Simulation study in Røros Sykehus

What is the current performance of Røros Sykehus and how to improve it?

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Management summary

This study is performed in Røros Sykehus, which is situated in the little old mining town Røros in Norway.

The goal of this research was to: *"Get an overview of the current performance of the OR department of Røros Sykehus and determine bottlenecks which can be changed to improve the current situation."*

Background

Røros Sykehus has been on the verge of doom 22 times in its history. In 2010 the hospital changed their case mix and built new ORs. At the moment there is a negative profitability and the projection is that by the end of the year 2011 there is a deficit. The head of department asked us to analyse the OR department on their performance and whether improvements would be possible. The head of department also wanted to know what the maximum possible number of patients is which can be operated and how he could get an insight in the current performance.

Research approach

This study is done by observing the processes in Røros Sykehus during our stay. We analysed the historic data from September 2010 to the start of June 2011. We made an analysis of the context, the control and the performance. This yielded the first half of the research question. Furthermore we analysed the data for bottlenecks.

We build a simulation model is to represent the current situation and to simulate improvements. In the simulations we test what would happen when time per surgery is reduced by 15 and 19 minutes. Furthermore we give recommendations on how to achieve this reduction in time.

Results

From the performance analysis we can conclude the following performances in utilization rate:

Specialty	Utilization rate	n	σ
2 Orthopaedics	72,6%	104	16,3%
1 Orthopaedic	86,1%	124	12,1%
Gynaecology	76,4%	16	7,7%
Oral surgery	67,5%	28	11,1%
ENT surgery	57,7%	24	12,4%

Furthermore the OR start time was off schedule by on average 20 minutes with the median of 17 minutes. The changeover time varied on average between 19 and 27 minutes. Furthermore 73% of the surgeries ended within time.

In the simulation study we concluded that reducing 15 minutes per operation would be possible and would increase the number of operated patients per year from 1720 to at least 1940. 19 minutes of improvement in surgery or changeover time yielded an even greater number of possible patients.

Conclusion

From the simulation, observations and the historic data we can conclude that there is room for improvement in Røros Sykehus and that the improvement lies within reach. The alignment of work processes and the use of empty ORs should yield the predicted improvements.

Management samenvatting (Dutch)

Deze studie heeft plaats gevonden in Røros Sykehus. Dit ziekenhuis is gelegen in het kleine mijnwerkersdorp Røros in Noorwegen.

Het doel van dit onderzoek was om: "Inzicht te krijgen in de huidige prestatie van de operatiekamer afdeling van Røros Sykehus en om het in kaart brengen van bottlenecks om de huidige situatie te verbeteren."

Aanleiding

Røros Sykehus heeft 22 keer op de rand van de afgrond gestaan in zijn historie. In 2010 heeft het ziekenhuis de case mix veranderd en zijn er nieuwe operatiekamers gebouwd. Op dit moment is het ziekenhuis verlieslijdend en is de prognose dat aan het eind van 2011 er een verlies geleden zal worden. Het hoofd van Røros Sykehus heeft ons gevraagd om de OK afdeling te analyseren op hun prestaties en of verbetering van de huidige situatie mogelijk is. Het hoofd van Røros Sykehus wou daarnaast ook weten wat de maximum capaciteit van de OK afdeling is en hoe hij inzicht kan krijgen in de huidige prestaties.

Onderzoek aanpak

Het onderzoek is uitgevoerd door de processen in Røros Sykehus te observeren tijdens ons verblijf. We hebben de historische data van september 2010 tot begin juni 2011 geanalyseerd. Daarnaast hebben we een analyse gemaakt van de context, de besturing en de prestaties. Ook hebben we een analyse gemaakt op de data om bottlenecks te vinden.

Daarna hebben we een simulatie model gebouwd die de huidige situatie representeert en die de verbeteringen kon simuleren. In de simulatie hebben we getest wat er gebeurt op het moment dat de operaties met 15 minuten en 19 minuten gereduceerd zou worden.

Resultaten

Uit de prestatie analyse hebben we de volgende bezettingsgraden geconcludeerd:

Specialty	Utilization rate	n	σ
2 Orthopaedics	72,6%	104	16,3%
1 Orthopaedic	86,1%	124	12,1%
Gynaecology	76,4%	16	7,7%
Oral surgery	67,5%	28	11,1%
ENT surgery	57,7%	24	12,4%

Daarnaast week het begin van de dag gemiddeld 20 minuten af met als mediaan 17 minuten. De tijd tussen de operaties verschilde tussen 19 minuten tot 27 minuten. Daarnaast was slechts 73% van de operaties klaar binnen normale werktijd.

In de simulatie studie hebben we geconcludeerd dat een reductie van 15 minuten per operatie mogelijk moet zijn. Dit heeft als effect dat dat het aantal geopereerde patiënten van 1720 omhoog gaat naar minimaal 1940. Met een reductie van 19 minuten per operatie wordt dit aantal nog veel groter.

Conclusie

Uit de simulatie observaties en de historische data blijkt dat er ruimte is voor verbetering in Røros Sykehus en dat deze verbetering ook binnen handbereik ligt. Het goed afstemming van werkprocessen en het gebruik van lege OK's zou voldoende moeten zijn om de gesimuleerde resultaten waar te maken.

Preface

Before this bachelor thesis I had an idea which was completely different than this report describes. The idea was to start a spa resort on top of a hill in a valley in Norway. Unfortunately the ground was not available to buy and there were too many objections to even consider proceeding in this plan. If there would have been a spark of hope that the project would be possible to realise I would have written a report on a completely other subject. It would have been a report how to make a spa resort feasible on that specific location with its 360 degree panorama and a swimming pool which would "flow" into the lake below. After my disappointment I still chose to do my bachelor thesis in this lovely country. I have visited the country quite frequently and I already spoke a bit Norwegian. The choice for Trondheim was because I wanted to explore places which I hadn't been before and places in which I didn't know anyone. Except for the contact I had with my later supervisor Andreas Seim. We came in contact through a former colleague of Erwin Hans and former member of the OMPL research group. I thank Luitzen de Boer for making the effort in finding a place for me where I could do my internship.

I especially want to thank Andreas Seim to react to the e-mail he got from Luitzen de Boer and to give me the opportunity to do my internship under the wings of Sintef. After the months at Sintef I can say it is an example company for me where I would love to work. The atmosphere in the company is great and you get support from everyone. The company is really encouraging you to excel in what you do best. The first drawback we both got was when St. Olavs Hospital rejected the idea of having me as a student to perform an analysis of the surgical department. Andreas did his best to find a new place to start my assignment. Fortunately this took not too long and I had the opportunity to go to Røros Sykehus, which is in the lovely mining town of Røros. Special thanks also goes to the head of department Jan Gunnar Skogås who made it possible to do my internship in Røros Sykehus and who made sure I could be at every spot in Røros Sykehus I wanted to be. A nice Dutch expression for this: "Iemand geen strobreed in de weg leggen".

I also want to thank Erwin Hans for being my supervisor with whom I had good talks. Unfortunately we didn't have much time to discuss everything extensively but the cues he gave me kept me on track and pointed me in the good direction.

I had a lovely time in Trondheim and I have met a lot of lovely people! At least a few names I want to mention are Hannah Eggink and Paul Mertens, the two Dutch who I spent a lot of my time with during my stay, and of course all the people from Trondheim: Nina, Alex, Kim, Iwe, Tanja, Lars & Kristine, who made me feel at home in Trondheim.

I had a great time living in Trondheim, but here are some advices when you go there. First of all: bring some money! Trondheim is not cheap. If you are a student, I have an extra advice: plan your visit during the semesters when there are a lot of students in town. Furthermore I want to mention that the nature is lovely. Due to the hills you are more aware of the nature around you.

The last person I want to thank is my girlfriend; she encouraged me to go abroad although she knew we were both going to miss each other a lot.

Rimmert van der Kooij

Enschede, 23rd of August

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Chapter 1. Introduction

1.1 Motivation of this research

Røros Sykehus has the goal to increase their performance in number of patients operated per year. Currently, negative profitability and the low volume of patients is a problem for the hospital. In this research we analyse the OR (operating room) performance of Røros Sykehus. To be more specific the performance of the OR department. We will measure performance, quantify it and analyse the data gathered. In chapter 4 we present the suggested improvements in performance which we asses by using simulation.

This chapter gives an overview of the history of Røros Sykehus, general information, the mission and explains why this research is conducted.

1.2 Context of the research: Røros Sykehus

1.2.1 History

Since the 1700's Røros Kobberwerk took care of the hospital facilities in the copper mining town of Røros. Since 1827 there has been a hospital in Røros (Vintervold, 2009). Since 1935 the hospital is driven from its current location (Riis, Røros sykehus, 2010). A part of the old structure is still used in the now expanded building. Since 1982 Røros hospital is part of the organizational structure of St. Olavs Hospital (Riis, Røros sykehus, 2010) and marked as department. Røros hospital experienced a rough history with 22 times on the verge of a shutdown. In 2010 Helse Midt Norge took the decision to continue Røros hospital, which led to the project Røros Nye Sykehus. The outcome of this project meant different surgery types and different organisation of the ORs.

1.2.2 General information

The hospital has around 55 employees. In 2010 the continuation of Røros Sykehus is decided. Politicians had a great influence in this decision; one of the motives to look whether Røros Sykehus was feasible to continue is that Røros Sykehus is one of the biggest employers of women in Røros. In 2011 two temporary operating rooms of St. Olavs Hospital were transported from Trondheim to Røros and rebuild (Smedås, 2011) At the moment Røros Sykehus has two modern operating rooms and one older operating room. One of the two old operating rooms is discontinued and used as storage space. So in total there are three operating rooms, see also Figure 4.

Besides the operating theatre, Røros Sykehus also has other functions. The function of Røros Sykehus is to provide the care in some specialties needed by the inhabitants of Røros. Furthermore, Røros Sykehus safeguards the lack of capacity of St. Olavs Hospital in certain specialties and provides this to the whole region Sør-Trøndelag (province) (St Olavs Hospital, 2008). The hospital has a few functions such as the operating rooms, policlinics, general practitioners and physiotherapy.

The policlinics are in the specialties of orthopaedics, gynaecology, cardiology and dermatology. Røros Sykehus also offers: dialyse, physiotherapy and nursing guidance, X-ray, and a laboratory. Dialyse is done for patients in the area and even for patients from Sweden. The orthopaedic policlinic is opened three times a week during the evening. The gynaecology policlinic is opened every four weeks. The dermatology policlinic is opened once a month by the dermatologist and four days a week by the dermatology nurse which does light therapy and wound care (Riis, Røros Sykehus, 2012).

Furthermore Røros Sykehus has an operating theatre which does daily elective surgery in four specialties, namely: orthopaedics, gynaecology, oral surgery, and otolaryngology. We will explain this in more detail in the section about the case mix: section 2.1.4.

1.2.3 Mission of Røros Sykehus

The mission of Røros Sykehus is to become the best small hospital in Norway and to become an example for other small hospitals. One of the goals is to show that a small hospital still has the right to exist. This is both in profitability and in terms of quality. Quality is measured by a number of indicators:

- Number of cancellations for planned surgeries;
- The number of reports sent to the general practitioner within a week after a policlinic visit;
- The number of infections in the hospital (Helsenorge.no, 2011).

1.3 Problem description

As described in the introduction, Røros Sykehus has been on the verge of doom 22 times. In 2010 the hospital started with new kind of surgeries, namely day surgery. The outcomes of the switch to day surgeries are not as expected. The number of patients operated is below the predicted number. This has its effect on the financing of the hospital which is financed by 60% through a basic share and for 40% based on their activities (Helsedirektoratet, 2010). The prediction is that by the end of the year there will be a deficit due to high costs and the lower number of patients operated.

The head of department wants to know whether further improvement in the operating department is possible. This is because the OR department is the most expensive and capital intensive. It is also the department which generates the most income for the hospital by operating patients, for which the hospital is paid. Furthermore the operating room department is the one which exceeds the projected budget in terms of costs. In order to improve the number of patients being operated and to reduce the costs, we believe that the logistics in the operating room department has to be investigated. This research focusses on the organisation and the logistics in the OR department of Røros Sykehus.

1.4 Research objective

The head of department wants to increase the number of patients being operated per day. The only performance indicator at the moment is the number of patients operated per week or day. There are no indicators of performance produced other than the number of patients operated, or the costs and incomes per department. This means there is a lack of understanding in the performance at this moment.

The goal of this research is to determine the current performance and how the performance can be improved.

- Determine the current performance in more logistical performance indicators
- Maximize the OR utilization rate

Main precondition:

- Improve logistical goals with the preservation of quality of care for the patient

At this moment there is no real understanding in how the OR department is performing. One of the goals of this research is to gain a clear understanding in the performance and make the performance visible by performance indicators. The next step is to find ways to improve the logistical performance indicators by organizing processes differently or plan these processes differently.

The main precondition for suggested improvement is that the care provided to the patient stays at least at the same level or should improve. There are probably a dozen ways to improve the performance but neglect or harm the quality of care to the patient. The goal therefore is to maintain the same level of quality of care or even improve it, by the suggestions made in this research.

1.4.1 Research goal

The goal of this research is:

"Get an overview of the current performance of the OR department of Røros Sykehus and find bottlenecks which can be changed to improve the current situation."

1.4.2 Scope of the research

The scope of this research is to determine the performance of the operating room department. Therefore the performance of the rest of the hospital is neglected in this research. Other departments such as the ward are not taken into account in this research. The view on this subject is with an operations research eye and not from a surgeon's perspective. This means that the research is conducted at the level of work processes, the organisation of processes, and the time certain activities take. This report will not state arguments on medical issues. The matter is from a performance overview and how processes are organised. Medical knowledge will be required whether certain tasks are necessary or not, and we do not possess this medical knowledge. This is out of our knowledge boundaries and therefore not taken into account in this research.

Hans, van Houdenhoven & Hulshof (2012), proposed a theoretical framework for planning and control in healthcare organisations. This framework illustrates the above mentioned and more clearly defines the scope of this research.

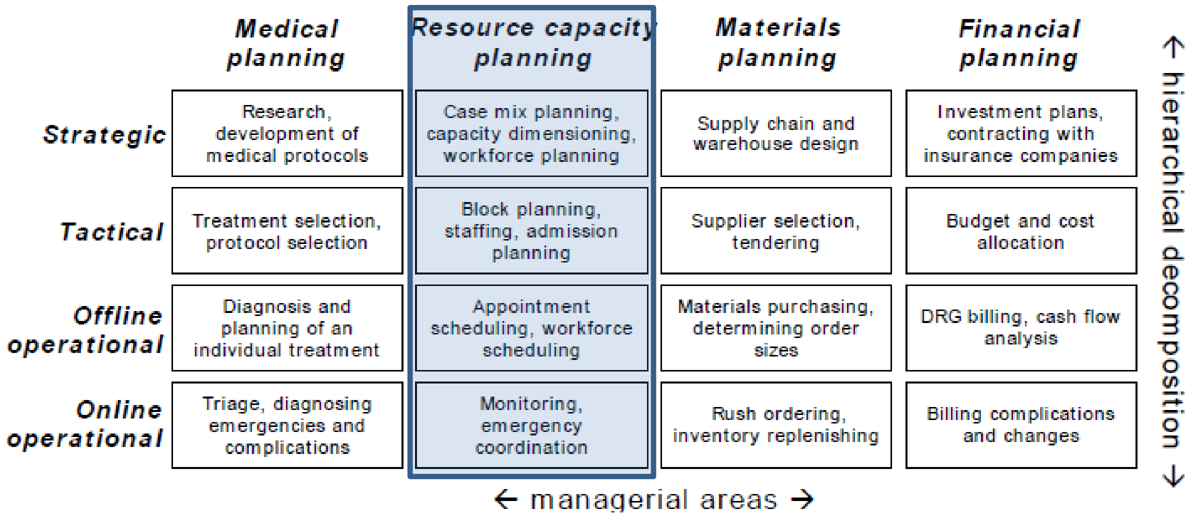

Figure 1: (Hans, Houdenhoven, & Hulshof, 2012)

In this framework the horizontal axis represents the managerial areas. The vertical axis represents the hierarchical decomposition. The focus of the research lies within the blue highlighted box, namely the resource capacity planning. The medical planning, materials planning and financial planning are not taken into account within this research. Within the resource capacity planning the strategic planning is already done and taken as given. More on the current situation and description will be given in Chapter 2.

1.5 Research questions

To achieve the goal of this study we posed the following research questions:

1. **What is the current situation of the OR department in Røros Sykehus** (Chapter 2)
   To have a good overview of the current situation we observed the activities in Røros Sykehus and interviewed the employees, nurses, surgeons and management. We will give an overview of the main characteristics of the system such as case mix, specialties an opening hours (system). Furthermore we looked at how the planning is done (control). In order to give an overview in terms of performance we looked at historic data. This research question will be answered in chapter 2.

2. **What are the main problems of the OR department?** (Chapter 2)
   This question answers which problems occur within the OR department and which problems are out of the scope of this research. This question is also to justify which problem we will choose to focus on. In our opinion, the problem we will choose contributes the most to solving the main problem.

3. **How can the current performance of the OR department be improved?** (Chapter 3)
   Which improvements are possible, given the scope chosen in chapter 2? This chapter will give an overview of the desired situation of the OR department in Røros Sykehus.

4. **How should the OR department be modelled in a Simulation model?** (Chapter 4)
   Chapter 4 will answer in which way the OR department can be modelled and how this is done in this research.

5. **How much would the simulated improvements yield?** (Chapter 4)
   This research question answers how the suggested improvements of chapter 3 perform in the simulation model and how much performance increase is yielded according to the model.

6. **What is the best way to implement these changes?** (Chapter 5)
   The results are not put into practice yet, but what is the best way to succeed in the implementation of the suggested improvements in order to let them succeed. This will be answered in chapter 5.

In chapter 6 we will draw conclusions and give recommendations on Røros Sykehus

1.6 Methodology

This study will be carried out by observing the processes in Røros Sykehus during our stay. The data which is available will be examined and this data will be used to measure the performance. We will make an analysis of the context, the control and the performance. We look where bottlenecks occur. Then a simulation model is built to represent the current situation and to simulate improvements. Furthermore something is said on how to implement the improvements and what the improvements would yield performance wise. At the end of this report we will draw conclusions on what is the best solution.

Chapter 2. Current situation

In this chapter the current situation of the OR department of Røros Sykehus will be described. This will be done by describing three main aspects of the OR department, namely process, control and performance. In paragraph 2.1 we will discuss the processes involved in operating a patient and how the process is organized. In paragraph 2.2 we will discuss how the department is planned and controlled. In paragraph 2.3 the performance of the current system is described and how the performance can be measured. In section 2.4 we will describe the bottlenecks found and in section 2.5 we will draw conclusions on which bottlenecks we are going to solve.

2.1 Organisation of the OR department in Røros Sykehus

To begin with is Røros Sykehus a department of St. Olavs hospital in Trondheim. The head of department is held accountable for the processes in Røros Sykehus and has to report to the board of directors of St. Olavs Hospital.

The processes of the OR department are not initiated at the OR department but are initiated most of the time within the policlinics by the patients. Here a diagnosis is made and the specialist states that surgery is necessary. In section 2.1.1 we will explain how the patient flows through the process and when it enters the OR department of Røros Sykehus. The case mix will only consists of elective outpatient surgeries. In section 2.1.4 we will explain the case mix and the specialties in more detail.

2.1.1 Patient flow

The process for a patient starts when he or she goes to a general practitioner (GP). The GP then refers the patient to a policlinic where the patient is seen by a specialist. The specialist can decide whether further diagnosis is needed and determines whether the patient has to receive surgery. Either the patient is put on a waiting list or an appointment for a certain week is made with the patient. The patient then receives a letter in which he or she is called up for surgery on a certain day.

In the letter which the patient receives the patient is also asked to stay sober and the whole process is explained. The patient will then be called a week before surgery by the nurses of the ward as a reminder the surgery is going to take place next week, and asks whether everything is clear to the patient.

