Evaluation of the 7-day release program

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Introductie

Dit rapport beschrijft het onderzoek aangaande optimalisatie van de Operatie Kamer (OK) planning van Vanderbilt University and Medical Center (VUMC). VUMC is gelegen in Nashville, Tennessee, in de Verenigde Staten en is het grootste universiteitsziekenhuis van de regio. In dit rapport hebben wij de prestaties en mogelijke verbeteringen, van de '7-day release progam' geëvalueerd.

Probleem omschrijving

VUMC maakt gebruik van een Blok Tijd (BT) schema voor de verdeling van de OK's. The specialismen plannen operaties in hun BT. In 2009 heeft VUMC het '7-day release program' geïntroduceerd waarin zij OK's vrijgeven aan andere specialismen, 7 dagen voor de operatiedag. Het doel is om: het kunnen plannen van operaties buiten BT van specialisme, onderbezetting verlagen en toegangstijd verbeteren. Het beleid is gebaseerd op een aanname: er is altijd genoeg onderbezetting om alle operaties te kunnen laten plaats vinden. Sinds 2009 is het operatievolume toegenomen, en de vraag is of de aanname stand kan houden. De probleemstelling is: *Moet in de toekomst VUMC het 7-day release beleid aanhouden als de vraag toe neemt?*

Methode

We hebben de huidige situatie geanalyseerd, de organisatorische processen, de planning en besturing, de operationele prestaties en de bottlenecks. Op basis van de analyse stellen we de volgende alternatieve interventies voor: variëren van totaal aantal geplande patiënten (testen maximum capaciteit), veranderen van de dag van vrijgave, veranderen van de voorkeur dag, versoepeling van de OK restricties, en het veranderen van het planningsbeleid.

Resultaten & aanbevelingen

De simulatie toont aan dat met het plannen van 730 operaties per week (16% toename, huidige 630) het maximum van het 7-day release program is bereikt. Het veranderen van de dag van vrijgave, leverde negatieve resultaten op. Het variëren van de voorkeur dag leverde gemengde resultaten, en bevelen aan om alleen, mits nodig, de voorkeur dag plus een te implementeren. De resultaten voor het versoepelen van de OK restricties was positief voor de OK's 4, 8, 31-34 en 25, en we bevelen aan dit toe te passen. Aangaande het planningsbeleid stellen we voor om van FCFS naar aflopende verwachte operatietijd te gaan.

Conclusies

De '7-day release progam' laat betere resultaten zien dan andere plannings-benaderingen. Het beleid van OK's vrijgeven houdt het evenwicht tussen: onderbezetting, toegangstijd, en het aantal mogelijk te plannen operaties. We bevelen aan om het beleid te verbeteren door implementatie van plannen op basis van aflopende verwachte operatietijd te gaan en om de restricties voor de genoemde OK's te versoepelen.

Management summary

Introduction

This report describes the research on the optimization of the Operating Room (OR) scheduling of Vanderbilt University and Medical Center (VUMC). VUMC is situated in Nashville Tennessee, USA, and is the largest university hospital in the region. In this report we evaluated the performance and possible improvements of the '7-day release program'.

Problem description

VUMC uses a Block Time (BT) schedule for the division of the ORs. The specialties schedule surgeries in their BT. In 2009 VUMC introduced the releasing of ORs to other specialties, 7 days prior to the day of service, by the 7-day release program. The aim is to allow surgery scheduling outside specialties BT, decrease underutilization, and improve access time to the OR. The policy is based upon one main assumption: there is always enough underutilization to accommodate all surgeries. Surgery volume increased since 2009, and the question is, whether the assumption can be maintained in that case. The problem statement is: *"Should VUMC maintain the 7-day release program in the future, when demand is expected to increase?"*

Methods

We analyzed the current situation, the organization of processes, the planning and control, the operational performance and the bottlenecks. Based on this analysis we proposed the following alternative solutions: vary the total number of cases scheduled (to test maximum capacity), alter the release day, vary the request day, relaxation of the room constraints, and changing the scheduling policy.

Results & recommendations

The simulation showed that with scheduling 730 cases per week (16% increase, currently 630) the maximum of the 7-day release program is reached. Altering the release day, yielded negative results in our simulation. The variation of the request day yielded mixed results, we only recommend implementing the one day after solution, when needed. The results for relaxation of the releasing policy for rooms yielded mixed results, we advise to implement relaxation for the following ORs: 4, 8, 31-34, and 25. Regarding the scheduling policy, we advise to change the priority rule from FCFS to decreasing expected duration.

Conclusion

The 7-day release program shows a better performance than other scheduling approaches. The releasing policy balances the trade-off between underutilization, access time and the number possible surgeries to schedule in the best possible way. We recommend to improve the policy by changing the priority rule and by relaxing some of room constraints.

Terminology and abbreviations list

Abbreviations

APS	Anesthesia Pain Service
BIM	Break In Moments
BS	Block Scheduling
BT	Block Time
DPC	Doctor Preference Cards
ER	Emergency Room
FCCR	Future Case Count Report
FEL	Free Electron Laser location
ICU	Intensive Care Unit
MCE	Medical Center East
MSS	Master Surgical Schedule
OR	Operating Room
ORMIS	Operating Room Management Information System
PACU	Post Anesthesia Care Unit
POU	Point Of Use
TVC	The Vanderbilt Clinic
VOR	Vanderbilt Operating Room location
VUH	Vanderbilt University Hospital
VUMC	Vanderbilt University and Medical Center

Terminology

Starpanel	Electronic Patient Record and contains also all digital forms for requesting and scheduling surgery.
e-OR board	Digital board that displays the schedule and information about the surgeries live on screens on the OR floor.
ORMIS	Back-end in which the scheduling of the surgeries is done. Also the name of the database with all the scheduled surgeries.

Case / different patient descriptions

On-stage cases / 7-day release cases	Cases/patients scheduled by the 7-day release program
Non-staged cases / regular elective cases	Cases/patients that are scheduled in regular BT, not by the 7-day release program.
Virtual rooms	Virtual ORs in ORMIS used as placement holder for 7-day release cases, until scheduled

Chapter 1 Introduction

This report describes the research on the optimization of the Operating Room (OR) scheduling of Vanderbilt University and Medical Center (VUMC).

This chapter gives an introduction to this research. Section 1.1 introduces the context of this research. Section 1.2 discusses the problem that initiated this research, Section 1.3 the research objective, Section 1.4 the scope, and finally Section 1.5 the research questions formulated to answer the problem.

1.1 Context of the research

The hospital of Vanderbilt was constituted in 1874, shortly after Vanderbilt University which was constituted in 1873. Vanderbilt was named in honor of commodore Cornelius Vanderbilt, who provided the initial funding. Since then it developed into the academic hospital of the Nashville area (Vanderbilt University Medical Center, 2013). Nashville is a county with approximately 580,000 inhabitants. Vanderbilt operates within the state Tennessee and Kentucky and has clinics in 32 locations covering 72 counties. In Nashville are the two main hospital locations: The Vanderbilt University Hospital and the Monroe Carell Jr. Children's Hospital (Vanderbilt University Medical Center, 2013). The two locations combined are called Vanderbilt University and Medical Center (VUMC). VUMC is the main university hospital in the region. In addition to VUMC, there are at least five hospitals in Nashville.

Vanderbilt has the only Level 1 trauma center in the area and the only level 4 neonatal Intensive Care Unit in the area and carries out over 3800 life flights a year (Vanderbilt University Medical Center, 2013).

To give an impression of the size of the Hospital, it has 12.76 million square feet of interior space, which is 1.18 million square meter (Vanderbilt University Medical Center, 2013). Table 1 shows more statistics about the hospital.

Table 1: Facts Vanderbilt University and Medical Center (Vanderbilt University Medical Center, 2013)

Vanderbilt University Hospital	
Beds	626
Surgeries	35,112
Emergency room visits	60,479
Ambulatory visits	1.5 million
Monroe Carell Jr. Childrens Hospital	
Beds	271
Surgeries	15,886
Emergency room visits	52,886
Ambulatory visits	215,442
LifeFlight air & ground transport of patients	3,828
People	
Faculty & staff	19,395
Students	1,821
Trainees	1,435
Innovation and Technology	
Patents	162 U.S. patents
Prescriptions based on patient DNA	10,500
DNA databank	150,000 samples
MyCancerGenome.com	Visitors 134 countries
Medical research funds	572 million
Unique stats	
World record holder	Most vaccines given in 8 hours
Vanderbilt e-health record system	165,000 patients
Donations to Second Harvest Food Bank	21,000 pounds of food

1.2 Problem description

This report focuses on the research conducted, within VUMC, department of Anesthesiology, and the department of Surgery. The departments are related and in charge of scheduling surgeries. In particular the research focuses on the Operating Room (OR) scheduling within VUMC.

