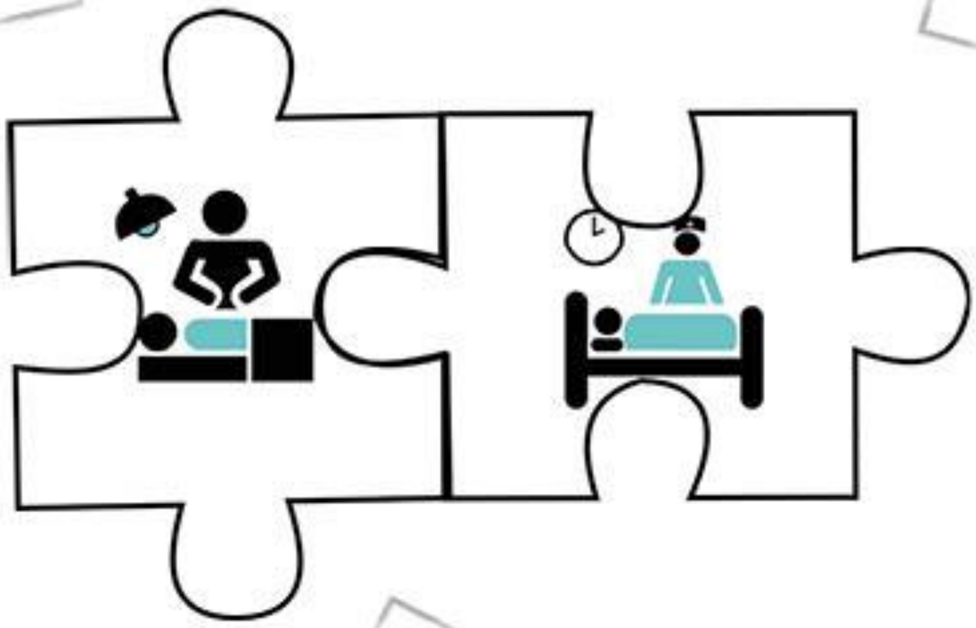
Improving the alignment between the operating room department and the nursing wards

Changing the current operating room scheduling method in order to minimize the variability in bed utilization at the nursing wards



Author:
Sophie Sieverink

Supervisors University Twente:
Prof. dr. ir. Erwin Hans
Dr. ir. Nardo Borgman

Supervisor Medisch Spectrum Twente:
Thijs Schopman

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Management summary

Health care costs are rising, the Dutch population is aging, and the government and health care insurers are cutting costs. These are only a few of the current developments in the Dutch health care sector, which obliges every hospital to take a closer look at their current processes. Medisch Spectrum Twente (MST) is one of the Dutch hospitals that needs to rearrange their processes in order to keep delivering the quality of care they do. The MST hospital found out their processes are too much organized around the specialties and departments instead of around the patient, which results in a lack of alignment between the several steps a patient follows through the hospital. Therefore, the hospital started an efficiency program where every step of the total chain of care, from the first patients visit up to their discharge, needs to be reviewed and improved.

This research takes a closer look at the alignment between the most expensive department of the hospital, the operating room (OR) department, and several nursing wards. Personnel members of both departments encounter problems as an effect of a deficiency between the two departments. The OR planning department aims to maximize the OR utilization since these expensive resources need to be used as much as possible. However, they barely have any insight in the consequence of their schedule for the nursing wards. The personnel members at the nursing wards encounter a strongly fluctuating bed utilization at the wards, since the OR scheduling department does not consider the length of stay of the patients they schedule, and to which ward these patients will flow. Therefore, the main research question is:

“How can the MST hospital reduce the variability in bed utilization at the nursing wards, while the OR capacity will be used in an efficient way?”

The objective is to propose a new way of scheduling where the OR scheduling department can take into account the patient characteristics in order to minimize the variability at the nursing wards. Moreover, when a forecast can be made for the nursing departments of how many and what type of patients will enter their ward, a more accurate personnel planning can be made.

During a literature study, we found a mathematical programming model (Glerum, 2014) which is designed to address a similar problem. After determining several patient types, this quadratic assignment problem (QAP) model can be used to schedule these patients while minimizing the variability in the number of patients at the nursing wards. After some adaptations, the model was suitable to use in the context of the MST hospital. Using historical data and in consultation with the 17 surgical specialties, we designed 118 patient groups and calculated their stochastic length of stay and average surgery duration. Using the mathematical model and current master surgical schedule (MSS), which is the OR division amongst the specialties, we were able to design a schedule which states how many and what kind of patients should preferably be treated per day, in order to create a more constant and predictable flow to the wards. Multiple plan-do-check-act (PDCA) cycles with a multidisciplinary team are performed in order to improve the accuracy of the patients group characteristics and the generated schedule.

The results of the QAP model showed significant improvement in the variability in the bed utilization at the nursing wards. The total variability of the ten nursing wards included in the model, decreased by 27% when patients would be scheduled according to the model. Figure 1 shows the effect of using the model for Ward A. The line of the realised situation represents the current bed utilization, while the line constructed by the model can be established when the model will be used. Cleary, inflow to the wards is more stable and predictable.

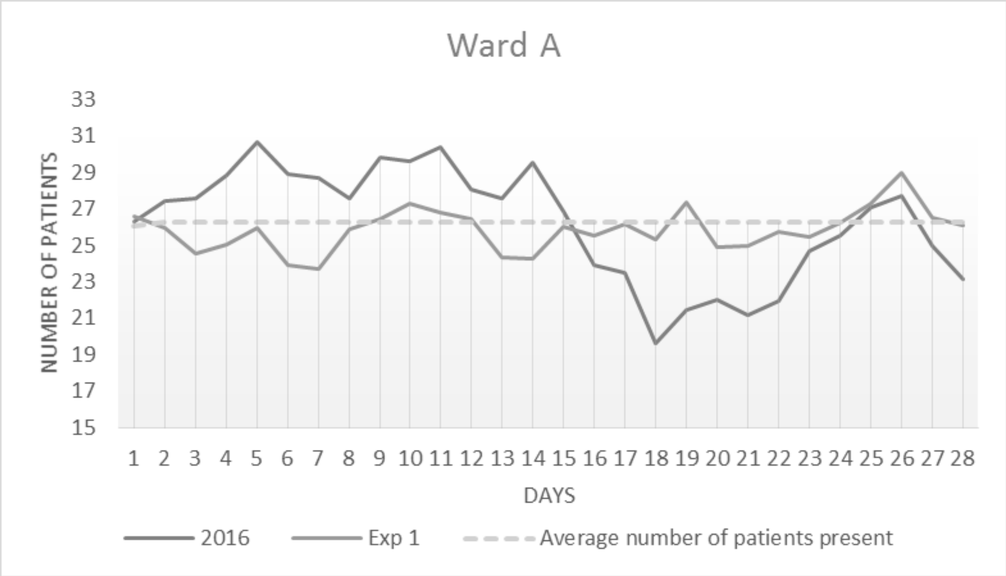

Figure 1. Results of reducing variability at Ward A. (n=56, T=28 days, source: MST data)

Moreover, a second experiment is performed in order to find out if additional OR time will improve the results even more. Table 1 shows the results of the first experiment (with current OR capacity) and the second experiment (with additional OR capacity) compared to the realized situation of 2016. The value of the objective function is the quadratic deviation of the average bed utilization divided by the number of bed types per day.

Table 1. Results of the 2 experiments compared to the current situation.

	Realized situation 2016	Experiment 1	Experiment 2
Objective function value	13.1	9.49	9.28
Average OR utilization	80%	80%	72%
Experiment running time	N/A	373 sec	738 sec

Based on the results of these experiments, we recommend to use the model to schedule patient types in the current MSS, in order to decrease the variability at the nursing wards. However, we do not recommend to increase the current OR capacity, since the benefits of adding one additional OR does not outweigh the costs of realizing increased capacity.

Using the model, we have to deal with some restrictions. First of all, it might be possible that one patients visits multiple wards after surgery, this cannot be taken into account in the model. Also visiting the recovery, PACU, or IC department after surgery is not taken into account since this is patient related and not necessarily surgery related. Moreover, we have to deal with limited resources and equipment. If multiple surgeries who need the same equipment, can be scheduled on the same day depends on the sequence of the surgeries. This sequence cannot be determined by the model since this is, again, influenced by patient related factors. Next, the model uses a cycle horizon of 28 days. The model calculates the number of patients in the system at the start of the cycle based on the end of the current cycle. However, in practice this is based on the previous cycle, that might look somewhat different. Also, due to this cycle of 28 days, the model can only calculate the number of patients at the wards on a daily level, and not on an hourly or minutes level.

The model proposed in this research can be used by the MST hospital to fill their MSS. This will reduce the variability at the nursing wards. Moreover, when the number and types of scheduled patients are known, MST can schedule their personnel member more accurately. To implement this model in their daily practice, their current software needs to adjusted or new software needs to be procured. Suitable software is essential in order to implement the model. Moreover, continuous improvement is needed in the continuously changing environment the hospital is operating in. They need to monitor and adjust the patient characteristics on a regularly basis, which also influences the MSS.

Preface

This master thesis is the final result of my study Industrial Engineering & Management. After my bachelor I chose the Production and Logistic Management track since I never had the intention to work or perform research in the health care sector. However, the enthusiasm and passion of Erwin Hans about health care convinced me to follow some of the health care track courses, and also perform a capita selecta assignment in a hospital. This triggered my interest towards the health care sector even more and it showed the various opportunities for optimization in this sector which I never thought of. This ultimately resulted in this master thesis, performed at the Medisch Spectrum Twente hospital in Enschede.

Although this is the final part of my study, I hope this report can be the starting point for Medisch Spectrum Twente to improve the alignment between the operating room department and their various nursing wards, and eventually optimize their total chain of care step by step.

Performing my research at Medisch Spectrum Twente was a great learning experience. Designing a new scheduling method turned out to be even more complex than I thought, fortunately many people at the hospital were willing to help me during this project. Therefore, I would like to thank some people for their contribution. First, I would like to thank Thijs Schopman for being my supervisor at Medisch Spectrum Twente despite his own busy schedule. I learned a lot of our weekly meetings and thanks to his experience at the hospital I gained a lot more insights in the complex hospital environment and all its connected processes and (in)possibilities. Next, I would like to thank Paul and Rein for accompanying me every day, and their support and help.

Next, I would like to thank Erwin Hans and Nardo Borgman for their guidance and feedback, which definitely improved my report and gained new insights. Furthermore, I also received a lot of support at home from my family, friends and housemates, for which I would like to thank them.

I am proud to show the results of my research in this report and I hope you will enjoy reading it.

Sophie Sieverink

Enschede, 2017

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List of abbreviations

Abbreviation	Definition	Explanation
ENT-surgery	Ear, nose, throat surgery.	Specialty that takes care of the treatment of diseases of the throat, nose and ears.
FOCUS-PDCA	Find, organise, clarify, understand and select – Plan, do, check, act.	Continuous improvement model used as research methodology during this research.
IC	Intensive care.	Ward for patients that need extra monitoring and care.
LoS	Length of stay.	Number of days a patient stays at the hospital after surgery.
MSS	Master surgical schedule.	A cyclic timetable where every OR session is assigned to one of the specialties.
MST	Medisch spectrum Twente.	Top-clinical hospital in Twente where this research is performed.
OR	Operating room.	A room in a hospital that is equipped to perform surgery.
PACU	Post Anesthesia care unit.	Special ward for patients who need extra monitoring after anesthesia.
POS	Post-operative screening.	Screening to do a final check on the patient before surgery.
QAP	Quadratic assignment problem.	Model designed by Glerum (2014) to minimize the variability of the bed utilization at the nursing wards.
RvE	Resultaat verantwoordelijke eenheid.	Every department / specialty in the hospital is called an RvE.

Chapter 1. Introduction

This chapter gives a brief context description (1.1), which includes the research motivation. Furthermore, the problem description (1.2) and research objective (1.3) will be introduced. Next, the research questions (1.4) and research methodology (1.5) will be discussed.

1.1 Context description

Medisch Spectrum Twente (MST) is a top-clinical hospital in the city centre of Enschede. The core task of the MST is to advance the health and well-being of the inhabitants of Twente. They do not focus on certain specialties or diseases but aim to deliver a wide spectrum of quality care, to make sure the inhabitants of Twente do not have to leave the region to receive the care they need. However, the catchment area of the hospital rises far beyond Twente, even up to Germany. The MST also collaborates with German hospitals, for example in transporting and treating emergency patients in the border area.

The hospital originated from a merger between two hospitals in 1990. The final step of the merger comprised the construction of a new building, where both hospitals could join together to improve the efficiency and reduce the number of duplicate facilities and logistic services (Breedijk, Buitelaar, Abels, & Prechtl, 2016). On June 11 2016, the new building of the MST hospital was officially opened. It is designed to improve quality of care and service to the patients. The MST aims to deliver good quality of care using the best and newest medical equipment. Additionally, the MST wants to make care more personal. This is done by designing building full of privacy and comfort for the patient, where he can rehabilitate in a relaxing and pleasant environment. During hospitalization, patients stay in one of the 670 single rooms with their own bathroom facilities to offer the best recovery possibilities. Single rooms offer the patients more privacy and make visiting hours superfluous, which also improves the recovery of the patient (MST, 2017).

While the new building created a lot more possibilities, it also caused financial difficulties for the hospital in an environment where healthcare costs are constantly rising. Therefore, the MST started an efficiency program. The goal of this program is to keep delivering the quality of care they already give (or even better), while reducing costs. This is done by increasing the efficiency of the primary process and making more efficient use of the current MST capacity. The program is based on four main points: patient oriented & patient satisfaction, costs, quality, and durability. The patient comes first and needs to be satisfied in his need of care, while keeping in mind the balance between quality, costs and durability. Moreover, the hospital aims to treat the patient ‘first time right’. During the efficiency program every step of the entire chain of care, from admission to discharge, should be analysed and improved. When every step is analysed and aligned to the previous and next steps in the chain, this will have a positive effect on the comfort and satisfaction of the patient and personnel, while reducing costs at the same time.

In the new building 15 operating rooms (ORs) are built, where annually more than 16.000 patients undergo surgery. One OR is still under construction, so not in use at the moment. 10 ORs are general ORs used by several specialties, and one OR is a hybrid operating room with more advance equipment. Finally, three ORs are thorax ORs, which are not in the scope of this research. Moreover, on a regular basis, one or two ORs in the old building are still in use, mainly to treat day care patients. However, in the future these patients will be treated in the new building as well.

The MST has 17 surgical (sub)specialties that make use of the ORs we are dealing with in this research. An overview of these specialties and a short description is stated in Table 2. Note that ‘Surgery’ is not a specialty itself, but it is divided into 4 subspecialties: general surgery, gastrointestinal and oncological surgery, trauma surgery, and vascular surgery (MST, 2017).

Table 2. Surgical (sub)specialties of the MST.

Specialty	Description
Anesthesia	For various forms of anesthesia and pain relief during a surgery.
Special dental care	For patients who cannot be treated by their dentist anymore
Cardiology	For common cardiovascular diseases.
Cardiothoracic surgery	For patients with disorders in the thoracic cavity, which includes the heart, lungs and large blood vessels.
Surgery	Surgery has 4 focus areas/subspecialties: General surgery, Gastrointestinal and oncology surgery, Trauma surgery, and Vascular surgery.
- General surgery	For patients with diseases such as infections, tumours, injuries and fractures.
- Gastrointestinal and oncological surgery	For patients who need large and complex digestive surgery and combating cancer.
- Trauma surgery	For the treatment of patients after an accident.
- Vascular surgery	For all patients with abnormalities of blood vessels.
Gynaecology	For female patients with disorders and abnormalities of the genitals.
Oral and maxillofacial surgery	For patients with diseases and problems with their teeth or jaw in their mouth or face
Ear, nose and throat surgery	For the treatment of diseases of the throat, nose and ears.
Gastroenterology	For the treatment of digestive disorders.
Neurosurgery	For the surgical treatment of local disorders of the nervous system.
Ophthalmology	For all patients with a disorder concerning the eye.
Orthopedics	For the prevention and treatment of disorders on the entire support and movement device (skeletal and muscular system).
Plastic surgery	For plastic, reconstructive, hand and wrist surgery.
Urology	For all diseases in the organs involved in urinary tract and male genitals.

This research forms one step in the whole project of optimizing the total chain of care. When the total chain of care is better aligned, the waiting times for the patient between several steps will reduce, and the patient knows where he stands. The patient satisfaction and therefore the quality of care will improve, while costs are being reduced. Moreover, improving the chain of care will make the process more predictable and therefore less variable. The working satisfaction of the personnel will improve when personnel planning can be performed more in accordance with the workload at the department (Kooij, 2016).

1.2 Problem description

The current structure of the hospital enables every department or specialty (which is called an RvE = resultaat verantwoordelijke eenheid) to set and reach their own goals. The hierarchical framework in Figure 2 shows the different levels of planning and control for the RvEs. On every level of this hierarchical framework (strategic, tactical, offline operational, and online operational) every RvE can make his own decisions and align them in their own (vertical) process. (Hans, Van Houdenhoven, & Hulshof, 2012). However, the patient does not follow this vertical process, but flows through the horizontal path on the online operational level of different departments (Figure 2). Since MST claims to be a patient centered hospital, the process should also be organised around the patients flow and not around the RvEs. Figure 2 shows the vertical processes of the RvEs and the horizontal process of the patients flow.

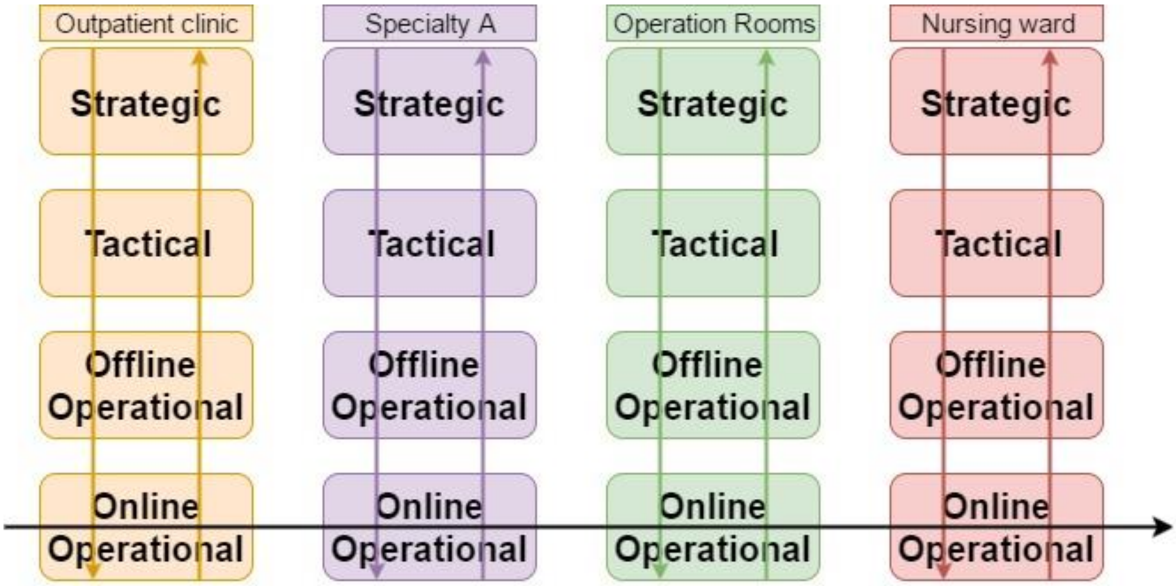

Figure 2. A framework for healthcare planning and control Hans, E. W., Van Houdenhoven, M., & Hulshof, P. J. (2012).

Since the OR department is the core of the surgical path (Agnetis, Coppi, M, & Sbrilli, 2013), we will focus on the alignment between the OR department and the nursing wards on the tacital level of the framework in Figure 2. Improving this alignment will also affect the flow on the online operation level that is followed by the patients. After improving the alignment between the OR department and the nursing wards, subsequently the alignment between the OR department and the consults on the outpatient clinics can be improved.

1.3 Research objective

The objective of this research is to design a blueprint on a tactical level, that can be used to fill in the current master surgical schedule (MSS) with patient types in order to create a more constant and predictable flow to the nursing wards. Tactical decisions such as the allocation of OR sessions to the specialties are already made. However, how these OR sessions should be filled in (what type of patients and how many) is not known. We aim to design a schedule where patients are assigned to the right OR in the right amount, as it is done in the current situation. Additionally, we want to schedule such an amount and type of patients that the variability in bed utilization of the nursing wards is minimized and the predictability of the amount and types of patients that will enter the wards increases. This schedule should be made taking into account the agreements made with the health care insurers and the availability of OR time of that specialty, beds, accompanying staff, and equipment.

1.4 Research questions

In order to create a less variable and more predictable patient flow from the OR department to the several nursing wards, we defined one main research question with accompanying sub questions which are stated below.