The process which happens within the OR department of Røros Sykehus can be visualised in the following flow chart:

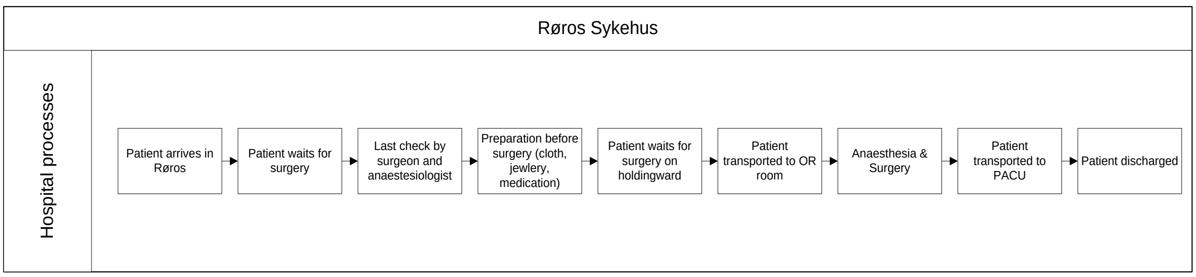

Figure 2: Patient processes in Røros Sykehus for outpatient surgery

The patient arrives at the hospital in the early morning and waits for the surgery to take place. The surgeon then discusses the last details of the surgery and checks the medical condition of the patient. The anaesthesiologist then discusses any allergies against narcosis and determines whether the patient is fit enough for anaesthesia. After both the anaesthesiologist and the surgeon have talked to the patient, the patient is prepared for surgery. This means the patient is put in a bed and will get the last medication before surgery. After this the patient waits until he or she is called up for surgery and is transported into the OR room. Next, the surgical procedure takes place in which the patient is put under narcosis and the surgery is performed. After the surgery, the patient is transported to the Post Anaesthesia Care Unit (PACU) where the patient will make a transition from an anesthetized state to an awakened state, and will be treated for nausea and post-operative pain. After that the when patient is out of pain and the analgesics are worked out the patient is either discharged, rolled into the holding ward or he/she is back in the waiting room. The last option rarely happens. Before the patient is discharged the patient will receive something to eat because they had to stay sober before surgery. After the patient is discharged the patient can head home and start rehabilitating from the surgery. Also the nurses make sure someone is accompanying the patient home and that there is someone present in the first 24 hours after surgery. This is for safety reasons and because of the narcosis which can cause complications for the patient.

After the patient is back home the patient is called up for a follow-up meeting or a plan is made for the rehabilitation.

2.1.2 Processes per stakeholder

The flow chart in Figure 3 shows all the stakeholders in the process of the outpatient surgery. Already a few stakeholders are named in the previous section, but more stakeholders are involved. The following stakeholders are identified within the OR process and we will discuss briefly their purpose:

- **Patient**
  The patient is the essential part of the system, without the patient the whole hospital would not be necessary.
- **Surgeon**
  The surgeon performs the surgery. He or she is the one who is held accountable when something goes wrong within the surgical procedure. In contradiction to the other employees, the surgeons who perform surgery in Røros Sykehus are not employed by the hospital but are employee of the bigger St. Olavs Hospital. A few surgeons are hired from a hospital in Namsos and Orkdal.
- **Anaesthesiologist**
  The anaesthesiologist has completed a medical education and thereafter is specialised into anaesthesia. Anaesthesiologists are authorized to give analgesics and perioperative medication such as strong pain killers. The anaesthesiologist takes care of a pain free surgery. The anaesthesiologist makes a plan for every patient based on their characteristics. They also monitor and supervise during the surgery for heart failure or other complications based on the individual patient being under narcosis.
- **Anaesthesia nurses**
  The anaesthesia nurses support the anaesthesiologist during the procedure of giving the patient sedation. The anaesthesia nurse is also monitoring the patient continuously during the operation, checking the vitals of the patient and making sure the patient is not in pain during the surgery. The nurse is not a physician as the anaesthesiologist but still has a thorough education, which means a bachelor degree within nursing and field experience as a nurse. Thereafter a further specialisation in anaesthesia follows (Olsen, Anestesisykepleier, 2012).

- **Surgery nurses**
  Surgery nurse or surgery assistant has a bachelor degree in nursing and a further specialisation into surgery nurse or a master's degree in nursing (Olsen, Operasjonssykepleier, 2012). The surgery nurse takes care of the transport to the OR room and of the correct position on the operating table. Furthermore the surgery nurse prepares the patient for surgery which means tasks as placing the sterile draping on the patient and the preparation of the sterile instrument trays. During an operation two surgery nurses are present in the OR. One is in the sterile area and supports the surgeon during surgery, with tasks such as handing over instruments or holding instruments. The other surgery nurse does the non-sterile tasks, such as getting instruments or other materials during the surgery from the areas which are not sterile. As extra tasks the surgery nurses have to prepare the instrument trays and have to sterilize the instruments in the sterilization area. The sterilization of the instruments is done in an autoclave.
- **Cleaning employees**
  There are a few people who are specially trained to clean the OR room. They clean up the OR room after surgery and prepare it for the next surgery. Some are also educated to do the sterilization of the surgical instruments.
- **PACU nurses**
  These are post anaesthesia care unit nurses which have an extra training in the recovery of the patient after surgery. They are specialised in treating post-operative nausea and pain. They can also give medication related to the situation after surgery.
- **Nurses**
  There are also nurses who are involved in the ward and the admission ward. They take care of the patient before and after the surgery. So before the patient goes into surgery and after coming back from the PACU ward. The nurses give the patient post-operative medication and something to eat. They also arrange transportation when needed or arrange other necessary things after surgery.

In the following flow chart the processes are illustrated and which stakeholder takes part where. As extra note the patient is not displayed because it is the subject of all the processes.

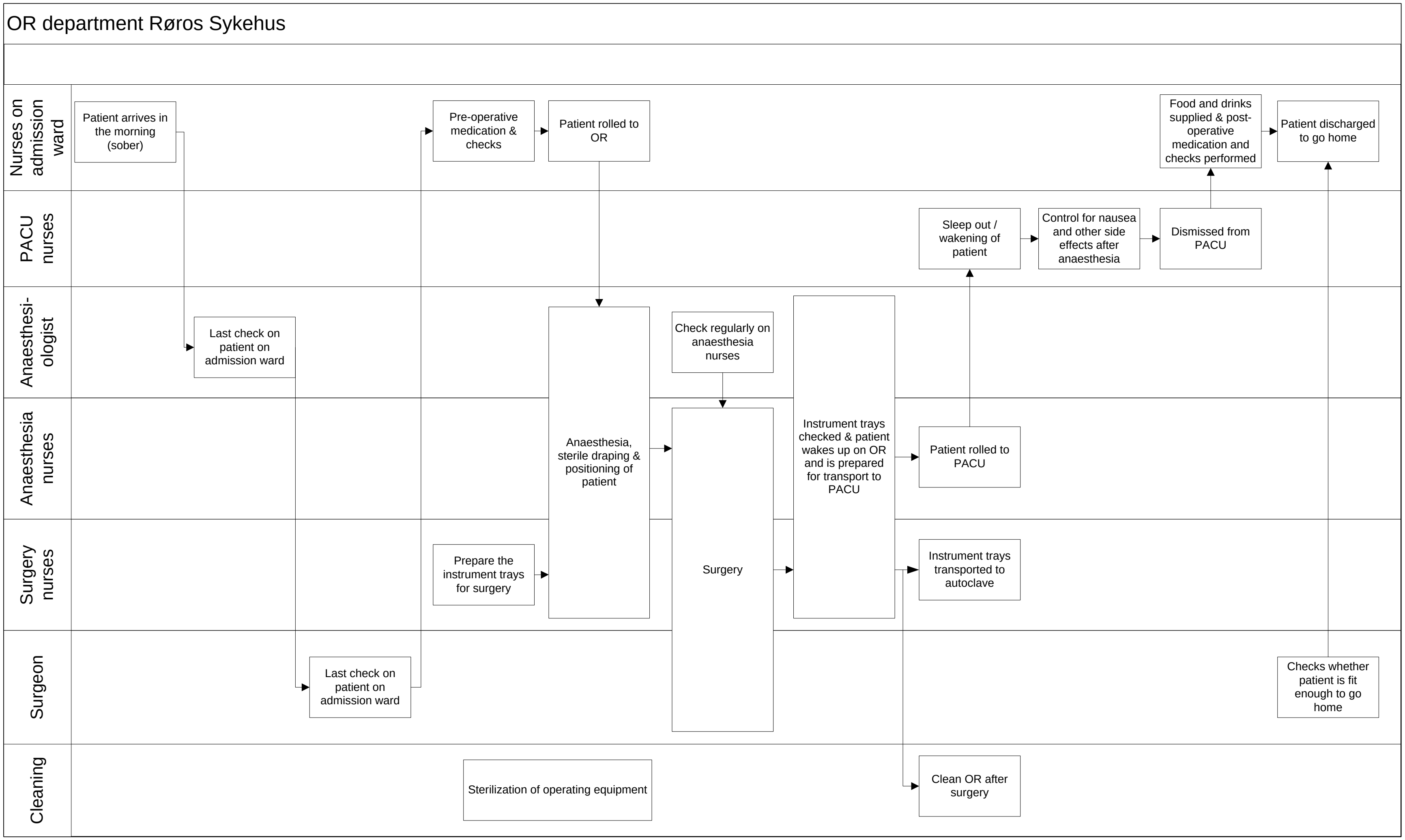

Figure 3: The processes that are performed in the OR department for outpatient surgery

The process starts when the patient arrives at the hospital in Røros. The admission ward then tells the patient to wait in the waiting area. In figure 4 the lay-out of the OR department is shown. The surgeon and anaesthesiologist will visit the patient on the admission ward or in the waiting area when they are not put into a bed yet. Last checks are performed by the surgeon to check whether everything is correct and no other complications have arised since the policlinic visit. The anaesthesiologist furthermore checks whether the patient is known to allergic reactions against analgesics or other medication and explains the last details on the anaesthesia process. When the surgeon and anaesthesiologist are done, and the patient is cleared for surgery, the pre-operative preparations start. A few steps in this process are: the patient has to empty their bladder, the patient is dressed into their pyjama or ward clothing, and receives the last medication before surgery.

Simultaneously the surgery nurses prepare the surgery. The instrument trays are prepared, other medical instruments are prepared and when arthroscopic surgery is performed also supports for the surgery table are prepared. Also the anaesthesia nurses prepare the medication and the analgesics for the surgery. When the OR is ready for the next patient the patient is called to the OR, which means the patient is transported from the admission ward into the OR.

When the patient arrives at the OR, the time is recorded into the OR planning system and the perioperative process starts. This means that the patient is put on the OR table first in such a position that the patient can receive anaesthesia. During the anaesthesia process tubes are inserted in the patient's airway and analgesics are administered. When the patient is under narcosis, the anaesthesiologist can leave the room to perform other duties such as assist in one of the other OR rooms or assist at the PACU. The surgery nurses position the patient in such a manner that the operation can take place. They also cover the area around the surgical wound with sterile draping. There are always two surgery nurses present with each operation. One of the surgical nurses moves within a sterile environment and is clothed especially to work in that area. The other surgical nurse assists with handing over sterile equipment and getting equipment or materials which are needed during the surgery, which were not foreseen. Another task for the non-sterile nurse is to call the surgeon when surgery is ready to start and to log certain data in the planning system.

The surgery starts when the surgeon puts a scalpel into the patient. This is again logged into the planning system to record the time. The surgery takes place with the surgeon, two nurses, one anaesthesia nurse, and as a backup there are: one anaesthesia nurse, one surgical nurse, and the anaesthesiologist. Mostly the anaesthesia nurses take turn during the surgery. The surgery stops when the surgeon is ready with stitching up the patient. The time at which this occurs is logged again. The anaesthesiologist is called to assist when the patient wakes up from narcosis.

During the wake up of the patient from narcosis the tubes are retracted from the patient. This procedure is called the post-operative procedure. The vitals are checked by the anaesthesiologist and the patient is put into a ward bed. The ward bed is then transported into the PACU ward where the patient will awake and recover from surgery. The time is again logged into the system when the patient is rolled out of the OR. During the wake up time and after the patient has left the OR the surgical nurses collect the instruments and transport them to the autoclave/sterilization area. After the patient is away and the instruments are tidied up, the cleaners clean the OR room on such a level that the next surgery can take place.

On the PACU ward the patient is guarded for nausea and post-operative pain. The anaesthesiologist also checks the patients who are on the PACU and assists when complications arise.

When all vitals are all right and the patient does not have any complications the patient is dismissed from the PACU ward back to the admission ward. This is checked by the anaesthesiologist and PACU nurses. On the admission ward the patient will get something to drink and something to eat, because they have been sober until the operation took place.

On the admission ward the surgeon will visit the patient to check whether the patient is fit enough to go home. When complications occurred it can happen that the patient has to stay overnight.

Aforementioned show all the processes involved in an outpatient surgery in Røros Sykehus.

2.1.3 Lay-out of the OR department & equipment

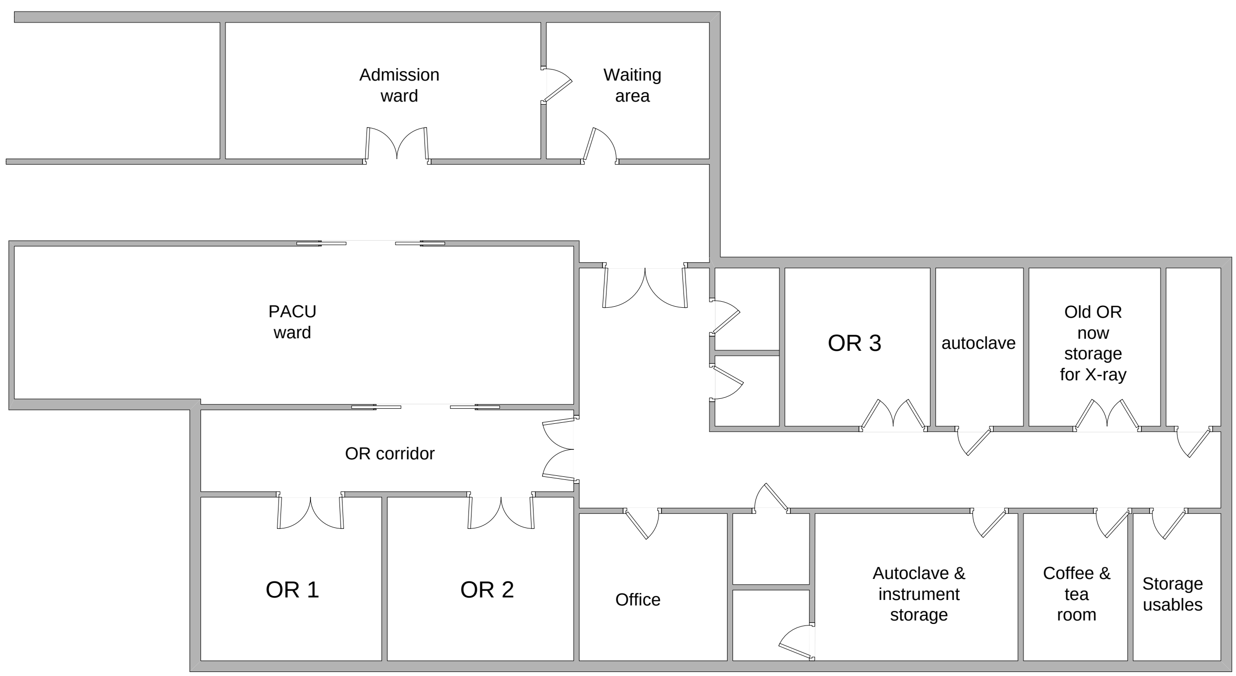

Figure 4: lay-out of the OR department

Figure 4 shows the lay-out of the OR department. With the explanation of all the processes in section 2.1.2 a good overview of transportation can be created. As can be seen is that transportation routes are rather short in comparison with bigger hospitals. The distance in time between the admission ward and the OR corridor is approximately 30 seconds to 1 minute.

The OR1 & OR2 are two newly build operating rooms. The ORs are not completely new but are reused from St. Olavs Hospital in Trondheim. The two ORs functioned in Trondheim as 'operating rooms of the future'. These ORs were not in use as regular ORs but were show models for the latest technology in healthcare. Since the hospital in Trondheim is completely rebuild, the two example operating rooms are taken apart for re-use in Røros (Skogås & Myhre, 2011). These ORs replace two old ORs in Røros Sykehus and form an addition to the old building.

At the moment there are three operating rooms in use. There is a difference which surgeries can be performed in the new ORs and the old OR. The two new ORs are also capable of performing laparoscopic or minimal invasive surgery. One of the addictions of the new ORs are the screens to visualise the laparoscopic surgery, and a new air flow system. There is better lightning in the new ORs and it is equipped with bigger windows for day-light (when wanted). Another advantage of the new OR is that there are storage compartments in the walls for usable materials. These storage compartments contain certain materials such as surgical needles and sutures, and can be accessed from the corridor.

The operational equipment that is larger and not required during every surgery, such as extra supports or X-ray equipment, are placed in the storage room, which is one of the old OR rooms.

The nurses, anaesthesiologists and surgeons who are having a break or a lunch break, most of the time go to the coffee and tea area which is especially for the OR department. This means that interaction with other departments is low because most other departments lunch in the central restoration.

2.1.4 Case mix of operating theatre

Per year around 2300 patients are operated in Røros Sykehus. The number of patients is divided among four specialties:

- Kjeve: Norwegian for Oral surgery
- Ortopedi: Norwegian for Orthopaedics
- Øre Nese Hals: Norwegian for Ear Nose Throat (ENT) or Otolaryngology
- Gynekologi: Norwegian for Gynaecology

The case mix changed in September 2010 from mixed inpatient and outpatient elective surgeries to only outpatient surgery. Earlier in this document we called outpatient surgery also day surgery, they are the same and will be called outpatient surgery from now on. In essence outpatient surgery means that the patient arrives on the day of surgery and is discharged the same day. The change to outpatient surgery took place in September 2010 and delivered a new type of case mix for Røros Sykehus.

The aforementioned surgeries have the following percentage of patients:

- Orthopaedics: 78,6%
- ENT: 9,3%
- Gynaecology: 7,4%
- Oral surgery: 4,8%

Orthopaedic surgery is the most, since every day of the workweek there are orthopaedics in the hospital. In most of the weeks there are even two orthopaedic surgeons.

2.1.5 Staffing of the OR during surgery

There are several configurations in which there are different employees present in the hospital. The physicians which perform the surgery are not permanently employed by Røros Sykehus but are hired from St. Olavs Hospital. Hiring from St. Olavs Hospital ensures the quality of the surgeries. This is because St. Olavs Hospital is also a training centre in which the surgeons are able to train themselves in more specialties than only outpatient surgeries. The surgeons are also able to perform more surgeries of one type which improves the quality of care.

The number of staffing of the four specialties is different. There is always just one physician in Røros Sykehus of the following specialties: oral surgery, ENT surgery and gynaecology. For orthopaedic surgery there can be either one or two surgeons simultaneously in Røros Sykehus.

When two orthopaedics work in Røros Sykehus there are three anaesthesiology nurses, five surgery nurses and one anaesthesiologist and one cleaning employee. There is always only one anaesthesiology nurse present in the OR during surgery. The third nurse is on standby and is taking turns with the other two anaesthesiology nurses which are in the OR. There are two surgical nurses in the OR during surgery, one who is acting and supporting the surgeon in the sterile region. The other is supporting during surgery by handing over equipment from the non-sterile area into the sterile area. Handing over is done in a particular way, all the equipment is packed in a certain way so that it can be unpacked and handed over in a sterile way although it was in a non-sterile environment. The fifth surgery nurse works on the corridor and functions as a backup and prepares the upcoming surgeries.

In the situation that there is only one orthopaedic surgeon in Røros there are two surgical nurses in the OR and one surgical nurse on backup, two anaesthesia nurses and still one anaesthesiologist.

The oral surgeon always brings along his own assistant. Therefore only one anaesthesiology assistant is required to assist his procedures and the anaesthesiologist to check when the patient has to receive narcosis.