In most hospitals, the ORs are divided among services/specialties (e.g., Urology, Plastic Surgery or Gynecology) in a Block Time (BT) schedule, where BT can be assigned to a service for the whole day or part of the day. For the division of the ORs, Vanderbilt, uses also uses a Block Time Schedule or Block Schedule (BS) in short. Based on this BS the different services are assigned Block Time (BT). The BT is given, in whole days, in

a weekly repetitive schedule to the different services/specialties. The services/specialties allocate their assigned Block Time to surgeons. Most surgeons do not perform surgery every day of the week since they also have to see patients in the clinic and has other academic responsibilities. As an example a schedule for Room 1 states: Monday Surgeon A is operating, Tuesday Surgeon B, etc. Currently, all the blocks of all the ORs are allocated to services and surgeons. So when a new surgeon comes to a specialty, he or she does not have block time.

Until 2009, the only option for new surgeons was to claim block time or operate on a day that another surgeon was away. Although, when looking at the schedule performed, there was enough OR time available to accommodate these surgeries, which means there was underutilization. To combat the combined problem of underutilization of the ORs and the inflexibility of scheduling outside the BT allocated to the services, VUMC introduced the 7-day release program. The 7-day release program was introduced in March 2009. The release program takes away unused BT 7 days prior to the surgery date, and allows any surgeon to use that BT to schedule surgeries.

The 7-day release program does not affect normal BT scheduling until 7-days before the Day of Service (DoS). DoS is the day on which a surgery is scheduled to take place. Seven days before the DoS, the surgeon schedulers are no longer allowed to directly schedule into their Block time. The Block time is "taken" away and scheduling happens via putting surgeries/cases on-stage. On-stage means that cases are scheduled into virtual rooms that are called on-stage rooms. The cases that are put on-stage are allowed to be placed in any available room, when constraints match. This means that for example a urology case can be performed in an orthopedic room. The 7-day release scheduler treats the cases that are put on-stage by first-come-first-served principle.

Putting the cases on-stage can be done even before the rooms are released (7-days before the surgery date). This is important because some surgeons/physicians do not have assigned Block time and others might want to operate on a different day then their block. They are allowed to put cases on-stage. Putting cases on-stage when also

having regular BT is only done in one particular case: when a surgeon wants to run two rooms at the same time, but the surgeon only has one room in the BT assignment.

At the 7-day mark, the cases are scheduled in the rooms that are released and where the constraints allow the surgery to be performed. The constraints that are taken into account with scheduling the on-stage cases from the 'virtual rooms' into the ORs can be found Appendix D.

When the 7-day release program was introduced, it was not clear whether the program would achieve the goals that were designed for: decrease underutilization and increase access time. Access time is defined as the time difference between day on which the patient requests the surgery and the first possible date to schedule the surgery, also described in Section 2.3.1.

Before the 7-day release program there was a 36-hour release policy. To explain this, the old deadline for releasing the rooms was 36 hours, and the new deadline is 7 days. The effect of this change is that the schedule is less changed in the new situation, which has an impact on the downstream processes. Such as ordering implants or equipment. The number of rush orders, and stress decreased according to staff, after the introduction of the 7-day release program. According to staff, one of the side effects, of the introduction of the 7-day release program, is that there is more time to get the surgery organized in the downstream processes.

Both the department of Surgery and the department of Anesthesiology want to evaluate the performance of the introduced 7-day release program. Since the introduction of the 7-day release program in March 2009, it was never evaluated. It was advocated by one of the surgeons and gradually introduced for all services. The question is whether the system still works as designed when the in the number of surgeries increase. The department of Anesthesiology and the department of Surgery believe that a review of the system should be executed, and other alternatives should be taken into account to answer the question whether they would perform better than the current system.

In this report we investigate whether the 7-day release program is the most efficient and effective method to deal with both underutilization and access time to the OR, particularly in the prospected scenario of demand growth.

One of the fundaments under the 7-day release program is underutilization. The unanswered question is what happens in the prospected scenario of demand growth, when underutilization becomes scarcer. Less underutilization happens in two scenarios: 1) the number of surgeries increases or 2) ORs are closed. What happens in the prospected scenario of demand growth? Are the requested on-stage cases performed in overtime, just to get them done? Are staged cases postponed to the next day? What is the maximum demand for which the 7-day release program still suitable?

Problem statement:

"Should VUMC maintain the 7-day release program in the future, when demand is expected to increase?"

1.3 Research objective

The department of anesthesiology and the department of surgery want to have the benefits of the absence or presence of the 7-day release schedule examined. The objective for this research is to assess (1) the 7-day release program in a scenario where the utilization rate rises and (2) whether other approaches for scheduling the surgeries would improve the performance.

The OR has various stakeholders with diverse interests. As stakeholders we consider: staff, the hospital and the patient. For the interpretation of the performance of the ORs, we take into account the interests of these stakeholders. In particular, a balance has to be found between patient satisfaction, staff satisfaction and organizational performance.

1.4 Scope of the research

The research concentrates on the operating room scheduling and resulting performance of the hospital's surgical process. The focus of the research is on the

offline operational scheduling, i.e., the in-advance allocation of elective patients to OR blocks.

1.5 Research questions

To answer the problem statement and find alternative solutions for the problem we pose some research questions. The research questions will systematically guide us through the rest of the research. The research questions are:

1. **What is known about releasing rooms in the literature?** (Chapter 2)

VUMC uses the releasing of rooms as a method to increase utilization and access time, but what is written in literature about this? Is there an optimal strategy for releasing ORs? Is there something written on when to exactly release ORs? We describe in Chapter 2 what can be found in literature on releasing ORs.

2. **What are the main OR performance indicators in the literature?** (Chapter 2)

We describe the main performance indicators found in the literature which we can use to evaluate the performance of VUMC. We can use the performance indicators also to evaluate the alternative solutions.

3. **What is the current situation in Vanderbilt?** (Chapter 3)

In order to come up with possible interventions for the problem, we need to know what the current situation is in VUMC. We want to know: What is the process of having surgery? How are the processes organized to schedule a surgery? Who is involved in the different processes? We also want to know the current performance: What is the utilization rate of the ORs? What is the over and underutilization of the ORs? Did the access time decrease for surgeons without block time, after introducing the releasing of ORs? How is the performance regarding access time? With the answers on these questions we can get a comprehensive overview on the current situation in VUMC.

4. **What is the main problem in the current situation?** (Chapter 3)

We will perform a root cause analysis to see whether there are any further causes linked to the posed problem. We will define a further scope for the report and draw conclusions on the current situation in VUMC.

5. **Which interventions can we do to solve the problem?** (Chapter 4)

Given the constraints and the current situation, which interventions can we propose to the problem to improve the current situation and to eliminate the problem.

6. **How can the prospective interventions be simulated to predict outcomes?** (Chapter 5)

We will describe how we can evaluate the prospective interventions or alternative solutions. We will model the alternative solutions by making use of simulation techniques in order to evaluate the best solution to the problem.

7. **What are the predicted results according to the simulation?** (Chapter 6)

After modelling the alternative solutions in the simulation program, which alternative solutions are feasible and improve the current situation in VUMC? We will answer this question in Chapter 6 and give recommendations on which alternative solution we advise VUMC to implement.

8. **What is the best way to implement and evaluate the recommended solution?** (Chapter 7)

Changes usually call for resistance. What is the best way to implement the alternative solutions? How can we evaluate the interventions after we put them into practice? We will answer this in Chapter 7.

These research questions will guide us through the rest of the report. In Chapter 2 we will start with the Theoretical framework and describe what we found in the literature.

Chapter 2 Theoretical framework

This chapter discusses the literature concerning the operating rooms and releasing rooms. Section 2.1 explains which search terms we used and what we searched for. Section 2.2 discusses the literature found about releasing rooms. Finally, Section 2.3 discusses the key performance indicators for operating rooms.

2.1 Search approach

The last couple of years there has been an increasing interest in the planning and scheduling of operating rooms (Cardoen, Demeulemeester, & Beliën, 2010). The number of articles increased from 132 between 1950 and 1999 to 115 between 2000 and 2009 (Cardoen et al., 2010). We searched for relevant literature in Scopus and PubMed and found the literature review of Cardoen et al. (2010) which gives a thorough overview of the available literature on several fields within OR scheduling. This review however does not have a section on releasing rooms. In order to find literature on releasing of rooms we searched PubMed, Scopus and Web of Science. The key terms used are: Releasing operating rooms; Operating room release; Staging cases; staged scheduling; and staged operating room. We selected the relevant articles based on title, after which we read the abstract when the title was no reason to exclude the article or when the title was unclear. Based on the abstract we decided whether we should read the whole article.

2.2 Literature on releasing rooms

This section gives an overview of what is known in the literature about releasing rooms. Dexter, Traub and Macario (2003) describe that it is common in many facilities in the US that patients and surgeons schedule the day of surgery together and that no patients are turned away. The surgeon or surgeon scheduler schedules the case together with the patient. This is called Open Scheduling or Any Workday scheduling (Dexter, Traub, et al., 2003). In the rest of the report we will refer to it as Any Workday Scheduling.

According to Dexter and Macario (2004) the definition of releasing ORs is: making allocated but unfilled block time available to other surgeons or services (Dexter & Macario, 2004). Dexter et al. (2003) suggest that releasing the room of the most underutilized service should not inconvenience that service. The services should be able to still book their cases in the released time.

