Total cost	€ 37,385.50	€ 57,081.20	

Run Simulation

Counter	10000				
Iterations	10000				
Average	€ 37,780.11	-€ 32,077.90	€ 3,679.47	€ 59,098.45	€ 6,807.01
Probability above					
€ 0.00	0.8936	0	1	1	1
€ 30,000.00	0.7918	0	0	1	0

Iteration	Total cost	Cost CID	Cost re-admissions	Cost Monitoring	Cost Policlinic
1	-€ 23,354.47	-€ 20,036.37	€ 2,955.49	€ 62,142.54	€ 4,141.27
2	€ 67,195.85	-€ 3,375.79	€ 3,512.05	€ 56,478.02	€ 9,493.99
3	€ 27,390.95	-€ 20,864.20	€ 2,740.80	€ 58,395.58	€ 11,485.67
4	€ 59,854.82	-€ 21,466.42	€ 2,675.88	€ 57,908.16	€ 4,346.12
5	€ 62,827.18	-€ 10,805.72	€ 6,078.94	€ 56,586.13	€ 4,619.34
6	€ 18,765.78	-€ 924.23	€ 6,148.93	€ 59,263.79	€ 9,636.86
7	€ 16,364.35	-€ 7,780.78	€ 4,046.92	€ 56,763.94	€ 4,843.43
8	€ 29,362.43	-€ 6,954.70	€ 4,000.20	€ 62,119.21	€ 9,339.77
9	€ 49,479.15	-€ 5,509.42	€ 2,544.94	€ 57,606.19	€ 4,944.42
10	€ 58,540.48	-€ 32,348.44	€ 4,615.38	€ 59,495.27	€ 7,828.83
11	€ 68,218.84	-€ 7,164.70	€ 2,765.10	€ 59,610.85	€ 4,365.20
12	-€ 147,147.41	-€ 23,010.51	€ 1,557.63	€ 58,320.72	€ 7,614.87
13	-€ 61,692.73	-€ 14,714.01	€ 4,197.54	€ 56,428.41	€ 3,962.25
14	€ 35,458.44	-€ 408.70	€ 7,026.46	€ 61,511.76	€ 4,095.29
15	€ 63,700.47	-€ 55,698.00	€ 2,079.75	€ 59,645.41	€ 4,219.85
16	€ 61,099.43	-€ 1,175.35	€ 3,105.50	€ 60,699.42	€ 9,309.85
17	€ 57,165.90	-€ 21,175.44	€ 8,769.13	€ 55,963.90	€ 10,411.98
18	-€ 9,126.87	-€ 35,944.54	€ 5,859.61	€ 56,874.11	€ 4,003.72
19	-€ 31,057.12	-€ 69,940.46	€ 5,912.79	€ 58,795.69	€ 5,195.89
20	€ 32,656.58	-€ 3,681.26	€ 3,496.53	€ 60,584.41	€ 8,214.05
21	€ 48,065.74	-€ 31,347.99	€ 3,391.51	€ 60,025.52	€ 4,062.37
22	€ 66,139.50	-€ 13,497.01	€ 4,178.46	€ 59,175.91	€ 3,949.23
23	-€ 71,239.43	-€ 17,480.22	€ 4,096.42	€ 57,053.03	€ 4,418.38
24	€ 58,751.84	-€ 56,523.63	€ 3,966.89	€ 57,801.16	€ 9,093.81
25	€ 66,041.27	-€ 5,540.03	€ 2,953.02	€ 60,793.34	€ 9,340.15
26	€ 62,020.37	-€ 19,243.12	€ 4,175.89	€ 60,126.48	€ 4,116.92
27	-€ 48,358.76	-€ 45,998.44	€ 5,103.58	€ 60,337.14	€ 8,949.17
28	€ 59,773.02	-€ 12,039.37	€ 278.26	€ 58,444.03	€ 5,134.13
29	€ 14,222.83	-€ 33,212.20	€ 3,530.77	€ 59,562.79	€ 4,473.91
30	€ 59,512.44	-€ 1,735.93	€ 3,483.00	€ 59,010.64	€ 5,024.63
31	-€ 55,929.10	-€ 11,805.40	€ 1,544.56	€ 60,482.89	€ 4,059.16