In the case when there is one gynaecologist: there is one anaesthesiologist, two anaesthesia nurses and three surgical nurses. So this is the same situation as with one orthopaedic.

When there is one ENT surgeon: there is one anaesthesiologist, two anaesthesia nurses of which one is backup, two surgery nurses and one in the corridor.

2.2 Planning and control of the OR department

The planning and control can be best described using the framework of Hans et al. (2012). Hans et al. suggest the differentiation between strategic planning, tactical planning, offline operational planning and online operational planning as shown in Figure 1.

2.2.1 Planning processes

In this paragraph we will describe the planning processes on four hierarchical levels. This is described for the column Resource capacity planning (Figure 1).

Strategic planning

The strategic planning has just been changed in Røros Sykehus. In April 2010 two completely new operation rooms were built and a new PACU ward was built. This is a strategic decision which has been made and is not up for debate. In addition to the new ORs and the new PACU the case mix is changed. In September 2010 the hospital switched from inpatient and outpatient surgeries to only outpatient surgeries. The workforce planning is as described under section 2.1.5.

Worth mentioning problems from Røros Sykehus: from a strategic point of view Helse-Midt-Norge buys extra capacity from private hospitals. Helse-Midt-Norge is the government organisation which regulates the healthcare market in Norway. Since there are long waiting lists in Norway they decided to buy extra capacity. The private hospitals are accused to pick the more profitable patients from the waiting list namely those with the least expected complications. This leaves the more obese/complicated patients to for example Røros Sykehus.

Tactical planning

The tactical planning of the OR includes the planning when surgeons are going to be in Røros. The orthopaedics will make a schedule for half a year who is going to Røros and when. So approximately half a year in advance the orthopaedic surgeons know when they are working in Røros Sykehus. Also a few weeks in advance the planning for all the nurses is made. The schedule for the surgeons is made this far in advance, because most of the surgeons work in Røros Sykehus during their vacations. The schedule of the nurses is therefore also easier to plan and in addition all the nurses are employees of Røros Sykehus.

Although the schedule of the nurses is easy to plan, the number of employees who are in fact available is not as preferred. The number of nurses is lower than preferred since some are on sick leave. They already tried to find surgery nurses even in Sweden but until now they did not succeed in finding enough nurses, which means they sometimes lack the surgery nurse which is working in the corridor and preparing the instrument trays.

Something important we noticed during our stay is that the alignment who is going to work when, lacks coordination. The admission ward starts at 7:30 and the surgeon at 8:00, but the surgeon and the anaesthesiologist both have to see the patient for one last check before surgery can start. This could be a clue to the performance measured in the morning described in section 2.3.2.1.

Offline operational planning

The offline operational schedule is made 4 weeks in advanced. The patients are planned and a letter is send to the patient to inform them about their upcoming surgery. The patients are planned by the "inntaks kontor" (admission office) of St. Olavs Hospital.

The offline planning furthermore results in a follow-up call by the ward department in Røros Sykehus to let the patient know when they are expected and what to bring. In the offline operational planning there are also patients which cancel their appointment for any reason. Cancellation of appointments results in extra work in making sure that this gap is filled by another patient on the waiting list.

Worth mentioning problems from the hospital: patients often cancel their surgery, this might be due to the travel distance to Røros Sykehus but this is unknown. Røros Sykehus also does not know with their current case mix, what their maximum number of surgeries is per year. So doubts have been arising about the planning, and the question is posed whether the planning could be improved.

Online operational planning

The online operational planning is not as extensive as it is in hospitals with emergency patients for example. Surgeons still change the schedule from time to time. This might be due to the fact that certain patients are not on time and others are. Another reason is for example that recovery time after surgery might be longer so if a patient can be operated earlier on the day this increases the chance of being discharged at the end of the day.

The surgeon has its last contact with the patient just before the surgery. There might be conditions to which the surgeon decides not to operate the patient that day, for example due to the fact that the patient is physically not healthy enough.

Notable problems: during the online planning there are several things which go wrong. But also noticed by the hospital is the overtime which the OR department produces. There is also a suspicion thaturgeries in the morning start later than planned. The overall conclusion is that it should be possible to operate more patients on a day.

In the next section we will check some of the above mentioned problems by measuring some performance measures.

2.3 Operational performance measurements

We performed the measurements on the historic data which was available. In the next paragraph we will explain how this data is logged into the operational schedule and what the procedure is to log the time at which we based the performance measures. In section 2.3.2 we explain the assumptions made by the performance measurements. In section 2.3.3 we show the utilization rates per specialty.

2.3.1 Time logging into the operational schedule

The timing within the operating room is logged into the planning system of the OR as historic data. This is done in a structured way. The times which are logged are mentioned hereafter, and logging of this time is a protocol in the OR and is done the same way every time.

- The time at which the patient enters the OR (patient in)
- The time at which the knife of the surgeon is put into the patient (start surgery)
- The time at which the surgeon is ready with stitching up the patient (end surgery)
- The time at which the patient is rolled out of the OR to the Post Anaesthesia Care Unit (PACU) (patient out)

As aforementioned this time logging is a protocol and is done every surgery by one of the surgery nurses.

The four points in time which are logged are visualised in Figure 5 to make it more comprehensible.

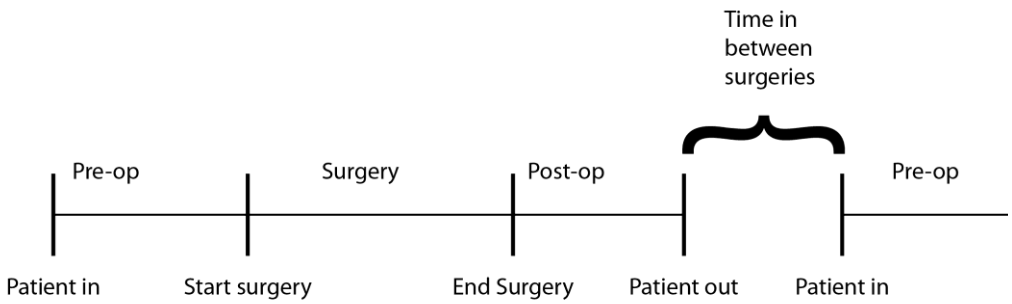

Figure 5: Points in time which are logged during the surgical procedure

- Pre-op is the pre-operative procedure, in which anaesthesiology and the sterile draping of the patient is performed.
- Surgery is the time in which the actual surgery takes place.
- Post-op is the post-operative time. In this time the patient wakes up from anaesthesiology and the tube which is inserted for anaesthesia is retracted.
- The time between pre-op and post-op is the time between surgeries in which the OR is cleaned up and made ready for the next surgery. This time we will call changeover time.
  (Helse Midt-Norge, 2010)

These are the times which are logged into the operating room schedule manager. We subtracted the anonymous data from the OR planning system. This data is structured as suggested by Van Houdenhoven et al. (2006) only with a few less time indicators and with the difference that sterile draping is not measured as surgical time.

Other parameters which are logged into anonymous data which are of use for this report:

- Operation date
- Specialty
- OR room number
- Day of the week
- Diagnosis code
- Operation code

The data we subtracted is from the 13th of September 2010 (start or new case mix) until the 31st of May 2011.

We will explain these parameters in more detail when we use them.

2.3.2 Assumptions made in the measurements

To actually measure timing within the OR we need to explain some assumptions we made during our data analysis.

The lunch time was not recorded in the system. This lead to the assumption that between 11:00 and 13:30, when the changeover time was longer than 40 minutes, we subtracted 30 minutes lunchtime from the changeover time.

Another assumption is that we count per OR days. An OR day is a day when an OR is in use. Normally an OR day is the same as the number of surgeons working in the OR department. Since neither the number nor which surgeon was performing the surgery is logged into the system we looked at the OR numbers. When one orthopaedic surgeon is performing surgery he 'cheats' with the system. He or she namely switches between two ORs. We were not allowed to make use of the non-anonymous data to be more precise in which weeks there was one orthopaedic and in which week there were more. To detect this we visualised the data, as shown in Figure 6.

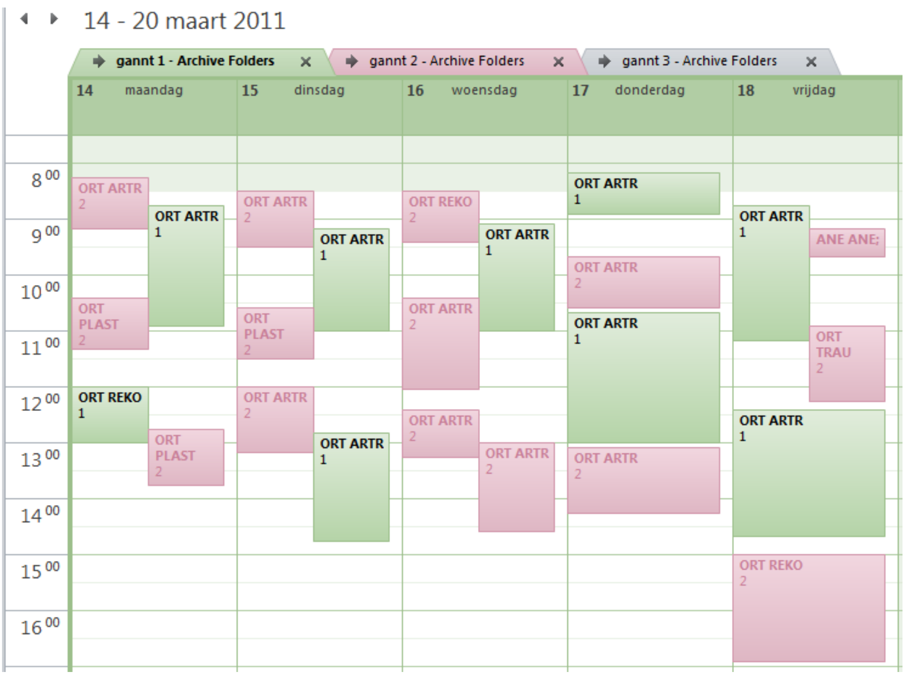

Figure 6: Example week schedule for one surgeon

In the data is as described the former section also the OR room number. Based on this figure we looked whether the surgery time had any overlay. This means the actual surgery time, not the pre- and post-operative time. When there was no overlay in surgery time the assumption is made that only one surgeon of the mentioned specialty was performing surgery. Also no data on how many nurses truly were working on that day was available, therefor we will assume the numbers as described in section 2.1.5 were working at that time. The distinction on how many surgeons are working, and not only looking at the room numbers, is important for the number of errors made. When we would only look at the data only from the point of view of the OR rooms we would create an error as Figure 6 shows. An error for example that could occur is that the start time of a day would be an hour late when we would assume an open OR is equal to an operating surgeon. These assumptions lead to the performance measurements described in the following paragraphs.

As extra notice the official working days are:

- Monday to Thursday: 08:00 – 16:00
- Friday: 08:30 – 16:00
- Saturday & Sunday: OR is closed.

In the section end time of the OR day we will tell something particular on the closing time of the OR.

2.3.2.1 Start time of the OR day

The start time is displayed in Figure 7. This time is displayed in a cumulative graph. At the y-axis the days are shown as a percentage of the time. That means all the OR days are added up, and converted into a percentage of the total. The x-axis shows the time sorted ascending. The shortest time of a day is shown at the start at zero and in ascending order to 100% the rising start time.

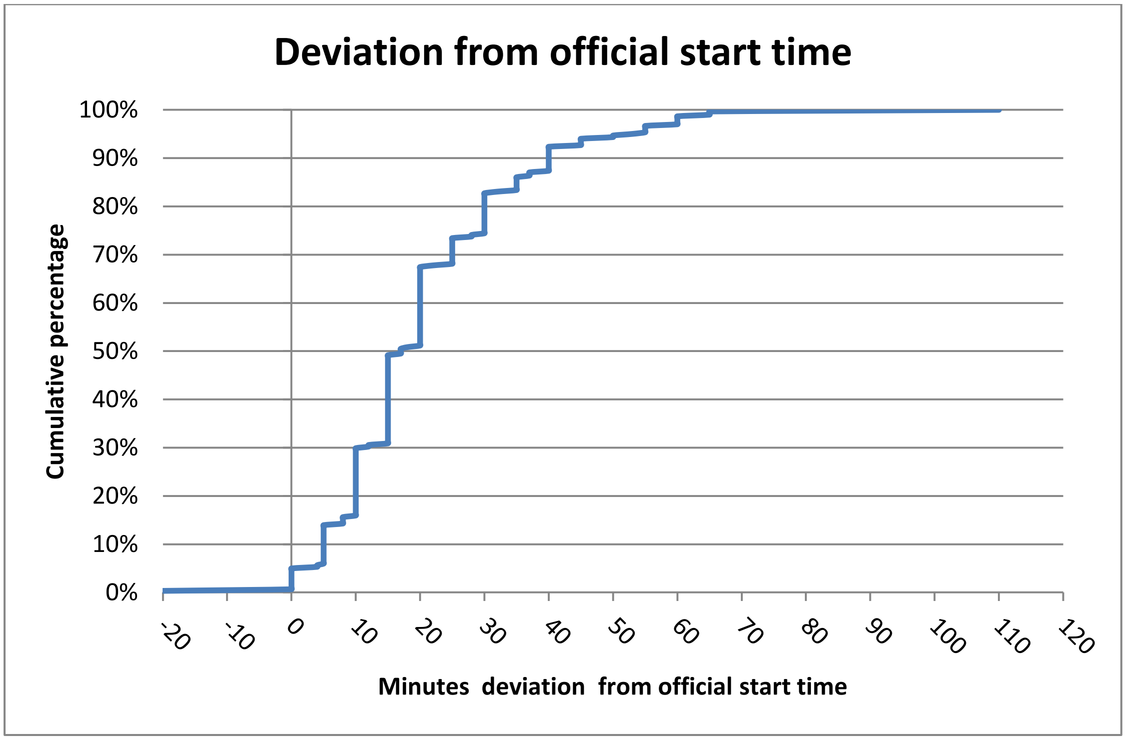

Figure 7: Start time cumulative graph. N=297 σ= 15 minutes

On average the OR day starts 20 minutes late with a standard deviation of 15 minutes and the median of the start time is 17 minutes.

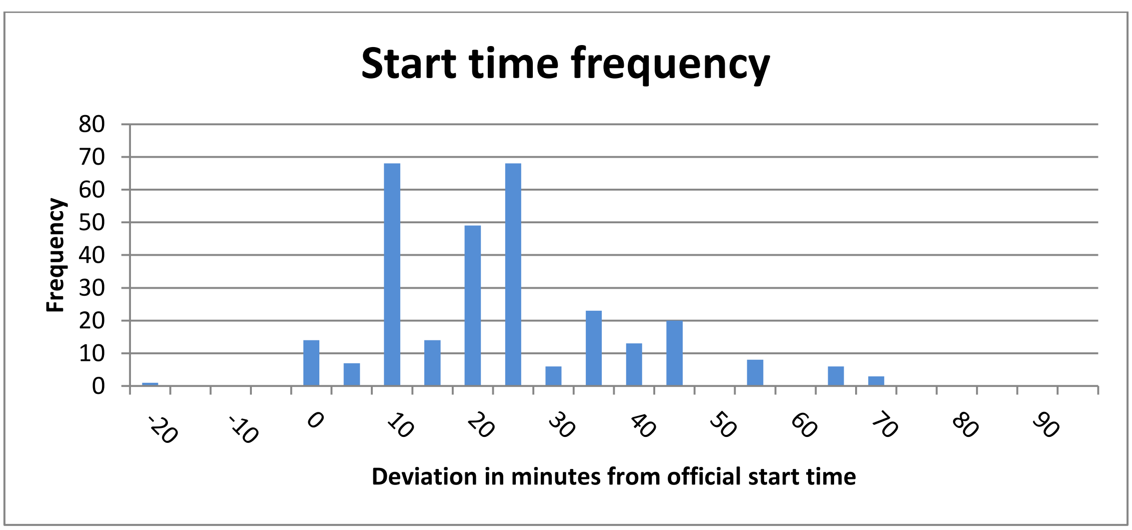

Figure 8: Start time frequency. N=297

This means that there is a deviation of schedule by on average 20 minutes and 50% of the OR days start after 8:17 and 8:47 on Fridays.

2.3.2.2 End time of an OR day

To measure the end of an OR day we looked at the data and subtracted the actual end time of the OR from the official this time. During our stay in the OR department something particular occurred, namely the official end time of the OR is 16:00, but the target time for the nurses is 15:30. That is the case because otherwise they have to clean up the OR themselves since the cleaners are already off duty from 15:30. The nurses work day ends also at 16:00 and in the last half an hour they have to clean the instruments used in the last surgery and make sure everything is in order to start the next day. So we used an official end time of 15:30 to compare with our data.

The following graph shows the end time in a cumulative graph relative to the end time taken at 15:30.

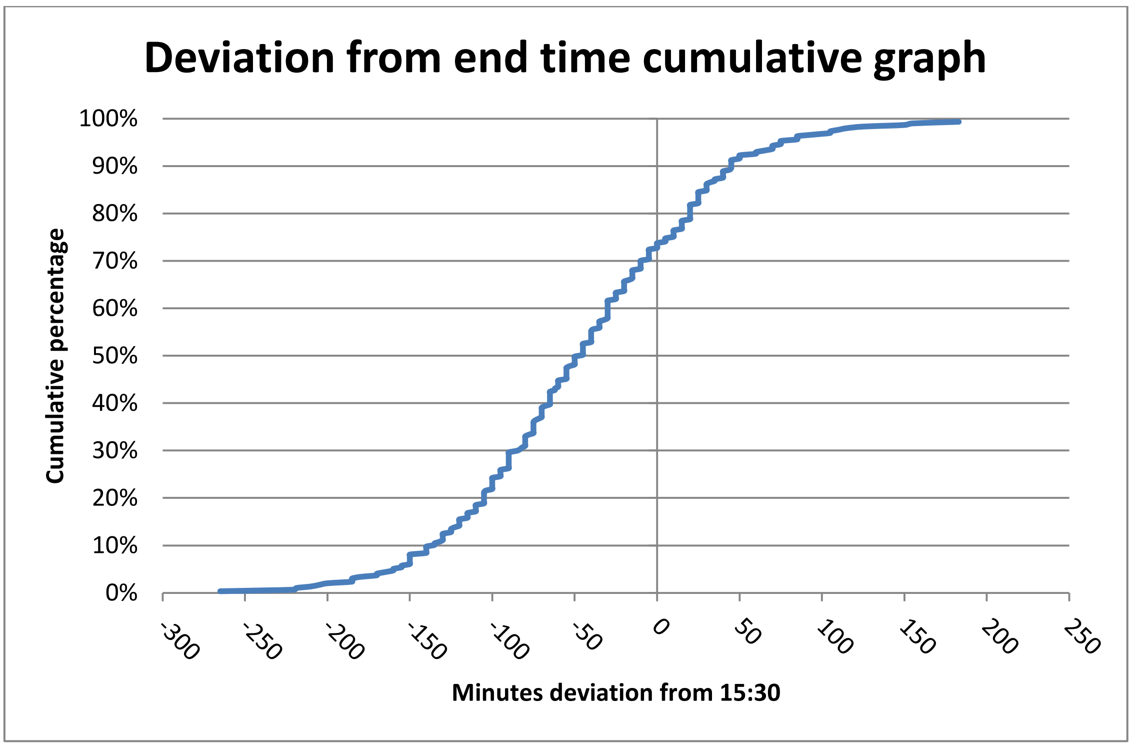

Figure 9: Cumulative graph of overtime and early finish. N=297 σ=74.5

The graph shows that 73% of the surgeries ended within time. The area left to zero below the blue line gives the degree of improvement possible when certain processes would not be subjected to chance and variability.