The main question of this research is:

"How can the MST hospital reduce the variability in bed utilization at the nursing wards, while the OR capacity will be used in an efficient way?"

In order to give structure to the report and finally answer the main question, the following sub questions are formulated.

1. Which model is suitable to apply to the MST context in order to schedule patient types resulting a minimized bed utilization variability?

2. How to cluster patients for the model?

   2a. What is the surgery duration for every patient group?

   2b. What is the length of stay (and corresponding probabilities) for every patient group?

   2c. What is the probability of every patient(group) to go to a certain ward after surgery?

As said, the MST hospital has one OR that is under construction. The hospital wants to know if creating additional OR time would improve the results. Therefore, we add an additional research question:

3. What will be the effect of additional available OR time?

Table 3 shows for every sub question the section where the question will be answered. The main question will be answered in chapters 6 and 7.

Table 3. (sub) Questions with corresponding answering sections.

(sub) Question	Answering section
1	2.4
2	5.2
2a	5.2 and Appendix IV
2b	5.2 and Appendix VI
2c	5.2 and Appendix VIII
3	6.2

1.5 Research methodology: FOCUS-PDCA

During (and after) this project we will make use of the FOCUS-PDCA model. This is a well-known continuous improvement model.

FOCUS is an acronym for find, organise, clarify, understand and select. The first step is to *find* an opportunity to improve. Next you *organise* an effort (including assigning a team) to improve the process and *clarify* the issue with the understanding of how the process works. Finally, you have to *understand* the sources of variability and *select* the process and strategy to improve.

When the team identifies the right process to improve, the first PDCA cycle can start to improve the process. PDCA stands for plan, do, check, act. During the PDCA cycle you start to *plan* what you (as a team) want to achieve and how you are going to do this. Subsequently, you *do* what you actually planned and *check* if it is executed according to the plan you have made. The last stage of the first cycle is to *act* on the results, and how these results can be improved the next time. The plan for the new improvement will be made in the next PDCA cycle. PDCA is a continuous improvement model, which means you do not stop improving after one cycle, but you start a new cycle and keep improving (Ransom, Maulik, & Nash, 2005) (Bader, Palmer, Stalcup, & Shaver, 2017).

This model is applicable in the MST context, since the hospital is operating in an continuously changing environment. The number of patients, their arrivals, and characteristics might change continuously due to various influences. This section will describe the model in general, while later on, Chapter 8 will describe the implementation of the model in the MST context.

Chapter 2. Literature review

The following chapter discusses the relevant literature per research topic. Every subject of interest will be discussed briefly based on found literature using Google Scholar and Scopus. The search strategy can be found in Appendix I. The subjects of interest are: definition(s) of a master surgical schedule (2.1), types of MSS scheduling (2.2), types of variability (2.3), and operating room planning models (2.4).

2.1 Definition(s) of a master surgical schedule (MSS)

Several definitions of the master surgical schedule can be found in scientific literature. Three of them will be discussed below to show the difference in usage and detail.

"MSS executes a master schedule of surgery types, which contains slots for surgery types that recur at least once every cycle (of, say, 4 weeks)." (Oostrum, Bredenhoff, & Hans, 2009)

"Master surgical schedule is a cyclic timetable that determines the ward associated with each OR session and must be updated whenever the total amount of OR time changes." (Tànfani & Testi, 2009)

"The master surgical schedule defines the number and types of procedures that will be performed by a hospital over the medium term, the MSS defines aggregate resource requirements, such as the demand for nurses, drugs, diagnostic procedures, laboratory tests, and perioperative nurses." (Blake & Donald, 2002)

The three definitions stated above show that not all papers refer to the same definition when they talk about a master surgical schedule. In this paper we will define an MSS as 'A cyclic timetable where every OR session is assigned to one of the specialties.' An OR session is the available time in one OR on one day. Filling in this MSS on a more detailed level can be done by assigning these OR session to patient types of the allocated specialty. Multiple patient types can be assigned to one OR session, as long as these patient types belong to the same specialty.

Preferably, every cycle of a timetable looks like the previous cycle in order to improve the alignment and repeatability between other activities in the chain of care. However, it does not necessarily have to be an exact copy of the previous cycle.

2.2 Types of MSS scheduling

In scientific literature, two master surgery planning methods are known: block scheduling and open scheduling. With a block schedule, every OR session will be dedicated to one specialty. This specialty needs to perform its surgeries in the given OR time. Open scheduling means there is one central planning that accounts for the total planning of all specialties (Carter & Ketabi, 2012). The MST makes use of block scheduling. This is preferable since every specialty has to deal with many restrictions, needs and preferences. It would be a lot more complex to take this all in account when using an open scheduling method.

Designing a master surgical schedule is a so called multiple stage process. The first (strategic) phase consists of the long term OR time allocation to the surgical specialties, based on historical patient demand patterns (the expected number of surgeries and their duration), and the agreements made with the health care insurers. Subsequently, in the second (tactical) phase, it will be decided when a specialty can use an OR. Every OR session will be dedicated to one specialty in order to reach the total number of OR sessions calculated in the previous step. In the third (operational) phase the detailed planning will be made. Patients from the waiting list will be scheduled in an OR session. Also the order of the surgeries will be determined. Finally, the last stage addresses the online operational decisions of monitoring and controlling the daily OR activities. This, for example, includes dealing with cancellations and emergency patients during an operation day (Vanberkel P. T., et al., 2009) (Beliën & Demeulemeester, 2007) (Hans, Van Houdenhoven, & Hulshof, 2012).

Based on historical data and availability of personnel, the various OR sessions are dedicated to the various specialties. During one OR session, one specialty is assigned to perform surgery. It is not desirable to assign more specialties (or surgeons) to one OR session. Since the surgery duration might take longer than expected, and delays will occur. When an OR session is delayed, this might affect the schedules in other ORs as well as the other activities the surgeon has to perform before or after his surgeries. By assigning one team of surgeons one OR per day, this domino effect can be lessened. Any delays can only affect the continuation of their own schedule.

Even though a clear multiple stage process in described in scientific literature, we want to add one more stage between the current second and third phase. This step is needed to align the OR schedule with the next step in the total chain of care, the nursing wards. When every OR session is dedicated to a certain specialty, we aim to make a schedule *in* this OR session of patient types. These are not the actual patients that will undergo surgery (with a name and number), however in every OR session we will determine how many and what kind of patients should preferably be treated in order to create a constant predictable flow to the nursing wards. Naturally, it might not always be possible to follow this blueprint completely. For example, more emergency patients might arrive than expected, surgeries might take longer than expected, or more/other patients might arrive than expected. Therefore, this blueprint should be used as a guideline when patients are scheduled but it is not fixed.

2.3 Types of variability

In scientific literature, two types of variability can be distinguished, namely natural and artificial variability. Natural variability (in this context) can be divided into three different types: clinical presentation, patient flow and professional expertise. These types of variability occur due to the typical uncertainties a hospital has to deal with. Clinical representation of natural variability is the uncertainty of the condition of the patient. The disease and severity of the patient are not known when a patient enters the hospital, this applies in particular for emergency patients. Also, the arrival interval of the patients is unknown, which is defined as the uncertainty of patient flow. In general, the approximate amount and types of patients are known but the exact arrival of these patients is hard to predict. Moreover, the professional expertise is an uncertain factor, since not every staff member is capable and/or educated to provide quality care to all types of patients (Litvak, 2005).

Artificial variability is a non-random and non-predictable kind of variability. This is driven by individual priorities. An example is the number of patients scheduled for admission, which varies every day. In most cases this results in a peak of bed occupancy before the weekend (Mac Knight & Gorke, 2014) (Litvak, 2005).

It is not possible to influence the clinical presentation, patient flow or professional expertise. Therefore, natural variability cannot be eliminated or reduced. However, you can reduce the impact by managing this type of variability. Artificial variability cannot be managed, but it can be reduced by controlling scheduled demand (Litvak, 2005) (Hans, 2015). When artificial variability is minimized, peaks and valleys in patient demand still exist, over which the hospital has no control. Therefore, the hospital needs sufficient resources to deliver an optimal quality of care (Litvak, 2005). During this project, our main goal is to reduce the artificial variability as much as possible between the OR department and the accompanying nursing wards.

2.4 Operating room planning models

In the literature, various models are known and can be used to construct an OR planning. However, not all models fit the MST context. Some of them will be discussed below.

Several models describe how an MSS can be constructed during the second phase of the multiple stage process mentioned in section 2.2. One of those models is the model of Carter (2012) who uses a mathematical program to generate an OR schedule in a way that the limited operating room capacity can be distributed based on smoothing expected demand for in-patient beds. For every surgeon, the model calculates the number of OR sessions he needs to perform and randomly generates the number of patients. Subsequently, the surgeons are allocated to as many OR sessions as calculated while the weighted sum of maximum bed requirements is minimized during the week.

Another model found in the literature is the model of Beliën (2007), that can be used to construct a new MSS. The model identifies seven factors that might have an impact on the complexity of the problem: the number of time blocks per day, the number of surgeons, the division of requested blocks per surgeon, the number of operated patients per surgeon, the probability of a no show, the length of stay distribution, and the bed capacity. Using these factors, the model designs an MSS taking into account the minimization of variability in bed utilization.

Both models might be converted to the MST context in order to reduce the variability in bed utilization. However, it is not preferable to reassign the OR sessions, since this requires many adjustments in the total chain of care. When a certain specialty or surgeon has to perform surgery on a different day than usual, this will also affect other steps of the horizontal process such as the outpatient clinic and their planning. Moreover, when calculating patient characteristics per surgeon, the whole model needs to be recalculated when a surgeon leaves the hospital or when a new surgeon enters, while no data of the new surgeon is available yet. Also, the different patients of one surgeon are grouped and scheduled as one type of patients, while the characteristics of the patients within this group may vary substantially.

The next model found in the literature is the model described by Agnetis (2013). This can be used to fill in the weekly MSS, based on a certain waiting list with patients per specialty. Moreover, it takes into account the 'intensity of care'. Every intensity of care corresponds to a different bedroom type and OR sessions. It uses different priority classes and OR session types to schedule patients into the current MSS while the objective is to minimize the standard deviation of the average bed utilization.

This objective function is also relevant for the MST context. However, it is quite hard to retrieve the required data. Mainly the intensity of care of a patient type is hard to measure, since it depends not only on the type of surgery, but also on the condition of the patient and skills of the nursing staff. Moreover, the model uses a very detailed bed allocation where patients from the same gender cannot stay in the same room. The model schedules according to a first come first serve principle that might not be optimal to reduce the variability in bed utilization. This model differs too much from the MST context and is therefore not appropriate to use in this research.

Glerum (2014) designed a quadratic assignment problem (QAP) model that can be used to determine the optimal patient mix while taking into account the minimization of variability in bed utilization. The model is used to schedule three types of patients in an MSS; day care patients, short stay patients, and long stay patients. It uses a given MSS, average time of surgery per patient type, and stochastic length of stay. Similar to the model of Agnetis (2013) the objective function is to minimize the variability of the average bed utilization. This would create a predictable and more constant flow of patients to the involved nursing wards.

Also Vanberkel (2009) designed a model that can be used. This model gives the distribution for the number of patients on each day of the MSS, while taking into account the ward occupancies, admissions and discharges and the number of patients in a specific day of recovery to determine the workload on a hospital department. The model is tested at the Netherlands Cancer Institute-Antoni van Leeuwenhoek Hospital. They used the model to reduce the fluctuations at the nursing wards.

The models of Glerum (2014) and Vanberkel (2009) are in line with the aims of this research within the MST hospital. However, we will use the model of Glerum (2014), since this model can be applied more quickly in the MST context. We can use the model in the current block scheduling method of the MST to reduce the artificial variability at the nursing wards.

Before the above mentioned model of Glerum (2014) can be used, data needs to be retrieved. However, using only three groups of patients is not specific enough for the MST. The model should be changed to make it suitable for scheduling more than three patient groups. Using data of last year, we can construct patient groups per specialty. For these patient groups we can determine the average surgery duration and probabilities of stay using the historical data.

Chapter 3. Problem analysis

This chapter defines the core problem of this research by demonstrating the relations between different problems in a problem cluster (3.1).

3.1 Problem cluster

The OR schedule is filled according to a 'first come first serve' principle. The first patient on the waiting list (longest waiting patient) will be scheduled first, as soon as the corresponding specialty has OR time available. The goal here is to use as much available OR time as possible. Since the OR department is the most expensive resource, it is important to maximize the OR utilization. However, the number of daily and weekly OR sessions per specialty do not change a lot, because the way the specialties fill in these sessions changes continuously and the OR schedule does not take into account the lengths of stay of the patient types, the variability in bed utilization is high. This is encountered by the nurses by a strongly fluctuating bed utilization on their wards.

By conducting interviews with personnel members of the MST hospital, it has been found that the planning department and the nursing wards encounter most of the problems as a result of the current scheduling method. The planning department has to find a suitable bed for every patient after their surgery. On a regular basis, the preferred department does not have a free bed for the patient, so the planning department needs to find an available bed at another unintended ward. This can happen due to various reasons: emergency patients might occupy a bed that was intended for another patient, the length of stay of an (elective) patient might be longer than expected, patients from other wards occupy a bed since their ward was already full, etcetera. When a patient is placed on a ward that is not necessarily specialized in the required type of care, it is possible the patient receives a lower quality of care. In the worst-case scenario, the hospital even has to cancel a surgery since they do not have any beds available at a nursing ward that suffices.

This erroneous placement of patients also has a direct effect on the nursing departments. Partly because of these incorrect placed patients, but mainly because of the changing unpredictable inflow of patients to the departments the workload is fluctuating every day. When the timetable for staff members is made, it is not known how many and what type of patients will (probably) enter the wards. Consequently, it is not possible to adjust the personnel planning to the number of patients. However, the workload at a nursing department is not only defined by the number of patients present at the ward. The intensity of needed care is also an important factor of the workload. However, the intensity of care can hardly be measured and is therefore out of the scope of this research.

Since staff members have to deal with an unexpected amount of patients arriving at the wards, they might not always be able to deliver the quality of care they would and should deliver. When a patient is placed at an undesired ward he or she will be transferred to the desired ward as soon as possible. This creates an unnecessary displacement of the patient, with associated additional administrative burden. All these changes and uncertainties lead to unsatisfied personnel and patients, as the personnel members mentioned during the interviews.

Moreover, when a fixed surgery schedule for patients types is missing, it is not always possible to make an appointment for the date of surgery in consultation with the patient at the hospital. Instead, the patient receives a letter with the appointment date at home, this increases the chance of cancellation by the patient and ultimately results into a lot of rescheduling. See Figure 3 for the relation between the problems shown in the problem cluster.

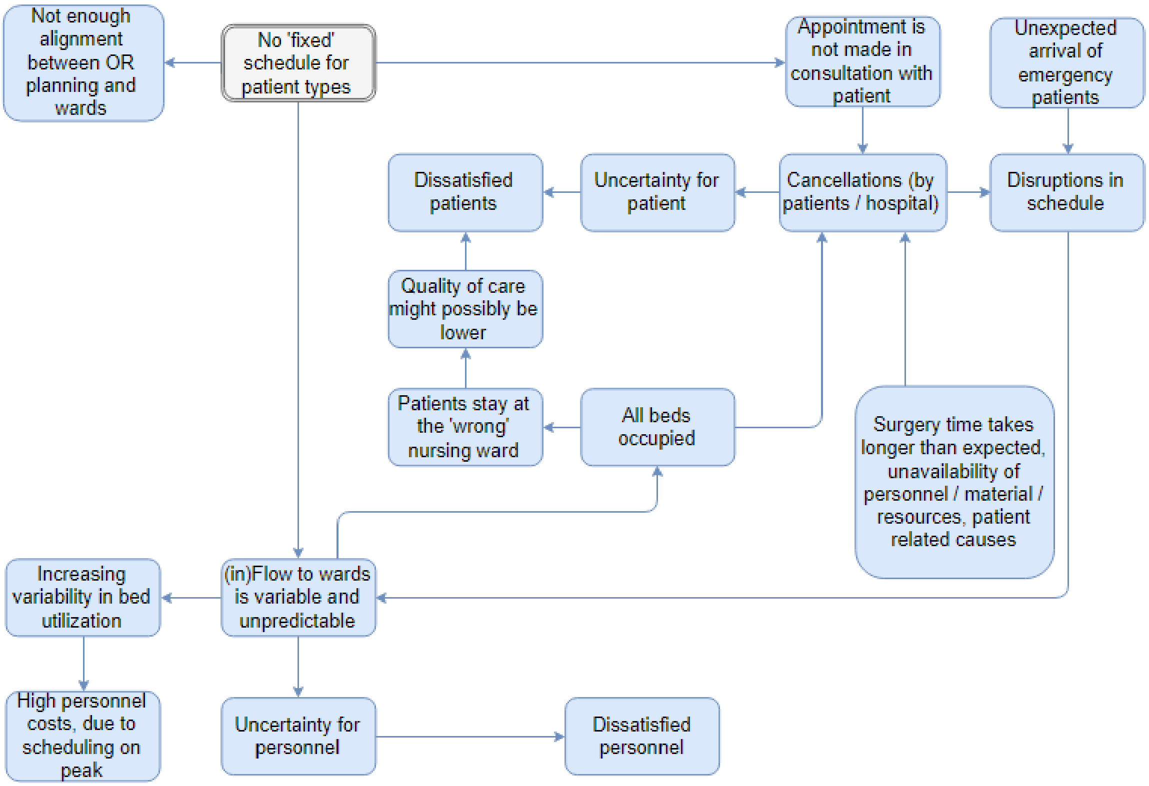

Figure 3. Problem cluster.

Figure 3 shows that the core problem of this research is defined as the absence of a 'fixed' schedule for patient types. The variability of the number of patients at the nursing wards should be as low as possible, but perhaps just as important is to *know* what type and number of patients will enter the ward for the coming days. If the predictability is higher and a forecast of the number of patients present at the ward can be made, the scheduling of personnel members can be done more adequately. This will increase the satisfaction of the personnel members as they will encounter less fluctuations in their workload. Moreover, the patient satisfaction will increase since better quality of care can be delivered as there are sufficient personnel members and the probability to stay at an undesired nursing ward will decrease.

Introducing a new schedule with patient types will not solve all problems shown in Figure 3. MST is still a hospital that operates in a continuous changing environment where dealing with all kinds of variability is a daily practice. Emergency patients will still arrive unexpectedly with an unknown acuity and might disrupt the schedule with possible cancellations as an effect. Surgeries will sometimes take longer than expected and lack of personnel, material and resources will still cause some cancellations and working in overtime. However, a larger part of the patient flow can be controlled and predicted. Therefore, we need to select a suitable model to schedule the patient types in the current OR sessions of the MSS. When characteristics of these patient groups are known, variability can be reduced and predictability can be increased in order to improve the patient and personnel satisfaction.

Chapter 4. Current situation at MST

This chapter will discuss the current situation at the MST. First, the process of patient flow will be shown (4.1). Next, the current way of scheduling elective patients will be discussed (4.2 and 4.3), and how the MST deals with emergency patients (4.4). Finally, the effect of the current scheduling method on the variability at the nursing wards (4.5) and the OR utilization (4.6) will be demonstrated.

4.1 Patient flow process

When an elective patient enters the hospital he visits the outpatient clinic where he has an appointment with a certain physician. This physician decides whether the patient needs surgery or not. When the patient needs surgery, he has to visit the pre-operative screening (POS). The POS usually consist of multiple appointments with for example the anesthetist, nurse, and dietician to gather and give all information needed for surgery and explain the surgery procedure to the patient. Moreover, the anesthetist will discuss and explain the anesthesia used during the surgery and will perform a final check on the health conditions of the patient. When all conditions are met, the patient can be scheduled for surgery. After surgery the patient will (shortly) go to the recovery, or when additional care and monitoring is needed, to the PACU (Post Anesthesia Care Unit) or intensive care (IC) unit. When the patient's condition has stabilized, the patient will rehabilitate at the nursing ward of the corresponding specialty. In most cases, an emergency patient enters the operating room, intensive care or nursing ward immediately, for acute treatment.