Dexter and Macario (2004) discuss when to release OR time based on maximizing OR efficiency. They describe eight points/conditions from previous work, summarized from Dexter and Macario (2004) those points are:

1. Maximizing OR efficiency by allocating time appropriately (Dexter, Traub, et al., 2003; Strum, Vargas, & May, 1999).
2. A service with released BT should still be able to schedule cases, with the condition they can be performed safely in the available ORs (Dexter, Epstein, & Marsh, 2001; Dexter, Traub, et al., 2003; Dexter & Traub, 2002; Strum et al., 1999).
3. ORs efficiency is not increased by releasing rooms before there is a case to be scheduled in the released time (Dexter & Traub, 2002).
4. Future OR allocations should not be affected by whether the OR is released or not. Allocations to maximize OR efficiency are based on the service's expected future OR workload, not utilization or release of allocated OR time (Dexter et al., 2001; Dexter, Traub, et al., 2003; Strum et al., 1999).
5. When service has filled all its OR time, but wants to schedule another case, it is more beneficial to perform this case in underutilized time of another service than in overtime (Dexter & Traub, 2002).
6. OR time should not be released other than in point 5 (Dexter, Traub, et al., 2003; Dexter & Traub, 2002).
7. Different arrival rates occur for different services. Room time should be released based on the expected underutilization on the day of surgery (Dexter & Traub, 2002). In practice there is only a slight difference between releasing the expected room and the room with the most underutilized time at the time of booking the case (Dexter, Traub, et al., 2003).

8. Releasing time of the second most underutilized OR time decreases OR efficiency (Dexter, Traub, et al., 2003).

These eight points originate from only a few papers having one author in common. Therefore, we believe this gives a rather one-sided view of the problem. Therefore, we see room for a different opinion, and further research in the specific field of releasing ORs.

In a discussion and interview of the 'OR manager' (2003), four different hospitals answer a number of questions regarding the releasing of rooms. Munson Medical Center, Northwestern Memorial Hospital, Poudre Valley Hospital and University of Wisconsin are the four participating hospitals. They all have different policies for releasing rooms. Munson hospital releases the rooms 7 days prior to the day of surgery with a few exceptions. Northwestern hospital releases the rooms automatically ranging from one week to one day prior to surgery, depending on the service. Poudre does not release open heart rooms but can move cases there from catheterization laboratory to the open heart room on the DoS. The other services release at 5, 48 and 24 hours. University of Wisconsin releases outpatient surgeries one week prior to the DoS and the inpatient ORs generally at 72 hours prior to surgery, with the exception of a couple of services. According to these hospitals the releasing of rooms happens in different ways. Releasing of the OR time happens also differently. In the same interview Dexter describes that ORs should not be released to all services on a number of pre-specified days (Shaneberger, 2003). Releasing ORs of other services should only be done when adding a case to the current service their OR would result in scheduling the case into overtime. The OR that is expected to be underutilized the most should be released, but only if the case would be expected to run into overtime in its own specialty OR. In our opinion this could be a possible solution if we only look at OR efficiency, but we wonder how staff would react to this uncertainty. Also for the surgeons who do not have assigned BT, this would increase their uncertainty. The exact timeframe on when the case is booked is uncertain in this case.

Dexter and Macario (2004) also describe that releasing the OR should not affect future OR allocations. We believe that problems will occur when a room is released and a

case is booked in the released time, thereafter the service wants to book a case, but this time is occupied by the case booked in the released time. This problem would become more apparent when the ORs are operating closer to 100% utilization rate, therefore we believe that, denying the service access to their BT should be possible, to prevent that released cases will be rescheduled all the time.

Dexter, Traub and Macario (2003) answer the question when to release the rooms and in which room the case should be placed according to OR efficiency. The room with the predicted largest difference between the scheduled and allocated OR time would be the best option to schedule the case (Dexter, Traub, et al., 2003). Scheduling a 3 hour case in a large site a week before surgery, compared to a day before surgery would increase the average overtime from 7 to 18 minutes. There is a difference in overtime but the difference is small (Dexter, Traub, et al., 2003). Scheduling the case in the second most underutilized room delivered results that are worse (Dexter, Traub, et al., 2003).

2.3 Key performance indicators

This section describes the main key performance indicators that might be applicable for Vanderbilt. The Key Performance Indicators are used as indicators for performance. These indicators measure performance and can be used to measure improvement in performance. These key performance indicators are derived from the literature on releasing rooms and the literature review of Cardoen et al. (2010).

2.3.1 Access time from booking to surgery date

According to Elkhuizen, Das, Bakker & Hontelez (2007) access time of the ORs is measured not in time but whether 95% of the new patients are accommodated within two weeks. They looked at the capacity needed to achieve this goal, and simulated this. In the literature there is not a clear definition of the best way to describe access time to the OR. We choose to define access time as the time the patient initiates the scheduling of the surgery and the first possibility of scheduling the case on a given day. The initiation with Any Workday Scheduling would happen in the clinic with the surgeon or the surgeon scheduler.

According to Baugh and Li (2012) after a few days patients are 'lost'. With lost is meant that patients schedule their surgery in another hospital. In the simulation model Baugh and Li (2012) have run, after a few days of waiting for new patients, they start already start to cancel appointments. Baugh and Li (2012) also note that this number depends on the availability of other hospitals nearby. In Nashville there are a number of surrounding hospitals that can potentially attract patients. According to Dexter, Macario, Traub, Hopwood & Lubarsky (1999) the OR manager should find a balance between the utilization of the OR and the waiting time the patient is faced with. Dexter et al. (1999) suggest a waiting time of two weeks.

2.3.2 Utilization rate

According to Houdenhoven, Hans, Klein, Wullink & Kazemier (2007) the focus in research has been on finding the holy grail of 100% utilization in ORs. A 100% utilization is possible, but with the risk of running into overtime and also depending on the patient mix (Houdenhoven et al., 2007). There is also a trade-off between access time and utilization rate (Dexter et al., 1999). Dexter et al. (1999) states that if the waiting time for the patient is small, the utilization of the OR cannot be near 100% utilization.

In addition to the regular BT scheduling, the 7-day release program was aimed at creating more flexibility, and also with the aim to increase utilization rate.

The definition Dexter et al. (1999) uses for utilization rate is: *"Utilization equals the time an OR is used (occupancy plus setup and cleanup) divided by the length of time an OR is available and staffed."*.

2.3.3 OR efficiency

According to Dexter and Traub (2002), OR efficiency is more than only the increase in utilization rate. It is not hard to increase the utilization rate, but it is harder to do this in harmony with overtime and underutilization. The goal is to minimize both, as far as possible. The cost of over utilized room time is higher than the cost of underutilized OR time (Dexter & Traub, 2002). To achieve the maximum OR efficiency, there are

numerous possibilities to schedule surgeries. Where to put an additional case for example to create the most effective schedule?

Regarding the OR efficiency, there are different perspectives. Minimization of overtime with all the rooms open can be possible, but also the reduction of costs by closing rooms at the costs of creating a little more overtime. This means that a trade-off has to be made between the cost of overtime and the cost of running a room in underutilized time. Dexter & Macario (2002) account the cost of overtime as 1.75 times the cost of underutilized hours. Different numbers can be used depending on how much overtime we want to allow compared to underutilized OR time.

2.3.3.1 Overtime

According to Hans, Wullink, van Houdenhoven and Kazemier (2008), introducing the planning of slack helps in reducing the chance of overtime. Slack is reserved unused time in the schedule. The OR efficiency can be increased when adding slack. The planning of slack would be based on the variance of the surgeries and a certain chance of overtime the hospital is willing to take. Linking two surgeries with the same variance would then reduce the chance of overtime and the "required" slack (Hans et al., 2008). Linking two surgeries means that they are both scheduled in the same room on the same day.

2.3.3.2 Allocation of block time

Many hospitals divide the BT among services or surgeons based on utilization rate (Dexter, Macario, Traub, & Lubarsky, 2003). According to Dexter, Macario, et al. (2003) utilization is not an accurate metric to divide blocks among services when case volume is low. The statistical deviation is too big to decide who needs a block when looking at three month and a year of data (Dexter, Macario, et al., 2003). This would support the idea of introducing the 7 day release schedule in favor of the surgeons who have lower volumes and not to assign them block time. Other parameters could be used for the block assignment, such as OR efficiency, but this is not further explained by Dexter, Macario et al. (2003).

2.3.4 Fixed and variable costs

Fixed costs are, e.g., the number of available ORs, the equipment that is available in the ORs, and the number of rooms that is opened. According to HFMA (Healthcare Financial Management Association) more than 40% of the hospitals total expenses and revenues are attributed to the OR (HFMA (2005) as cited in: Denton, Miller, Balasubramanian, & Huschka, 2010). Also Dexter et al. (2002) describe that the variable costs are not only overtime but consist of more factors. Certain surgeries are more expensive than others, and some create more revenue. Therefore, planning according to revenue is possible, although it is ethically questionable.

Whether VUMC needs to build new ORs is a strategic decision. The current situation with the 7-day release schedule can be evaluated, and a maximum capacity that is acceptable for all shareholders can be determined. The key performance indicators of access time, utilization rate and overtime or OR efficiency would form the basis. Other incentives for building new ORs might consist of new techniques and equipment that would not fit in the current ORs.