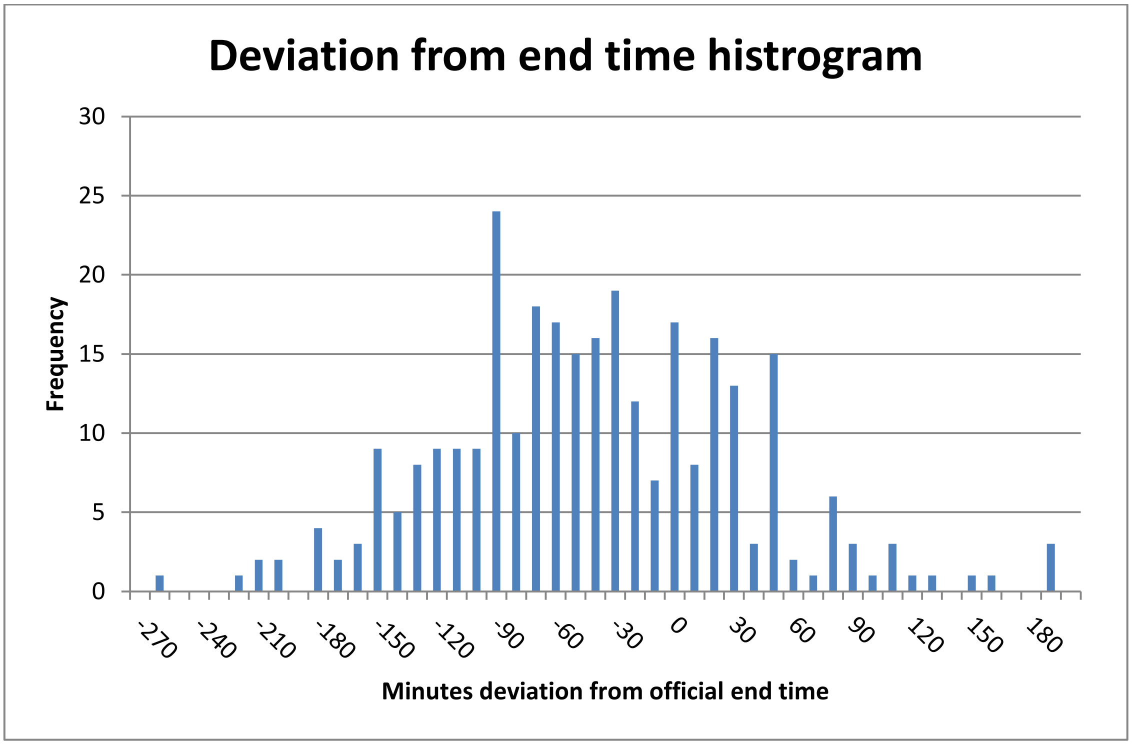

Figure 10: frequency of end time N=297

Looking at Figure 10 we see that the end time is normally distributed. The mean and the median are also almost the same at -44.5 minutes and -45 minutes. This means that the OR is on overage 45 minutes to early ready with surgery. Which confirms the suspicion by the head of department that there is still room for improvement in the OR department.

Just to show what the difference is between 15:30 and 16:00 end time cumulative graph this is shown in Figure 11.

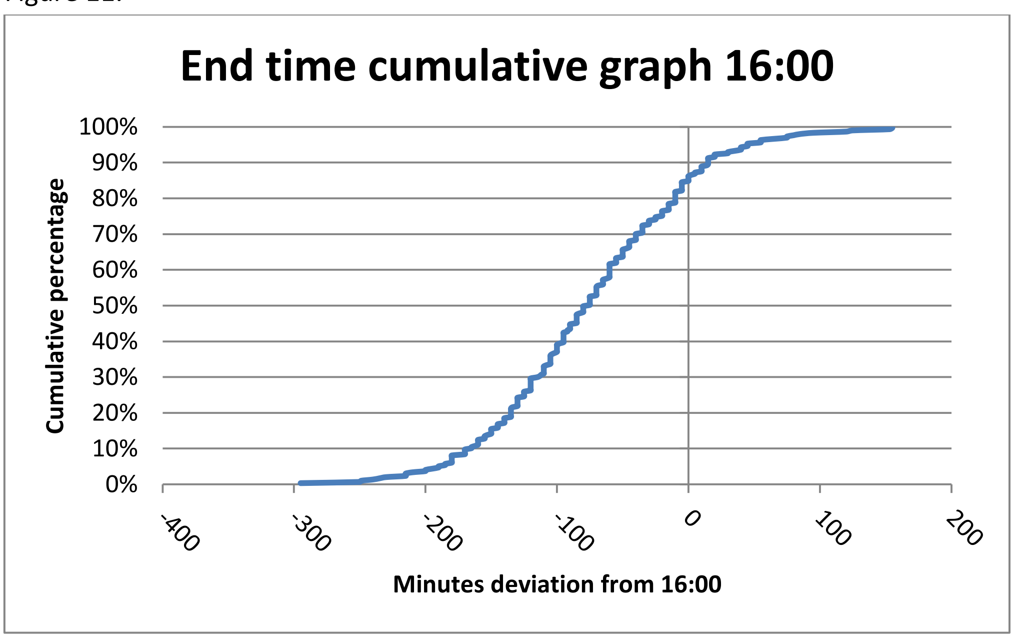

Figure 11: Cumulative graph with deviation from official end time N=297

This graph shows that 85% of the surgeries finish within time and shows an even larger area for improvement.

The start time of a day and the end time of a day are not the only measurements which can be taken. Also the changeover times can be looked at. The changeover times will be described in the next section.

2.3.2.3 Changeover time

As described in section 2.3.1 the changeover time from one surgery to the other is also deducible from the data logging. The following graphs shows the changeover times for the different specialties. This is done because when there is one orthopaedic performing surgery the patients are already prepared for surgery in the other OR.

The changeover times of Gynaecology are shown in Figure 12.

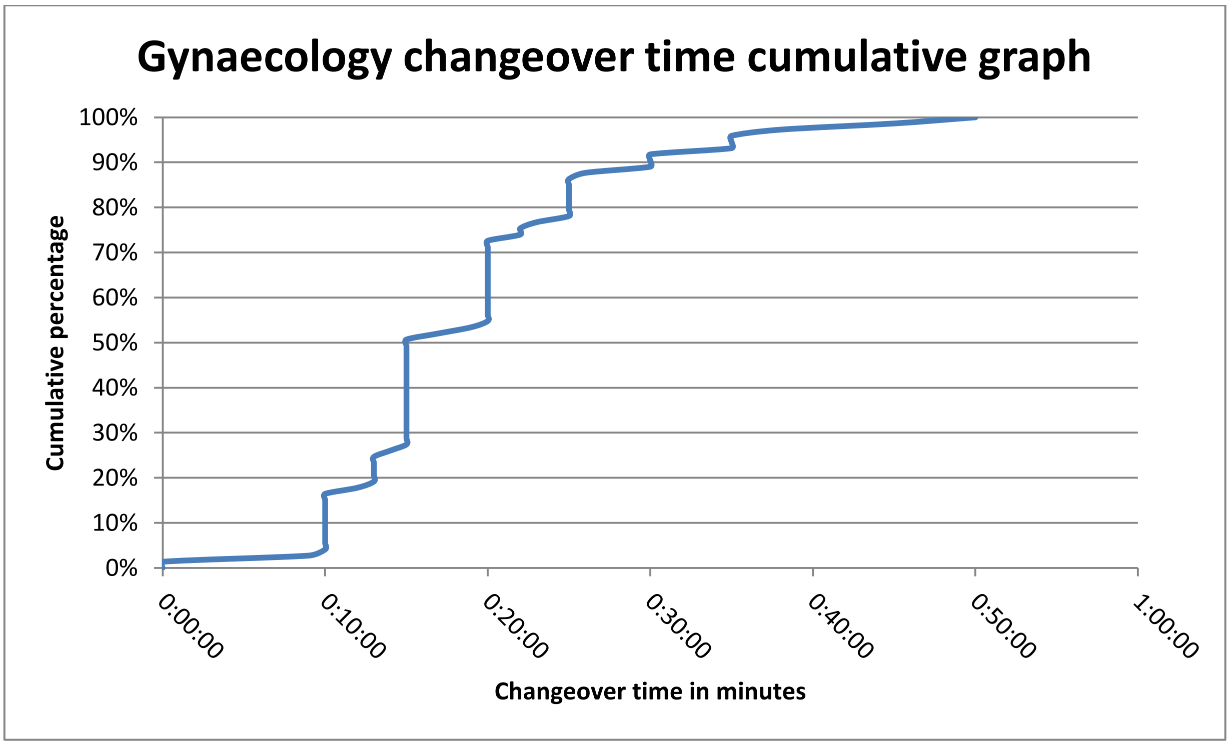

Figure 12: in between surgery time Gynaecology N=73 σ=8.5

The histogram of the changeover times of gynaecology is shown in Figure 13.

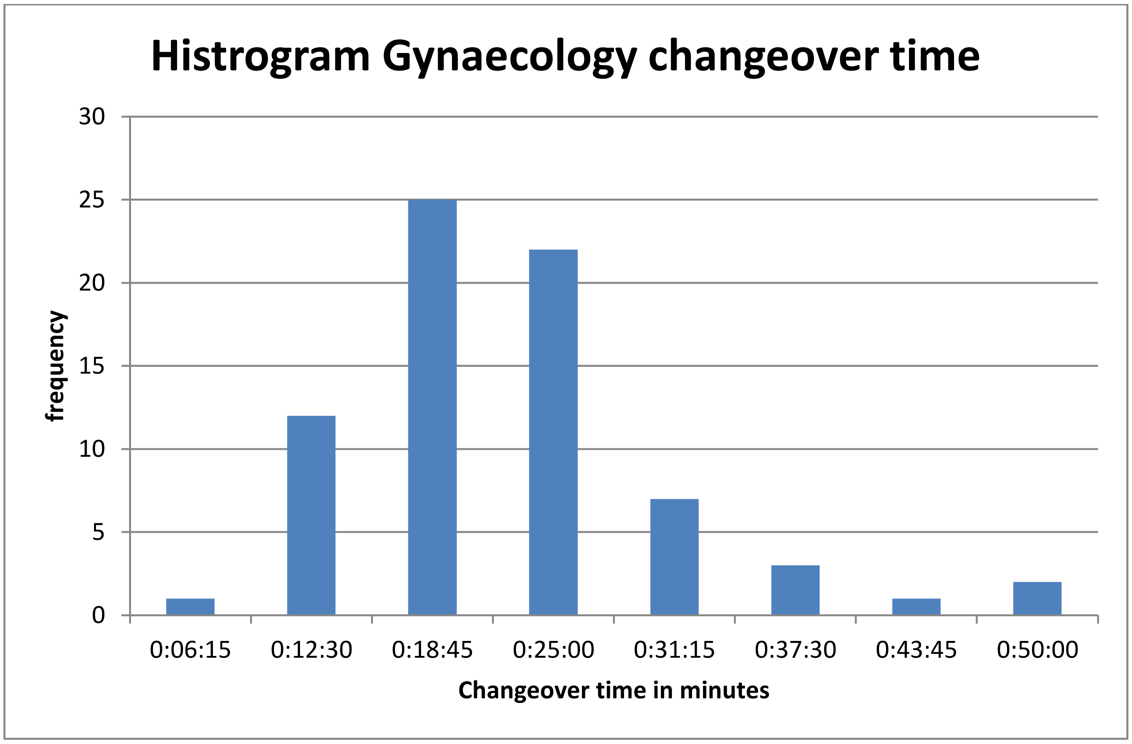

Figure 13: Frequency Gynaecology N=73

The mean of the changeover times is 18:56 minutes and the median is 15:00 minutes.

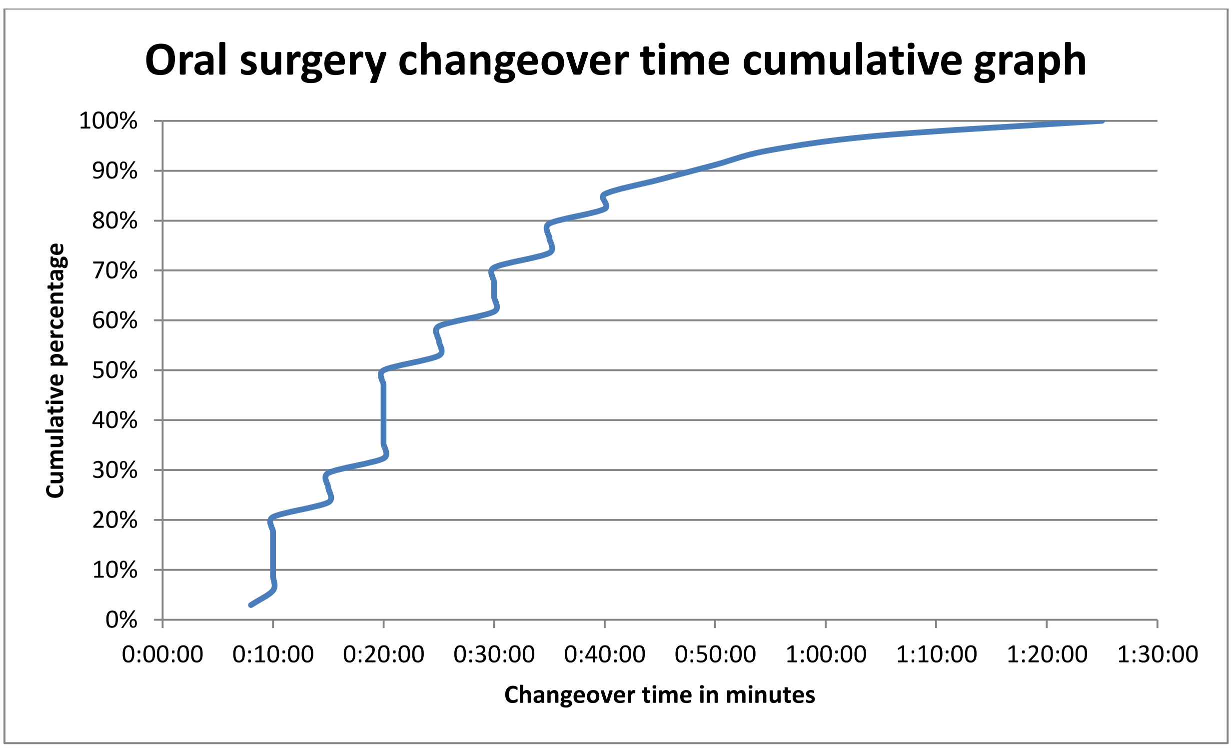

Figure 14: Cumulative graph of in between surgery time Oral surgery N=34 σ=17.3

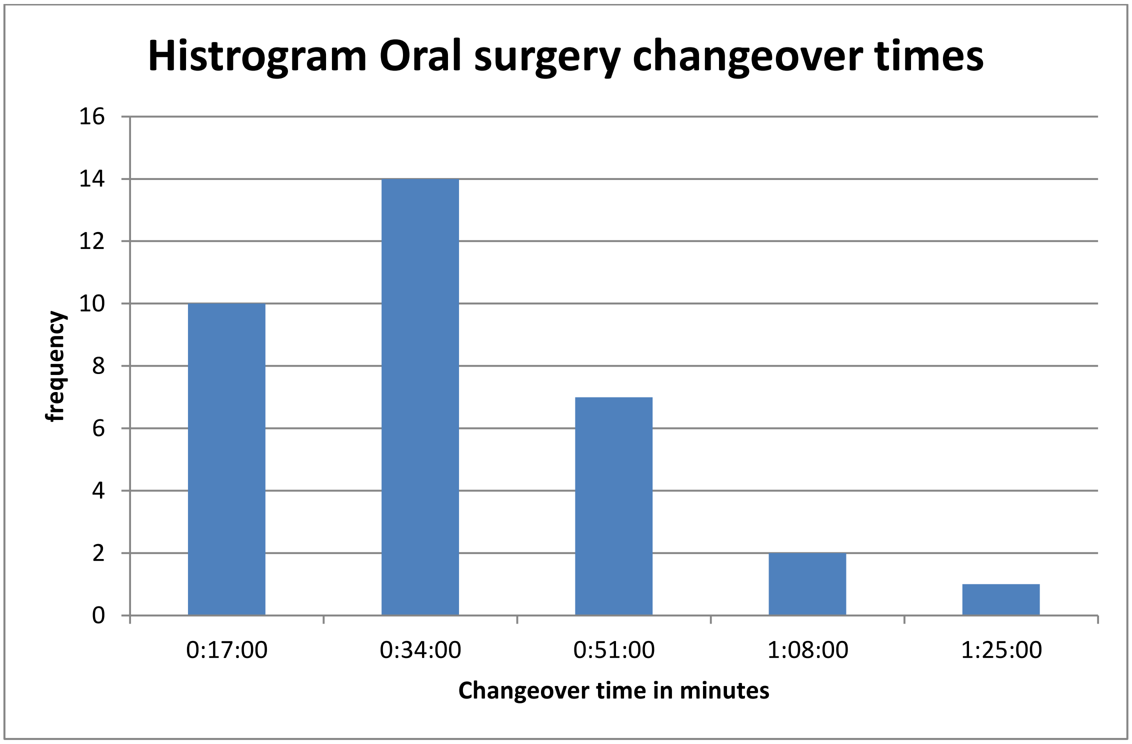

Figure 15: frequency changeover time Oral surgery. N=34

The mean changeover time is 27:26 minutes and the median of the changeover time is 22:30 minutes.

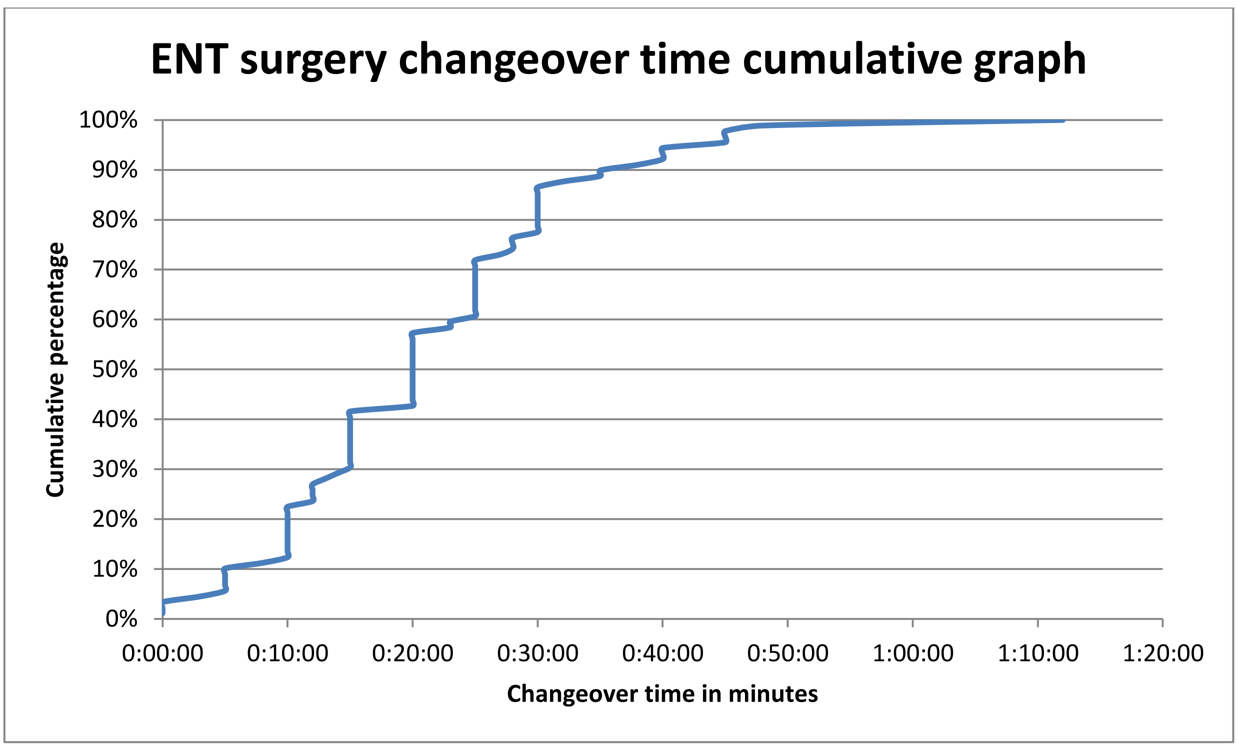

Figure 16: Changeover time ENT surgery. N=89 σ=12.2

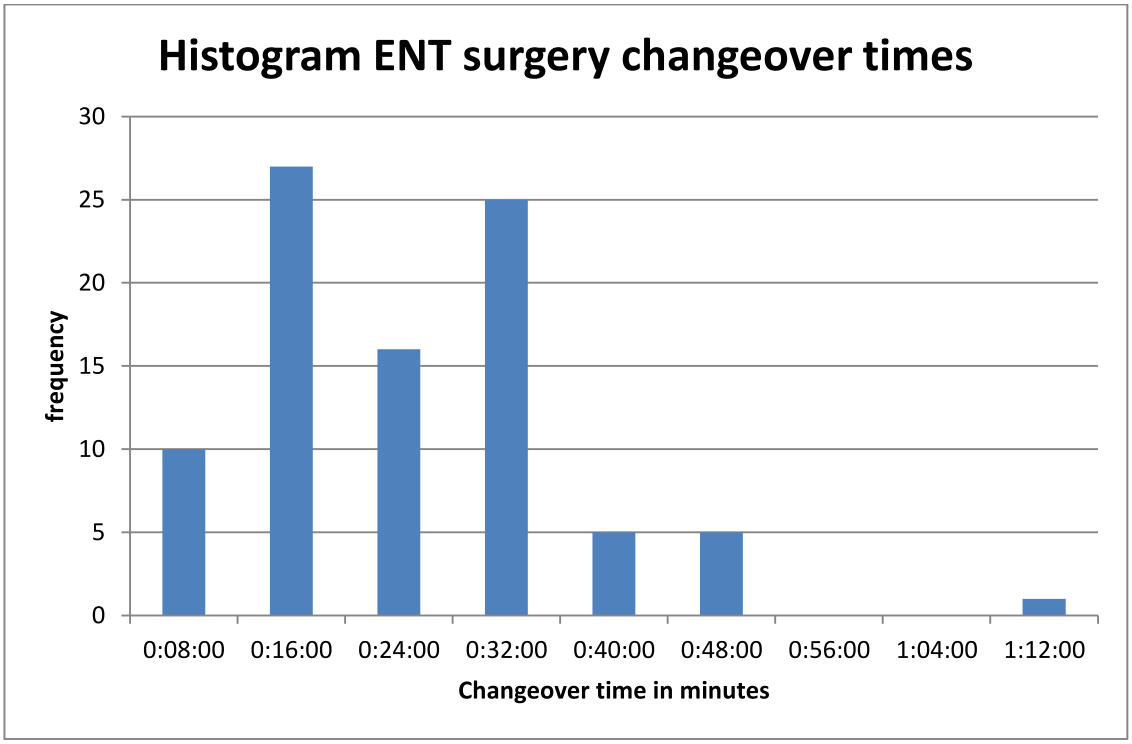

Figure 17: frequency in between surgery time ENT surgery. N=89

The mean changeover time is 21:03 minutes and the median lies on 20:00 minutes.