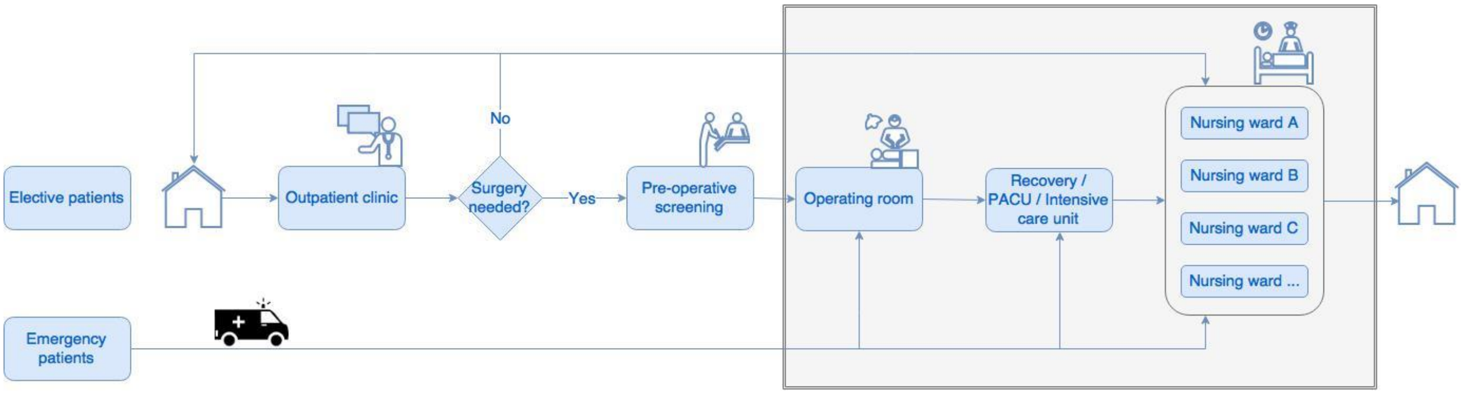

Figure 4. (simplified) Overview of the patient flow process.

This research will consider both patient flows (emergency and elective). However, we will only consider patients treated during office hours, since these patients are scheduled or added to the schedule in the MSS. The remainder of the emergency patients is treated by the night and weekend shifts. The scope of this research is indicated with a grey rectangle in Figure 4.

4.2 Available OR time per specialty

Based on historical data and agreements with the health care insurers, the expected number of patients is determined. The arrangements of 2017 are loosely based on the type and number of patients treated in 2016. Combining these numbers and their (historical) surgery duration, the current MSS schedule is constructed. Most of the time, every OR session is dedicated to one specialty. It is not preferable to assign one session to multiple specialties, since this may cause delays (at multiple ORs) when one surgery takes longer than expected. An example of the OR division can be found in Appendix I, which shows that not all OR sessions are dedicated to a specialty, due to personnel restrictions, not every OR session can be used every day.

Additionally, not every OR is equipped with the same facilities. Therefore, it is important for every specialty to know, in which OR(s) their surgeries can be performed. Due to movable equipment, the flexibility of specialties to perform surgery in several ORs is relatively high. As a result, every specialty can perform at least some of their surgeries in any available OR. However some surgery types require more advanced equipment, which is not available in every OR. Therefore, Table 4 shows an overview of these preferable ORs that are suitable for more specialized care. This should be taken into account when patient types are being scheduled.

Table 4. Preferable ORs per specialty.

Specialty	Preferable OR(s)
Anesthesia	All
Special dental care	1,4
Cardiology	12
Cardiothoracic surgery	13, 14, 15
Surgery	
- General surgery	All
- Gastrointestinal and oncological surgery	5
- Trauma surgery	7
- Vascular surgery	12
Gynaecology	10
Oral and maxillofacial surgery	4
Ear, nose and throat surgery	1
Gastroenterology	1, 9
Neurosurgery	2, 4
Ophthalmology	5
Orthopedics	9, 11
Plastic surgery	11
Urology	6

4.3 Scheduling elective patients

As mentioned in section 2.2, scheduling can be done on several levels in an organization. During this research we will focus on the resource capacity planning on a tactical level, as indicated in the framework of Figure 5. Subsequently, we will discuss how this tactical scheduling process is organized in the current situation of MST.

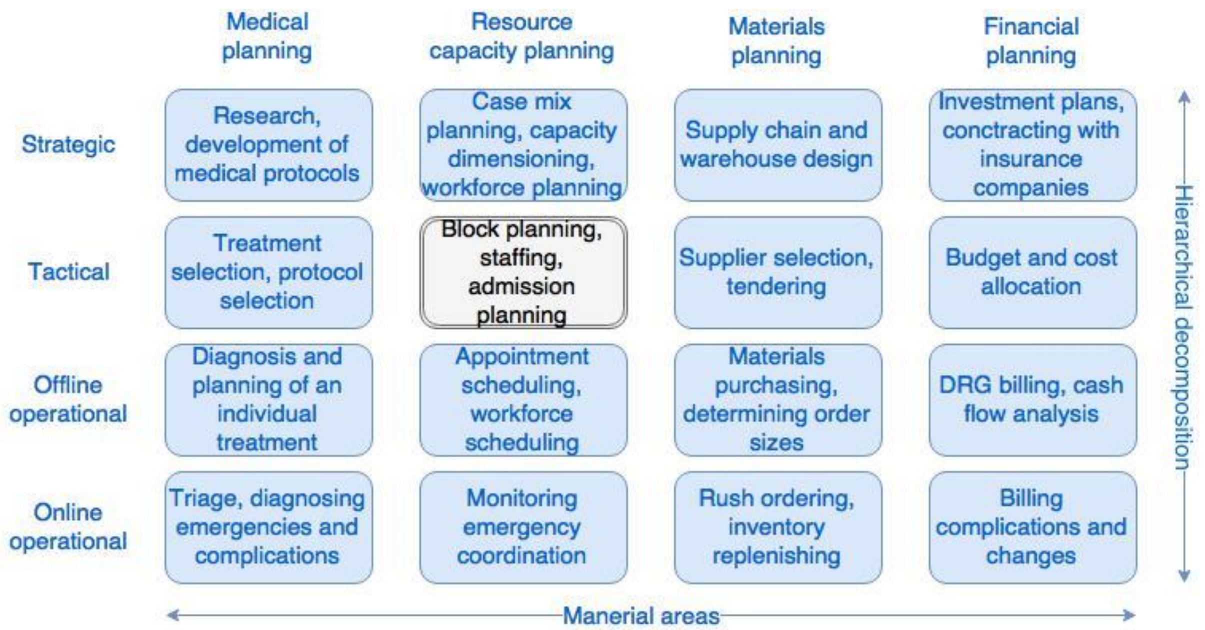

Figure 5. A framework for healthcare planning and control Hans, E. W., Van Houdenhoven, M., & Hulshof, P. J. (2012).

Every specialty or group of specialties has its own planner, who schedules according to a 'first come first serve' principle. The longest waiting patient will be scheduled first, as soon as there is available OR capacity for the corresponding specialty. The aim of the planners is to use the available 480 minutes per OR session as efficiently as possible. If the OR planner is not able to fill in the program efficiently enough (>75%), the hospital has the right to cancel this entire OR session (Schopman, van Houte, & Kampshoff, 2015). Moreover, the OR planner has to deal with a significant number of restrictions and rules. Resources are limited, so it is not possible to schedule more surgeries of one type at the same time (in different ORs) when resources are not available. Limited resources are for example surgery tools (X-ray equipment, supplies) and staff members. Furthermore, not every OR is suitable for every type of surgery, so this is taken in to account when designing the offline operational schedule.

Since the OR department is the most expensive resource, it is quite logical to aim for a high utilization. However, while aiming for a high OR utilization, there is limited connection between the OR schedule and the nursing wards. As an effect, patients might end up staying at an undesired nursing ward, since there is no available bed at the preferable nursing ward. This is the case since the planners do not have insight into, or make use of the length of stay of the patients, and therefore do not know beforehand how many beds are still free to schedule for other patients. Moreover, they have little insight in the scheduling of the other specialty (groups), even though they have to share the same resources.

4.4 Handling emergency patients

Aside from the elective patients, MST categorizes three types of emergency patients. Table 5 gives an overview of the three groups. It also shows the time this patients should be treated in after arrival at the hospital.

Table 5. Emergency patient groups.

Group	Should be treated within
1	30 minutes
2	Five hours
3	24 hours

Every day, one OR is dedicated as emergency OR. This OR is used to schedule the <24 hours emergency patients. Moreover, this OR is used for emergency patients arriving during the day. When an emergency patient arrives and is categorized as <30 minutes, this patient will be treated in the first available OR, which might be the emergency OR but also one of the dedicated ORs, and other patients are cancelled and/or delayed as and when required. The time of treatment for emergency patients that need surgery < 5 hours after arrival depends on the urgency and type of surgery they require. When an OR session is finished in time, this OR can be used to perform surgery. However, it might also be possible that elective patients need to be cancelled or delayed in order to perform surgery on time. For every type of (emergency) patient the right surgical team should be present.

Figure 6 shows the number of emergency patients treated per day. Note: this is the average number of emergency patients treated during office hours. This is relevant to note since these are the patients that were not taken into account when the original schedule was made, but are still treated during office hours. However, it is not known if these patients really disrupted the schedule, or if they were treated since there was free time available during or after an OR session. It can be seen that the number of emergency patients is very similar throughout all days of the week.

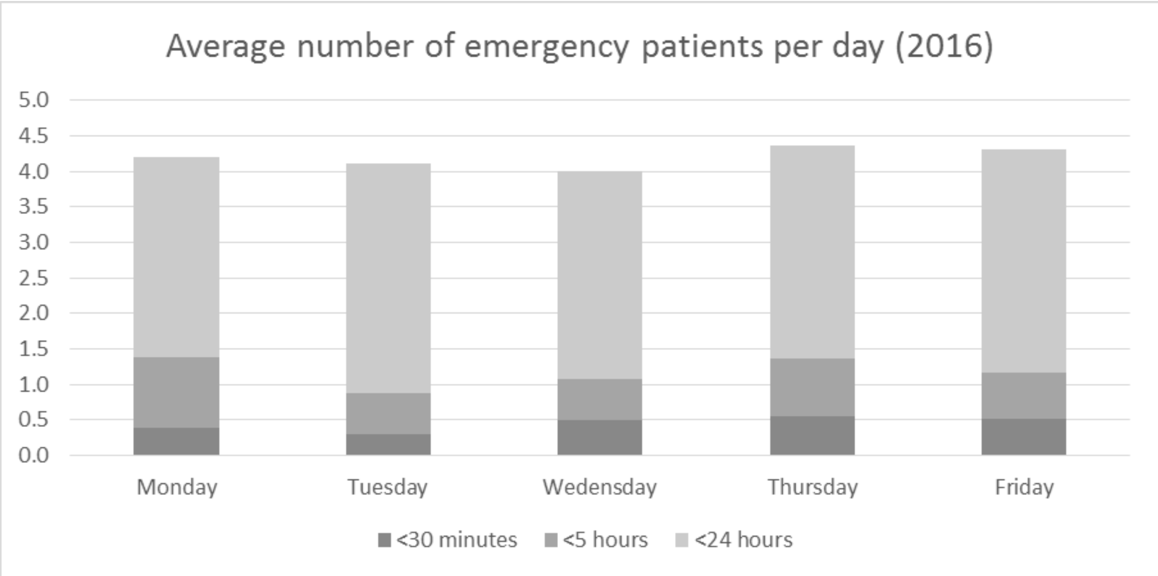

Figure 6. Average number of emergency patients per day (2016). (n=739, T=365 days, source: MST data 2016)

When constructing a schedule with patient groups, these three types of emergency patients as well as their characteristics should also be taken into account. In the current situation, one OR is used to treat emergency patients. Table 6 shows the characteristics of emergency patients. Based on the average surgery duration, it seems reasonable to use the capacity of one OR as emergency OR.

Table 6. Emergency patients characteristics.

	Average surgery duration (minutes)	Average cases during office hours
<30 minutes	86	0,5
<5 hours	93	0,7
<24 hours	77	3,1

Based on data of 2016 we analysed the number and types of emergency patients. As Table 7 shows, most of the emergency patients treated during office hours are general surgery patients. Also, gynaecology covers a substantial part of the emergency patients (mainly C-sections). The remaining specialties rarely have to perform surgery on emergency patients. So, when OR time is reserved for emergency patients, this should mainly be done in the OR sessions of general surgery and gynaecology.

Table 7. Emergency patients per specialty.

Specialty	% of the emergency patients during office hours
General surgery	66%
Gynaecology	13%
Neurosurgery	4,7%
Orthopedics	4,7%
Cardiothoracic surgery	4,1%
Plastic surgery	2,6%
Urology	1,9%
Remaining specialties	<1% each

Since emergency patient flow to various wards, we cannot take them into account using the model. But, we do know the reserved OR time for emergency patients seems quite reasonable, based on their average surgery duration. The way the MST hospital reserves OR time for emergency patients is out of the scope of this research, however we recommend this as a subject for further research.

4.5 Variability at nursing wards

The current way of scheduling creates too much variability in bed utilization at the nursing wards according to the staff members at the nursing wards. This is the consequence of the limited connection between the OR planning and the nursing ward. When patients are scheduled for surgery, the planner does not know how long the patient will stay at which nursing ward and which patients are already at that particular nursing ward. Therefore, the number of patients present at the wards on a given day cannot be foreseen until that day. This results in high peaks and lows in the number of patients at the wards, which is not desirable for the patients nor the nursing staff.

To show the effect of the current way of scheduling, the number of patients at one of the nursing wards during a random period of four weeks is shown in Figure 7. The figure shows the highs and lows at the nursing ward. The average number of patients present at this ward fluctuates between 14 and 33. Since this effect is not known beforehand, it cannot be taken into account when scheduling personnel members. This causes fluctuations in their daily workload. Other nursing wards and other periods show a similar effect.

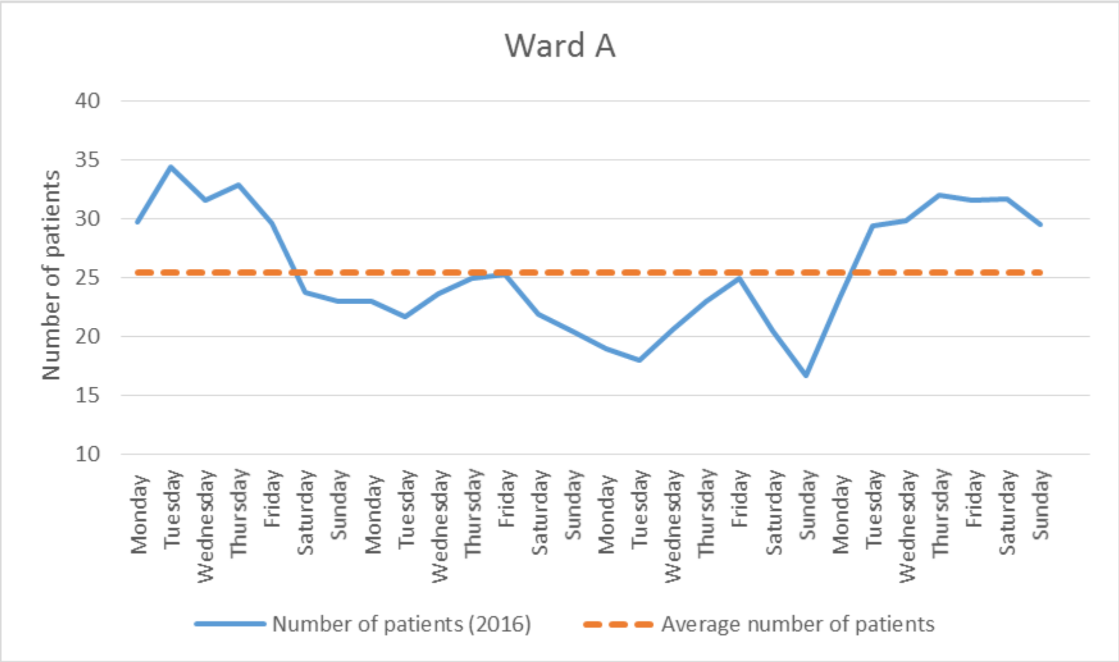

Figure 7. Example of number of patients at nursing ward in one period of four weeks. (n=28, T=28 days, source: MST data)

For the same nursing ward, Figure 8 shows a boxplot for every day of the week. Clearly, the number of patients at Ward A is significantly lower than on the other days. Mainly on Tuesday and during the weekend, the spread is relatively high.

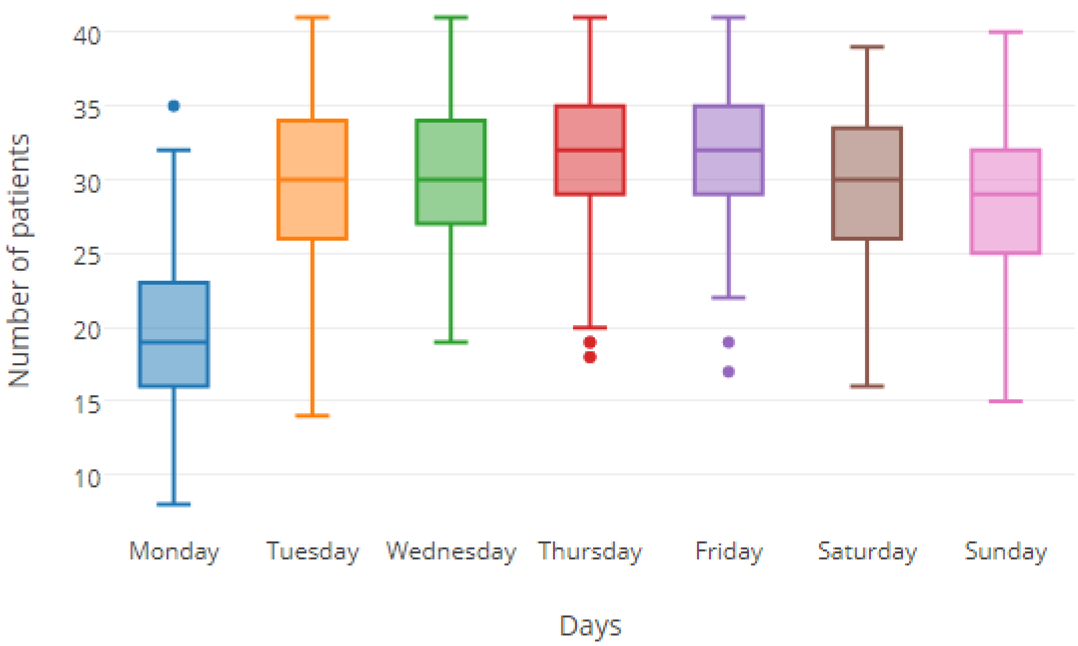

Figure 8. Boxplot of nursing ward A. (n=4188, T=365 days, source: MST data)

4.6 Utilization of the operating rooms

MST uses 'Business Objects' to display data from the database in several reports. For every specialty, it can show the number of OR sessions every specialty used and the utilization of these sessions. 2 types of utilization can be distinguished: OR usage without setup time and OR usage with setup time. Setup time is defined as the time required between two surgeries to clean up and prepare the OR for the next surgery with all material and equipment needed. The average OR utilization without setup times equals 73% in 2016. The OR utilization including setup times equals 87%, where one OR session equals 480 minutes. However, for a restricted number of OR sessions it is allowed to exceed the 480 minutes limit since an additional team is present at the end of the day. Because of this, it is possible to realise an OR utilization of more than 100%.

Appendix II shows the OR usage per specialty with and without setup times. These numbers are used to determine the average setup time of an OR session of a certain specialty. This should be taken into account when designing a schedule. We have to use averages to calculate the setup time per specialty. It would be ideal to calculate the setup time more precisely (for example, per surgery type) but this is not possible since the setup time depends on many different factors, such as the type of surgery, or the next type of surgery, amongst other factors. If two similar surgeries are scheduled in a row, the setup time will be lower since equipment is already at the OR and only limited changes are needed. Moreover, the location of the OR can influence the setup time. A surgery can only start when all staff members are present at the OR. When an OR is located 'far' from the recovery, it takes a while before the anesthesia worker is back at the OR after he transported the previous patient, so setup time increases.

4.7 Conclusion

In the current situation elective patients are scheduled according to a 'first come first serve' principle. The longest waiting patient is scheduled as soon as possible when there is available OR time of the corresponding specialty. Three types of emergency patients can be distinguished. These patients enter the system unexpectedly and are scheduled in the first available OR, when the right surgeon team is present. To make sure the waiting time of emergency patients is not too long, one OR is kept free to treat (at least) the first arriving emergency patient.

The current way of scheduling results in a strongly fluctuation bed utilization. Since this high variability is not known in advance, the MST is not able to match their personnel planning to the number of patients at the wards. The QAP model of Glerum (2014), discussed in Chapter 2, seems suitable to reduce this variability at the nursing wards.

Chapter 5. Intervention model

This chapter will discuss the model that will be used to minimize the variability in bed utilization (5.1). Next, we shows how patient groups are constructed and their characteristics are calculated (5.2). These patient groups are used as input for the optimization model. We will also show the limitation of the model (5.3), and describe the experiments we will perform (5.4).

5.1 Quadratic assignment problem model (QAP)

This section will answer research question 1: 'Which model is suitable to apply to the MST context in order to schedule patient types resulting a minimized bed utilization variability?'.

As discussed in Chapter 2, several models are known to construct the MSS, with or without a connection between the workload at the nursing ward(s). The QAP model of Glerum (2014) seems to be the most suitable model. This model is most appropriate to take into account the relation between the MSS and the bed utilization at nursing wards in the MST context.