32	€ 26,555.66	-€ 47,693.61	€ 1,629.34	€ 59,093.95	€ 4,286.64
33	€ 13,009.38	-€ 42,294.79	€ 3,832.82	€ 58,347.69	€ 9,334.19
34	€ 69,915.59	-€ 4,341.09	€ 1,548.28	€ 64,019.00	€ 9,787.40
35	€ 66,124.47	-€ 35,890.16	€ 5,470.47	€ 58,770.78	€ 9,217.70
36	€ 71,774.30	-€ 14,057.54	€ 6,884.37	€ 58,013.62	€ 8,643.28
37	€ 56,049.18	-€ 15,224.94	€ 3,491.36	€ 54,743.38	€ 3,936.21
38	€ 49,041.78	-€ 7,415.11	€ 2,686.17	€ 56,093.56	€ 5,151.00
39	€ 62,164.32	-€ 6,742.13	€ 3,843.59	€ 59,068.39	€ 7,985.77
40	€ 73,899.79	-€ 69,900.95	€ 1,900.00	€ 60,314.46	€ 4,172.45
41	€ 53,644.54	-€ 4,698.28	€ 3,965.65	€ 58,384.11	€ 9,847.92
42	€ 67,657.14	-€ 7,202.11	€ 1,945.77	€ 60,819.18	€ 7,010.81
43	€ 57,096.48	-€ 56,769.95	€ 3,600.91	€ 55,283.23	€ 9,402.19
44	€ 65,389.93	-€ 2,968.00	€ 3,634.78	€ 58,506.20	€ 4,954.31
45	€ 18,056.57	-€ 40,695.23	€ 6,019.85	€ 58,618.30	€ 9,372.54
46	€ 59,319.44	-€ 127,009.41	€ 3,619.19	€ 59,397.01	€ 9,207.02
47	€ 59,344.01	-€ 9,959.93	€ 4,012.14	€ 62,237.92	€ 8,491.86
48	€ 41,561.78	-€ 16,709.30	€ 4,776.71	€ 59,257.64	€ 9,303.11
49	€ 56,425.92	-€ 11,885.58	€ 2,323.40	€ 59,645.71	€ 5,101.50
50	€ 27,398.52	-€ 27,509.56	€ 3,849.13	€ 58,229.14	€ 3,731.45
51	€ 43,872.88	-€ 16,659.86	€ 3,692.99	€ 59,491.14	€ 8,329.16
52	€ 48,407.68	-€ 45,748.69	€ 2,215.56	€ 55,587.81	€ 4,428.52
53	€ 68,015.43	-€ 10,277.19	€ 3,795.70	€ 55,283.67	€ 4,416.94
54	€ 53,842.85	-€ 56,316.23	€ 1,216.22	€ 59,513.30	€ 9,142.70
55	€ 36,515.12	-€ 9,136.08	€ 6,801.46	€ 60,611.37	€ 3,900.68
56	€ 60,080.45	-€ 25,387.19	€ 3,230.35	€ 60,101.97	€ 9,439.62
57	€ 61,344.33	-€ 9,498.57	€ 1,582.57	€ 61,932.94	€ 9,276.21
58	€ 58,031.33	-€ 4,993.72	€ 2,672.40	€ 59,197.84	€ 8,611.88
59	€ 55,157.33	-€ 37,857.42	€ 2,638.18	€ 63,223.22	€ 5,171.45
60	€ 61,975.68	-€ 88,444.83	€ 2,376.96	€ 59,190.55	€ 9,004.30
61	€ 68,580.07	-€ 15,370.21	€ 3,955.19	€ 59,175.83	€ 5,102.14
62	€ 74,155.85	-€ 17,787.23	€ 4,304.36	€ 59,756.88	€ 4,401.05
63	€ 68,646.71	-€ 48,311.88	€ 6,787.69	€ 60,386.34	€ 8,843.20
64	€ 64,088.58	-€ 33,006.54	€ 5,140.80	€ 57,762.88	€ 4,361.04
65	€ 48,155.94	-€ 5,919.12	€ 2,696.22	€ 58,027.53	€ 10,397.31
66	€ 59,928.08	-€ 4,214.29	€ 4,084.27	€ 55,511.17	€ 5,495.10
67	€ 15,823.71	-€ 3,546.10	€ 1,944.42	€ 57,882.07	€ 4,316.39

Figure 36:Entire dashboard