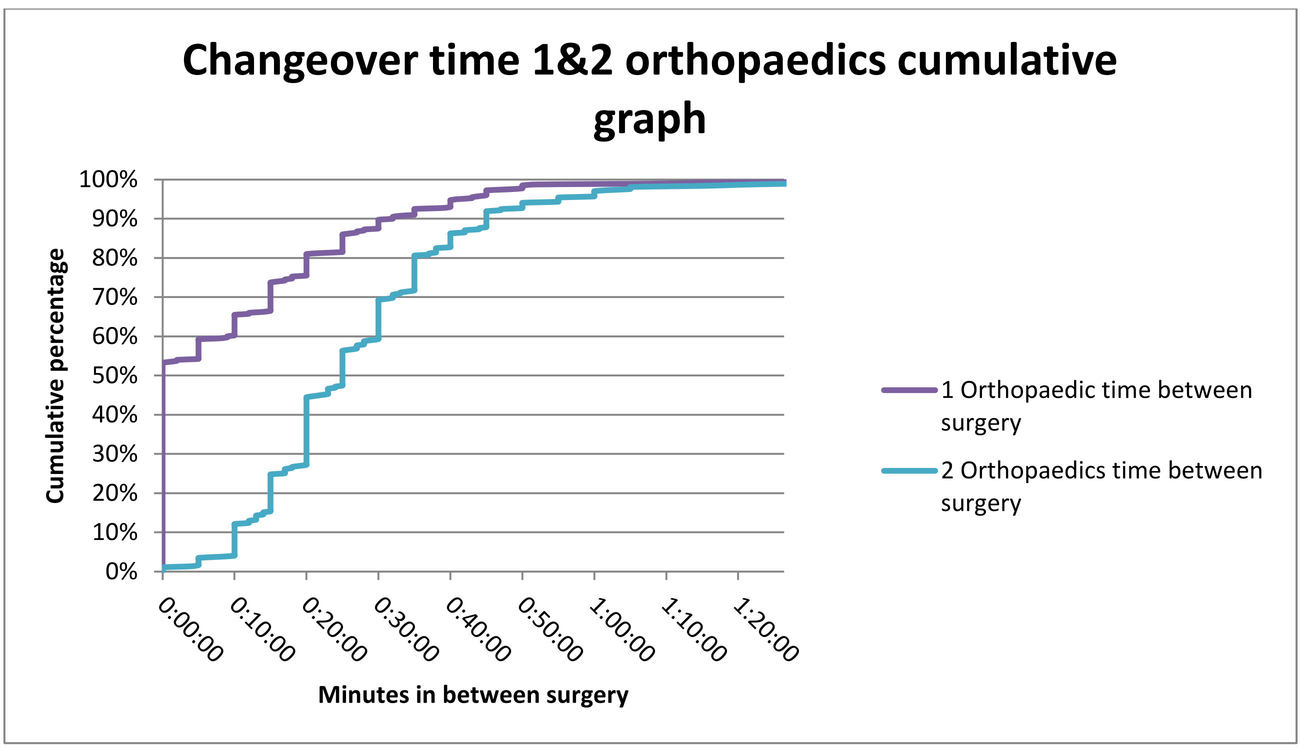

Figure 18: Changeover time for 1&2 Orthopaedics. One orthopaedic: N=398 σ=15.0. Two orthopaedics: N=372 σ=15.1

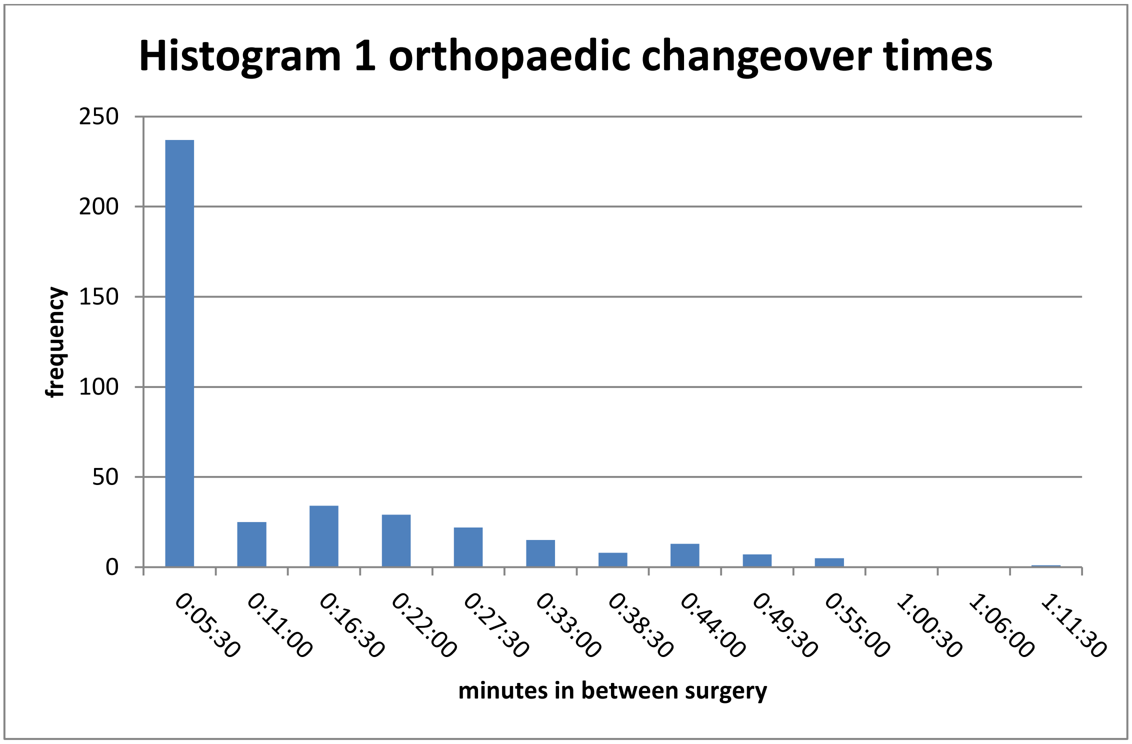

Figure 19: frequency changeover time 1 orthopaedic. N=398

The average changeover time for 1 orthopaedic lies at 10:14 minutes and the median at 0:00 minutes. A time of 0 can occur since the orthopaedic surgeon switches between ORs and the next patient is already prepared in the second OR so preoperative time is negative, and the two surgeries overlap.

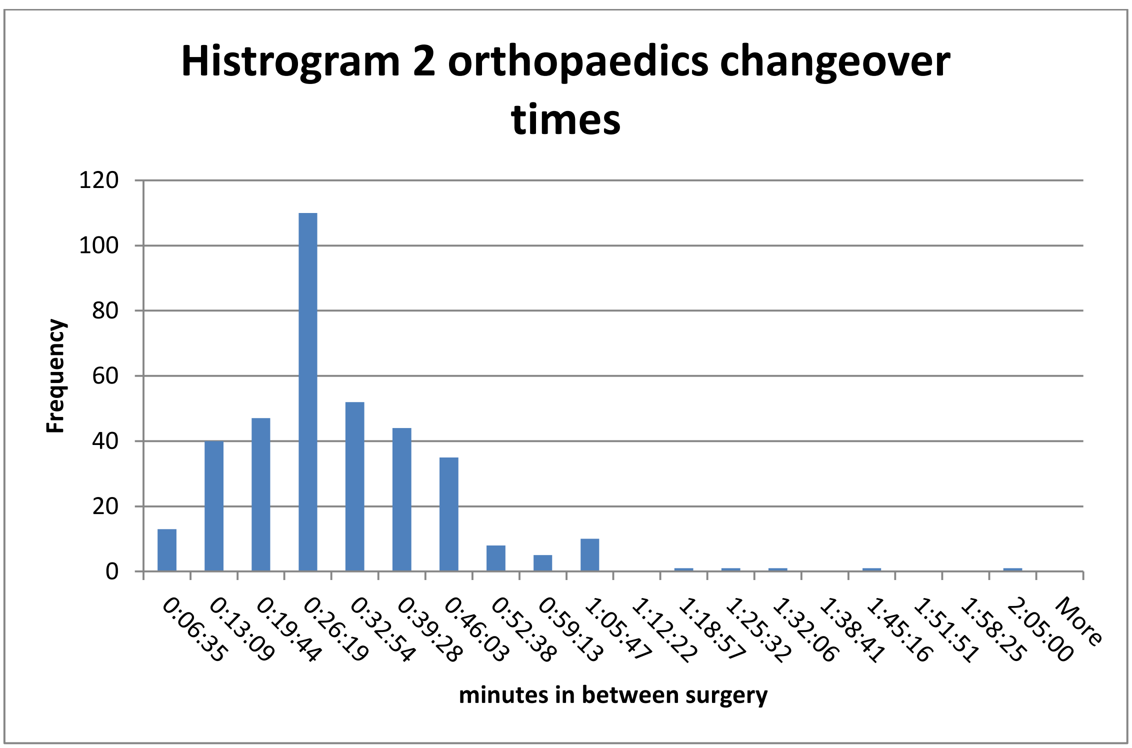

Figure 20: frequency changeover time 2 orthopaedics. N=369

The mean in changeover time when two orthopaedic surgeons are working is 26:56 minutes and the median lies on 25:00 minutes. The graph with two orthopaedic surgeons is completely different from the graph with one orthopaedic because with one orthopaedic the patient is already prepared in the other OR and then the surgeon walks to the second surgery when he finishes the first surgery. With two orthopaedic surgeons at work this practice is not done. Sometimes not even possible when ENT or oral surgery is performed in the third OR.

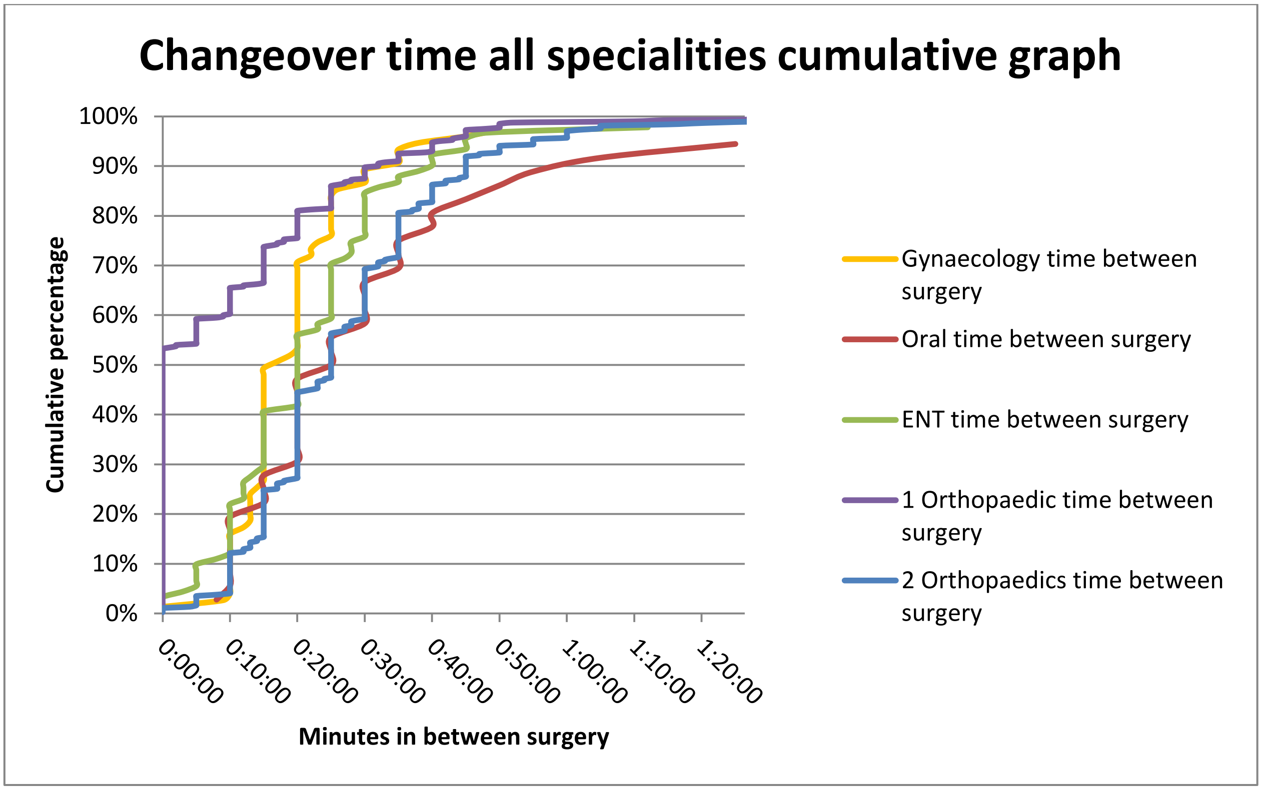

Figure 21: In between surgery time all specialties

The graph above shows the changeover times for all the specialties and shows the difference between one or two orthopaedic surgeons. Something remarkable is that the situation with one orthopaedic is the best performing situation and the situation with the two orthopaedic surgeons is the least favourable.

2.3.3 Utilization rates per specialty

The overall utilization rate is calculated as the time that a patient is in the OR and the nurses and surgeons are operating on the patient. Surgeries which happen in overtime are counted until the end of the workday. We took this time as 15.30 because of the earlier described target time by the nurses.

Specialty	Utilization rate	n	σ
2 Orthopaedics	72,6%	104	16,3%
1 Orthopaedic	86,1%	124	12,1%
Gynaecology	76,4%	16	7,7%
Oral surgery	67,5%	28	11,1%
ENT surgery	57,7%	24	12,4%

Table 1: utilization rates per specialty

2.4 Bottlenecks

To decide which problems occur in Røros Sykehus we made a problem tree. This tree shows the causal relations between problems which occur and is made according to the ABP by Heerkens (2004). The causal relations show also which factors influence each other and which influence the main problem, which was posed by the head of department. The problem tree is made based on the conversations we have had with the surgery nurses, anaesthesia nurses, the surgeons and the financial advisor. This left us with a scattered view of all the problems which occurred within Røros Sykehus. We brought this together in the problem tree. In figure 22 we will also explain the problem tree and in section 2.5 we will give our scope for the rest of this report and which problem we picked to solve.

2.4.1 Problem tree

An extra note about the problem tree is that it also describes problems outside the scope stated in section 1.4.2.

The description belongs to figure 22. The main problem mentioned by the head of department was negative profitability. Negative profitability is divided into two parts. High costs and not enough earnings. Both are a reason for the negative profitability.

Problems which influence not enough earnings are: a different amount of patients recorded than are actually logged in the operating room schedule. This is a problem which exists between the Røros Sykehus and St. Olavs Hospital in Trondheim. The difference is not substantial; the difference is a few patients per month. This problem seems to be more of an administrative matter. Another cause of not enough earnings is the fact that the case mix has changed from patients which were mixed patients between inpatients and outpatients to only outpatients. This is due to the fact that a lower DRG (diagnose related group) points is acknowledged for these surgeries.

Fewer patients than expected is a cause for lack in earnings. Partially this is caused by the high cancellation rate of patients before surgery and partially because there are not enough patients on the waiting list.

Not enough patients on the waiting list has three causes. A problem occurs when surgeons visit Røros Sykehus from the hospital in Trondheim to work there for a few weeks, but don’t bring their own patients along, mostly because they are specialised in for example hip replacement. These operations are inpatient surgeries and therefore too extensive for Røros Sykehus. Since the surgeon is specialised in hip replacements he doesn’t bring along a lot of patients.

Another problem occurs with the distribution of patients between hospitals. The government organisation (Helse Midt-Norge) buys operating capacity from private hospitals in order to reduce the waiting lists. The private hospitals prefer patients which are the most profitable for them, therefore leaving the more costly and high-risk patients to the government owned hospitals.