The quadratic assignment problem (QAP) model is designed to construct a patient mix, using a given MSS, aiming to minimize the variability of the bed utilization at the wards. For every OR and every day, a patient mix will be constructed. This patient mix shows how many patients of which type should be scheduled per day per OR (Glerum, 2014). The original model was not ready to use for the MST context, therefore we made some adjustments. We do not consider a priority factor for a certain bed type, and we do not have multiple objectives with corresponding weights. Also, we do not use a fixed setup time per surgery, but decrease the OR session time with the average setup time per OR session of a certain specialty. Moreover, we added an extra entity G which is used in an additional constraint to take into account the length of stay before the date of surgery (some patients are hospitalized one day before their date of surgery and thus already occupy a bed).

The input of the model consists of entities and parameters. Table 8 shows an overview of the entities, the parameters can be found in Table 9 (Glerum, 2014).

Table 8. Input entities.

Entities	Set	Index	MST
Cycle horizon	T	t	28 days
Operating rooms	J	j	13 ORs
Bed types	B	b	10 nursing wards
Patient types	I	i	118
Set of ORs j and days t where specialty i can perform surgery	A^i	j,t	
Patient types that are hospitalized one day before their date of surgery	G	g	5, 30, 32, 33, 37…

When the cycle horizon (T) is too long, seasonal effects cannot be taken into account sufficiently, but when the cycle is too short the predictability of the arrivals is insufficient. We chose to use a cycle horizon of 28 days to find a good balance between the seasonal effects and predictability of arrival intervals. Moreover, the current MSS also has a repeatable schedule of 28 days. In the model, patients will be scheduled in the 13 ORs (J). The 3 thorax ORs are not in the scope of this research, but 2 ORs of the old building are added to simulate the circumstances of 2016 as precisely as possible. Moreover, we have to deal with the different types of beds, where every type represents a different ward (B). We included the 10 nursing wards where the patient should flow to after surgery. For every specialty, the allocated OR sessions (A) are denoted as already determined in the realized situation in the MSS of last year.

Table 9. Input parameters.

Parameters	Parameters Notation
Expected surgery duration in minutes needed by patient type i	$e_i \in \mathbb{Z}+$
Capacity of OR j on day t in minutes	$o_{j,t} \in \mathbb{Z}+$
Number of patients type i	$s_i \in \mathbb{Z}+$
Probability of patient type i being in bed type b after t days	$p_{b,I,t} \in \mathbb{R}$, $0 \leq p_{b,i,t} \leq 1$
Maximum number of nights required in bed b by case type i	$l_{b,I} \in \mathbb{Z}+$

Using historical data, the expected surgery duration in minutes (e) is given for every patient group. The daily capacity of an OR session equals 480 minutes (o) minus the average setup time of that specialty as discussed in section 4.6. For every cycle, we know how many patients of every group (i) should be treated. For every patient type, we know the probabilities of staying at a certain ward after surgery (p), which also denotes the maximum number of nights per patient type (l). Moreover we also take into account the length of stay before date of surgery (g). The objective function of the model depends on the decision variable stated below in Table 10 and auxiliary variables in Table 11.

Table 10. Decision variable V.

Decision variable	Notation
Number of patients of type i scheduled in OR j on day t	$V_{i,j,t}$

Table 11. Auxiliary variables.

Auxiliary variables	Notation
Maximum demand for bed type b	Z_b
Average utilization of bed type b on day t	$ZZ_{b,t}$
Utilization of OR j on day t	$UU_{j,t}$
Average bed utilization of bed type b over the cycle horizon	AV_b

Decision variable V will show how many and what type of patients should be scheduled in which OR on which day. This results in a maximum demand for a certain bed type (Z). Moreover, the utilization of a bed type (ZZ) and the utilization of an OR (UU) are calculated. Finally, the average bed utilization per bed type is shown (AV).

The objective function of the QAP model is to minimize the deviation of the average bed utilization:

$$\min \frac{\sum_{b \in B} \sum_{t \in T} (ZZ_{b,t} - AV_b)^2}{T * B}$$

With this objective Glerum (2014) made some constraints of which a modified version is stated below. Constraint (1) makes sure every patient will be scheduled in an OR when the right specialty is dedicated to that OR. Constraint (2) makes sure $ZZ_{b,t}$ reflects the bed utilization of bed type b on day t. Note: the length of stay of patients before and after their date of surgery is also incorporated. Constraint (3) sets Z_b as the peak of bed demand for bed type b over the planning horizon. Constraint (4) determines the OR capacity needed by all patient types scheduled on that day and OR. Constraint (5) makes sure the scheduled capacity does not exceed the available capacity of an OR. Constraint (6) sets AV_b to the average bed utilization for bed type b during the planning horizon (Glerum, 2014).

$\sum_{t\in T}\sum_{j\in J}A_{t,j,i} * V_{i,j,t} = s_i \qquad \forall i \in I \qquad (1)$

$\sum_{i\in I}\sum_{j\in J}\sum_{f=1}^{i_{b,i}} p_{b,i,(f-1)} * V_{i,j,(t-f+1)^{\circ}} + \sum_{j\in J}\sum_{g\in G} p_{b,g,1} * V_{g,j,(t+1)^{\circ}} = ZZ_{b,t}$

$\forall b \in B, t \in T \qquad (2)$

$ZZ_{b,t} \leq Z_b \qquad \forall b \in B, t \in T \qquad (3)$

$\sum_{i\in I} e_i * V_{i,j,t} = UU_{j,t} \qquad \forall j \in J, t \in T \qquad (4)$

$UU_{j,t} \leq o_{j,t} \qquad \forall j \in J, t \in T \qquad (5)$

$\frac{1}{T}\sum_{t\in T} ZZ_{b,t} = AV_b \qquad \forall b \in B \qquad (6)$

° = should be read as the modulo to incorporate patients still in a bed from the previous cycle.

The model is built in, and solved by IBM ILOG CPLEX Optimization Studio Version: 12.6.3.0.

5.2 Constructing patient groups for the QAP model

Before we can apply the QAP model as discussed in the previous section, we need to construct patient groups, to answer research question 2: 'How to cluster patients for the model'. Moreover, the characteristics of these patient groups will be calculated in this section and shown in several appendices, to answer the following three sub questions (2a, 2b, and 2c): 'What is the surgery duration for every patient group?', 'What is the length of stay (and corresponding probabilities) for every patient group?', and 'What is the probability of every patient (group) to go to a certain ward after surgery?'.

The construction of the patient groups is done according to the PDCA model. The PDCA cycle starts with a meeting with the involved team members of a certain specialty (medical specialists, planners etcetera). We aim to make a schedule that includes the number and types of patients that need to be scheduled in that particular MSS period, while the variability at the nursing wards is reduced. Therefore, we need to design several patient groups and calculate their characteristics. The medical staff is asked to make a first group classification. They decide for every type of surgery they perform, to which of the groups it belongs, according to their insight on medical and logistic characteristics. Next, we will check if the data also confirms this group classification. We check the surgery duration for all patient types within a group, as well as the length of stay. A patient does not fit in a certain group when the surgery duration and/or length of stay is not comparable with the other patient types of the group. This will probably lead to some suggestions of changing groups. This will be discussed with the medical staff of that specific specialty in the next PDCA cycle. We perform as many PDCA cycles as needed to finalize the group classification.

Based on medical and logistical characteristics, every surgery type the specialty performed in 2015 and/or 2016 is assigned to one of the patient groups. Next, we use data of 2016 to determine the following characteristics needed as input for the QAP model:

- Average surgery duration (Appendix IV)
- Number of surgeries per patient group per period (Appendix V)
- Length of stay probabilities (Appendix VI)
- Probabilities of staying at a certain ward (Appendix VIII)
- Length of stay before date of surgery (Appendix VII)

The average surgery duration is determined based on historical data of the patients treated in 2016. We chose to use only data from last year since the situation of commissioning the new building with new equipment might influence the data before 2016.

Using the same data we calculate the length of stay with their probabilities. So, for every patient group we calculate the chance of being in a bed after one day after surgery, two days after surgery, etcetera. These probabilities are multiplied by the chance of this patient type going to a certain ward.

Outliers of both surgery duration and length of stay are removed from the data since the characteristics of these outliers are most likely patient related instead of surgery related. This could be the case with patients that deal with comorbidity, obesity or diabetes.

An example of surgery duration and length of stay for one patient group is shown in Figure 9 and Figure 10.

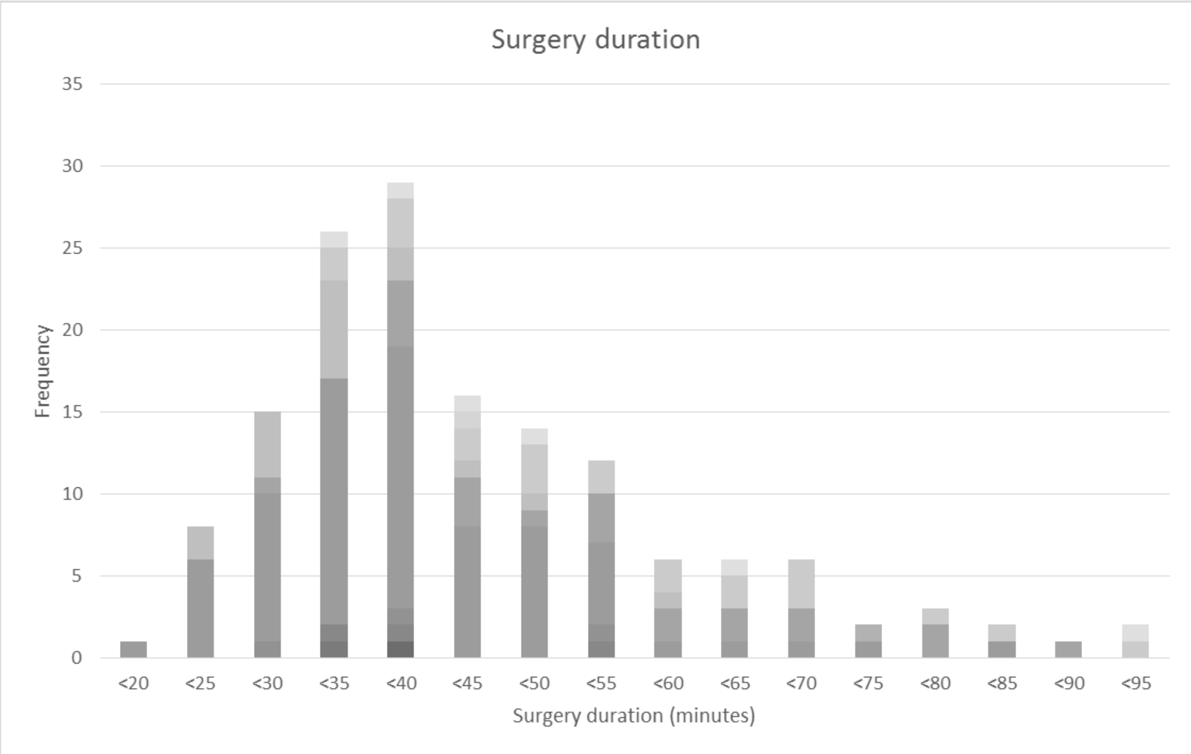

Figure 9. Surgery duration of a gynaecology patient group. (n=149, T=365 days, source: MST data)

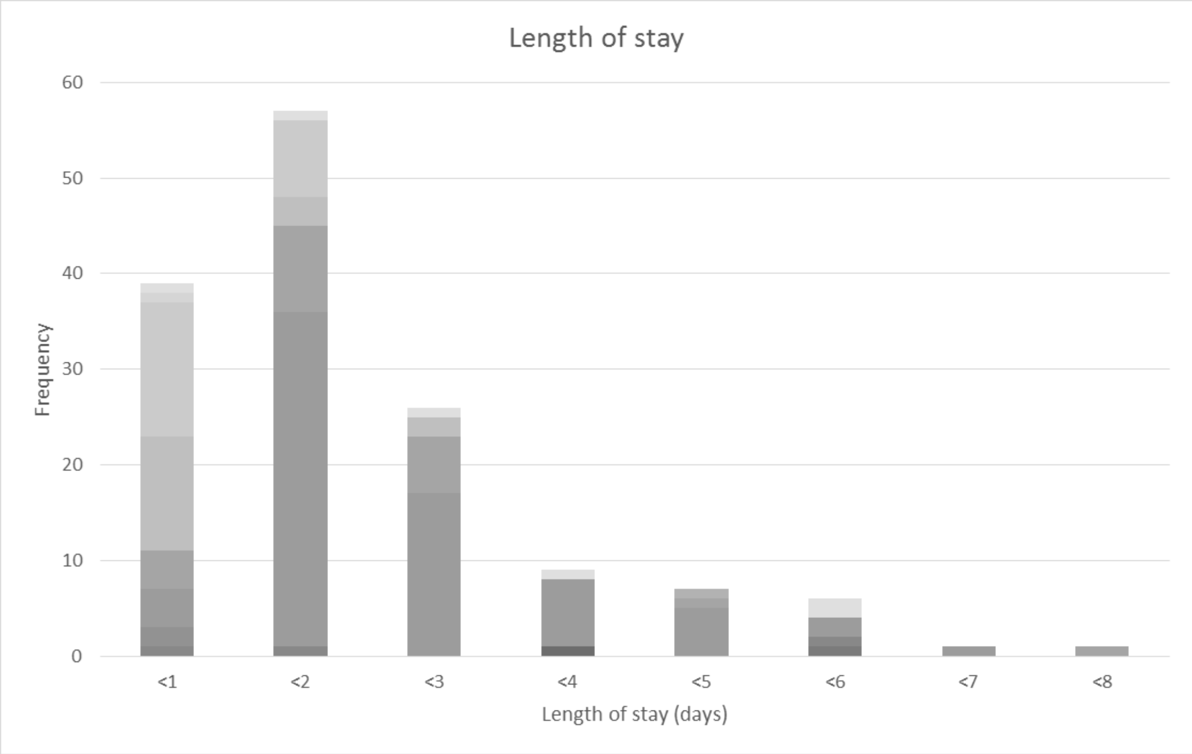

Figure 10. Length of stay of a gynaecology patient group. (n=146, T=365 days, source: MST data)

The two figures (Figure 9 and Figure 10) show the characteristics of a patient group from gynaecology. Every colour represents a type of surgery allocated to this group. Outliers are removed and it can be seen that these surgery types fit into the same group, based on their surgery duration and length of stay. When a surgery type does not seem to fit in the allocated group, we try to allocate this surgery to another group (with similar logistic and medical characteristics) where the length of stay and surgery duration fits to the group better. Similarly, this is done for all 118 patient groups.

However, not only the length of stay is relevant information for the new scheduling model. We should also take into account, for every patient group, where this length of stay is spent. Again we use data of 2016 to determine to which wards the patients went after a certain surgery. For example, we have to deal with a limited number of Intensive Care (IC) and Post Anesthesia Care Unit (PACU) beds. But also, for every type of regular bed we want to minimize the variability at that ward. Therefore, for every patient group we determined the probabilities of going to a certain ward after surgery. An example is shown in Table 12. For every ear, nose and throat (ENT) surgery group, this table shows the probability of going to a certain ward after surgery. Note: the total of each row might add up to more than 100% since a patient may visit multiple wards after surgery.

Table 12. Probabilities per ward per patient group of ENT surgery.

ENT surgery	Ward A	Ward B	Ward C	Ward D	Ward E	Ward F	Ward G	Ward H
Group 1	47%	24%	20%	4%	4%	5%	4%	0%
Group 2	19%	74%	4%	4%	0%	0%	4%	0%
Group 3	65%	5%	20%	20%	0%	5%	0%	0%
Group 4	66%	3%	6%	11%	34%	17%	14%	9%

After performing one PDCA cycle, one of the team members mentioned that not all patients may arrive at the hospital on their day of surgery. Therefore, for every patient group we used data to determine if the majority of the group arrives on the day of surgery or not. Clearly we only use data of the elective patients, since emergency patients (almost) always enter the hospital on their day of surgery.

Table 13 shows the length of stay before surgery date for every patient group undergoing ENT surgery. It shows that for Group 2, most of the patients arrived zero days before surgery, so their admission happened on the same day as their surgery did. However, most of the patients in Group 1 (39) arrived one day before their date of surgery. Additional scans or treatment may cause these early admissions. For every patient group we calculate the length of stay before surgery and use this as input for the model since this will affect the bed utilization.

Table 13. Length of stay (days) before the date of surgery.

ENT surgery	0	1	3	5	7	8	41	Total
Group 1	**10**	**39**						**49**
Group 2	**18**	**8**						**26**
Group 3	**1**	**16**				**1**	**1**	**19**
Group 4	**1**	**18**	**1**	**1**	**2**			**23**

5.3 Limitations of the QAP model

The QAP model can be used to design an OR schedule while the variability on the nursing wards is minimized. Although the model is able to simulate the MST situation in a realistic way, we have to deal with some limitations of the model.

After surgery, a patient might flow to several nursing wards. It might be the case that a patient needs treatment of multiple specialties and therefore stayed at multiple wards after surgery. However, the model cannot place a patient at different wards one after the other. This is a limitation since this is not always the case in practice. When a patient stays at multiple wards, it is most of the time the case when a patient is (temporary) placed at an alternative ward since there is no available bed at the preferred ward, or due to complications the patient has to be transferred to another ward. So, in most cases, visiting more than one ward after surgery is not intended. However, when a certain ward is aware of the fact a patient will enter their ward within a short period of time, the bed will be reserved before the patient arrives. Therefore, it is possible that multiple beds are administratively occupied by one patient. These probabilities of administratively going to multiple wards at the same are included in the model, so the effect of this limitation will be small.

Before a patient enters the nursing ward (after surgery), he will first stay at the recovery, PACU or IC for a short period of time. However, this is not taken into account in the model since this is, most of the cases, a patient related factor and not necessarily surgery related. Before a patient is being scheduled, the surgeon completes a pre-operative screening (POS) form where he indicates if a patient needs a PACU or IC bed after surgery, so this can be taken into account during the offline scheduling phase. Furthermore, the bed at the nursing ward will be reserved and therefore cannot used by another patient when the ward is notified of the (future) arrival of a patient. Hence, this will barely influence the bed utilization at the nursing wards of the model.

Not every restriction from the MST context can be added to the model. We have to deal with limited resources and equipment. For example: there is a limited number of surgery tools to perform a certain surgery. So we cannot schedule multiple surgeries of one type while only one set of surgery tools is available. However, when there is enough time between two of those surgeries, the surgery tools can be sterilized in between, so an additional surgery can be performed on the same day. We do not only have to take into account the surgeries in one OR session, but also other OR sessions may affect the schedule. Multiple specialties might use the same surgery tools. Oral and maxillofacial surgery use the same tools as special dental care sometimes, but also shares recourses with gynaecology. Moreover, not every surgeon uses the same tools, so this should be manually checked in the offline operational schedule, when a surgeon is dedicated to the OR session. It is not possible to model this in the QAP model, since these restrictions depend on the combination of patients and their sequence, as well as the surgeons preferences. In addition, not every restriction is hard, and must strictly be complied.

Besides that, the sequence of the OR schedule is not determined by the model. Again, many patient related factors can influence this sequence during the day. For example, children and patients with diabetes should be scheduled first. When the sequence during the OR sessions is determined, the material and equipment restrictions can be taken into account as stated above.

The model uses a cycle horizon of 28 days. To make sure we do not start with empty wards at the start of a new cycle, a restriction is made to calculate the number of patients who are still at the wards based on the end of the current cycle. However, the previous cycle might have a different OR division and a different number of patients than the current cycle, but the model uses the current cycle pattern to determine the number of patients at the start of the cycle. So, the number of patients present at the wards at the beginning of a new cycle might be somewhat different than in practice. However, the cycles do not differ to a great extend form each other. A second effect of this fixed cycle horizon is the limitation in length of stay. The 28 days cycle horizon is also the maximum number of days a patient can stay 'in the model'. However, the number of patients with a length of stay of more than 28 days (and not being an outlier) is very small.

The patient's length of stay is limited to a number of days. The model cannot calculate the length of stay on an hour or minutes level. As an effect, the number of beds used per day is the average number of beds used throughout that day. Moreover, mainly for the day care nursing ward the average number of patients being at the ward is significantly higher than in practice. In practice, these patients only stay at the ward for a couple of hours, while the model is only able to use a length of stay in days and discharges all patients at the end of the day.

Finally, the model uses probabilities and averages based on data of 2016. Naturally, these numbers will deviate in practice. Unfortunately, it is not possible to run a pilot to validate the model, due to many developments at the hospital. Therefore we do not know to what extend the difference between the real numbers and calculated numbers affects the quality of the schedule. However, Glerum (2014) was able to run a pilot to validate the model in the St. Anthonius hospital. It turned out the model functions as intended. However, the accuracy of the model largely depends on the reliability of the data. At the time of performing this research, only data of 2016 was suitable to use , but in the future more data can be gathered in order to improve the accuracy of the data and therefore improve the results of the model.