2.4 Conclusion

There is little described in the literature on the releasing of ORs. Foremost Dexter with co-authors has published work on this subject. This leaves enough room to diversify and quantify more on the subject of releasing rooms. This chapter also contains an overview of the main performance measures for Vanderbilt to take into consideration when judging the 7-day release program and its implications. Section 2.3.1 and Section 2.3.2 show the trade-off between access time and utilization rate. Section 2.3.3 shows OR efficiency and the division of block time based on utilization rate. We suggest to consider the 7-day release program as an alternative or addition to the division of BT based on utilization rate. In the next chapter we will describe the current situation and use the key performance measures where possible to indicate the performance of VUMC.

Chapter 3 Current situation

This chapter describes the current situation and gives an overview of the issues we found in VUMC. Section 3.1 describes the organizational aspects of Vanderbilt. Section 3.2 describes the planning and control of the Operating Room department. Section 3.3 describes the operational performance of the OR scheduling. Section 3.4 is on the bottlenecks we found in VUMC. Finally in Section 3.5 we draw conclusions and a further demarcation of scope for the remainder of the report.

3.1 Organization of Vanderbilt surgeries

In this section we describe the current organizational situation from the scheduling of patients to the surgeries taken place in the OR. This overview will be given from different perspectives: the locations, the case mix, patient flow, scheduling processes, the 7-day release program, and how planning systems are interrelated.

3.1.1 Various locations

There are different surgical sites or locations. In this research we limit ourselves to three locations, namely the surgical sites: FEL (Free Electron Laser location), VOR (Vanderbilt Operating Room location) and MCE (Medical Center East). The FEL site is the outpatient site, and is situated on campus. The locations VOR and MCE are both inpatient sites, and also situated on campus. Campus refers to the physical location where all the university and medical buildings are grouped together. The physical distance between VOR and MCE is not large; there is a walking bridge in between the two locations. Usually there is no transfer of patients between the two locations. Sometimes patients show up at the wrong admission office. The processes are the same for the three locations. VOR rooms are sometimes also called VUH (Vanderbilt University Hospital), there were two different locations that were merged during the last construction work. The VUH ORs were merged with VOR ORs, which means the floor of two adjacent buildings (VOR and VUH) were merged and made it into one big floor with ORs.

The three locations have a different number of ORs. The VOR location has in total 35 inpatient ORs of which at the moment there are 33/34 in service. One OR is in maintenance and another is closed Monday and Friday. More details on which service operates in which OR can be found in 0. MCE has 11 inpatient ORs and FEL has three outpatient ORs. So see an overview of the physical locations of VOR, MCE, and FEL, see Appendix B.

3.1.2 Various services and case mix

Table 2 displays the data of Fiscal Year 2013. The dataset is pulled from the ORMIS (Operating Room Management Information System) data system and based on the historic information from July 2012 up to June 2013.

Table 2: Case mix and number of cases of various specialties (Source: ORMIS, FY2013, N=32918)

Specialty	Number of cases	Percentage of total	Specialty	Number of cases	Percentage of total
Urology Surgery	3551	10.8%	Emergency General Surgery	975	3.0%
General Surgery	2439	7.4%	Thoracic	707	2.2%
Neurosurgery	2360	7.2%	Trauma	646	2.0%
Orthopedic Trauma	2346	7.1%	Renal Surgery	570	1.7%
General Oncology Surgery	2303	7.0%	Oral & Maxillofacial	521	1.6%
Otolaryngology	2250	6.8%	Neuro Interventional	479	1.5%
Gynecology	2115	6.4%	Hepatobiliary/ Liver Transplant	324	1.0%
Orthopedics	1953	5.9%	Burn	269	0.8%
Plastic Surgery	1835	5.6%	Gastroenterology	48	0.2%
Cardiac	1268	3.9%	Anesthesiology	32	0.1%
Head And Neck Surgery	1254	3.8%	Tennessee Donor Services	32	0.1%
Ortho Sports/Hand	1224	3.7%	Bone Marrow Transplant	12	0.0%
Pulmonary	1148	3.5%	Cardiology	7	0.0%
Ophthalmology	1138	3.5%	Radiology	4	0.0%
Vascular Surgery	1106	3.4%	Dentistry	2	0.0%
			Total:	32918	100%

Table 2 shows that the first 7 out of the 32 services represent already 52% of all surgical cases in a year. Table 2 also shows that there are seven services that have a

very small number of patients per year, these services do not have assigned Block Time in the Block Schedule and depend on getting their cases placed under the 7-day release program.

The total number of cases done in fiscal year 2013 at the locations FEL, MCE and VOR is 32,918, this is on average 633 cases per week. In the fiscal year 2012 all surgical locations of Vanderbilt together performed a total number of 33,140 (including the outpatient sites) surgeries (Vanderbilt University and Medical Center, 2012). The total number of surgeries for the fiscal year 2013 is 35,112 (including the outpatient sites) (Vanderbilt University Medical Center, 2013). This means an increase of 6.0% in surgeries in 2013. The prognosis is that this growth will continue for the coming years.

3.1.3 Patient flow of surgeries

Figure 1 shows the main processes concerning elective patients undergoing surgery in VUMC, beginning with the patient arriving at the admittance office or being an inpatient. Elective refers to patients that can be scheduled; the patients that are not in urgent need of a surgery such as emergency patients.

Figure 1 shows the five possible locations the patient can be transported to, and every column contains the processes performed at these locations.

The initiation starts when the patient either arrives from home or when the patient is an inpatient and is called for surgery. Patients arriving from home go through the admission and admittance office which checks all the paperwork and verifies whether all the required information from and for the patient is present before surgery can take place.

An inpatient is either an ICU patient or a ward patient. When surgery is performed on an ICU patient, the holding area is skipped, the patient is directly transported to the OR.

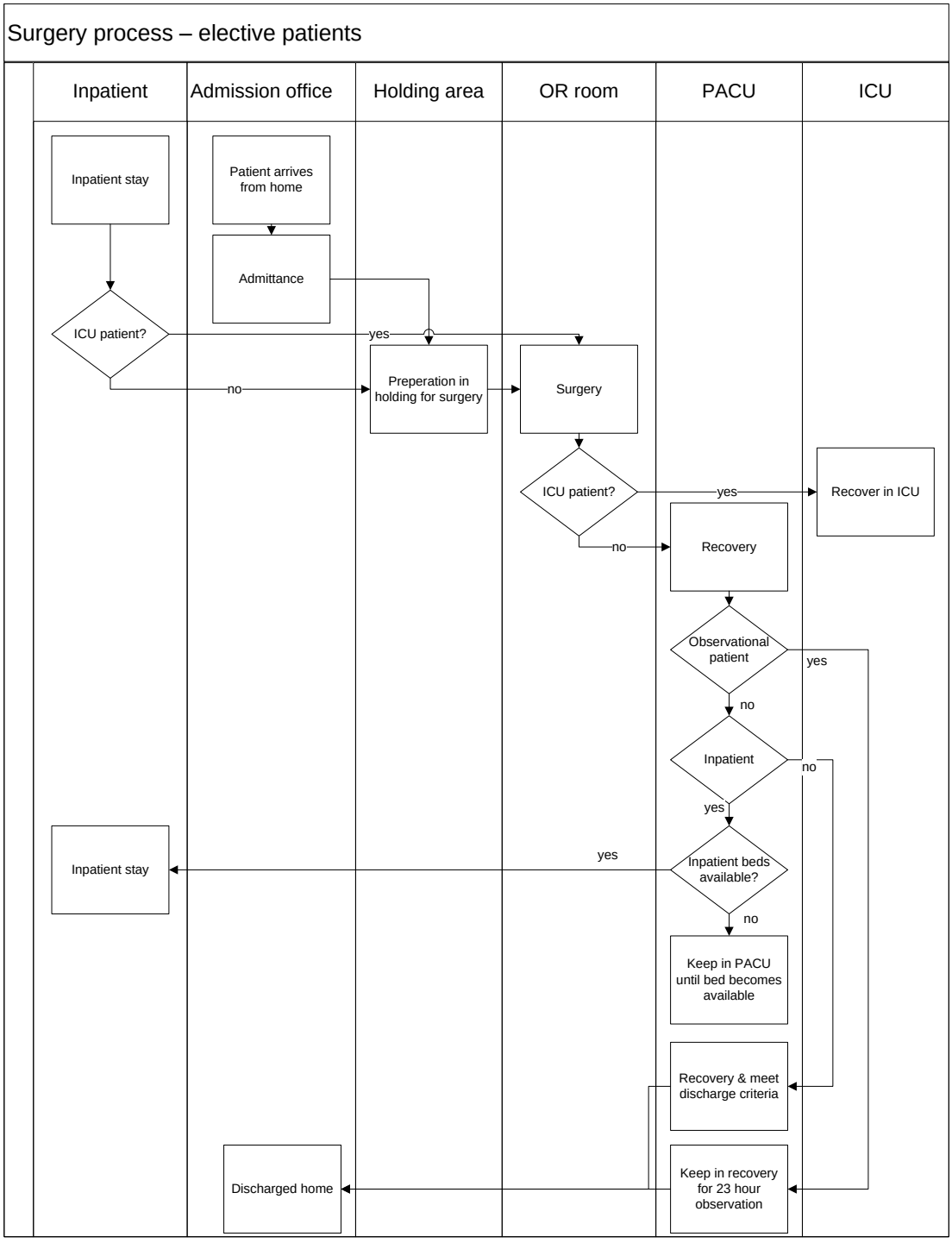

Figure 1: Surgery process – elective patients

All non ICU patients are transported to the holding area. In the holding area the surgeon and the anesthesiologist will see the patient for a last time before the surgery. In the holding area also the medication before the surgery is administered. Sometimes marking of the surgical site on the patient also happens in the holding area when

needed. After the all the checks and verifications the patient is transported to the OR where the surgery takes place.