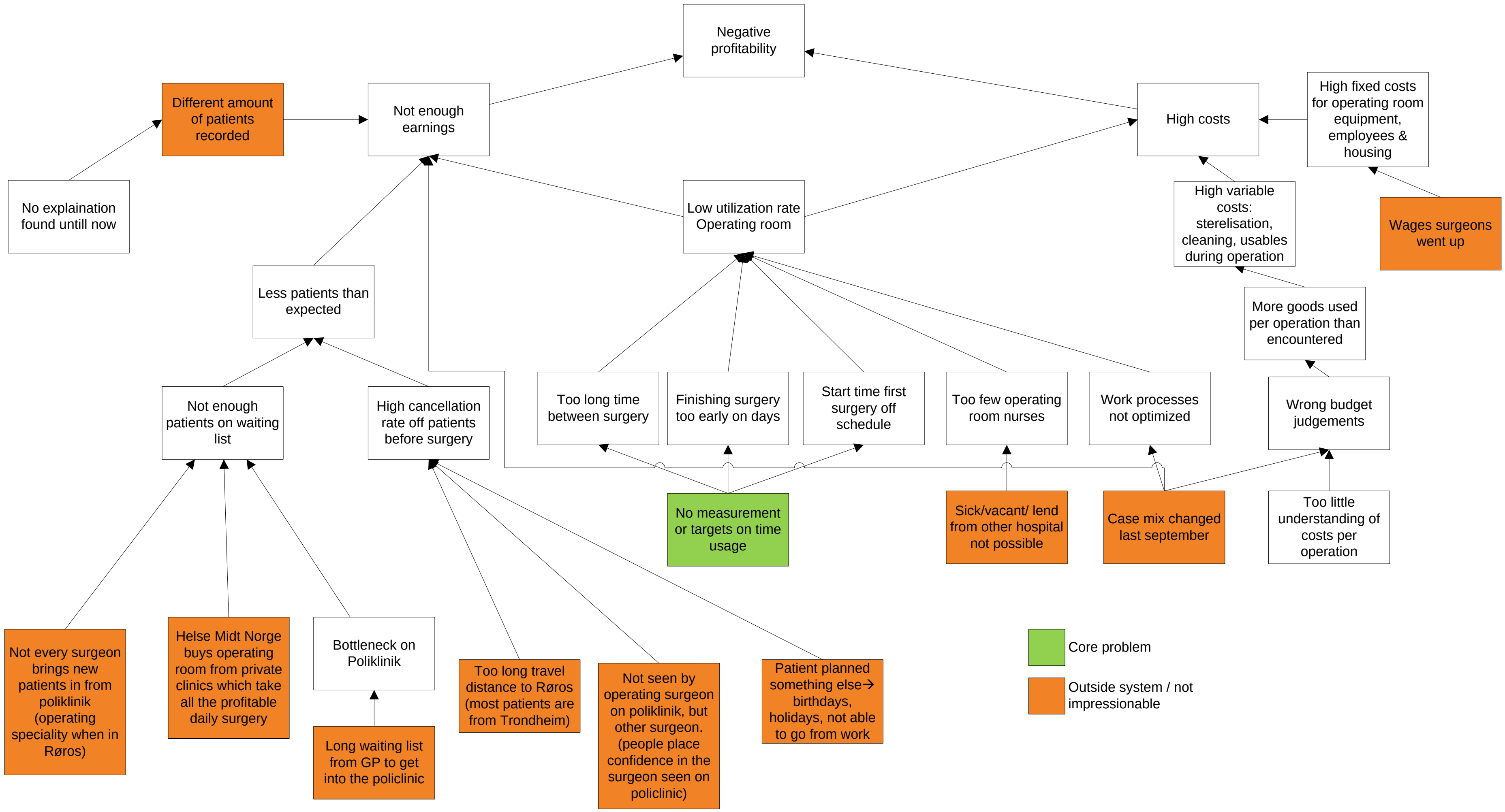

Figure 22: Problem Tree

One of the bottlenecks is the policlinic. There are long waiting lists to get from the GP to the specialist. But there also still exists a waiting list after the policlinic to get surgery. In St. Olavs Hospital they perform already more policlinics, which should solve the problem.

The high cancellation rate by patients is caused by a few factors. The first to name is the travel distance between Røros Sykehus and Trondheim. Most of the patients are from Trondheim and have to travel 160kilometers to Røros to be operated. The patients are not able to travel this far distances, find it to costly or don't like the fuss and cancel their operation and wait for their surgery to happen in Trondheim.

Another problem is the preference of patients; they place confidence in the surgeon they have seen at the policlinic. Therefore they cancel their surgery when they will not be operated by another surgeon than they met at the policlinic.

Other reasons are also mentioned, like: birthdays, holidays, work related obligations and other reasons to cancel surgery.

High costs is displayed at the right side of the figure and is influenced by three factors. The high fixed costs of the operating room equipment, employees and housing. One of the causes for the increased high fixed costs is the increased wages of last year.

The other cause is the high variable costs, a few factors of variable costs are sterilization, cleaning and disposable goods used during surgery. These costs are high because there were more goods used per surgery than encountered. This was due to wrong budget judgements made last year. The cause of the wrong budget judgments were partially because the case mix of patients changed and partially due to too little understanding of costs per surgery.

High costs and not enough earnings are both influenced by the low utilization rate of the operating room. The low utilization rate of the operating room can be divided in multiple factors: too long time between surgeries, finishing surgery too early on some days, start time of first surgery off schedule, too few operating room nurses, work processes not optimized. The work processes which are not optimized because of the new operating rooms which were built just before the case mix changed and because the case mix has changed to only daily surgery. There are also too few nurses; most of the time they would prefer one or two more. The hospital tried to fill this gap already but did not succeed. It is a problem for more hospitals in Norway and because Røros is close to the Swedish border they already tried to hire people from Sweden but they did not succeed until now.

The long durations between surgeries, finishing surgery too early on a day and the off schedule start time of the first surgery is caused by the fact that there are no measurements of these times and also no targets.

2.5 Conclusions and demarcation of scope

The problem tree looks at all the facets of the framework stated in section 1.4.2. The problem tree also includes problems which would be immediately marked as outside of the scope stated in section 1.4.2. However the problems stated in the problem tree are all up for debate. We marked a few orange which means they are out of the system. This means either they are not impressionable or they happen outside Røros Sykehus. The problems which are left are the timing in and around the OR and the lack of understanding the budgeting of the materials. In our opinion choosing the problem of the lack of measurements and target times is the most promising one to solve. It influences both the earnings side due to the DRG payment system and also the costs by making less use of the costly resources.

The other problem of the wrong budget judgements could also be solved. It seems that it does not solve the core of the problem namely the high costs, it only makes the causes of what the high costs caused comprehensible or it would provide us with the answer of how to judge future costs. This does not help when the costs are still too high.

To demarcate the scope of the further research we look at the framework and see that the problem stated fit in the offline operational planning from the hierarchical decomposition point of view and in the field of resource capacity planning from the managerial point of view.

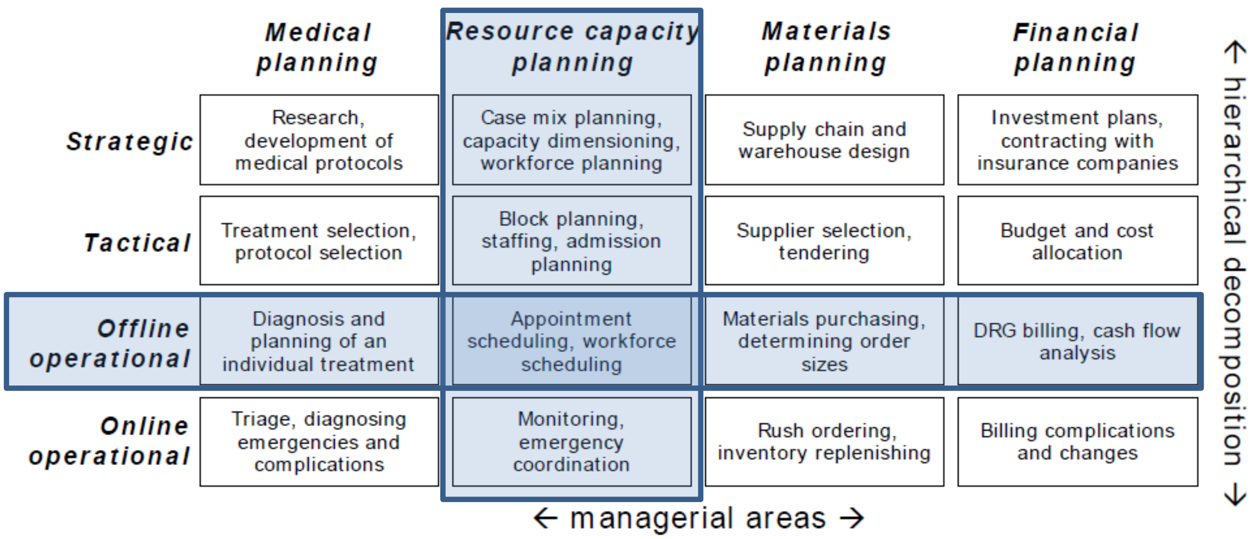

Figure 23: (Hans, Houdenhoven, & Hulshof, 2012)

In chapter three we will describe the desired situation and also some theory around the offline operational planning. The main problem we focus on is the performance of the OR and in special the planning of the surgeries. Furthermore the hospital wants to know what improvements would yield. This is done by simulating the improvements in a simulation study. The desired situation will be simulated and a prediction is given on the improvements.

Chapter 3. Desired situation & literature

In this chapter we will discuss the desired situation. In section 3.1 we will discuss the start time of the day and the end time of the day and what would be the ideal situation. In section 3.2 we will discuss the desired time frames of the OR.

3.1 Desired utilization rate

The desired utilization rate for the head of department is to maximize the OR utilization to the total capacity. The problem with this is that this creates a lot of over time due to the variability in the processes. This can also be seen in the graph that represents the end time of the OR day, presented in Figure 9.

According to McQuarrie (1981) it is not realistic to schedule to 100% because of the non-uniform length of procedures and the non-repetitiveness. McQuarrie also suggests that with selective algorithms the OR utilization should be above 60% and sometimes could exceed 75%. This article is from 1981 and there has been a lot of improvements in the OR scheduling research. According to Cardoen et al. (2010) there has been an extensive interest in OR room planning and scheduling with also the focus on utilization rate. The number of reports published after 2000 is almost as extensive as the number since the 1950's to 2000. According to Ballard & Kuhl (2006) a maximum capacity for the Orthopaedic surgery could yield 88.6% which is much higher than the current situation in Røros Sykehus.

3.2 Desired time frames

From the point of view of desired time frames we divide this into three parts, namely the start time of surgeries on a day, the changeover times between surgeries and the end time of the day.

The current start time of the surgeries is off schedule with an average of 20 minutes. The ideal situation is that all surgeries start at 8:00 or 8:30 on Fridays. There are several suggestions made by Does et al. (2009) of which the most important was the planning and scheduling process. Also visualisation of the week before the current week did improve performance and yielded more on time starts of surgery (Cardoen, Demeulemeester, & Beliën, 2010).

The question is whether changeover times could be further reduced. The ideal situation is when there would be no time needed to prepare the next surgery and just start with the new patient in another OR. When there is no other OR available the ideal situation would be that the only changeover time would be the cleaning of the OR. During our stay in the ORs we measured the time and this varies between 6 to 15 minutes, with an average of 10 minutes. This is more than the current changeover time of 19-27 minutes depending on the specialty.

The end time of the surgery would preferable be one straight steep line at 15:30 or 16:00, but this is not possible. At the moment there are no measurements at Røros Sykehus to plan the surgery to a certain degree and accept a certain percentage of overtime. At the moment Røros Sykehus estimates that they have approximately 30% of overtime claimed by the employees. The desired situation for Røros Sykehus is an increase in the number of patients while maintaining or reducing the current overtime measured.

3.3 Reduction of variability

A surgery always has certain variability and is less predictable than a pre-programmed machine which does the repetitive tasks for you. The ideal situation would be to have no variability. That is not achievable since the tasks which are performed in the OR are not predictable enough and since it is done by humans. There is however a possibility to reduce the variability. This is described by Hans et al. (2008) as the portfolio effect when slack is planned to reduce overtime. Hans et al. also suggests to plan slack in order to reduce the risk of overtime, or at least to manage the overtime.

3.4 Interventions to attain the desired situation

To achieve the desired times at the OR room we will simulate the current situation and simulate whether planning and scheduling of the OR room would improve the utilization rate and reduce overtime. The question is also whether better scheduling would achieve better performance or that the current scheduling and planning policy already is sufficient for Røros Sykehus. Also the question is what improvement could be yielded by reducing the time needed per surgery. They do not have a clue what their maximum capacity is and what would for example be the overtime when they would plan more surgeries.

To attain the desired situation first a simulation model is built to predict the current situation and what the changes in overtime and utilization rate would achieve. After the simulation study an implementation group will be formed to look how the improvements are actually implemented.

3.5 Conclusion

In order to judge whether better planning of the OR room in Røros Sykehus is possible a simulation model is build. In this model there it is possible to see whether overtime can be reduced and which utilization rate is achievable with the current case mix. Also interventions can be simulated in this model. This will be done in chapter 4.

Chapter 4. Simulation & Results

In this chapter we will pose the problem definition once again but more in the direction of the simulation study. In section 4.1.1 we explain the goals which we want to achieve by making use of the simulation model. In section 0 we will explain the model used to simulate and in section 4.4 we will discuss the results of the simulation.

4.1 Problem definition for the simulation model

The problem definition from chapter 2 and the research question.

What is a representative way to build a simulation model for Røros Sykehus in order to predict the performance and overtime.

4.1.1 Goals to achieve by simulating

The goals we want to achieve with this simulation model are:

- To predict the utilization rate with the current case mix for a different number of patients;
- Predict overtime and with which number of patients this occurs;
- Judge whether planning algorithms could improve performance;
- Judge what the benefit would be of improvements in time per surgery.

4.1.2 Restrictions

One of the limiting factors is that the patients are all outpatient. This means that the patient can not be checked the day before in order to be sure the patient is fit enough for day surgery and that there are no other complications. Furthermore is it not possible to extend the number of ORs or to reduce the number of surgeons. These strategic choices have been made and will shape the scope in which this simulation study has to take place.

4.2 Model design

In order to make an appropriate model we looked again at the framework by Hans et al. (2012). As presented in Figure 1 the framework distinguishes strategic, tactical, offline operational and online operational levels. The strategic level involves the planning of the number of ORs which are opened and the case mix planning. Also the number of employees per OR are stated. With the tactical level the specialties and specialists are assigned to the ORs. Furthermore, with the tactical level the master surgical schedule (MSS) is determined. This schedule defines on which days certain specialties are allowed to operate in which OR. On the operational level single patients are assigned to the specific ORs of their surgeon.

We used the program “OR manager” made by E.W. Hans of University of Twente for the simulations. A screenshot of the program is presented in Figure 24.

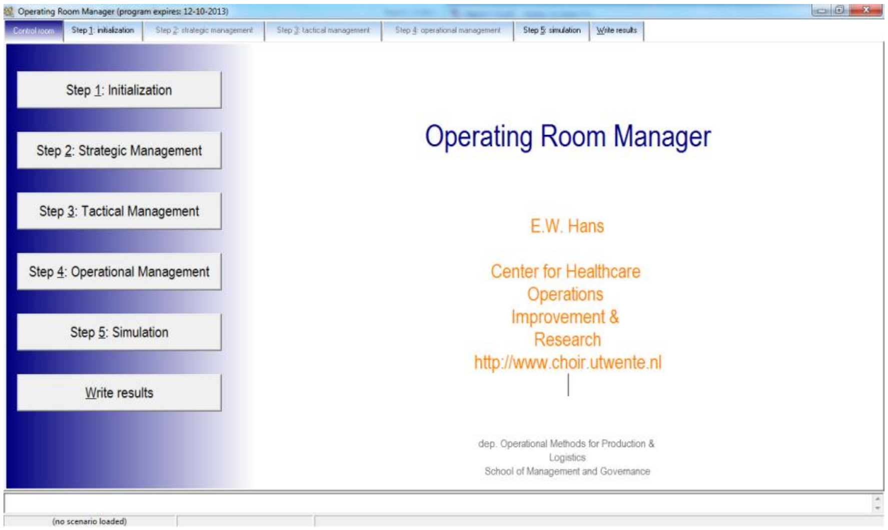

Figure 24: OR room manager, the simulation software

4.2.1 Specification of the model

A paper model on how the surgeries are performed can be found in the process overview in Figure 3. We will simulate and plan these processes. The scope to which extend we are going to simulate these processes shown in Figure 3 is determined by the framework of Hans et al. (2012).

In order to build the model we need to acquire data. On the level of strategic management we need to know which kind of patients the case mix constitutes of. We need to know the opening hours of the OR and the number of nurses per surgery and the number of anaesthesiologists. But we also need to know which kind of surgeries are exactly scheduled and which surgical cases the case mix constitutes of and what kind of statistical distribution they have. How we will acquire this data is described in section 0. At the level of tactical management we need to know the master surgical schedule. At the operational level we need to know how the current surgeries are planned and what makes a surgeon change the schedule if done so.

4.2.2 Data collection

Strategic management: this data is collected during our stay in Røros Sykehus and through observations and talking to employees such as the surgeons, anaesthesiologists, surgery nurses, anaesthesia nurses and ward nurses. Also the head of department is involved in the data collection.

For the master surgical schedule we asked the surgeons what their planning was, which they make half a year in advanced, and looked at the historic data. Furthermore we looked at when people start their working day and when certain processes start. This data collection is done during our stay in Røros Sykehus.

For the operational level and also the tactical level we have to know exactly which surgeries are performed and what the statistical distributions of these surgeries are. We subtracted this data from the historic data. This data was available and also already used in Chapter 2 to calculate the performance measures. This data also provides us with the historic data for the MSS.

We subtracted the data from the 13th of September 2010 until the 31st of May 2011. This data is reliable enough since it is recorded according to the clear protocol (Helse Midt-Norge, 2010). During our stay we observed whether the nurses did comply with the procedure. All of the recorded cases were appropriately registered during our stay. Since this is a protocol we assume that the rest of the historic data also is reliable.

We cannot use more historic data since the case mix was changed in September 2010. Older historic data might also be less reliable since the time logging protocol is introduced in 2010. Therefore we used this data in the simulation.

4.2.3 Construction of the model

The construction is done based on the tabs of the program which correlate with the area's in the framework.

4.2.3.1 Strategic management

The case mix has been analysed and there are four specialties. In the historic data we have found the following percentages for the patient volume:

- Orthopaedic surgery 78,6%
- Gynaecology 7,4%
- Oral surgery 4,8%
- ENT surgery 9,2%

Furthermore we subtracted the surgeries from the data and gave them a statistical distribution. The different surgeries can be found in Appendix A. ~~In which~~ 52 different surgeries were differentiated based on their surgery coding which was logged in the raw data. From the surgeries which are performed more than five times the statistical distribution was determined. As suggested, whenever the fit was best we used the log-normal distribution (Strum, May, & Vargas, 2000) and when possible the normal distribution. Sometimes a Gamma distribution did best fit the data. The way of logging in Røros Sykehus differentiates between the pre- and post-operative process and the actual surgery. The program does not have the option to differentiate between these times. The question is also whether this is of influence because the kind of patient also influences the perioperative procedure.

All the surgeries which were performed less than five times were aggregated to their specialty and a distribution fitted over the data. They are not marked by an operation code but by vergyn, verkje, veronh and verort. This abbreviation is a combination between two languages and two abbreviations, namely the Dutch abbreviation of collection and the Norwegian abbreviations for the specialties. The other distributions are presented in Appendix A: Surgery distributions. In Appendix B: Surgery description per operation code is given in Norwegian.

One of the other settings are the opening hours of the OR. The choice has been made not to schedule a lunch break but to subtract a half an hour from the end time of the day. This is because the lunch break scheduling kept giving errors and this yields the same result. So in the simulation model the days are from Monday to Thursday from 08:00 to 15:00 and on Friday from 08:30 to 15:00.

4.2.3.2 Tactical management

On the tactical level we had to construct a scheme which surgeon would operate on which day. We extracted this based on the historic data. This has lead to a repetitive schedule of 12 weeks, which we have repeated 4 times. This leads to a schedule with the following amount of OR days per specialty:

Specialty	Historic OR days	Simulated OR days
Orthopaedics	79,1	80
Gynaecology	5,6	6
Oral surgery	9,7	9
ENT surgery	8,7	10

Table 2: Specialties with simulated OR days

The first numbers are not full numbers because the total number of OR days per specialty in the historic data is divided by the total number of weekdays and then multiplied by the number of weekdays in the 12 week scheme. This resulted in the best schedule to fit the 48 week which the OR is opened in a year in Røros Sykehus. Which day which specialty is performing surgery, with how many surgeons, can be found in Appendix C.

4.2.3.3 Offline operational management

In the offline operational management we have applied the level fit technique to schedule the initial amount of patients in order to make the overtime as low as possible and to distribute the patients as evenly as possible over the available ORs. In the offline operational management section the number of patients can be selected to simulate.

4.2.3.4 Online operational management

In the online operational management the simulations can be triggered. In this section based on the scheduled surgery distribution a number is drawn and this represents the actual surgery duration. The surgeons do not have to take into account emergency patients since they are not apparent in Røros Sykehus.