5.4 Experiment design

The QAP model and patient group characteristics are now ready to use. We will run two experiments that will be discussed below.

Experiment 1

The first experiment is a rescheduling experiment of the realized situation of 2016. We schedule the same 1117 patients that had surgery in a certain period of four weeks. Moreover, we use the same OR division for the specialties as in that period of 2016 in order to reproduce this cycle as accurate as possible. MSS-10 (which is the tenth period of four weeks in 2016) is used to reschedule, since this period is not affected by holidays or OR capacity reduction. This period starts on the fifth of September and ends on the second of October. The OR capacity is calculated as the 'normal' session time of 480 minutes (= 8 hours) minus the average setup time we calculated per specialty in section 4.6 plus an additional 30 minutes. When an OR session delays for less than 30 minutes, this has to be performed by the regular team of surgeons, which is already at the OR, if a delay of more than 30 minutes occurs, the surgery will be continued by the night shift.

OR capacity = 480 minutes – average setup time + 30 minutes

The results of this experiment will give us insight in the degree of improvement that can be established by scheduling according to the model, instead of randomly assigning patients to an OR session of the corresponding specialty.

Experiment 2

The second experiment is again a rescheduling experiment of the realized situation of 2016. However, we will add additional time to the OR capacity. The MST would like to know what the effect is of additional OR time how this should be used. This additional OR time can be generated in different ways. One OR is under construction so not in use at the moment, but it can be made operational which will increase the available OR time. Also, the current sessions can be expended by adding an extra shift. During this experiment we will add additional OR time to one OR session, but this additional time can thus be created through different ways. Since General surgery treats the biggest amount of patients, we add the additional OR time to their current capacity.

For both experiments we use the OR division of MSS-10 in 2016 (tenth period of four weeks in 2016). We use the patient characteristics (deterministic surgery duration and stochastic length of stay) of 118 patient groups, including 1117 unique patients. Moreover, we include 10 nursing wards and 13 ORs (without the thorax ORs but including two 'OBC' ORs, which are ORs that where still used in the old building). The integrality gap, which is the tolerance between the best integer objective and the objective of the best node remaining, is set to 6% in order to receive a good solution in reasonable time. When the integrality gap will be lower, this will result in a better solution, however the model cannot be executed on a regular computer which will give an 'out of memory' message.

Chapter 6. Results: new situation

Several PDCA cycles are performed, the final group division is made and their characteristics are known. Now the model can be used to determine an optimal schedule. The two experiments discussed in section 5.3 will be performed. The results of Experiment 1 (6.1) and Experiment 2 (6.2) is stated in this chapter. Moreover we will perform a sensitivity (6.3) and what-if analysis (6.4).

For both experiments, the integrality gap, which is the tolerance between the best integer objective and the objective of the best node remaining, is set to 6% in order to receive a good solution in reasonable time.

6.1 Result of Experiment 1: rescheduling

The first experiment includes rescheduling of the patients in MSS-10, the tenth period of four weeks in 2016. We use the same OR capacity and division as in the realized situation of that period last year. The only thing that will change is the sequence of scheduled patients, in order to create a more predictable and less variable inflow to the nursing wards.

A part of the OR schedule calculated by the model is shown in Figure 11. This figure shows how many and which type of patients should be scheduled on the first Monday of the cycle period. It can be seen, that two patients of Group 22, one patient of Group 24, one patient of Group 26, and two patients of Group 28 should be scheduled during the OR session of OR 1.

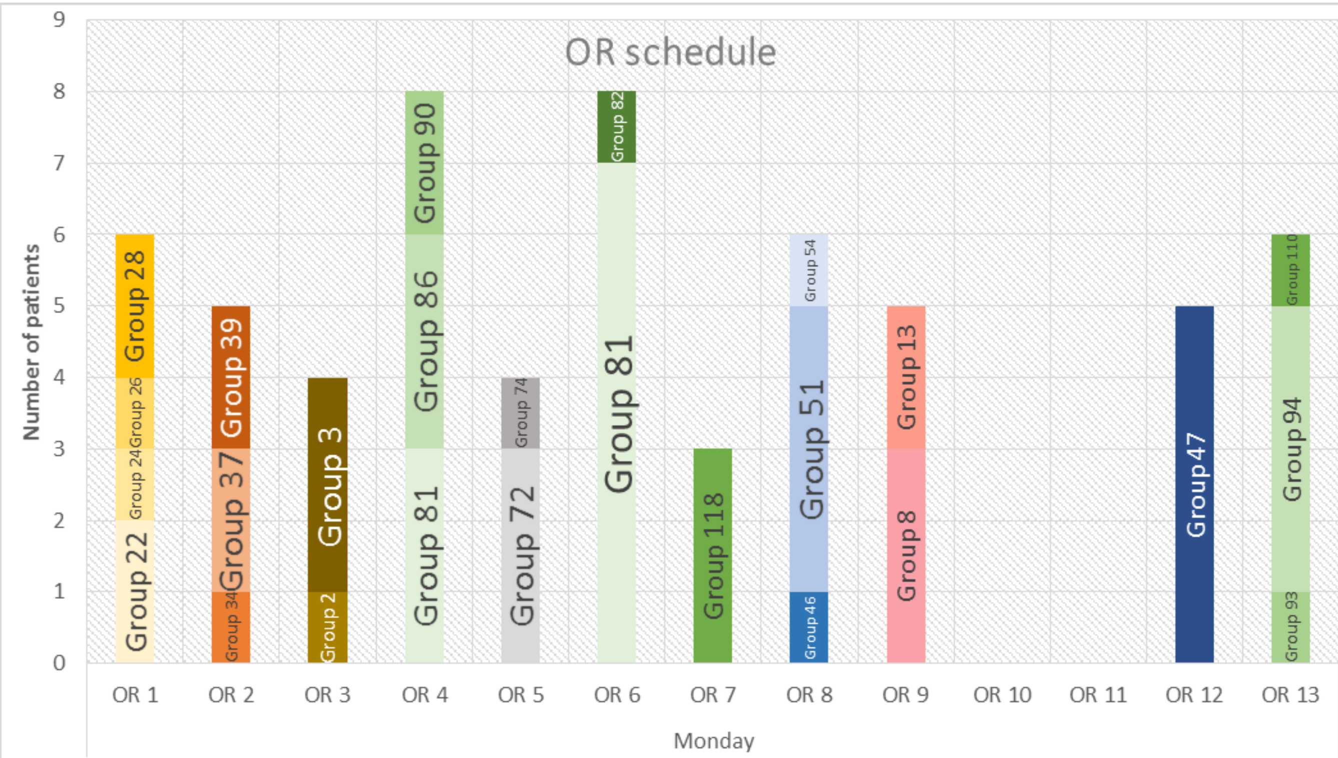

Figure 11. Part of rescheduling result Experiment 1.

A similar schedule is designed for every day of the 28 days cycle horizon. OR 10 and OR 11 are not used on this particular day. This might be because the OR is used by the thoarx specialty (out of the scope of this research) or because no personnel or patients were available to fill this OR session. When using the average surgery duration of these surgeries, the OR utilizations equals 80%.

When the schedule designed by the QAP model will be executed, this will have a positive effect on the number of patients at the nursing wards. The results of the bed utilization of the three nursing wards that appear to be the busiest are shown below. Figure 12 compares the number of patients at the ward as in the realized situation of 2016 to the number of patients at the ward when the OR schedule is designed according to the QAP model. It can be seen that Ward A has the best result since the line constructed by the model is very close to the average number of patients. This result can be established since a relatively high amount of patients, with a mix of long and short lengths of stay visit this ward after surgery.

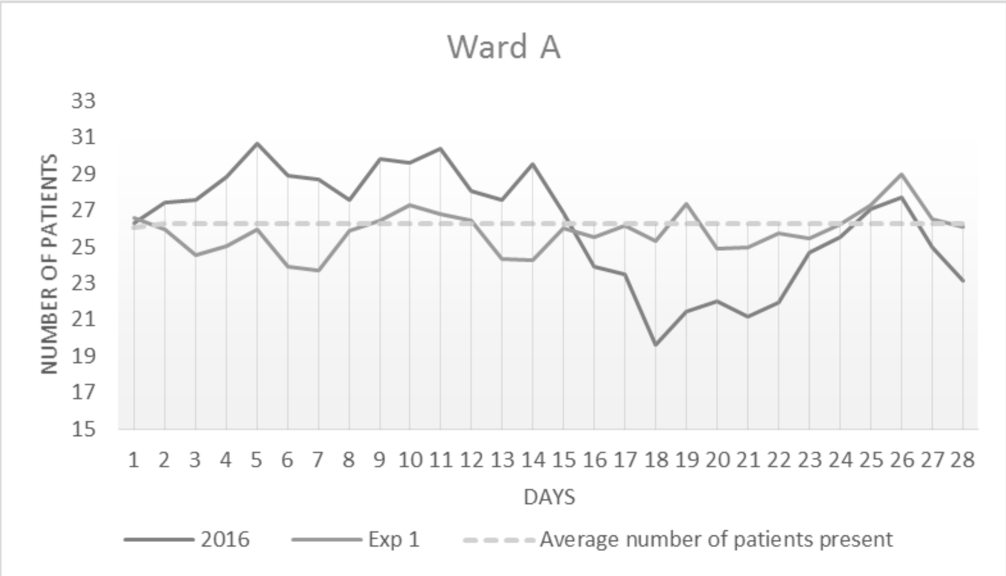

Figure 12. Results of Experiment 1 at the surgical oncology ward. (n=56, T=28 days, source: MST data)

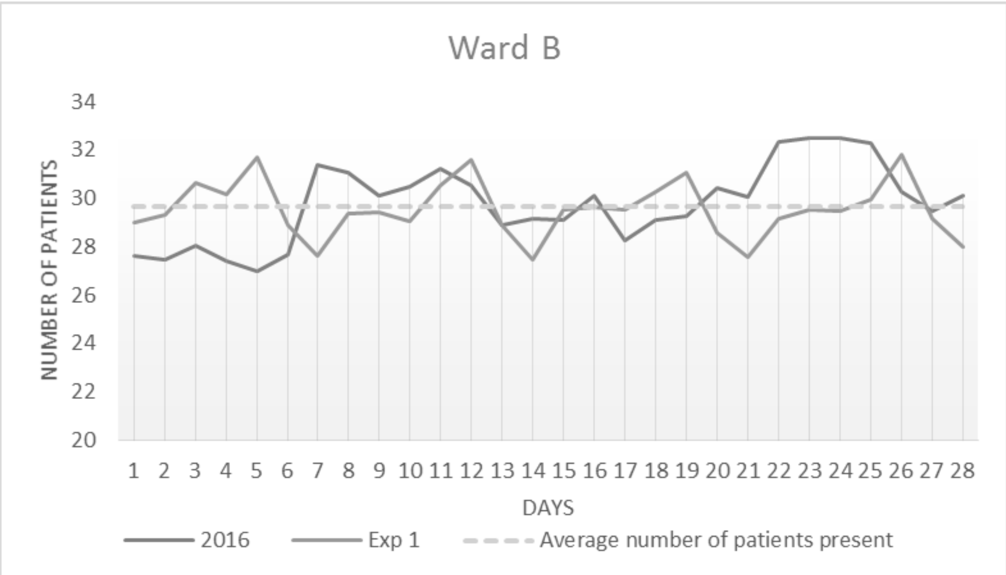

Figure 13. Results of Experiment 1 at the nursing ward for vascular surgery, traumatology and orthopedic patients. (n=56, T=28 days, source: MST data)

Figure 13 shows the results of the bed utilization at Ward B. Although there is a decrease in the variability at the bed utilization, one might say this is just a small gain. However, the line constructed by the model clearly shows a pattern, while the line of the realised situation does not. The model could not decrease the variability to the extent of Ward A, but it does allow to increase the predictability and therefore enables the hospital to create a better match between the number of staff members and the number of patients present.

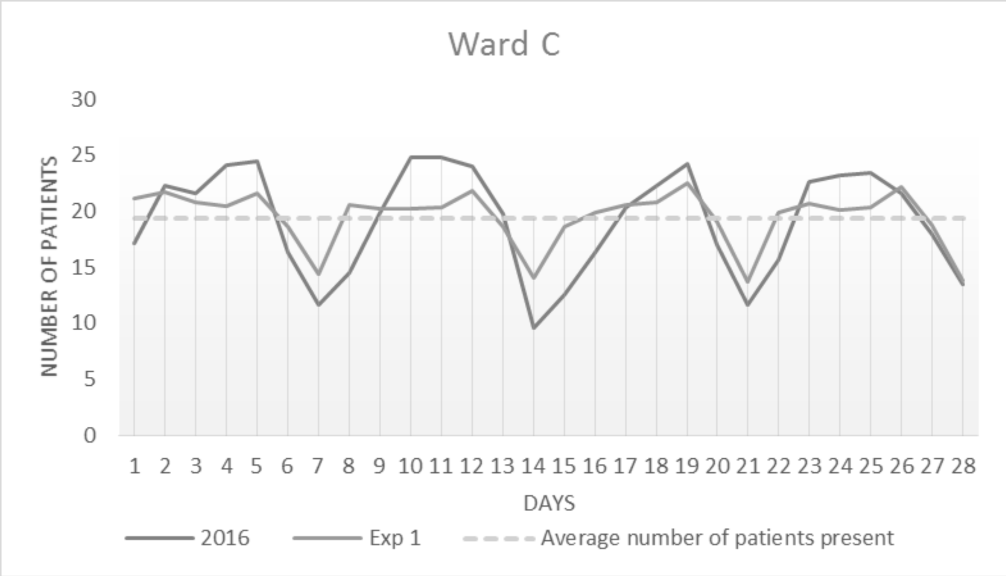

Figure 14. Results of Experiment 1 at the nursing ward for gynecology, urology and orthopedic patients. (n=56, T=28 days, source: MST data)

Figure 14 shows that the impact of the weekend (where no surgeries are performed) is relatively high at Ward C. This can be explained by the fact that every ward groups patients with the same characteristics. Since the length of stay of the patients at Ward C is relatively low, the weekends are clear to distinguish in the graph.

Including all 10 nursing wards, the objective function value equals 9.49, which is the squared sum of the deviation from the average number of patients per type of bed. When comparing this value with the realized situation of 2016, the model established an improvement (= decrease) of 27% in the variability of bed utilization. The running time of this experiment equals 373 seconds.

6.2 Result of Experiment 2: rescheduling with additional OR time

The second experiment also considers MSS-10, a period of four weeks from the fifth of September until the second of October in 2016. Again, we schedule the same amount and type of patients, but we increase the available OR capacity, in order to answer research question 3: ‘What will be the effect of additional available OR time?’.

The hospital wants to know what will happen when additional OR time is available. We add the capacity of one extra OR session. When scheduling the same amount of patients, logically the OR utilization will decrease, but this experiment is designed to consider if this lower OR utilization outweighs the lower variability at the nursing wards. The running time of this experiment is somewhat higher than the previous experiment, namely 738 seconds.

Comparing this experiment with the results of Experiment 1, an improvement of only 2 percent could be accomplished. The results of the (same) three busiest wards are shown below.

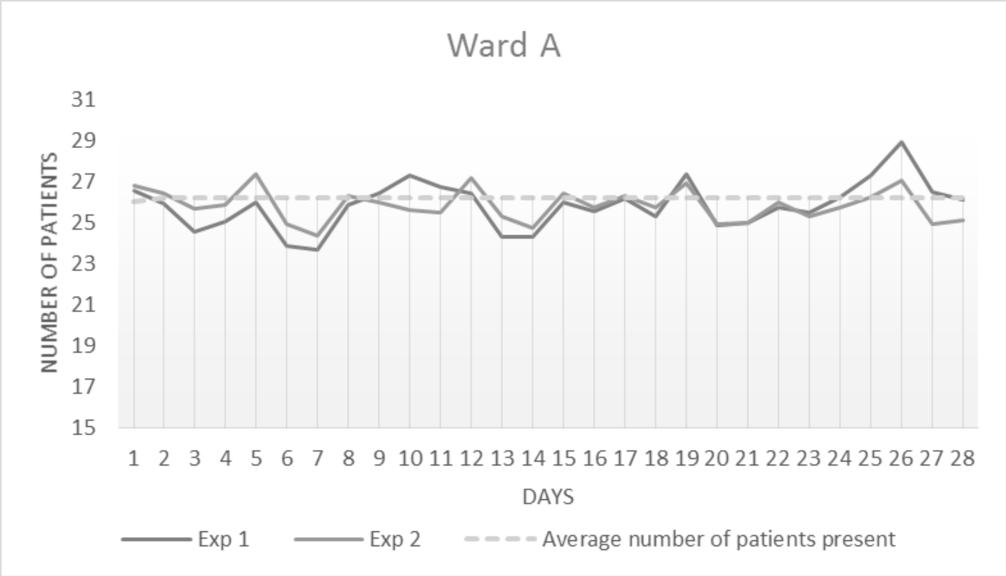

Figure 15. Results of Experiment 2 at the surgical oncology ward. (n=56, T=28 days, source: MST data)

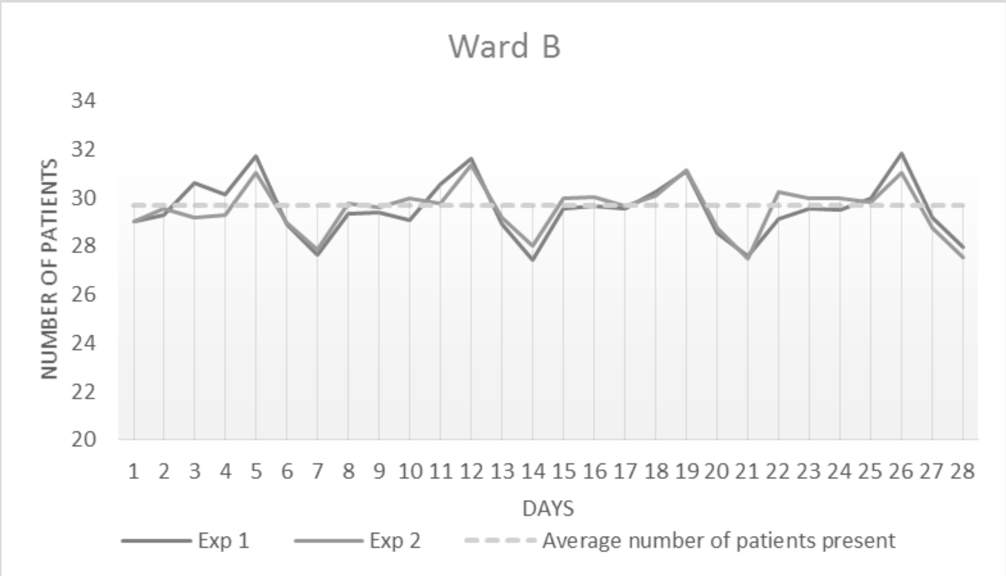

Figure 16. Results of Experiment 2 at the nursing ward for vascular surgery, traumatology and orthopedic patients. (n=56, T=28 days, source: MST data)

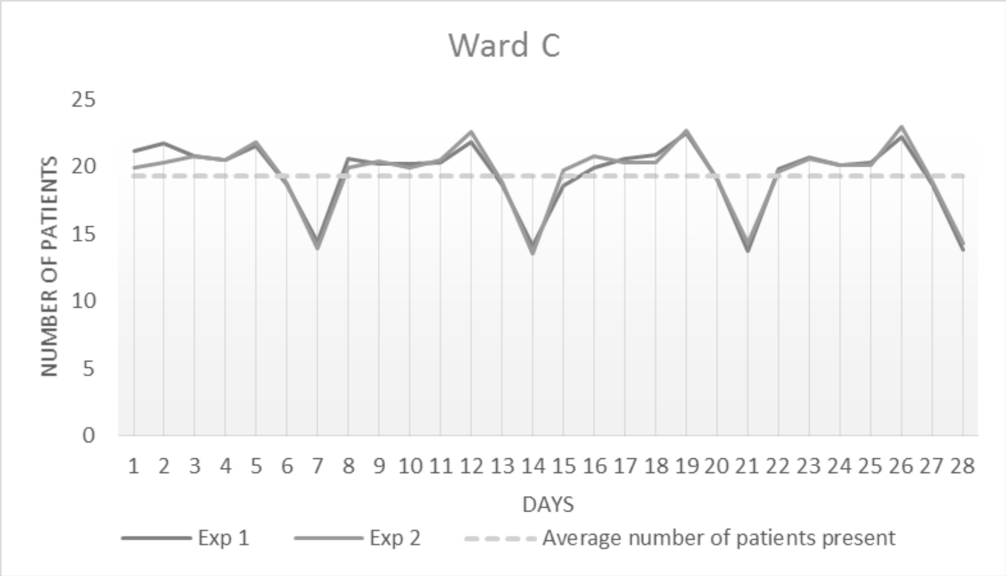

Figure 17. Results of Experiment 2 at the nursing ward for gynecology, urology and orthopedic patients. (n=56, T=28 days, source: MST data)

However additional OR time gives more space to schedule patients in an optimal way, but as Figure 15, Figure 16, and Figure 17 show, the results of adding one extra OR session is small. Comparing this small gain with the major costs and effort that need to be made in order to create this additional OR time, it is not beneficial.