After surgery the distinction is made regarding post-operative activity. The Intensive Care Unit (ICU) patients are directly transported from the OR to the ICU. All other patients are transferred from the OR into the PACU where they will recover from the surgery. In the PACU they will stay until they meet discharge criteria. When a bed is available, the inpatients will return to the ward. Sometimes the patient needs to be observed for another 23 hours (policy) and are then discharged the next day, they will stay in the PACU for those 23 hours.

3.1.4 Scheduling process of elective surgery per stakeholder

Section 3.1.3 described the processes involved from the point in time when the patient shows up for surgery. This section describes the scheduling of the surgery. The processes involved with scheduling the surgery are shown in Figure 2. The initial process is started when the patient arrives via the Emergency Room (ER) or one of the clinics. Figure 2 does not include the processes involved in cancelling or rescheduling a surgery. A larger version of Figure 2 can be found in Appendix A. The rows in Figure 2 represent the different stakeholders involved within the scheduling processes.

The patient can see a surgeon either via the ER or via a clinic. The surgeon will determine whether the patient is an elective case or an urgent case. At Vanderbilt, urgent or emergency cases are categorized as being Leveled cases. Leveled cases bypass the rest of the scheduling and are directly boarded into the schedule via the OR board nurses. The level indication will determine the timeframe within the cases needed to be in the OR. E.g., a Level 1 is trauma and needs to be in the OR within 20 minutes. See Section 3.2.4.2 for the details on leveled cases.

Most of the elective patients schedule their surgery in the surgeon's office together with the surgeon scheduler. Some offices hand the patient a folder with a sheet of paper with the time the surgery takes place and when to show up (see Appendix F). Other offices send a confirmation per mail or call the patient to confirm the time of surgery. The surgeon scheduler fills out a digital form to schedule the surgery into

Starpanel. Starpanel is the system that handles the electronic patient records. From Starpanel, the form is handled by the Perioperative Scheduling Team. The Perioperative Scheduling team inputs the Starpanel form into ORMIS (Operating Room Management Information System). ORMIS is the leading system used for the scheduling of surgeries and also used by the OR board on the day of surgery.

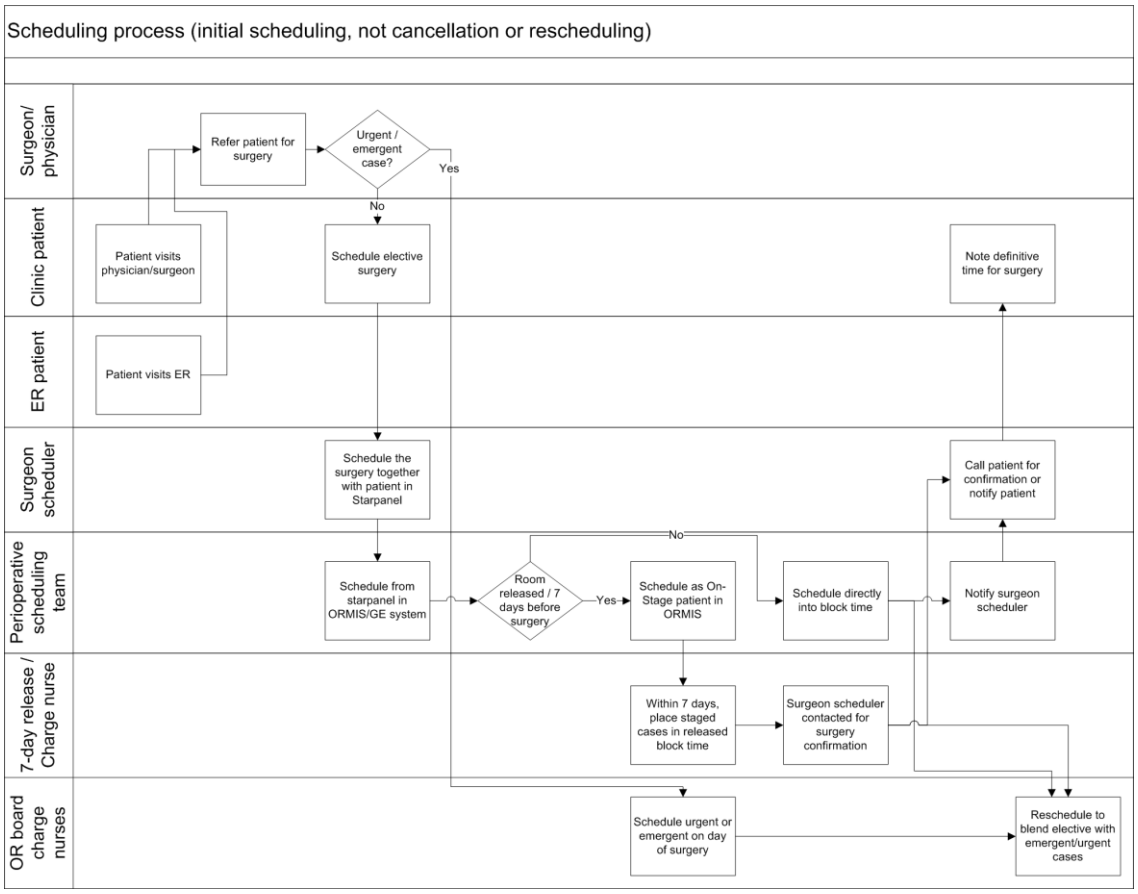

Figure 2: Scheduling process

The perioperative scheduling team releases the operating room 7 days before the surgery to all the other specialties. This is done at 10AM manually. Some rooms do not release until the day of surgery. Room 8, 12, 13, 21, 25, 26, 32 and 33 do not release until the morning of the surgery. These rooms are not released earlier, because the surgical cases appear in the last 7 days before surgery, e.g., orthopedic trauma.

Requests that come after the rooms are released are managed by the Perioperative Scheduling Team, and these cases are placed in the 'virtual rooms' and are called on-stage. If the ORs are not released they are immediately scheduled into the block time,

which is assigned to the service and surgeon. The surgeon scheduler is notified after the case has been put into ORMIS. The surgeon scheduler then calls the patient to notify the patient with the definitive time of surgery.

When cases are put on-stage, they are placed in 'virtual rooms' in the ORMIS system. These virtual rooms function as a placeholder or waiting list, until they can be scheduled, which is 7 days before the DoS. The cases are placed after the rooms are released. As noted in Section 1.2, some cases might be put on stage before the rooms are released because the surgeon does not have block time or a surgeon wants to operate outside his/her block time. When the rooms are released these cases are placed from the virtual staged rooms into "real" ORs. This is done by the charge nurse who is responsible for the placement of on-stage cases. When the cases are placed in the "real" ORs, the surgeon scheduler is notified where the case exactly is placed. The case might not be placed exactly as requested due to, e.g., limitations in availability of staff, rooms or equipment.

After the case is scheduled the surgeon scheduler notifies the patient again and hopefully the patient will note the definitive time into their calendar. The last step is done on the day of surgery by the OR board nurses, the patients (should) show up, and the board nurses blend/manage the add-on/leveled cases together with the elective cases.

3.1.5 Distinction in time & involved stakeholders in the 7-day release program

In Figure 3 the distinction is made who is involved with the scheduling of the surgeries. Also the distinction in time is made.

The vertical bars in Figure 3 marks the distinction in time, and also marks a difference in processes. The first vertical bar makes the distinction between when the rooms are released and when not. This means that most of the rooms are released 7 days before surgery, and some stay unreleased until the day of surgery. The second bar marks the distinction between the time period before surgery and the day of surgery. All of the phases are marked with numbers. Phase one in Figure 3 is the regular block

scheduling. Phase two represents the on stage scheduling of the released rooms. Phase three represents the day of surgery.