4.2.4 Verification & Validation

For the verification we extracted a lot of information from the model and tried to match this to the historic data. Also we calculated the number of runs needed for the simulation model. In each run different random numbers should be used. We should use the same simulation settings and counters on statistics should be reset. According to Law (2007) we can calculate the number of runs making use of the sequential procedure. The number of runs for the average utilization rate with a confidence level of $\alpha=0{,}05$ and $\gamma=0{,}025$ after three repetitive runs the model is sufficient. However when we look at the over time this number is significantly different. With a confidence level of $\alpha=0{,}15$ and $\gamma=0{,}15$ we need 200 runs. Therefore we took 200 as our number of runs. The model improves the standard deviation of the utilization rate but increases the average number of over time minutes.

Specifications	Historic information	N	σ	Initial model	N	σ
Utilization rate	75,2%	297	15,5%	75.3%	84000	10%
# Patients	1293 in 297 OR days			1828 in 420 OR days		
Average overtime	43 min	82	43,2min	56.5 min	37136	51,3 min
Avg. duration surgery:						
Orthopaedic surgery	76,7 min			75,6 min		
Oral surgery	128,04 min			128,8 min		
ENT surgery	53,7 min			50,3 min		
Gynaecology	59,8 min			63,0 min		

Table 3: comparison between historic data and the simulation model.

We also have discussed the model with the head of department and the employees. They accept the model as a representation of reality.

4.3 Experiments in the simulation

At first, the historic data is runned through the model and checked whether the model represents the reality. Furthermore we did a run at the initial model to know what the maximum capacity would be of the system.

Furthermore we looked what improvements would yield. For example, we wondered what happens when the time in between surgeries is reduced or the time within the surgeries. Also we questioned what happens when the time is reduced by 15 minutes and what happens when the time is reduced by 19 minutes. The graphs which simulated outcomes are presented in section 0. These graphs will show that a decrease in surgery time will get them at the wanted number of surgeries per day.

4.4 Results from simulation

The current situation is simulated and the overtime is displayed in a cumulative graph.

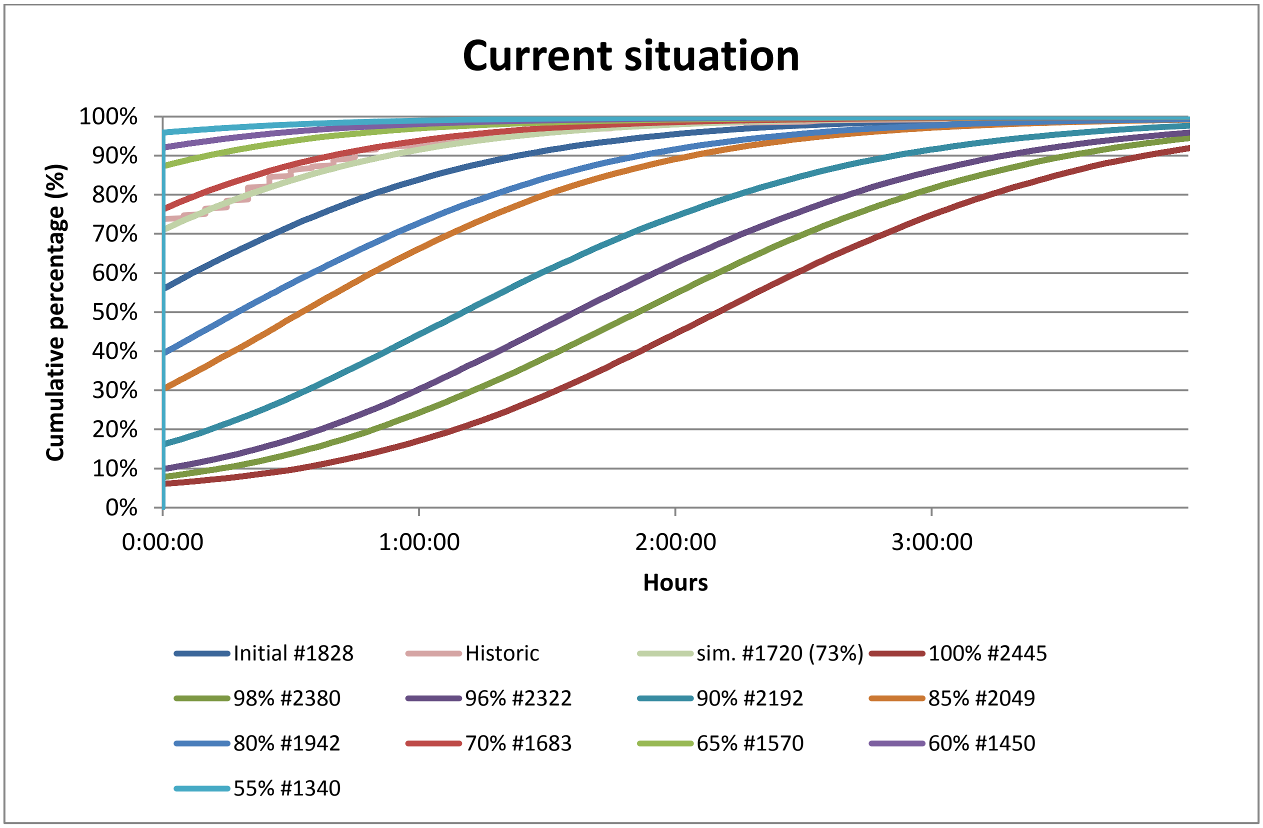

Figure 25: current situation with different utilization rates

The cumulative graph does not show early finishes as is shown in Figure 9 but it only shows the cumulative graph of the overtime. The historic data is presented also in Figure 25 in order to compare it to the simulated data.

In Figure 25 we can see the current situation in Røros Sykehus. The graph initial model represents the 1827 patients which we accepted as a plausible model. The question is why this model performs worse than the historic situation in Røros Sykehus. This is because, if one orthopaedic surgeon is operating in Røros Sykehus the in between surgery times are very often zero or are even negative because the preparations are already in progress in the other room. In the historic model in 16 out of the 84 days there is only one surgeon from which in 50% of the cases the changeover times are zero. In the simulation model we did not used a change over time of zero. By plotting the overtime of the simulation model and the historic data (figure 25) we looked which utilisation rate fitted the historic data. We found that 73% utilisation rate in the simulation model corresponds with the historic data.

It also shows that with their current practice the 100% capacity fill would deliver around 2445 patients, with the current amount of staff. This is not achievable due to the variability and the excessive overtime, but it will only suggest that the figure of 6 surgeries per OR day by the head of department is quite optimistic. 2445 patient in 428 OR days means 5.7 patients per OR day. Unless something changes this number is never achievable.

The other utilization rates just show a figure of how much overtime certain utilization would give. In our opinion a calculated maximum should be put on the overtime after which you should plan the patients to that maximum. When that maximum is reached, a trade-off has to be made whether opening another OR room with the costs of an extra surgeon is best or that it is cheaper to let the other ORs run more overtime.

4.4.1 Simulated improvements

What will happen when we would be able to erase 15 minutes in the perioperative process or in the time in between surgeries? This question is simulated in the program with the amount of patients of the original simulation. The utilization rate can in this case be seen as the number of simulated patients. Figure 26 shows the cumulative overtime graph of the 15 minutes improvement per surgery. It shows that between 1942 and 2049 patients can be treated with the same amount of overtime. This is a serious increase in the number of patients operated per year.

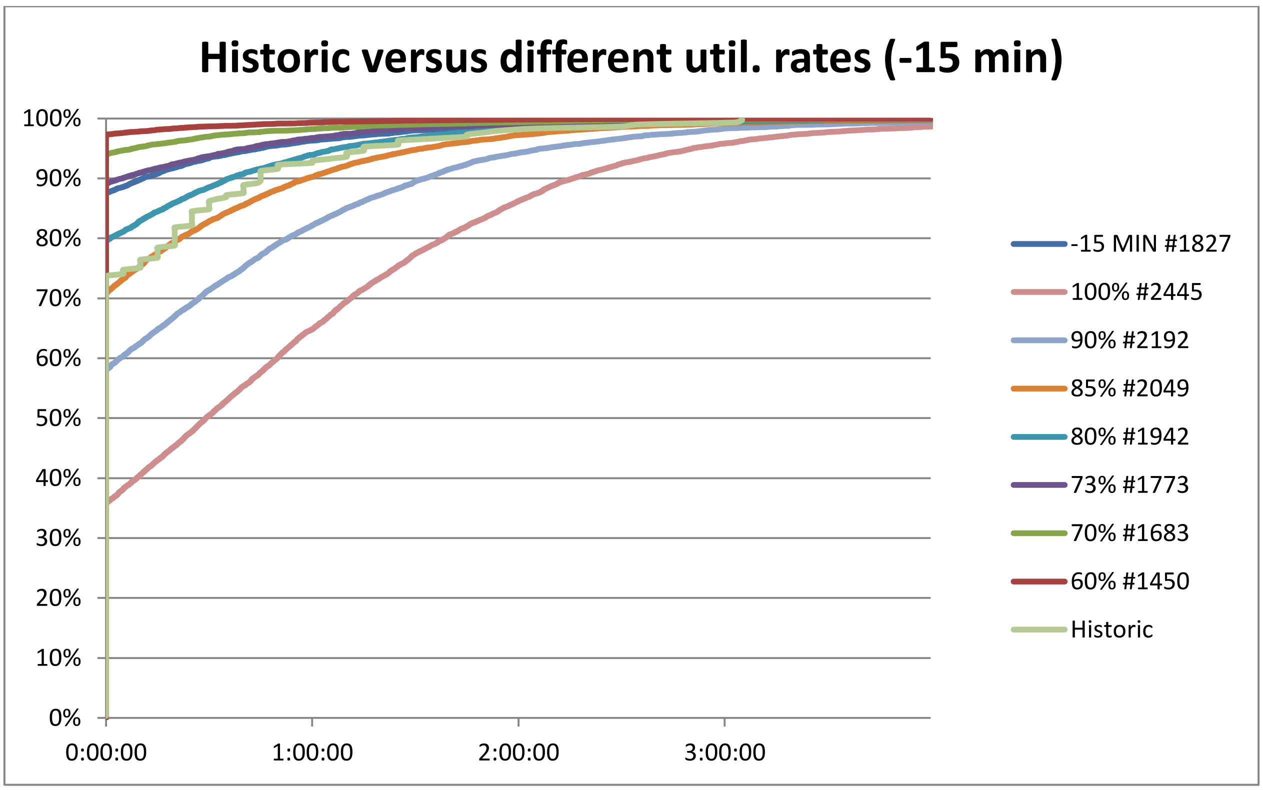

Figure 26: improvement by 15 minutes

The same question was asked what would happen when 19 minutes of improvement is possible. Figure 26 shows the answer.

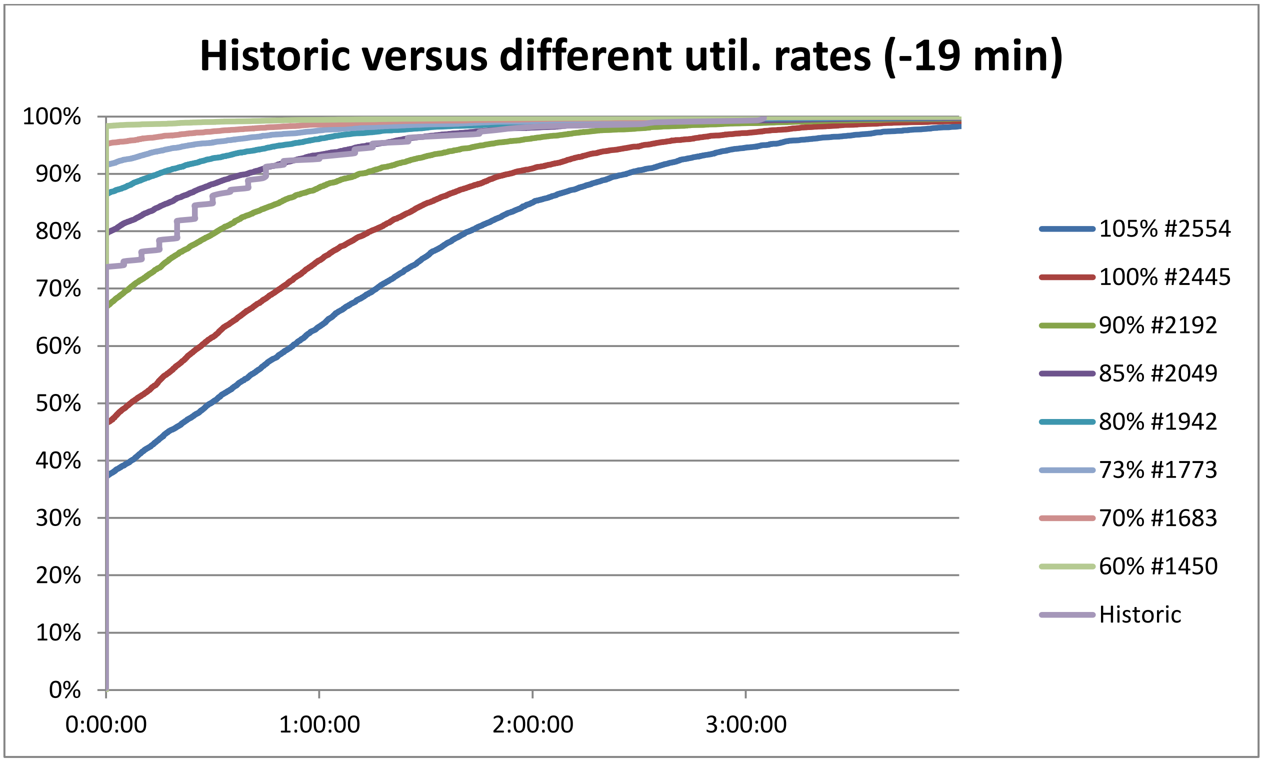

Figure 27: improvement by 19 minutes

4.5 How to achieve these improvements

The simulations show how much would be improved in the current situation when 15 to 19 minutes could be saved per operation. How can this be achieved? We have a couple of suggestions which lie partially in the medical field and partially in the scheduling part.

Start with the relatively easy part. The cleaners stop working at 15:30. When surgery is going in overtime the cleaners are already heading home and the nurses will clean the OR themselves. In the morning the cleaners also start at 08:00 or 08:30, the same as the OR staff. In the morning everything is still clean till the first surgery has taken place. This means that the cleaners would not have to clean until one hour after they started there working day. The choice could be made to change the working hours of the cleaners by starting their working day on a later hour and stopping their working day on a later hour. With this, the surgery nurses would be more eager to have more patients on the OR because of a shift of the end time of OR.

The late start time of the surgeries gives the same problem. The surgeons start at 08:00 and still have to see their first patient. When the surgery also has to start at 08:00 this is in conflict with each other. Let the surgeons start at a quarter to eight or half past seven. This is also according to Does et al. (2009) the most promising.

The other option lies more in the medical field but was discussed with one of the anaesthesia nurses to check whether it would be a plausible option. At the moment all of the surgeries are done under narcosis. Local anaesthesia is more of an exception than regular. A regional nerve block would be possible for all ambulatory surgeries which would save time in the OR room. The procedure still has to take place but can be done outside the OR which would save precious time on the OR. The regional nerve block has the advantage of longer duration which means that the anaesthetic can be given earlier and post nausea and post-operative pain are to be less than with general anaesthesia. The anaesthesia nurse confirmed this would indeed yield a time reduction on the OR but from the point of view where to perform the local anaesthesia the almost only option is to do this at the PACU.

Another intervention that can be made is to use the empty OR when there are only one or two surgeons performing surgeries. One of the remarks with this is that not all of the surgeries can take place in the third OR but with a bit of careful planning it should be possible to have more simultaneous surgeries or preparations.

Figure 28 shows in the first graph the current situation and in the second graph when surgeries are done in the other OR. This should yield a way higher performance than at the moment.

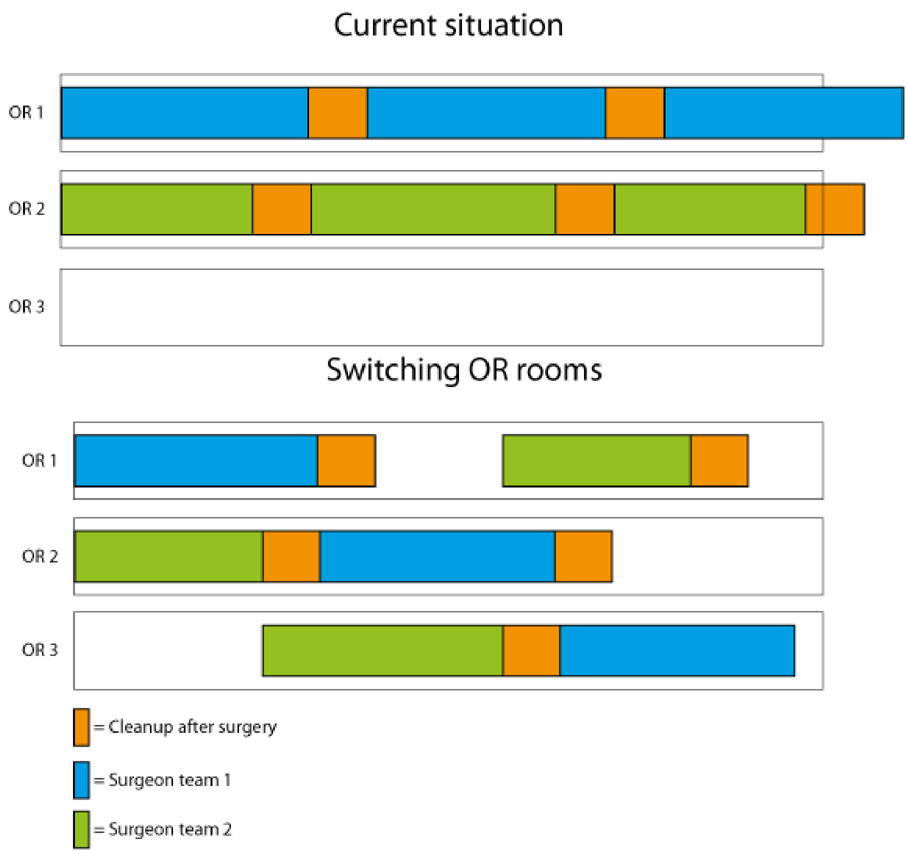

Figure 28: using more empty ORs

4.6 Conclusions

From our simulation study we learned that in the current situation 100% utilization rate represents 2445 patients. Also we learned that with an improvement of 15 minutes per surgery, the number of surgeries could increase from 1774 per year to 1940 per year. That is an increase of 200 cases at no additional cost. How the improvements can be implemented we will discuss in the next chapter.

Chapter 5. Implementation & evaluation

In this chapter we will discuss how to implement some of the suggested interventions. Finally we discuss how in our opinion Røros Sykehus should proceed in improving their operating room.

5.1 Implementation of interventions

Healthcare processes are hard to manage and even harder to change (Glouberman & Mintzberg, 2001). Since we want to bring the four worlds together for this report (?nog een keer bron), we suggest that a group of volunteers should be selected or chosen. This group should discuss which processes are up for a change and which ones affect the quality of care of the patient. The extent to which the change in processes suggested are possible is not completely clear. However, when we for example consider who starts the working day and when, which means the surgeon starts earlier and the cleaners stop later, this should in our opinion not affect the quality of care of the patient. In our opinion the quality of care is most likely to improve than decrease.

When we look at the suggestion of changing from one OR to the other OR, this should be possible with the current amount of staff since it already has been done in the historic data and seems to already have proven itself. The only step further is to make this a protocol and to implement these steps.

Regarding the local anaesthesia, other hospitals such as St. Olavs Hospital can be asked what their experience is. When they have a positive experience or when scientific literature provides an answer on this matter this could yield an enormous improvement in the use of the OR in Røros Sykehus

The problem is that the employees themselves have to execute all the changes. Therefore we want to have the employees themselves to form a group who should make new guidelines how to work and what to do when. This group should not only consist out of surgery nurses and anaesthesia nurses, but also the PACU nurses and the Admission nurses. Preferable also the head of department or someone else from the management should be included in the group to guide the improvement process and to keep it on track.

How should improvements be evaluated? We will discuss this in the following paragraph.

5.2 Evaluation

For the evaluation we would suggest visual feedback. Every week there should be a report of the performance of the week before. This has proven to work in the on time scheduling of the first surgery (Does, Vermaat, Verver, Bisgaard, & Van Jaap Heuvel, 2009).