Table 14. Overview number of beds per ward.

	Number of available beds	Maximum number of beds used in realised situation (2016)	Maximum number of beds used in Experiment 1
Ward A	40	31	29
Ward B	47	33	32
Ward C	28	25	23

Table 14Table 16 shows an overview of the number of beds per ward. However, the availability of 40 beds does not mean these can also be used every day. Depending on the number of available personnel members, the number of 'open' and 'closed' beds is determined. This means Ward A can be full, while not all of the 40 bed is occupied.

6.3 Sensitivity analysis

This section will show the results of the sensitivity analysis. We will run two experiments to show the changes in the results of the model when some parameters are slightly changed. First, we reschedule one of the other MSS periods of 2016. Next, we run an experiment with the patient population of 2017.

According to the historical data of 2016, MSS-4 (the fourth period of four weeks in 2016) was the busiest period of the first half year, moreover less OR time was available due to reduction because of holidays. Therefore, we will run the model again with data of this period, to see if the results of the model changes during such a busy period. When we calculate the objective function in the realised situation of MSS-4 in 2016, we get a value of 9.51. When scheduling according the QAP model, including the 987 patients of 2016, the objective value decreased to a value of 7.10. This lower value means these is less deviation between the average number of patients per day and the average number of patients during the whole period. This is a similar result as the model showed in MSS-10, a decrease of 26%. The running time of this experiment is similar to the running time of Experiment 2, namely 624 seconds.

Next, we schedule MSS-4 again, but now using the patient population of 2017. It turned out, the number of patients in 2017 of MSS-4 is 10% less than 2016. Using the model, the objective value improved by 36%. This seems logical since less patients are treated in the same OR time. The OR utilization decreased (from 80%) to 60%. In practice this will lead to many ORs with a very low utilization. The number of available OR will be reduced in order to increase the utilization.

The experiments stated above show that making small changes in parameters only have a small effect on the results of the model. Changing the patient population will only have a marginal effect on the results of the model. When scheduling a smaller patient population the results improved significantly, however, in practice the number of ORs will decrease since the OR utilization will be too low.

6.4 What-if analysis

We will perform a what-if analysis to calculate the results of the model when we do not have to deal with different nursing wards (Analysis 1), and when we do not use the current MSS (Analysis 2).

Analysis 1

MST has only single rooms, which are situated on three floors. There is no clear separation between the beds of two nursing wards at the same floor. Therefore, we will perform a what-if analysis where we do not consider the ten nursing wards, but only make a distinction between the three floors. So all nursing wards on the same floor are considered as one nursing ward. This results in three different nursing wards, where Ward 1 consists of two wards we used in the previous experiments (A and B), Ward 2 consists of three of the ten wards we used in the previous experiments, and Ward 3 consists of the other five nursing wards. As said, the objective value equals the squared sum of the deviation from the average number of patients per type of bed per day. However, the number of nursing wards, and thus the number of bed types changed from ten to three. Therefore, the objective value will be higher, since we divide the total squared deviation by three instead of ten. When we divide the total deviation by ten instead of three, we can still compare the results of this analysis to Experiment 1. Table 15 shows this comparison of the objective values and running times. The objective value increased compared to Experiment 1. Pooling of the nursing wards did not have a positive effect on the total variability. This is the result of the changed probabilities of patients going to certain nursing wards. With ten nursing wards, the patients flow to Ward A or Ward B with a certain probability. Using the three big nursing wards, patients flow to one of these wards with a 100% chance, instead of, for example, 20% to Ward A and 80% to Ward B. This might cause the small increase of the objective function. Moreover, the fixed MSS might be a reason for the increased objective function. When, for example, a specialty has only one OR session per week, the model can barely spread the patients compared to a specialty with multiple sessions per day. Moreover, when multiple of these specialties perform surgery on the same day and these patients now flow to the same ward, the variability amplifies on these days. Figure 18, Figure 19, and Figure 20 show the results of the average number of patients present at the three big nursing wards.

Table 15. Results what-if analysis 1.

	What-if analysis: only 3 big nursing wards	Experiment 1
Objective value	10.99	9.49
Running time	13373	373

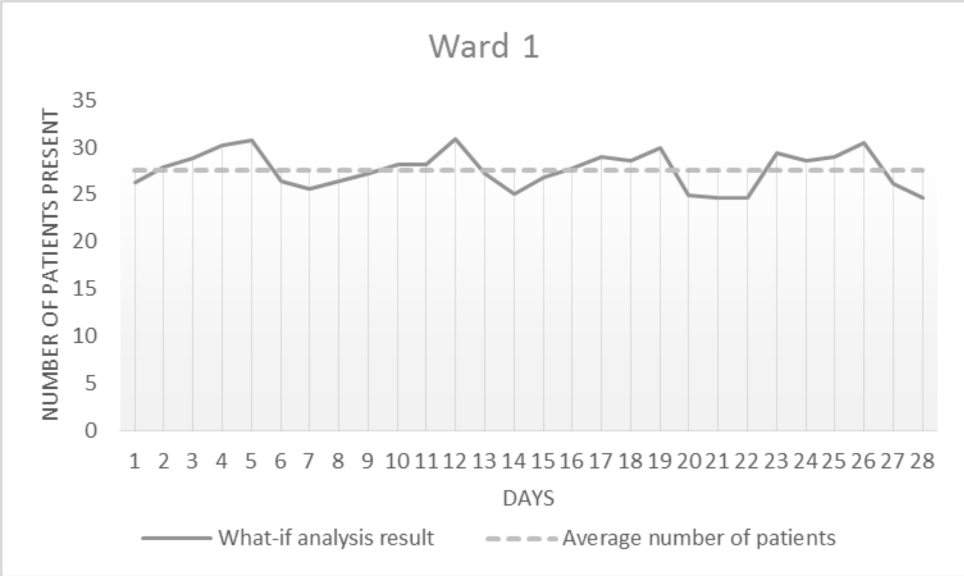

Figure 18. What-if analysis results of Ward 1. (n=56, T=28)

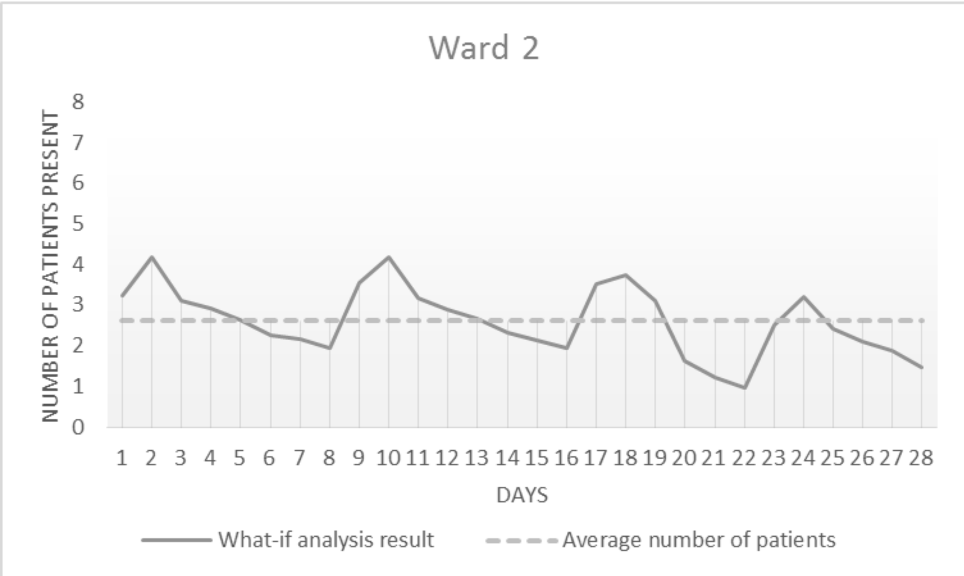

Figure 19. What-if analysis results of Ward 2. (n=56, T=28)

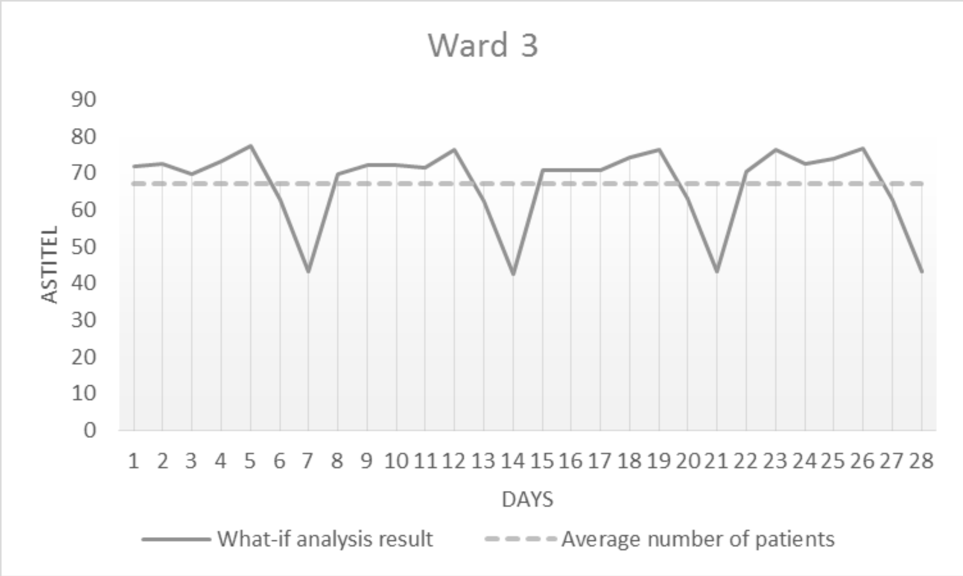

Figure 20. What-if analysis results of Ward 3. (n=56, T=28)

These three figures show the result of the number of patients present at the three combined nursing wards. Mainly the effect of the weekends is clearly visible at Ward 3, since this ward includes the day care and short-stay patients.

Analysis 2

Changing the current MSS schedule is not preferable, since it is not easy to change the days of surgery of a certain specialty. Changing the MSS requires many changes in the schedule of all involved staff members in the total chain of care. Moreover, the current schedule considers the availability of equipment. However, it might be useful to conduct further research to analyse the effort and gains of a new MSS. Therefore, we perform a second what-if analysis in order to use the QAP model to determine the best OR division for every specialty to perform surgery. Every specialty receives an excess amount of ORs, but the number of actually used OR is restricted to thirteen. Running the model shows again the scheduling of patient types, but also the optimal OR division amongst the specialties taking into account the minimization of the variability of number of patients at the nursing wards.

To determine a new MSS we add one auxiliary variable $D_{j,t}$. This is a boolean variable that is 0 when an OR is not used on a certain day and 1 if patients are scheduled in that OR on that day.

Moreover we add two restrictions. The first restriction makes sure variable D is set to 1 when patients are scheduled, using the 'big M' method (where M is a high number, for example 1000).

$$\sum_{i \in I} V_{i,j,t} \leq M * D_{j,t} \qquad \forall j \in J, t \in T$$

The second restriction makes sure we do not use more than the 13 available ORs:

$$\sum_{j \in J} D_{j,t} \leq 13 \qquad \forall\, t \in T$$

The objective value hardly improved (0.5%) when optimizing the current MSS. However, the MSS is quite different from the current MSS. We do not recommend to change the current MSS since the gains do not outweighs the costs and effort to change the MSS schedule.

Chapter 7. Conclusions and recommendations

This chapter will discuss the conclusions drawn from this research (7.1). Subsequently, it states the recommendations for further research (7.2).

7.1 Conclusions

We performed a literature review to answer the first research question:

“Which model is suitable to apply to the MST context in order to schedule patient types resulting a minimized bed utilization variability?”

Several models where found, but we chose to use the QAP model of Glerum (2014). Next we performed multiple PDCA cycles, in order to answer the second research question:

“How to cluster patients for the model?”

Based on historical data we compiled 118 patient groups and calculated their characteristics. These characteristics include the surgery duration, length of stay (before and after surgery), and the probabilities of visiting a certain ward after surgery. These characteristics are input data for the QAP model. The model is used to schedule patient types in an already existing MSS during the tactical planning phase of resource capacity, in order to minimize the variability in bed utilization at the 10 nursing wards.

Next, we designed the first experiment to answer the main research question:

“How can the MST hospital reduce the variability in bed utilization at the nursing wards, while the OR capacity will be used in an efficient way?”

The results of the first experiment showed the QAP model is, after some adjustments, suitable to use for the MST hospital. Taking into account the current MSS schedule, deterministic surgery duration and stochastic length of stay of the 118 patient groups, the model was able to design a new schedule, that includes patient types. As a result, the variability in bed utilization at the nursing wards decreased by 27%. Moreover, not only variability decreased, but also predictability increased. In the current situation it is not possible to predict for more than a couple days ahead, how many patients will enter which ward and for how long they will stay. Using the model, the hospital is able to predict what kind of patients will undergo surgery on which day and to which ward they will flow for how many days. When variability decreases and predictability increases, the hospital is able to improve their personnel planning based on the expected number of patients present at the nursing wards. As the problem cluster of Figure 3 showed in Chapter 3, decreasing the variability at the nursing wards will have a positive effect on satisfaction of both patients and personnel members. Patients will barely stay at an undesired nursing ward and personnel costs will decrease since the maximum number of patients at a nursing ward decreases.

During the first experiment, we used the OR capacity and division as used in the realized situation. Since we also schedule the same amount and type of patients, the OR capacity remained the same. The MST claims the current OR utilization is sufficient, so also the second part of the research question ‘while the OR capacity will be used in an efficient way’ is satisfied.

In addition, we designed Experiment 2 to answer the third research question:

“What will be the effect of additional available OR time?”

On a regularly basis, personnel members claim they need more OR capacity. Therefore, we performed the second experiment to find out if additional OR time will improve the results even more. One extra

OR session was added to the current OR capacity. The results show the variability will decrease, but only by 2%. To arrange this extra OR time, the hospital has several options. One of them is to hire an extra team of surgeons to continue performing elective surgery after the current 'closing time'. They might also finalize the OR that is still under construction. However, increasing the current OR time does not outweigh the decreasing variability, so this is not recommended.

To summarize the experimental results, we refer to Table 16, which also shows the values of the realized situation of 2016. Adopt a different way of scheduling patients would be beneficial for the hospital. The variability at the nursing wards will decrease with 27% when the schedule generated by the model will be executed. However adding additional OR time will slightly decrease the variability, but this would be in such a low degree it would not outweigh the costs of increasing the OR capacity.

Table 16. Overview of experimental results.

	Realized situation 2016	Experiment 1	Experiment 2
Objective function value	13.1	9.49	9.28
Average OR utilization	80%	80%	72%
Experiment running time	N/A	373 sec	738 sec

7.2 Recommendations

Several recommendations for further research are found while conducting this research. We will discuss five subjects where further research is recommended, namely: data registration, patient selection, workload, emergency patients, and new MSS.

Data registration

While conducting this research, data is used to determine group allocation and calculating their characteristics. Some inconveniences were found in the data that could be improved.

First, about 2 percent of the patients is not registered with an admission and discharge date. This is probably because someone forgot to fill in this field. However, for financial reasons, this field must be manually adjusted, but this is not corrected in the database. Therefore, the data of these patients was not suitable to use during this research. It is recommended to also correct these data fields in the database and to designate this as a mandatory field that cannot be left empty.

Second, the registration of the movements of patients between nursing wards and the OR department is not very accurate. Therefore, the data is not suitable to distinguish the wards where patients stayed before and after surgery. For example, the surgery of a certain patient started at 14:45, but it can also be seen that the nursing ward registered admission of this patient at 14:41. This is done to reserve a bed for this patient after surgery. According to this data, the patient was at the nursing ward and the OR department at the same time. However, this ensured it was not possible to make a clear distinction between the departments a patient stayed before and after surgery. This might slightly affect the length and probabilities of stay at the wards. This could be improved to register the patients movement real-time, but this is hard to do manually since there is not always a nurse available to register an arriving or leaving patient. For example, automatic patient tracking, using RFID technology can be used to create a more accurate overview of the location of the patient (Daniel, 2016) (Stanley, 2017). Using this technique, real-time data of the patients location can be retrieved, which makes the data about length of stay at different departments more reliable.

While conducting this research, we mainly used data of 2016 since this was the most reliable data in the current context. However, in the coming years more data should be collected and used to improve the reliability of the patient group characteristics and therefore improve the results and accuracy of the model.

Patient selection

In the current situation, the MST hospital aims to help every patient that enters the hospital as soon as possible. However, this is not always in accordance with the agreements of the health care insurers. Every year, the hospital makes agreements with the health care insurers about their patient volume of the coming year. When they do not meet these agreements, but treat more of a certain type of surgery, the MST does not get payed for this. The current way of working can be seen as a push strategy, while a pull method would be more efficient for the hospital as Agnetis (2013) also mentioned. However the hospital wants to help every patient, they can slightly influence their patient population. This can be done by 'using' their waiting times. Access times for the first appointment and the waiting times for surgery can be influenced in order to strive for the desired patient mix. Also, using the connections with primary care providers can be used to 'promote' certain type of surgeries to increase the referrals to the MST hospital.

Workload

When the MST fills the MSS schedule according to the model. They are able to schedule their personnel members more accurately. In the current situation they schedule the same amount of personnel members every day regardless the number of patients at their ward, since this is not know in advance. Using the model they can make a better prediction and therefore make a better match in their personnel planning.

During this research we aimed to improve the alignment between the OR department and the nursing wards by reducing the variability at the number of patients present at the nursing ward. However, not only the number of patients present at a certain ward influence the workload of the nurses. A frequently mentioned factor, in practice and scientific literature, is the severity of the disease and therefore the level of care a patient needs. Depending on the type of surgery, condition of the patient and nursing qualities, the time needed to provide care to the patient might change per patient. However, also mentioned in literature and practice, it is hard to measure or consider this in advance, since this depends on several unpredictable factors. Further research is recommended to include the level of care in the workload.

Emergency patients

During this research we implemented the current method of scheduling emergency patients in the new schedule. One OR is dedicated as emergency OR to schedule the emergency patients. When it does not fit in this OR, surgeries need to be cancelled or rescheduled. Based on the data of 2016, it seems reasonable to use one OR to take care of emergency patients. However, further research might be conducted to examine if other emergency patients handling methods would be more efficient. For more information, we refer to Borgman (2017).

Simulation model

During this research we focused on levelling the bed utilization at the nursing wards and less on the probabilities of overtime at the ORs. A simulation study might give more insight in this. A simulation model can be used to add more stochastic features, for example the probability of every surgery to be longer than expected. This will enable the hospital to make more efficient use of the available OR time.

Chapter 8. Implementation

In this chapter we will briefly look back on the FOCUS-PDCA steps already taken, whereafter we will discuss the steps needed to be performed in order to successfully implement and maintain the results of the research.

The opportunity found to improve at the MST hospital is to improve the alignment between the OR department and the nursing wards. Therefore a team is composed that includes a member of every specialty and corresponding RvE. On a regularly basis, meetings are and should be organised to keep all members involved and aware of the urgency and progress of this project. Next, the current situation and (progress of) the desired situation should be communicated.

The hospital is operating in a continuous changing environment, which requires continuous monitoring and adaptation. Therefore, multiple PDCA cycles are already performed to construct patient groups and a schedule including these patient groups. However, it is essential to keep track of the data and recalculate group characteristics and subsequently designing a new schedule on a regularly basis. Every year, a review has to be done to update the data of all patient groups. Three main checks have to be done:

1. Is every surgery allocated to a group still performed (on a regularly basis)?
2. Is every surgery performed also allocated to one of the groups?
3. Recalculate the group characteristics (# patients per MSS block, surgery duration, length of stay).

Surgery duration and length of stay probabilities should be evaluated since they might change due to various influences. Examples are: new (medical) developments or training of specialists. Also, during this research only data of 2016 was suitable to use, but in the future more data can be used to improve the reliability of the group characteristics.

Moreover, throughout the year, when the hospital is going to perform a new type of surgery, it has to be allocated to one of the groups. Next, the new group characteristics have to be calculated and changed in the QAP model.

Subsequently, when group characteristics are changed, a new schedule needs to be designed. The QAP model can be used to design a first version of this schedule. The QAP model will design a schedule where every patient group is scheduled in the right amount, in the right OR, taking into account minimization of the variability in bed utilization at the wards. However, the model cannot take into account every restriction and preference, as mentioned in section 5.3, so the team has to evaluate and adjust the schedule if needed.