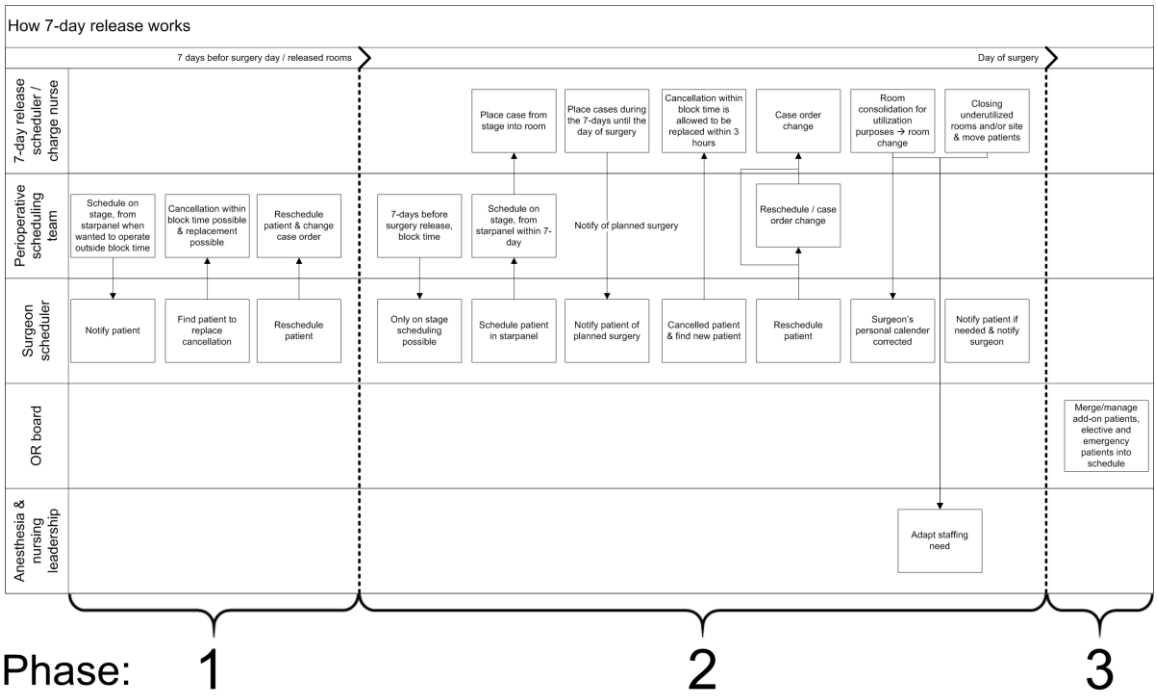

Figure 3: Diagram of how 7-day release works

In phase one, the perioperative team can schedule a request from Starpanel into ORMIS as being a staged case, when the surgeon wants to run two rooms, or want to operate outside his block time or when the surgeon does not have block time. The surgeon-scheduler will be notified and, if needed, the patient will be notified. But mostly this will happen after the cases are placed in a definitive room.

When the surgeon scheduler gets a cancellation, by either the surgeon, or the patient, the surgeon scheduler has 3 hours to replace the cancelled case by a new case, with about the same duration. If a replacement case cannot be found, the other scheduled cases will be moved to an earlier point in the day. The perioperative scheduling team will reschedule the rest of the patients or replace the cancelled patient with a new case. Afterwards, the surgeon scheduler will be notified about the rescheduling.

Sometimes, patients need to be rescheduled. Mostly this process is initiated by the surgeon scheduler. The surgeon scheduler reschedules the patient and therefore the perioperative scheduling team will have to reschedule that patient. When a gap

between surgeries arises, mostly, the rest of the cases are moved to eliminate this gap. Eliminating this gap is also done by the perioperative scheduling team.

In phase two, when the rooms are released, the processes change. The perioperative scheduling team is still involved but less. The perioperative scheduling team releases the rooms 7 days before the surgery at 10AM. Physically, the perioperative team is still able to place cases in the blocks but they are prohibited to do so. The ribbon in the ORMIS program changes when the rooms are released. The surgeon scheduler knows that, when this ribbon occurs, the cases, to be scheduled, are going to be put on stage as 7-day release case.

When the surgeon scheduler fills out the digital scheduling form (Starpanel), the perioperative scheduling team will put the patient in a virtual on-stage room. Thereafter, will the charge nurse, who is in charge of the 7-day release scheduling, look at the cases and schedule them appropriately.

Scheduling of non-block time is sometimes like making a puzzle, because more aspects, e.g., room and equipment constraints, have to be taken into account. When the case is placed into one of the rooms, the surgeon scheduler is notified when the surgery is going to take place. This is done either via e-mail or a call, but mostly via e-mail.

As soon as the rooms are released, a cancellation is more risky. A similar case with approximately the same case length has to be found within 3 hours to replace the cancelled case. When a replacement case is not found within 3 hours the case order is changed, and the time that is not “filled” is released to other specialties as well.

When a patient needs to be rescheduled within the 7-day release program, two things can happen. Either the case goes to the perioperative scheduling team or the case goes to the 7-day release scheduler, either of them can reschedule the case. When rescheduling needs to be done within the released rooms most likely this will be done by the 7-day release scheduler. Rescheduling within the normal Block Time will most likely be done by the perioperative scheduling team.

The 7-day release scheduler also takes into account room utilization. Due to the lack of cases, sometimes two rooms will be merged, when possible, or closed. Closing or rescheduling involves changing the schedule, surgeon schedulers are notified about these changes, so the surgeon scheduler can notify the patient and adjust the personal calendar of the surgeon.

When closing surgery sites and rooms, also the anesthesia and nursing leadership are notified, because it means that the staffing needs to change. This means less staffing for the days that rooms are closed, or complete sites are closed. This happens for example during holidays.

Phase three is the day of surgery. On the day of surgery, only the OR board nurses have a role in the scheduling. They manage the add-on cases, and the emergency cases, that arrive during the day of surgery. They might close rooms and cancel patients as well, but none of the other departments are involved any more.

3.1.6 Communication between the systems and differences on data recorded

In this section we describe how the different computer systems, which are involved in the scheduling of cases, communicate with each other, and how this affects the recorded data.

The scheduling of a case starts with a digital Starpanel form. The surgeon scheduler fills out this form to schedule the surgeries. These forms are then stored in Starpanel. They are also entered into the ORMIS system that is mainly used to plan and schedule patients. The surgeries are stored in ORMIS. The dataset is then pushed to Point Of Use (POU). The POU system makes sure that the Doctor Preference Cards (DPC) are going to the locations where they pick the surgery equipment (such as instruments). There is a hard close at 6PM the day before surgery. By hard close we mean that the DPCs cannot be changed after this point in time without cancelling the original order, and by rush-ordering with the DPC the case carts with equipment for the surgery. At the end of the day, VPIMS pushes back the data into ORMIS. For example, the actual start time of the surgery is pushed back into ORMIS.

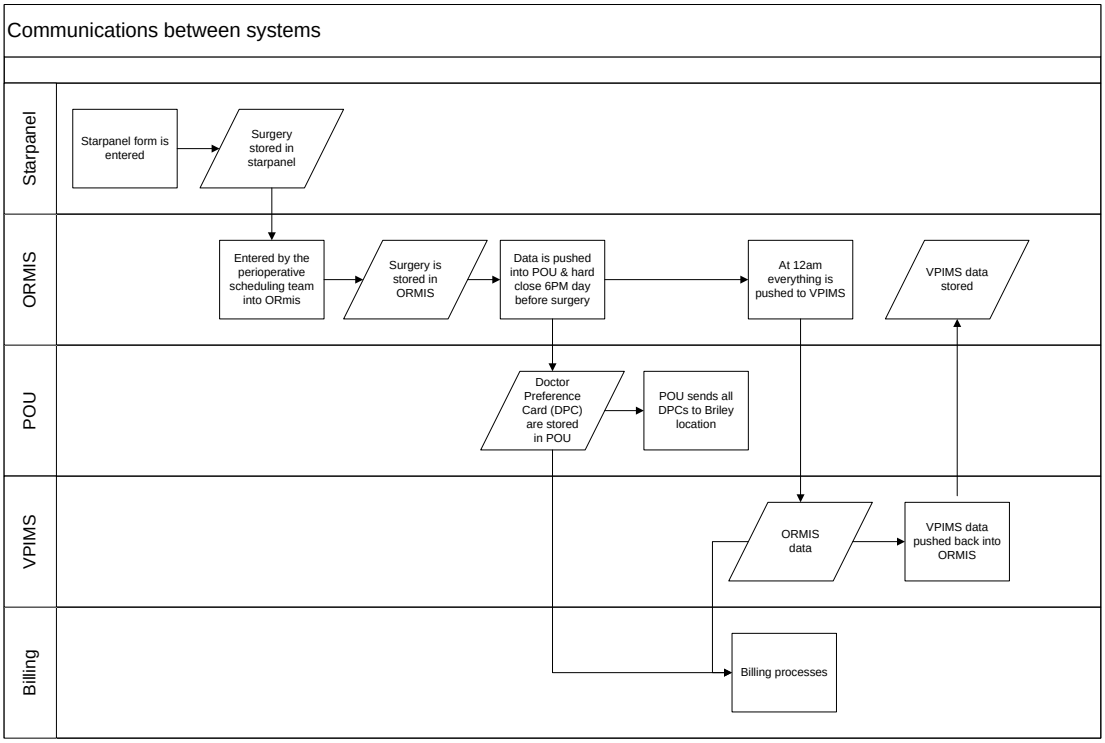

Figure 4: Diagram of the communication between systems

The data from POU and VPIMS combined also deliver the information the billing department uses to bill the patients. For example, the drugs used, the disposables used, and the kind of surgery.

There is one risky part in the system that has to be noted. When after the hard close of 6PM the day before surgery, a change in ORMIS is made, that effects: the surgery date, the surgery type, or the DPC, the surgery ID in ORMIS changes. This cannot be traced back into the system. But this has to be done since POU is not capable of making changes within the system but can only be cancelled and reloaded with new information. Therefore sometimes the surgery ID will change in ORMIS. This means that unique identifiers used in the ORMIS system do not show up in VPIMS or vice versa when comparing two datasets from both systems.