Visual feedback will give the employees encouragement to improve their work and try to perform in a better way. This is with the remark that the employees should be favourable disposed towards improving their work. Our visit showed a great cooperation with us as researchers and also an atmosphere where the employees had indeed the courtesy to improve the hospital. Evaluating the improvements could be done for example every Friday morning when the OR department has a short meeting. After a few month a larger check should be done whether the initial goal is reached.

Chapter 6. Conclusion & recommendations

In paragraph 6.1 we draw the main conclusions based on this report. In paragraph 6.2 we will discuss the findings in this report. In paragraph 6.3 we will suggest other recommendations and ideas for further improvement.

6.1 Conclusion

Goal of this research was:

"Get an overview of the current performance of the OR department of Røros Sykehus and determine bottlenecks which can be changed to improve the current situation."

With the framework of Hans et al. (2012) we made an analysis of the organisation. We looked at how the processes are organised, how the processes are controlled and how the performance is at the moment. Based on the extensive context analysis we can conclude that the performance still has room for improvement. The current performance shows that the ORs do not start on time in the morning and the time in between surgeries is quite substantial. Figure 21 shows exactly how much time there is between the surgeries and an utilization rate of 75% still leaves some room for improvement. So far the first part of our research question, on the current performance of the OR department of Røros Sykehus.

We looked at what the desired situation would be and simulated this. An improvement of 15 minutes per operation yields already the improvement shown below in figure 29. The improvement of 19 minutes looks rather small in the view of overtime, but it is a big improvement.

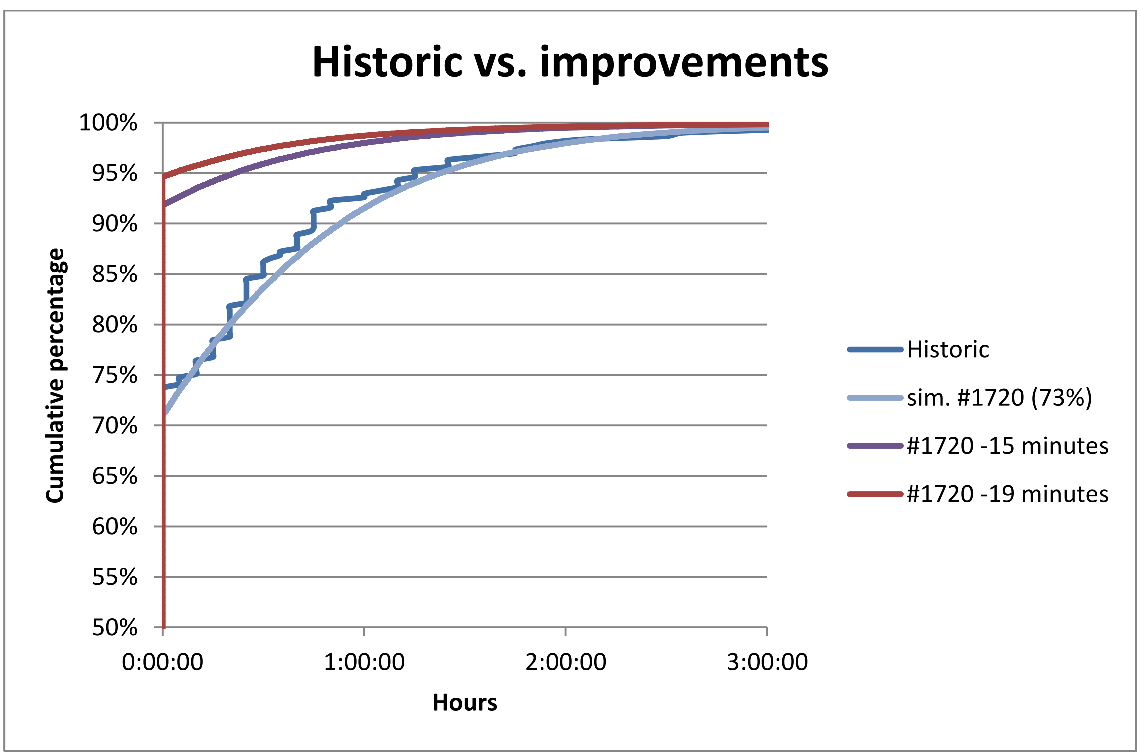

Figure 29: Historic versus improvements using a simulation model with a utilization rate of 73% and 1720 patients

The graph shows that only with a few minutes of improvement per surgery the overall overtime can be reduced by a few percent. Since the graph is leveled off to the right it looks like a small improvement. Figure 27 shows that with 2049 patients undergoing surgery the improvement of 19 minutes still produces less overtime than the historic data.

We think that by implementing a group who is responsible for improvements, the projected improvement can be yielded. Visual feedback should help understand where problems occur and new bottlenecks arise. The alignment of work processes should help in the improvement of starting surgery on time. Furthermore, the usage of the empty OR on days that there are two surgeons should help in the reduction of time between surgeries. In our opinion the 15 minutes reduction per surgery should be possible to achieve.

6.2 Discussion

A few question marks can always be placed in making use of simulation. In this simulation study a projection is made based on the historic data which was available. In this case this was only three quarters of a year. Since the number of different surgeries is quite extensive, the question is whether the simulated results completely represent the actual situation. Also the case mix was changed which means that some kind of warm up period could be in the data. Since there was already this little data to perform the statistical distributions on, we took all of the data. In the ideal situation we would have taken more data than the current situation. But with a α=0,15 the data is still significant. The simulation is based on the historic data of three quarters of a year and this means that when the current performance is already higher the simulated results are even more likely to be achieved. Therefore we believe that although with the remark of less productivity in the historic data the simulated results represent the reality in a good way.

6.3 Other recommendations & further possible research

The recommendations for further research would be:

- Make a schedule based on historic data. At the moment the data is not elaborate enough, but this would improve the planning of the surgeries and might reduce the variability which is measured in the current data.
- Make sure that the “intakks kontor” of St. Olavs Hospital sends the patients their letters in time to call them up for surgery. This could reduce the number of cancellations drastically.
- Look at how the material planning is done. A look in the storage area did raise some question marks on how efficient this is done. A simple system that tells which products go over their expiration date would be helpful. When such a system would be implemented there also should be looked at whether the system can tell how much materials are used for which kind of operations in order to predict the budget on materials in a better way.

Chapter 7. References

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Chapter 8. Appendixes

Appendix A: Surgery distributions

//ID	SpecID	Specialty	Surgery code	Percentage	DistrType	P1 (min.)	P2 (min.)	P3 (min.)
1	1	Orthopaedic	NGD11	0,125	lognormal	62,276	16,949	24,871
2	1	Orthopaedic	NBK13	0,067913	lognormal	87,261	24,232	0
3	4	ENT	EMB10	0,5	gamma	20,172	2,4693	0
4	1	Orthopaedic	ACC51	0,051181	lognormal	42,977	10,456	21,758
5	1	Orthopaedic	NDM19	0,050197	lognormal	92,959	31,867	0
6	1	Orthopaedic	NGA11	0,049213	lognormal	57,603	15,058	0
7	1	Orthopaedic	NHU49	0,041339	lognormal	63,798	28,165	8,1384
8	1	Orthopaedic	NHK57	0,037402	lognormal	71,298	21,752	44,011
9	1	Orthopaedic	NGU49	0,029528	gamma	1,0107	13,319	5,9056
10	1	Orthopaedic	NGF11	0,028543	lognormal	65,345	15,321	-50,239
11	1	Orthopaedic	NBK13	0,027559	lognormal	149,43	42,245	18,306
12	3	Oral	TEB10	0,430769	lognormal	137,95	75,411	65,478
13	2	Gynaecology	LGA11	0,263158	lognormal	64,305	11,396	0
14	1	Orthopaedic	NGE45	0,024606	lognormal	122,97	24,691	-836,78
15	1	Orthopaedic	NFU49	0,022638	lognormal	77,04	23,667	0
16	3	Oral	EBA10	0,246154	lognormal	108,05	90,296	46,174
17	1	Orthopaedic	NDG02	0,015748	lognormal	76,016	27,112	35,087
18	1	Orthopaedic	NDU49	0,015748	lognormal	64,938	30,708	-36,608
19	1	Orthopaedic	NGF31	0,015748	lognormal	71,945	14,875	58,162
20	1	Orthopaedic	NDM39	0,014764	lognormal	53,386	26,345	32,631
21	2	Gynaecology	LDC03	0,147368	lognormal	33,273	9,5971	12,888
22	1	Orthopaedic	NDK12	0,01378	lognormal	68,928	22,974	28,519
23	3	Oral	EBA00	0,2	lognormal	132,11	82,137	70,635
24	1	Orthopaedic	NBH71	0,012795	normal	139,85	23,387	0
25	1	Orthopaedic	NDM49	0,012795	lognormal	46,061	24,828	21,582
26	1	Orthopaedic	ACC19	0,011811	lognormal	50,083	17,117	0
27	4	ENT	DJD20	0,103448	lognormal	92,105	11,282	52,18
28	1	Orthopaedic	ACC53	0,010827	lognormal	73,478	26,196	0
29	2	Gynaecology	LEF00	0,115789	lognormal	96,275	22,518	-4,571
30	4	ENT	QAE10	0,094828	lognormal	44,741	22,146	16,43
31	4	ENT	DCA20	0,086207	normal	27,9	5,6657	0
32	1	Orthopaedic	NBA11	0,009843	lognormal	103,85	31,432	28,431
33	2	Gynaecology	LEG10	0,094737	lognormal	45,551	4,6605	0
34	1	Orthopaedic	NHE49	0,008858	normal	79	24,449	0
35	1	Orthopaedic	NCL39	0,007874	lognormal	58,241	14,109	0
36	1	Orthopaedic	NHK17	0,007874	normal	55,875	13,206	0
37	2	Gynaecology	LCD00	0,073684	normal	118,29	27,723	0
38	1	Orthopaedic	NBE21	0,00689	lognormal	118,57	29,592	82,386
39	1	Orthopaedic	NCU49	0,00689	lognormal	92,142	50,294	26,271

40	1	Orthopaedic	NHK18	0,00689	lognormal	54,122	21,43	26,702
41	1	Orthopaedic	NDG46	0,005906	lognormal	77,35	19,794	-296,83
42	4	ENT	EMB20	0,043103	lognormal	63,422	10,785	0
43	2	Gynaecology	LEF10	0,052632	lognormal	55,679	33,746	0
44	1	Orthopaedic	NDK02	0,004921	normal	75,2	5,02	0
45	1	Orthopaedic	NGL59	0,004921	lognormal	67,278	16,306	51,712
46	1	Orthopaedic	NGM09	0,004921	lognormal	65,988	23,599	0
47	1	Orthopaedic	QDH10	0,004921	lognormal	48,344	13,32	28,719
48	2	Gynaecology	vergyn	0,252632	lognormal	43,644	36,593	10,18
49	3	Oral	verkje	0,123077	normal	136,88	57,566	0
50	4	ENT	veronh	0,172414	lognormal	44,816	38,31	0
51	1	Orthopaedic	verort	0,227362	lognormal	84,543	37,791	-16,775
52	1	Orthopaedic	NBU49	0,012795	lognormal	67,136	15,296	44,688

Appendix B: Surgery description per operation code

This table describes the surgery ID's, their surgery code and their long name in Norwegian.

//ID	Specialty	Surgery code	Long name
1	Orthopaedic	NGD11	Endoskopisk meniskreseksjon
2	Orthopaedic	NBK13	Reseksjon eller eksisjon av scapula
3	ENT	EMB10	Tonsillektomi
4	Orthopaedic	ACC51	Dekompresjon og adheranseløsning av nervus medianus
5	Orthopaedic	NDM19	Reseksjon eller eksisjon av fascie i håndledd eller hånd
6	Orthopaedic	NGA11	Artroskopi i kneledd
7	Orthopaedic	NHU49	Fjerning av osteosyntesemateriale fra ankel eller fot
8	Orthopaedic	NHK57	Osteotomi i metatars med aksekorreksjon, rotasjon eller forskyvning
9	Orthopaedic	NGU49	Fjerning av osteosyntesemateriale fra kne eller legg
10	Orthopaedic	NGF11	Endoskopisk partiell synovektomi i kne
11	Orthopaedic	NBK13	Reseksjon eller eksisjon av scapula
12	Oral	TEB10	Tannfylling med fast materiale
13	Gynaecology	LGA11	Laparoskopisk sterilisasjon ved destruksjon eller deling av tubene
14	Orthopaedic	NGE45	Endoskopisk rekonstruksjon av fremre korsbånd uten protesemateriale
15	Orthopaedic	NFU49	Fjerning av osteosyntesemateriale fra femur
16	Oral	EBA10	Kirurgisk eksisjon av tann
17	Orthopaedic	NDG02	Eksisjonsartroplastikk i første karpometakarpalledd
18	Orthopaedic	NDU49	Fjerning av osteosyntesemateriale fra håndledd eller hånd
19	Orthopaedic	NGF31	Endoskopisk reseksjon av leddbrusk i kne
20	Orthopaedic	NDM39	Eksisjon av synovialt ganglion i håndledd eller hånd
21	Gynaecology	LDC03	Konisering av cervix uteri med diatermi eller laser
22	Orthopaedic	NDK12	Reseksjon eller eksisjon av metakarp
23	Oral	EBA00	Tannekstraksjon
24	Orthopaedic	NBH71	Endoskopisk operasjon for habituell skulderluksasjon
25	Orthopaedic	NDM49	Spalting av seneskjede i håndledd eller hånd
26	Orthopaedic	ACC19	Overskjæring av annen eller uspesifisert nerve
27	ENT	DJD20	Neseseptumplastikk
28	Orthopaedic	ACC53	Dekompresjon og adheranseløsning av nervus ulnaris
29	Gynaecology	LEF00	Fremre kolporafi
30	ENT	QAE10	Eksisjon av hudlesjon på hode eller hals
31	ENT	DCA20	Reseksjon av mellomøre
32	Orthopaedic	NBA11	Artroskopi i skulder
33	Gynaecology	LEG10	Vaginal urethrocystopeksi
34	Orthopaedic	NHE49	Rekonstruksjon av ligament i ankel eller fot uten protesemateriale
35	Orthopaedic	NCL39	Myotomi eller tenotomi i albue eller underarm
36	Orthopaedic	NHK17	Reseksjon eller eksisjon av metatars
37	Gynaecology	LCD00	Hysterektomi

38	Orthopaedic	NBE21	Endoskopisk sutur eller reinserering av ligament i skulder
39	Orthopaedic	NCU49	Fjerning av osteosyntesemateriale fra albue eller underarm
40	Orthopaedic	NHK18	Reseksjon eller eksisjon av bein i tå
41	Orthopaedic	NDG46	Artrodese i interfalangealledd med intern fiksasjon
42	ENT	EMB20	Adenotonsillektomi
43	Gynaecology	LEF10	Kolpoperineoplastikk
44	Orthopaedic	NDK02	Eksisjon av beinfragment i metakarp
45	Orthopaedic	NGL59	Tenolyse eller tenosynovektomi i kne eller legg
46	Orthopaedic	NGM09	Fasciotomi i kne eller legg
47	Orthopaedic	QDH10	Eksisjon av negleseng på tå
48	Gynaecology	vergyn	#N/A
49	Oral	verkje	#N/A
50	ENT	veronh	#N/A
51	Orthopaedic	verort	#N/A
52	Orthopaedic	NBU49	Fjerning av osteosyntesemateriale fra skulder eller overarm

Appendix C: Tactical scheme ORs

Day	ORT	GYN	ENT	ORAL	#ORs open
1	1	1			2
2	1	1			2
3	1		1		2
4	1			1	2
5	1				1
6	0	0	0	0	0
7	0	0	0	0	0
8	2				2
9	2				2
10	2		1		3
11	2			1	3
12	2				2
13	0	0	0	0	0
14	0	0	0	0	0
15	2				2
16	2				2
17	2				2
18	2			1	3
19	2				2
20	0	0	0	0	0
21	0	0	0	0	0
22	2				2
23	2				2
24	2		1		3
25	2			1	3
26	2				2
27	0	0	0	0	0
28	0	0	0	0	0
29	1	1			2
30	1	1			2
31	1		1		2
32	1			1	2
33	1				1
34	0	0	0	0	0
35	0	0	0	0	0
36	2				2
37	2				2
38	2				2
39	2			1	3
40	2				2
41	0	0	0	0	0
42	0	0	0	0	0
43	2				2
44	2				2
45	0		1		1
46	1			1	2
47	1				1
48	0	0	0	0	0
49	0	0	0	0	0
50	1				1
51	1				1
52	1		1		2
53	1			1	2
54	1				1
55	0	0	0	0	0
56	0	0	0	0	0
57	1	1			2
58	1				2
59	1				1
60	1			1	2
61	1				1
62	0	0	0	0	0
63	0	0	0	0	0
64	1				1
65	1				1
66	1		1		2
67	1				1
68	1				1
69	0	0	0	0	0
70	0	0	0	0	0
71	1				1
72	1				1
73	1		1		2
74	1				1
75	1				1
76	0	0	0	0	0
77	0	0	0	0	0
78	1	1			2
79	1				2
80	1		1		2
81	1			1	2
82	0				0
83	0	0	0	0	0
84	0	0	0	0	0

Appendix D: Simulation settings

#General settings	
4	Number of periods
84	Number of days per period
0.33333333	Start of working day
420	Length of working day (minutes)
350000	Outpatient OR costs / year
400000	Dedicated Inpatient OR costs / year
500000	Generic Inpatient OR costs / year
400000	Emergency OR costs / year
1828	Expected number of patients / year
1	Maximum number of waiting periods
60000	Anesthesia Assistant costs / year
170000	Anesthetist costs / year
60000	Surgery Assistant costs / year
1	Anesthesia Assistants per inpatient/emergency OR
0,5	Anesthetists per inpatient/emergency OR
2	Surgery Assistants per inpatient/emergency OR
1	Anesthesia Assistants per outpatient OR
0,5	Anesthetists per outpatient OR
2	Surgery Assistants per outpatient OR
roros	Scenario name
TRUE	Use advanced interface features instrument trays
TRUE	Elective surgeries may start before planned start
999999	Nr of ORs that can deal with emergencies
20	Nr of simulation runs
0	Default surgery startup time
19	Default surgery cleaning time
FALSE	Delayed elective surgeries may move to another OR
FALSE	Elective surgeries may move to another available and suitable OR
TRUE	Elective surgeries may not move to another available and suitable OR
TRUE	Cancel elective surgeries that have not been performed on their planned day
FALSE	Cancel emergency surgeries that have not been performed on their arrival day
FALSE	Cancel semi-emergency surgeries that have not been performed on their arrival day
TRUE	All patients are available at the start of the day
TRUE	outpatient surgeries must be performed in outpatient ors
FALSE	Use appointment slots
TRUE	Write detailed simulation output in Excel files
FALSE	Schedule lunchbreak
0.45833333	Schedule lunchbreak after
0.52083333	Schedule lunchbreak before
FALSE	Use no-show

TRUE	Emergency surgeries may be performed in any type of OR
TRUE	Semi-urgent surgeries may be performed in any type of OR
100	do not start elective surgeries if more than x% is outside working hrs
100	do not start (semi) emergency surgeries if more than x% is outside working hrs
FALSE	enable do not start elective surgeries if more than x% is outside working hrs
FALSE	enable do not start (semi) emergency surgeries if more than x% is outside working hrs
TRUE	surgeries cannot last into the next day (i.e. are stopped at midnight)
2,15E+09	surgery duration cannot be more than x minutes
2,15E+09	multiplication factor is proportional to x patients
1	multiplication factor for the number of emergency surgeries
FALSE	allow overtime
TRUE	surgery with an mss slot may only be performed in the mss slot
FALSE	close empty ors after planning
TRUE	use casemix
FALSE	fill capacity
FALSE	waiting list
100	percentage capacity
1	initial periods of waiting list
0	Number of warm-up periods
1	Option regarding which arrivals to consider
duration variance	job priority rule
descending	job selection rule