Performing these PDCA cycles in practice as part of continuous improvement model is show in Figure 21.

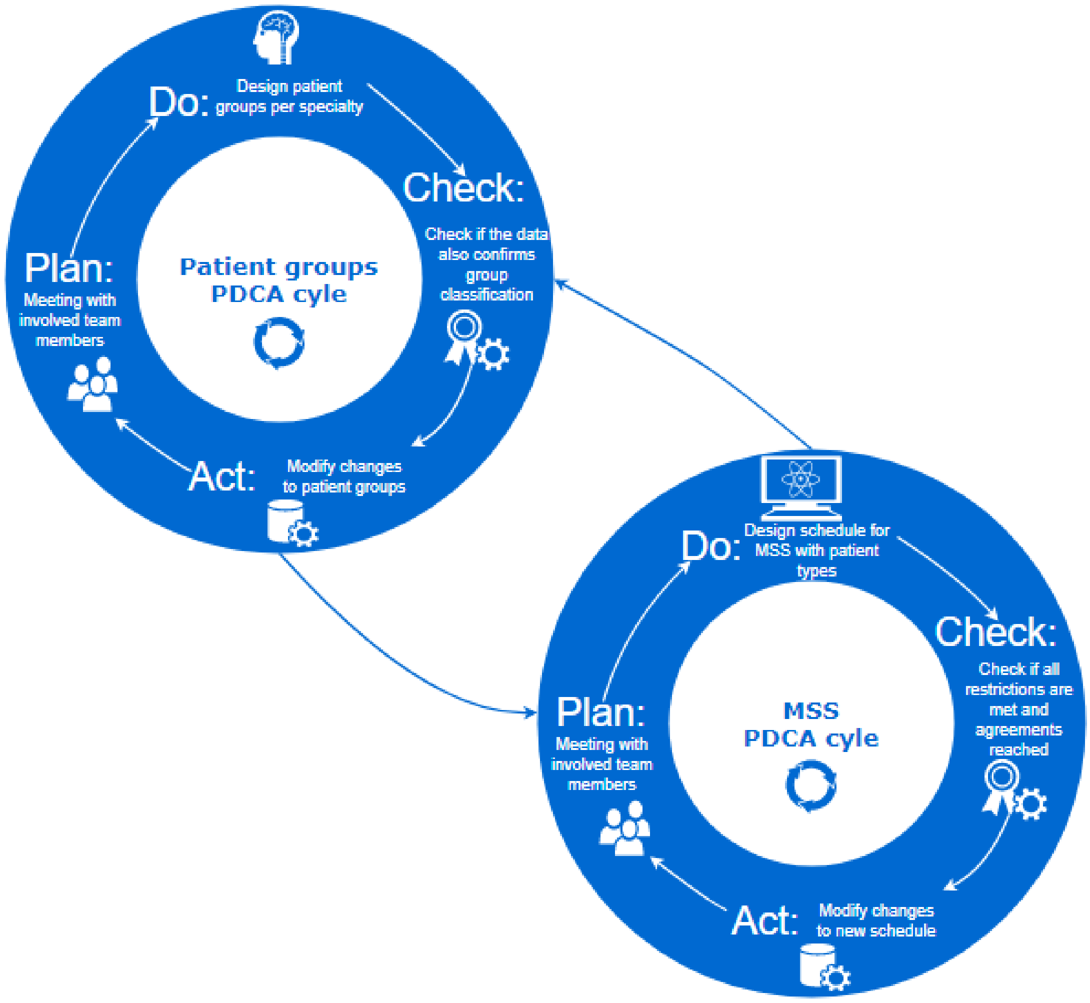

Figure 21. Plan-do-check-act cycles.

Moreover, after every MSS period (of 4 weeks) there is a meeting to review the progress of the agreements made with the health care insurers. If this is not according to the expectations, it is important to know the causes of this unexpected behaviour. Due to many factors, e.g. weather influence, certain events, and epidemics, the expected number of patients or their characteristics might be different than expected. When changes have to be made on the schedule, this will become operational two MSS periods later (Figure 22). This enables the coordinator to schedule the staff members and publish their timetables in time. Performing these PDCA cycles will guarantee the continuous improvement, which is essential in the environment the hospital is operating in.

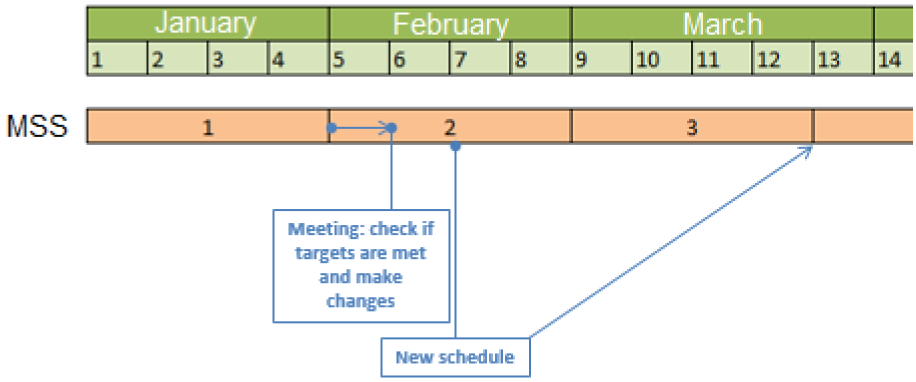

Figure 22. PDCA cycle in practice.

The current MST systems are not (yet) suitable to implement this new scheduling method. However, in some way the current systems should be adapted or new ones should be purchased in order to enable planners to work according to the new method.

After a patient successfully completed the postoperative screening, the date of surgery can be determined. Every type of surgery is allocated to a certain patient group. When a patient needs to be scheduled for surgery, a list of the upcoming surgery dates (of that patient group) should pop up and the appointment can be made in consultation with the patient. Also, some alternative dates of surgery should be calculated. Due to the severity of a disease or other circumstances, it might be possible that the patient cannot be scheduled on a surgery date of his group within a certain timeframe. Therefore, alternative dates of surgery should automatically be calculated based on similar group characteristics. For example, a patient's surgery is classified as Group 46, but the first available date of surgery is in 4 weeks. This timeframe is too long for this patient, so alternative dates should be found. The characteristics of Group 47 (surgery duration & length of stay) are most similar to Group 46, and has a free spot within two weeks. Assuming that Group 46 and Group 47 are allocated to the same specialty, the patient can be scheduled on this alternative spot. Naturally, scheduling patients on alternative spots should be limited as much as possible.

During the offline operational scheduling process, the system (or, if not yet available, the planners) should keep track of the limited number of PACU and intensive care beds. Before a patient is scheduled, the surgeon fills in the POS form, so it is known if this patient has an increased risk and therefore (probably) needs a PACU or IC bed after surgery. When patients are scheduled, the system should count the number of patients per day who need a PACU or IC bed and limit this to the number of available PACU and IC beds. This PACU and IC identification could not be taken into account when designing the schedule with the QAP model, since this is not necessarily surgery related but mostly patient related. Patient related aspects can only be taken into account during the offline (and online) operational scheduling process.

Mainly at the start of using this new scheduling model, utilization of the OR sessions should be monitored very accurate. An OR session can only be performed when the filling rate is high enough. During the scheduling process, it should be monitored if the sessions are filled properly or if the arrival of patients is not as expected. In the latter case, patients should be scheduled on alternative spots to fill the sessions, or the model should be used to determine a new schedule with other amounts of patients. This is also part of the PDCA cycles as mentioned at the beginning of this chapter.

Until systems are operational to work according to the new scheduling method, a manual pilot can be executed. Therefore, every planner should receive a list with an overview of the group classification with classified surgeries. Preferably a digital list, which enables the planners to use a lookup function. When a patient needs to be scheduled for surgery, the planner needs to determine the group of this patient's surgery using this list. Next, the first available date of surgery should be found. With the output of the model a blueprint OR schedule can be made (example in Figure 23). It shows for every OR session the allocated specialty and the preferred patient groups. When a patient is scheduled, the planner needs to block this spot in the scheme and mention if the patient (probably) needs a PACU or IC bed. The scheme should be printed out hard copy an placed on a wall, where every planner can see and use the scheme. To avoid duplication, only one hard copy version should be printed and used. This gives a tangible overview and also eases monitoring of the sessions.

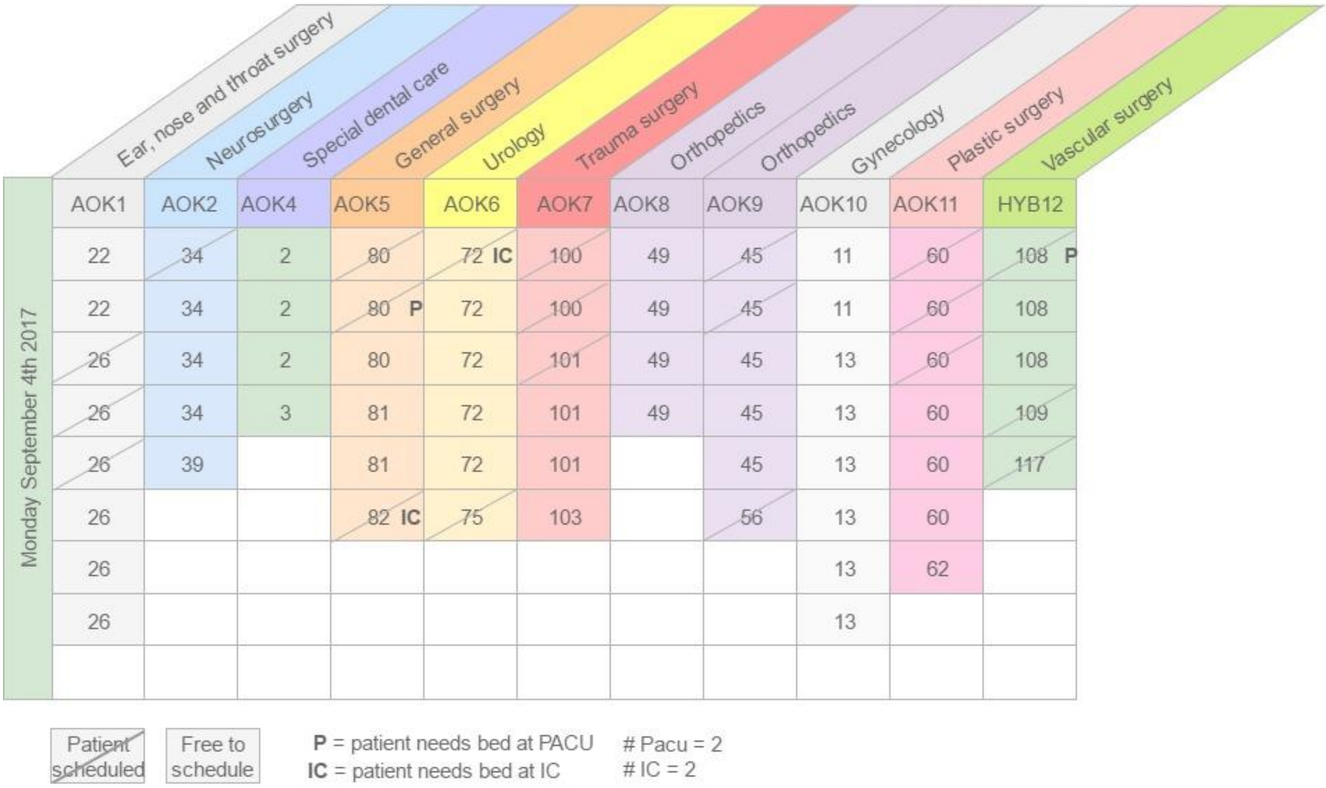

Figure 23. Example of an OR scheduling scheme with patient types.

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Appendix I Search strategy

This appendix gives an overview of the search items and strategy used to find relevant literature for this research.

1. Goal: find definitions of an MSS and MSS scheduling methods.

Table 17. Search terms (1).

Term	Synonyms	Search field(s)
MSS	Master surgical schedule	Title, abstract, keywords
Operating room	Operating theatre, OR	Title, abstract, keywords
Scheduling	Planning, schedule	Title, abstract, keywords

Literature database: Scopus

Date range: 2000-2017

Results: 15
Results after first selection: 3

2. Goal: find models that can be used to minimize the variability in bed utilization.

Table 18. Search terms (2).

Term	Synonyms	Search field(s)
Reduce	Minimize, balance	Title, abstract, keywords
Variability	Variation, workload	Title, abstract, keywords
Utilization	Occupation, demand	Title, abstract, keywords
MSS	Master surgical schedule, planning, schedule	Title, abstract, keywords

Literature database: Scopus

Date range: 2000-2017

Results: 30
Results after first selection: 8
Additional results found in references: 4

Using the same search terms in google scholar:

New results: 14
New results after first selection: 3

Appendix II Example OR division

An example of the OR division can be found below in Table 19, where Table 20 shows a list of abbreviations.

Table 19. Example OR division.

	AOK01	AOK02	AOK04	AOK05	AOK06	AOK07	AOK08	AOK09	AOK10	AOK11	HYB12	TOK13	TOK14	TOK15
Monday	CH-A	NE	NE	CH-O	UR	CH-T	CH-V	OR	GY		CH-V	CTC	CTC	CTC
Tuesday	KN	NE	CH-A	CH-O	UR	CH-T	CH-A	OR	GY	OR	CTC	CTC	CTC	
Wednesday	MDL & KN	NE	BT	CH-O	UR	CH-T	OR	OR	CH-A		CH-V	CTC	CTC	CTC
Thursday	KN	NE	NE	OO	CH-O	CH-T	CH-A	OR	GY		CH-V	CTC	CTC	CTC
Friday	KN		KA	CH-O	OR	CH-T	CH-A	OR	GY	PL	CH-V	CTC	CTC	CTC
Saturday														
Sunday														
Monday	KN	NE	BT	CH-O	UR	CH-T	CH-V	OR	GY	CH-A	CTC	CTC	CTC	CTC
Tuesday	NE	NE	CH-A	CH-O	UR	CH-T	CH-V	MDL & OR	GY	PL	CH-V	CTC	CTC	CTC
Wednesday	KN	NE	BT	CH-O	UR	CH-T	OR	OR	CH-A		CH-V	CTC	CTC	CTC
Thursday	KN	NE	NE	CH-O	UR	CH-T	CH-A	OR	GY			CTC	CTC	CTC
Friday	BT	NE	CH & KA	CH-O	CH-A	CH-T	CH	OR	GY	PL				
Saturday														
Sunday														

Table 20. List of specialty abbreviations.

ABBREVIATION	SPECIALTY
AN	Anesthesia
BT	Special dental care
CH-A	General surgery
CH-O	Gastrointestinal oncology
CH-T	Traumatology
CH-V	Vascular surgery
CTC	Cardiothoracic surgery
GY	Gynaecology
KA	Oral and maxillofacial surgery
KN	Ear-nose-throat
MDL	Gastroenterology
NE	Neurosurgery
OO	Opthamology
OR	Orthopedics
PL	Plastic surgery
UR	Urology

Appendix III OR usage per specialty

The table below (Table 21) shows the OR usage per specialty, with and without setup times. Based on data of 2016, retrieved from Business Objects. Note: one OR session equals 480 minutes. The difference between these values is the average setup time per OR session of that specialty.

Table 21. OR usage per specialty.

- Table 21 is not included in the public report -

Appendix IV Group allocation and average surgery duration

The table below (Table 22) shows the specialty and description of every group of patients. Moreover, the average surgery duration is shown based on data from 2016.

Table 22. Group allocation and average surgery durations.

- Table 22 is not included in the public report-

Appendix V Number of surgeries per patient group per MSS block

The table below (Table 23) shows for every patient group the expected amount of patients per MSS block (period of four weeks) based on data of 2016.

Table 23. Number of surgeries per MSS block.

Number of surgeries per MSS period of 4 weeks (S)													
MSS / Group	1	2	3	4	5	6	7	8	9	10	11	12	13
Group 1	0	3	0	0	5	0	1	4	0	0	3	1	5
Group 2	8	12	10	7	8	8	18	7	8	8	6	19	6
Group 3	3	11	9	6	7	8	7	8	8	16	8	4	11
Group 4	0	1	0	2	0	1	1	0	1	0	2	0	2
Group 5	4	4	4	5	4	4	6	2	1	1	4	7	0
Group 6	8	5	8	9	6	4	9	6	5	8	16	11	12
Group 7	0	1	2	1	2	1	4	1	1	1	3	2	2
Group 8	11	30	26	22	16	25	21	20	14	23	22	29	28
Group 9	0	4	1	3	0	1	0	1	2	3	1	2	1
Group 10	6	13	11	5	4	5	7	2	8	12	13	9	11
Group 11	0	7	4	5	1	7	5	5	1	7	6	6	1
Group 12	0	4	1	1	1	1	2	1	1	3	3	2	2
Group 13	6	19	17	13	15	10	17	21	11	22	14	12	19
Group 14	0	0	1	0	0	0	2	0	0	0	0	1	0
Group 15	1	3	2	3	3	4	3	0	1	3	2	2	2
Group 16	0	0	0	3	0	1	0	0	2	0	0	0	1
Group 17	1	8	3	17	6	4	23	12	1	20	15	8	14
Group 18	0	5	4	3	7	2	9	3	3	9	10	14	4
Group 19	0	1	2	1	2	2	2	3	1	3	4	4	0
Group 20	0	1	0	2	2	0	1	0	3	4	2	3	3
Group 21	0	1	0	0	0	0	0	1	1	0	2	2	2
Group 22	13	30	63	67	89	64	42	57	31	34	38	52	63
Group 23	2	4	1	1	2	4	3	0	4	4	5	5	5
Group 24	6	14	12	12	11	13	11	8	10	18	13	12	13
Group 25	4	7	17	11	16	9	10	6	11	20	15	18	21
Group 26	20	44	41	48	53	34	56	25	55	55	48	47	48
Group 27	7	15	3	0	2	3	1	2	0	5	2	0	1
Group 28	3	6	7	14	8	7	11	8	6	13	11	7	13
Group 29	0	1	1	1	1	0	2	3	1	1	0	0	2
Group 30	2	2	9	4	0	4	8	3	3	9	3	0	2
Group 31	0	6	2	4	2	0	2	2	0	1	4	1	2
Group 32	0	3	2	1	1	3	2	1	1	1	1	2	3
Group 33	1	1	5	0	2	2	3	1	1	2	0	4	1
Group 34	29	32	28	41	23	27	36	30	44	27	32	47	30
Group 35	4	3	3	4	5	1	5	1	3	4	4	4	6
Group 36	2	6	3	5	5	6	6	5	6	5	11	7	4
Group 37	0	2	0	2	1	0	3	3	0	2	2	5	2
Group 38	2	8	8	8	4	8	5	3	3	5	2	7	8
Group 39	5	3	13	3	7	9	6	6	6	4	7	7	9
Group 40	2	9	6	3	7	3	7	8	14	6	13	5	9

Group 41	0	2	2	4	3	2	2	3	5	3	2	2	5
Group 42	2	4	1	2	0	6	4	1	0	4	4	2	0
Group 43	6	10	7	8	3	6	10	3	4	8	6	3	7
Group 44	0	1	0	2	2	3	2	3	0	4	1	3	4
Group 45	6	16	14	12	16	17	17	9	20	20	16	16	18
Group 46	0	2	1	3	3	4	2	0	1	4	4	3	4
Group 47	13	19	20	32	13	16	20	15	12	19	29	23	24
Group 48	1	0	0	0	1	0	0	2	1	0	0	0	0
Group 49	11	21	20	26	27	25	25	17	24	16	33	37	32
Group 50	3	2	5	4	1	3	4	8	0	7	2	4	7
Group 51	14	61	29	38	33	34	47	36	26	40	40	37	30
Group 52	8	24	26	19	17	15	31	21	22	20	21	33	29
Group 53	3	1	4	3	0	5	2	1	0	3	5	1	7
Group 54	2	2	2	8	4	1	4	3	3	11	5	6	4
Group 55	2	2	2	2	1	1	3	1	1	2	1	2	0
Group 56	1	12	10	6	13	7	5	9	7	12	7	5	15
Group 57	3	3	5	1	1	3	0	2	2	3	2	1	0
Group 58	3	6	6	9	6	14	6	4	5	10	7	7	5
Group 59	3	5	3	2	5	2	3	3	2	0	0	2	1
Group 60	7	13	13	13	11	8	19	8	14	14	13	11	21
Group 61	4	7	10	4	10	8	14	3	12	7	5	9	7
Group 62	0	2	3	4	4	1	1	0	2	2	1	1	7
Group 63	2	0	1	3	0	3	1	1	1	5	1	2	3
Group 64	0	1	0	1	0	2	0	0	1	0	0	1	2
Group 65	7	16	15	10	13	23	12	4	11	9	14	11	14
Group 66	1	3	4	1	1	3	1	5	1	4	0	3	2
Group 67	3	2	2	2	2	1	2	0	0	1	0	0	2
Group 68	0	3	0	1	1	0	4	1	0	0	1	0	2
Group 69	3	8	8	9	5	7	4	5	4	5	3	5	5
Group 70	2	2	5	2	5	0	6	4	1	3	0	0	2
Group 71	1	1	3	1	1	0	2	0	1	2	0	1	1
Group 72	18	36	40	38	23	30	37	20	29	37	43	40	38
Group 73	4	9	9	6	8	8	5	4	8	8	7	6	9
Group 74	4	0	2	3	3	4	2	5	1	2	3	2	4
Group 75	1	2	1	1	0	0	0	2	0	1	1	1	1
Group 76	9	9	16	17	10	17	8	5	12	13	14	18	17
Group 77	2	1	3	4	5	5	0	1	1	1	2	2	5
Group 78	15	38	34	25	14	37	40	20	21	55	35	30	38
Group 79	0	3	2	6	6	5	12	4	3	18	18	19	24
Group 80	3	2	3	3	4	6	4	8	3	3	4	3	2
Group 81	7	44	36	46	25	32	34	23	22	73	36	42	47
Group 82	1	4	1	4	2	4	1	0	2	11	4	4	3
Group 83	10	28	23	32	28	8	7	6	8	23	11	11	18
Group 84	0	0	0	1	2	9	16	6	5	26	18	8	17
Group 85	4	3	4	3	2	5	6	5	1	4	2	6	9
Group 86	10	19	13	20	13	9	20	8	9	12	12	13	7
Group 87	2	5	2	6	2	4	2	1	1	4	1	2	3
Group 88	10	9	18	17	12	21	20	15	16	8	8	17	18
Group 89	8	23	30	20	24	22	19	12	8	38	13	17	22