An example of and surgery ID change, would be rescheduling on the day of surgery to another day, because the patient is not fit for surgery or does not show up. The surgery is cancelled and rebooked, although it remains the same patient, and the same surgery.

3.2 Planning and control of the Operating Room department

This section describes the planning and control of the operating room by using the framework of Hans, Houdenhoven & Hulshof (2011) that describes the different managerial areas and the hierarchical decomposition within the hospital. The framework is shown in Figure 5. We focus in this report on the column Resource capacity planning.

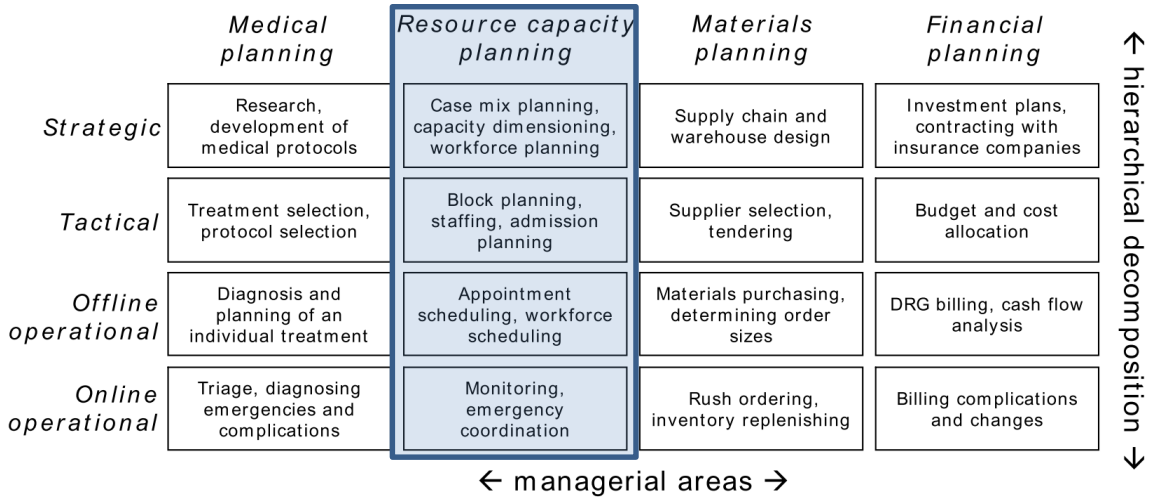

Figure 5: Framework for health care planning and control (Hans et al., 2011)

To obtain a comprehensive overview of the hospital, this section covers all of the hierarchical levels of the managerial area Resource capacity planning. In Section 3.5.1 we will further demarcate the scope for this research.

3.2.1 Strategic control

Strategic decisions can vary depending on the subjects included. Since the hospital is quite big and tied to Vanderbilt University, the decision structure is not as clear as in smaller hospitals, where a board of directors usually makes most of the strategic decision. For VUMC there are more managerial layers, and depending on the subject and investments involved, the decisions are made on different levels. For example, the expansion of ORs or the decision to buy more anesthesia machines is made by the Perioperative Executive Committee. The committee consists of the Anesthesiologist in Chief, Surgeon in Chief, Chief Nursing Officer/Associate Hospital Director. When the Perioperative Executive Committee makes the decision to expand the ORs or buy new

machines such as anesthesia machines, then higher hierarchy levels are consulted for approval of these plans. This is done since the investments are extensive and have an impact on the total performance of VUMC.

The most recent strategic decision was taken in January 2013 when VUMC decided to build 6 more operating rooms in the location of The Vanderbilt Clinic (TVC) (Vanderbilt University and Medical Center, 2013). This should enable for 8000 more surgeries over the next 5 years. However, this plan is put on hold for an uncertain period of time. This might be due to the sequester (automatic budget cuts by US government to reduce the deficit) or because volume has dropped in March and has not recovered up completely in and after April. When volume is returning to the level of before March the need for building the extra ORs might be apparent.

At the strategic level also the decision was taken that no ORs are reserved for emergency cases. The emergency cases are blended with the regular elective cases. That means that sometimes cases are getting delayed because of an emergency case. The moments that emergency surgeries can be scheduled are called the break in moments (BIM) (Lans et al., 2005).

When we propose a different scheduling approach in one of our alternative solutions, this might involve a strategic decision. For example, when we would propose emergency ORs instead of the BIM, VUMC is currently using. We will have to take into account that VUMC is hesitant to completely change the scheduling approach on a strategic level.

3.2.2 Tactical level

Tactical control and planning can partially be explained by the Block Schedule. The Block Schedule represents the questions what, where, when and who. Which surgery (what) is taking place in which OR (where), at what time (when) by which surgeon/specialty (who).

Figure 6 is a snapshot of the Block Schedule, it shows that the specialties are divided among rooms and days. The specialty names in Figure 6 are abbreviated and behind

the abbreviation the opening hours of the OR are shown. This schedule repeats itself every week. The open-10 OR (VOR22) in Figure 6 is used to place on-stage cases. The whole schedule and the exact description of the locations and abbreviations can be found in 0.

When surgeons are going to be away for a conference for example, they have to notify this at least 2 weeks before their leave or absence. Otherwise, this will be counted against their utilization rate of their BT. The service will either find a surgeon who can operate that day or will notify the perioperative scheduling team, and the 7-day release scheduler, that the particular room of that surgeon can be used to schedule on-stage cases.

4/1/2012					
ROOM	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
	VOR3	VOR3	VOR3	VOR3	VOR3
VOR1	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-10
VOR2	Plastic-12	Plastic-10	Oto-HN-10	Oto-HN-10	Plastic-10
VOR3	Oto-HN-10	Plastic-10	Oral-10	Plastic-10	Oto-HN-10
VOR4	Ophtho-12	Ophtho-10	Ophtho-12	Ophtho-10	Ophtho-12
VOR5	Oto-HN-12	Oto-HN-12	Oto-HN-12	Oto-HN-12	Oto-HN-12
VOR6	Plastic-10	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-8
VOR7	Neuro-10	Neuro-12	Neuro-10	Neuro-10	Neuro-10
VOR8	NeuroInv-12	NeuroInv-12	NeuroInv-12	NeuroInv-12	NeuroInv-12
VOR9	Vascular-12	Vascular-10	Vascular-12	Vascular-12	Vascular-10
VOR10	Neuro-12	Neuro-10	Neuro-12	Neuro-12	Neuro-12
VOR11	Ortho-12	Ortho-12	Ortho-10	Ortho-10	Ortho-12
VOR12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12
VOR13	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12
VOR14	Ortho-12	Ortho Sports-10	Ortho-10	Ortho Sports-12	Ortho-10
VOR15	EP-	EP-	EP-	EP-	EP-
VOR16	EP-	EP-	EP-	EP-	EP-
VOR17	Ortho-12	Ortho-10	Ortho-12	Ortho-10	Ortho-10
VOR18	Ortho-10	Ortho-10	Ortho-10	Ortho Sports-12	Ortho Sports-10
VOR19	Neuro-10	Neuro-10	Neuro-10	Neuro-10	Neuro-10
VOR20	Neuro-10	Neuro-10	Neuro-10	Neuro-10	Neuro-10
VOR21	Neuro-10	Neuro-10	Neuro-10	Neuro-10	Neuro-10
VOR22	Open-10	Open-10	Ortho-10	Oral-10	Open-10

Figure 6: The Block Schedule

3.2.3 Offline operational level

Offline operational level involves the scheduling of the surgeries. The decision of which surgery is placed in which room, this is already described under Sections 3.1.4 and 3.1.5. In these sections the processes are described that are involved with the offline operational planning and the different stakeholders who are involved.

The way of scheduling is based on a first come first serve basis. There is no logic behind the scheduling. Strategies to minimize the variance or overtime are not used. Dexter and Macario (2002) characterize this approach as the Any Workday approach.

3.2.4 Online operational level

The online operational level involves the management of the elective surgeries, on the day of surgery, which have to be delayed to a later point in time, because there is an emergency case coming in. Also, this level involves the planning which rooms can be closed or whether an extra room needs to be opened.

An extra aid, to the staff and the OR-board, is the eOR-board. This is a digital representation of the schedule of that day in the different rooms. The expected duration is visible and changes can be seen on the board. Also the different phases of the surgery are displayed. We will discuss this in Section 3.2.4.1. In addition to the eOR-board, there is VigiView, an app via which the surgeon, or other staff members, can access the live stream cameras in the ORs. During our stay we have seen that the two system are used frequently by staff, and that they found it very useful.

Online operational level involves also taking care of urgent cases. Urgent cases are called leveled cases, where the level/urgency is determined based on the condition of the patient. More information can be found in Section 3.2.4.2.

3.2.4.1 eOR-board: tracking patients & surgeons

On the eOR-board all the surgeries of that surgery site (e.g., VOR or MCE) will be displayed. The predicted total duration from wheels into the OR until wheels out of the OR is displayed on the screen. While things are in progress, different situations are displayed on the screen, by changing the color of the surgery. So the color of the predicted duration changes according to the status. An example of how the eOR-board looks like can be seen in Figure 7. The legend of the eOR-board can be found in Appendix G.