Group 90	3	5	12	9	8	11	14	12	10	8	10	9	15
Group 91	2	4	4	2	0	1	2	4	3	1	1	3	1
Group 92	6	7	5	9	0	2	5	3	2	5	13	6	7
Group 93	5	5	8	16	10	15	27	18	18	33	24	29	32
Group 94	4	8	8	8	22	16	8	11	10	8	5	8	10
Group 95	4	2	1	0	4	5	4	2	1	0	2	1	1
Group 96	1	6	5	4	6	4	11	5	4	9	7	7	3
Group 97	5	5	4	5	4	2	0	0	0	0	1	0	0
Group 98	2	2	1	2	5	2	3	1	1	2	4	2	0
Group 99	2	6	5	4	5	5	9	4	2	3	1	6	7
Group 100	0	3	4	7	1	1	4	2	1	5	2	4	5
Group 101	7	6	14	10	21	16	11	16	8	12	12	3	11
Group 102	5	13	15	2	7	17	13	13	5	5	11	9	8
Group 103	0	1	1	2	4	0	2	1	0	1	0	0	1
Group 104	0	1	1	4	2	2	6	3	3	4	1	5	1
Group 105	0	1	3	1	0	5	0	2	1	2	0	1	2
Group 106	4	15	17	25	17	12	19	13	10	28	14	22	27
Group 107	0	0	1	1	1	0	0	1	0	0	2	0	0
Group 108	1	4	8	3	5	2	6	1	6	4	4	6	4
Group 109	6	14	7	9	10	8	5	9	9	12	5	12	6
Group 110	2	4	4	3	4	3	4	6	3	3	8	5	3
Group 111	5	10	4	6	4	7	6	3	4	7	5	3	9
Group 112	0	1	2	3	1	1	0	0	0	2	0	1	1
Group 113	3	3	3	7	6	4	2	3	3	2	3	4	3
Group 114	2	4	1	3	4	2	0	2	1	4	2	1	8
Group 115	1	2	5	3	2	0	3	3	1	3	1	4	1
Group 116	3	1	4	2	2	8	6	1	1	1	1	0	2
Group 117	2	8	2	7	4	5	10	7	8	7	1	4	4
Group 118	0	4	1	5	5	4	7	10	16	12	17	10	19

Appendix VI Length of stay probabilities (days)

The table below (Table 24) shows for every patient group the length of stay probabilities. 0 days means the patient stayed at the hospital less than 24 hours, 1 means the patient stayed less than 48 hours etcetera.

Table 24. Length of stay per patient group.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Group 1	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 5	1.0	1.0	0.9	0.9	0.8	0.6	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 6	1.0	0.9	0.9	0.7	0.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 7	1.0	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 8	1.0	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 9	1.0	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 10	1.0	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 11	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 12	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 13	1.0	1.0	0.9	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 14	1.0	0.7	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 15	1.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 16	1.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 17	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 18	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 19	1.0	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 20	1.0	0.9	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 21	1.0	0.9	0.6	0.5	0.5	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 22	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 23	1.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 24	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 25	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 26	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 27	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 28	1.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 29	1.0	0.9	0.6	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 30	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 31	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Group 32	1.0	0.9	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 33	1.0	0.7	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 34	1.0	1.0	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 35	1.0	1.0	0.8	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 36	1.0	1.0	0.5	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 37	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Group 38	1.0	0.9	0.9	0.9	0.8	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 39	1.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 40	1.0	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 41	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Group 42	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 43	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 44	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 45	1.0	0.7	0.5	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 46	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 47	1.0	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 48	1.0	0.7	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Group 49	1.0	0.9	0.9	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 50	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Group 51	1.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 52	1.0	1.0	1.0	0.6	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 53	1.0	1.0	1.0	0.9	0.8	0.6	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 54	1.0	1.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 55	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 56	1.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 57	1.0	0.7	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 58	1.0	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Group 59	1.0	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Group 60	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 61	1.0	0.8	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 62	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 63	1.0	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 64	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 65	1.0	0.6	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Group 66	1.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 67	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 68	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 69	1.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 70	1.0	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Group 71	1.0	1.0	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 72	1.0	0.9	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 73	1.0	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 74	1.0	1.0	1.0	1.0	0.9	0.7	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 75	1.0	0.9	0.7	0.6	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 76	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 77	1.0	0.7	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 78	1.0	1.0	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 79	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 80	1.0	0.8	0.7	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Group 81	1.0	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 82	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 83	1.0	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 84	1.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 85	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Group 86	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Group 87	1.0	0.8	0.4	0.3	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 88	1.0	1.0	1.0	1.0	0.8	0.6	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 89	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 90	1.0	0.9	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 91	1.0	0.9	0.5	0.5	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Group 92	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 93	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 94	1.0	0.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 95	1.0	0.9	0.9	0.9	0.7	0.5	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Group 96	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 97	1.0	0.7	0.3	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 98	1.0	1.0	0.9	0.8	0.7	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 99	1.0	0.9	0.5	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Group 100	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 101	1.0	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 102	1.0	0.8	0.6	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 103	1.0	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Group 104	1.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 105	1.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 106	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 107	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Group 108	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 109	1.0	1.0	0.8	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Group 110	1.0	1.0	1.0	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 111	1.0	1.0	0.8	0.7	0.5	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Group 112	1.0	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0
Group 113	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1
Group 114	1.0	0.9	0.7	0.7	0.6	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Group 115	1.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Group 116	1.0	1.0	0.6	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Group 117	1.0	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Group 118	1.0	0.9	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix VII Length of stay before surgery

The table (Table 25) below shows for every patient group the length of stay (LoS) in days before the date of surgery. 0 means patients are hospitalized on the day of surgery, 1 means patients are hospitalized one day before surgery.

Table 25. Length of stay before date of surgery.

Group	LoS before surgery
Group 1	0
Group 2	0
Group 3	0
Group 4	0
Group 5	1
Group 6	0
Group 7	0
Group 8	0
Group 9	0
Group 10	0
Group 11	0
Group 12	0
Group 13	0
Group 14	0
Group 15	0
Group 16	0
Group 17	0
Group 18	0
Group 19	0
Group 20	0
Group 21	0
Group 22	0
Group 23	0
Group 24	0
Group 25	0
Group 26	0
Group 27	0
Group 28	0
Group 29	0
Group 30	1
Group 31	0
Group 32	1
Group 33	1
Group 34	0
Group 35	0
Group 36	0
Group 37	1
Group 38	1
Group 39	0
Group 40	0

Group	LoS before surgery
Group 41	1
Group 42	0
Group 43	0
Group 44	0
Group 45	0
Group 46	0
Group 47	0
Group 48	0
Group 49	0
Group 50	0
Group 51	0
Group 52	0
Group 53	0
Group 54	0
Group 55	0
Group 56	0
Group 57	0
Group 58	0
Group 59	0
Group 60	0
Group 61	0
Group 62	0
Group 63	0
Group 64	0
Group 65	0
Group 66	0
Group 67	0
Group 68	0
Group 69	0
Group 70	0
Group 71	0
Group 72	0
Group 73	0
Group 74	1
Group 75	0
Group 76	0
Group 77	0
Group 78	0
Group 79	0
Group 80	0

Group	LoS before surgery
Group 81	0
Group 82	0
Group 83	0
Group 84	0
Group 85	0
Group 86	1
Group 87	0
Group 88	0
Group 89	0
Group 90	0
Group 91	0
Group 92	0
Group 93	0
Group 94	0
Group 95	0
Group 96	0
Group 97	1
Group 98	1
Group 99	0
Group 100	0
Group 101	0
Group 102	0
Group 103	0
Group 104	0
Group 105	0
Group 106	0
Group 107	0
Group 108	0
Group 109	0
Group 110	1
Group 111	0
Group 112	0
Group 113	0
Group 114	0
Group 115	0
Group 116	0
Group 117	0
Group 118	0

Appendix VIII Probability of going to a certain ward after surgery

The table below (Table 27) shows for every patient group, the probability of going to a certain ward after surgery. Table 26 gives a description of these wards.

Table 26. Wards with description.

-Table 26 is not included in the public report-

Table 27. Probability of going to a certain ward per patient group.

Group	Ward A	B	C	D	E	F	G	H	I	J
1	8.3%	0.0%	0.0%	0.0%	4.2%	4.2%	8.3%	0.0%	75.0%	25.0%
2	1.6%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	9.0%	33.6%
3	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	3.8%	18.9%
4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	30.0%	70.0%
5	0.0%	2.0%	0.0%	0.0%	4.0%	0.0%	0.0%	94.0%	0.0%	0.0%
6	42.9%	0.0%	33.7%	20.4%	1.0%	0.0%	0.0%	0.0%	1.0%	6.1%
7	10.3%	0.0%	24.1%	17.2%	0.0%	0.0%	0.0%	0.0%	3.4%	37.9%
8	12.2%	0.0%	36.9%	28.6%	0.0%	0.0%	0.8%	0.0%	3.9%	19.2%
9	7.7%	0.0%	23.1%	15.4%	0.0%	3.8%	0.0%	0.0%	3.8%	42.3%
10	1.2%	1.2%	60.7%	32.1%	1.2%	0.0%	0.0%	0.0%	1.2%	13.1%
11	5.4%	0.0%	17.9%	12.5%	0.0%	0.0%	0.0%	0.0%	1.8%	51.8%
12	0.0%	0.0%	18.2%	27.3%	0.0%	0.0%	0.0%	4.5%	0.0%	50.0%
13	0.0%	0.0%	0.0%	99.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
14	0.0%	0.0%	0.7%	88.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
15	4.5%	0.0%	9.1%	22.7%	0.0%	0.0%	0.0%	4.5%	0.0%	59.1%
16	18.8%	0.0%	18.8%	12.5%	0.0%	0.0%	0.0%	0.0%	6.3%	18.8%
17	1.5%	0.8%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	6.1%	67.9%
18	11.5%	0.0%	1.3%	0.0%	1.3%	0.0%	2.6%	0.0%	24.4%	30.8%
19	14.8%	0.0%	0.0%	0.0%	3.7%	0.0%	0.0%	0.0%	29.6%	44.4%
20	90.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%
21	14.8%	25.9%	0.0%	0.0%	0.0%	0.0%	14.8%	0.0%	11.1%	7.4%
22	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	2.0%
23	9.5%	2.4%	73.8%	0.0%	0.0%	0.0%	2.4%	2.4%	7.1%	19.0%
24	0.6%	0.6%	39.1%	1.9%	0.6%	0.0%	3.2%	0.0%	5.1%	39.1%
25	1.2%	0.0%	33.1%	0.6%	1.7%	0.0%	0.6%	0.0%	5.2%	49.4%
26	0.9%	0.0%	24.6%	2.1%	0.0%	0.2%	0.9%	0.2%	1.8%	6.5%
27	0.0%	0.0%	9.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.6%
28	0.0%	0.0%	47.7%	3.0%	0.0%	0.8%	0.0%	0.0%	3.8%	12.9%
29	61.5%	0.0%	23.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.7%
30	3.6%	1.8%	3.6%	0.0%	20.0%	47.3%	3.6%	0.0%	5.5%	3.6%
31	3.7%	0.0%	0.0%	0.0%	3.7%	18.5%	0.0%	0.0%	0.0%	3.7%
32	20.0%	0.0%	0.0%	0.0%	20.0%	65.0%	0.0%	0.0%	5.0%	0.0%
33	11.4%	0.0%	2.9%	0.0%	5.7%	65.7%	0.0%	0.0%	17.1%	14.3%
34	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	97.3%	0.0%	3.3%	12.7%
35	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	98.2%	0.0%	3.5%	0.0%
36	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	98.8%	0.0%	1.2%	1.2%
37	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	81.6%	0.0%	2.6%	5.3%
38	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	92.1%	0.0%	1.3%	0.0%

39	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	63.5%	0.0%	3.5%	34.1%
40	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	64.7%	0.0%	5.9%	29.4%
41	1.1%	0.0%	0.0%	0.0%	0.0%	1.1%	89.5%	0.0%	1.1%	0.0%
42	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	43.3%	0.0%	0.0%	56.7%
43	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%	1.2%	0.0%	8.5%	85.4%
44	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.0%
45	0.6%	1.7%	60.6%	2.2%	0.0%	0.0%	0.6%	0.6%	2.2%	41.1%
46	6.5%	3.2%	74.2%	0.0%	0.0%	0.0%	3.2%	0.0%	3.2%	67.7%
47	0.8%	3.5%	66.4%	0.4%	0.0%	0.0%	1.6%	0.0%	4.7%	52.7%
48	16.7%	33.3%	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%
49	1.4%	14.1%	78.9%	0.3%	0.0%	0.0%	0.8%	0.0%	1.4%	9.7%
50	5.6%	14.8%	79.6%	3.7%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%
51	0.2%	2.2%	9.1%	0.0%	0.0%	0.0%	0.4%	0.0%	2.6%	83.2%
52	1.4%	2.1%	94.5%	0.0%	0.0%	0.0%	0.3%	0.3%	2.1%	14.0%
53	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	2.9%	0.0%	2.9%	0.0%
54	1.9%	5.6%	83.3%	0.0%	0.0%	0.0%	0.0%	0.0%	3.7%	61.1%
55	0.0%	5.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	80.0%
56	0.0%	5.4%	22.5%	0.0%	0.0%	0.0%	1.8%	0.0%	2.7%	53.2%
57	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
58	0.7%	37.5%	30.3%	0.7%	0.0%	0.0%	2.0%	1.3%	3.3%	10.5%
59	0.0%	7.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
60	1.2%	0.0%	0.0%	0.0%	1.2%	0.6%	0.6%	0.0%	11.7%	80.9%
61	2.0%	1.0%	1.0%	2.0%	0.0%	0.0%	0.0%	1.0%	82.4%	43.1%
62	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.7%	35.7%
63	14.6%	7.3%	0.0%	0.0%	2.4%	0.0%	0.0%	2.4%	34.1%	26.8%
64	0.0%	0.0%	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	11.1%	27.8%
65	10.3%	5.1%	2.3%	0.0%	0.6%	0.0%	2.9%	1.1%	52.0%	39.4%
66	0.0%	2.7%	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	24.3%	51.4%
67	4.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	19.0%	52.4%
68	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.7%	84.6%
69	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	1.2%	0.0%	24.4%	56.1%
70	0.0%	0.0%	94.1%	2.9%	8.8%	0.0%	0.0%	0.0%	0.0%	0.0%
71	7.7%	0.0%	84.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
72	2.0%	0.0%	88.1%	0.4%	1.8%	0.2%	1.1%	0.0%	1.8%	22.4%
73	4.3%	0.0%	83.0%	1.1%	1.1%	0.0%	0.0%	0.0%	2.1%	6.4%
74	0.0%	0.0%	94.4%	2.8%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%
75	0.0%	0.0%	92.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
76	1.1%	0.0%	16.2%	0.0%	0.6%	0.0%	1.1%	0.0%	0.6%	44.1%
77	0.0%	0.0%	71.9%	9.4%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%
78	16.6%	2.4%	1.5%	0.4%	2.0%	1.8%	1.1%	0.0%	75.5%	18.2%
79	6.1%	2.2%	1.3%	0.9%	0.0%	0.4%	0.0%	0.0%	9.5%	43.7%
80	10.2%	62.7%	0.0%	0.0%	0.8%	0.0%	2.5%	0.0%	9.3%	2.5%
81	6.3%	4.1%	1.2%	0.0%	1.2%	0.0%	0.8%	0.0%	22.5%	63.7%
82	6.8%	2.3%	4.5%	0.0%	2.3%	0.0%	2.3%	0.0%	50.0%	68.2%
83	9.5%	15.0%	0.3%	0.3%	0.3%	0.0%	1.1%	0.0%	13.4%	32.7%
84	11.7%	5.8%	0.8%	0.0%	0.8%	1.7%	2.5%	0.0%	12.5%	60.8%
85	59.7%	4.0%	0.0%	0.0%	0.7%	3.4%	1.3%	1.3%	9.4%	4.0%
86	87.0%	3.3%	0.7%	0.0%	1.4%	5.1%	1.1%	0.4%	0.7%	0.7%
87	22.9%	6.1%	1.1%	2.1%	1.1%	0.4%	0.0%	0.0%	17.9%	0.7%

88	97.9%	0.5%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	1.6%	0.0%
89	4.5%	1.0%	0.6%	0.3%	0.6%	0.0%	0.0%	0.0%	9.1%	69.5%
90	76.4%	1.6%	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%	11.8%	7.9%
91	3.7%	7.4%	0.0%	0.0%	81.5%	0.0%	0.0%	0.0%	0.0%	0.0%
92	2.3%	4.6%	0.0%	1.1%	89.7%	1.1%	0.0%	1.1%	0.0%	0.0%
93	6.3%	0.4%	0.4%	0.4%	0.0%	0.0%	0.8%	0.0%	45.4%	51.7%
94	4.8%	0.0%	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	90.5%	10.3%
95	92.6%	0.0%	0.0%	0.0%	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%
96	6.8%	2.7%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	41.1%	52.1%
97	24.0%	0.0%	4.0%	0.0%	0.0%	4.0%	0.0%	0.0%	60.0%	8.0%
98	9.5%	80.6%	5.5%	0.0%	1.2%	0.0%	0.8%	1.2%	3.2%	0.0%
99	1.6%	90.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	4.8%
100	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	15.0%	72.5%
101	2.5%	18.3%	1.0%	0.0%	1.0%	0.0%	1.5%	0.0%	24.8%	28.7%
102	6.8%	47.4%	3.8%	0.0%	0.9%	0.0%	2.1%	0.0%	23.9%	10.3%
103	0.0%	26.3%	5.3%	0.0%	0.0%	0.0%	5.3%	0.0%	15.8%	52.6%
104	4.1%	22.4%	6.1%	0.0%	2.0%	0.0%	4.1%	0.0%	14.3%	42.9%
105	1.2%	6.2%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	8.6%	2.5%
106	2.2%	6.3%	2.2%	0.0%	0.0%	0.0%	0.4%	0.0%	10.3%	62.3%
107	0.0%	94.1%	5.9%	0.0%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%
108	5.8%	95.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.0%
109	2.1%	97.9%	0.0%	0.0%	0.0%	0.7%	0.7%	1.4%	0.0%	0.0%
110	5.1%	88.1%	3.4%	0.0%	3.4%	0.0%	11.9%	0.0%	0.0%	0.0%
111	2.8%	91.7%	0.9%	0.0%	0.0%	0.0%	0.9%	1.9%	0.0%	0.9%
112	12.5%	37.5%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	25.0%
113	9.6%	95.9%	1.4%	0.0%	0.0%	0.0%	1.4%	0.0%	4.1%	0.0%
114	6.7%	91.1%	0.0%	0.0%	0.0%	2.2%	0.0%	0.0%	6.7%	4.4%
115	9.7%	12.9%	0.0%	0.0%	0.0%	6.5%	0.0%	0.0%	16.1%	35.5%
116	0.0%	97.6%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%	2.4%	0.0%
117	3.5%	60.5%	1.2%	0.0%	1.2%	1.2%	1.2%	0.0%	2.3%	12.8%
118	5.8%	93.4%	0.0%	0.0%	0.8%	0.0%	0.8%	0.0%	2.5%	0.8%