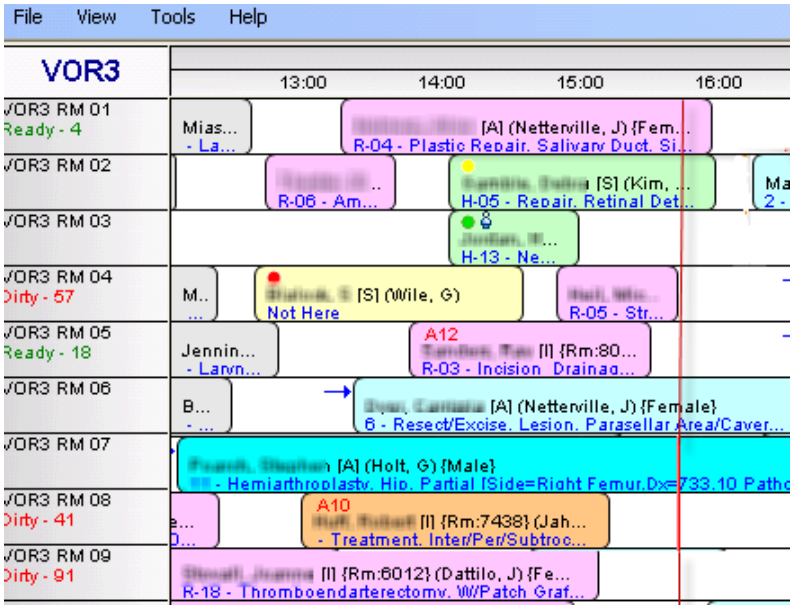

Figure 7: Example of the eOR-board

A lot of information for both the Charge nurses in the Command Center and the staff in the ORs is displayed on this screen and the Charge nurses can anticipate on the activities that will happen. E.g., a surgery is prolonged an a different comes available in which the case following the prolonged case can be performed, the board can to decide to move the case, so time can be saved.

3.2.4.2 Leveled (urgent) cases and time constraints

For the Leveled cases there are targets on timing. There are four different levels of Leveled cases that can be distinguished.

We quote from the Policy Manual (Feistritzer et al., 2010):

Level 1 Emergency (Emergent): Critical condition, which is an immediate threat to life to go in the next available room. Case must go immediately into first available room within 20 minutes.

Level 2 Emergency (Urgent): Patient Condition will deteriorate significantly if not done urgently; Case should be expected to start no later than 2 hours from posted time. Case to preferentially go in room of same surgeon/service.

Level 3 Emergency (Urgent): Nature of condition permits delay of surgery of up to 4 hours. Case to preferentially go in room of same surgeon/service.

Level 4 Non-Emergent Case: A non-emergent case which for cost-containment or other reasons, should not be delayed until the next business day.

Level 4 is planned to be renamed to Administrative leveled case, and will be used for: transplants, organ donation and open abdominal surgery. This rename is not yet implemented, but Level 4 is rarely used in practice.

The case will be displayed on the eOR-board and a number will be running in front of the case that represents the number of minutes left before the above mentioned deadline is missed. An example is shown in Figure 8, there are 120 minutes left until the deadline of this leveled case is passed.

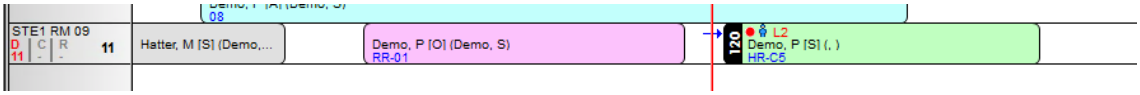

Figure 8: Leveled cases timer

3.3 Operational performance of the OR scheduling

In this section the operational performance of the OR and the scheduling process will be described.

For Section 3.3.1-3.3.4 we used data from the ORMIS system. In total four months of historic data are used to give an oversight of the current performance and to analyze bottlenecks. Only four months have passed since Vanderbilt started to collect and summarize the OR data into Future Case Count Reports (FCCR). In the FCCR the OR data is summarized, and it makes a snapshot of the scheduled surgeries in the upcoming 14 surgery days. The FCCR runs every day at 5PM. The FCCR does not capture the DoS, it only captures the next 14 days, so it starts with the next day. This means that no historic information is captured in the FCCR.

The FCCR runs every day, and makes a snapshot every day, 14 days out, this means we can analyze the data and see where changes are made when we compare the daily reports. In the FCCR the following data is collected: case number, site (e.g., MCE, VOR), case start time, case end time, surgery date, OR name, service, and the run date of the FCCR. By analyzing this data in excel we can find cancelled cases, rescheduled cases, and staged cases. For the Sections 3.3.1-3.3.4 we used the data collected in the FCCR,

and for Section 3.3.5 we used historic data from ORMIS. The historic ORMIS data contains all the information on what actually happened on the DoS, but data is only logged when the surgery actually happened. The historic ORMIS data and the FCCR contain different information, the FCCR looks ahead in time, where the other collects what actually happened on the DoS.

3.3.1 Number of rescheduled surgeries

We expect to see a number of rescheduled surgeries in the period two weeks before the DoS. Vanderbilt wants to know whether there is a difference between elective case scheduling and (7-day release) staged case scheduling, regarding the rescheduling of surgeries. We expect that staged cases are rescheduled more frequently, cancelled more often, and postponed more than regular elective scheduling.

3.3.1.1 Data modelling assumptions

In the data analysis we make the distinction between, the elective non-staged patients/cases, and the staged patients/cases. With elective non-staged cases we mean regular elective patients. So two groups are created: staged cases and non-staged cases.

Also a distinction is made whether a case gets rescheduled to a different date or that the case only gets rescheduled on the same day, in the timeframe of 14 days in advance of the scheduled surgery day. Since the snapshot is only made 14 days in advanced, changes outside this time-span are not recorded.

Rescheduling to a **different day** can happen in four different ways:

- Same time, same room
- Same time, different room
- Different time, same room
- Different time, different room

Both staff and patients are affected negatively by rescheduling to a different day. For the patient, it might cause the most inconvenience since patients sometimes have to make a lot of arrangements for their surgery. For the staff this means that they have extra work by rescheduling the case, preparing DPC, and case carts again.

When rescheduling on the **same day** occurs, then there are three different rescheduling possibilities, and one situation where everything stays the same, namely: Same time, same room.

The other three possibilities with their impact are:

- *Same time, different room*: patient is operated the same time, same day only the staff is affected by this change.
- *Different time, same room*: Patient is affected, because the patient is rescheduled to a different time, does not really affect staff.
- *Different time, different room*: Staff and Patient are both affected because the room changes and the time of the surgery changes.

So this means that there are 7 different situations that involve rescheduling, since same date, same time and same room means no rescheduling. The option 'same date, same time, same room' is not a reschedule, and therefore excluded from the totals of Table 3-Table 5.

In the data that is collected by ORMIS, in the form of the FCCR, there is no data field that tells whether a case is: a 7-day release case, or regular elective case. We will refer to the 7-day release cases as: staged cases, and to the regular elective cases, scheduled in regular BT, as: non-staged cases. In order to make a clear distinction between the staged and non-staged cases we had to make some assumptions. When a cases is scheduled in a virtual room, we can mark the case as a staged case. During the analysis we found out that we did not capture all of the staged cases, this because not all staged cases showed up in the virtual rooms. In order to capture the cases we 'missed' we applied a set of rules, which we will refer to as **heuristic**.

The basic rules applied for the heuristic, to mark the cases as staged:

- The case shows up, in the FCCR, for the first time, within 7 days prior to the DoS.
- The cases is scheduled in a OR that releases according to the 7-day release program.

We apply this heuristic because it is possible to by-pass the virtual on-stage rooms, within the 7 days prior to the DoS. The on-stage cases sometimes do not show up in the data because they are placed within a day, so the case bypasses the on-stage virtual rooms in the daily capture. Since we also want to capture the 'bypass' we applied the heuristic to find these cases and mark them as on-stage cases. More assumptions, exceptions, sorting methods and parameters for the analysis can be found in Appendix C.

3.3.1.2 Descriptions of the various cases

This section gives a short summery of the different type of cases.

- Non-staged: regular elective cases that are scheduled in regular BT, not a 7-day release program case.
- On-stage: all cases that are scheduled under the conditions of the 7-day release program (and a combination of the following two sub bullet points).
    - On-stage via virtual room: cases that show up in the FCCR in one of the virtual rooms, in the data analysis marked as 7-day release program case.
    - On-stage via heuristic: cases that bypass the virtual rooms in the FCCR, and marked in the data analysis by applying a set of rules, the heuristic, to mark these 7-day release program cases.

We use these descriptions further on in the remainder of this chapter to clarify and distinguish between different situations.

3.3.1.3 *Total of rescheduled cases: on-stage and non-staged*

This section shows the overview of all of the rescheduled cases, where we make no distinction between on-stage and non-staged the cases. The data we used for this analysis, is from October 30 2012 to March 27 2013, and consists of 13,904 scheduled cases.

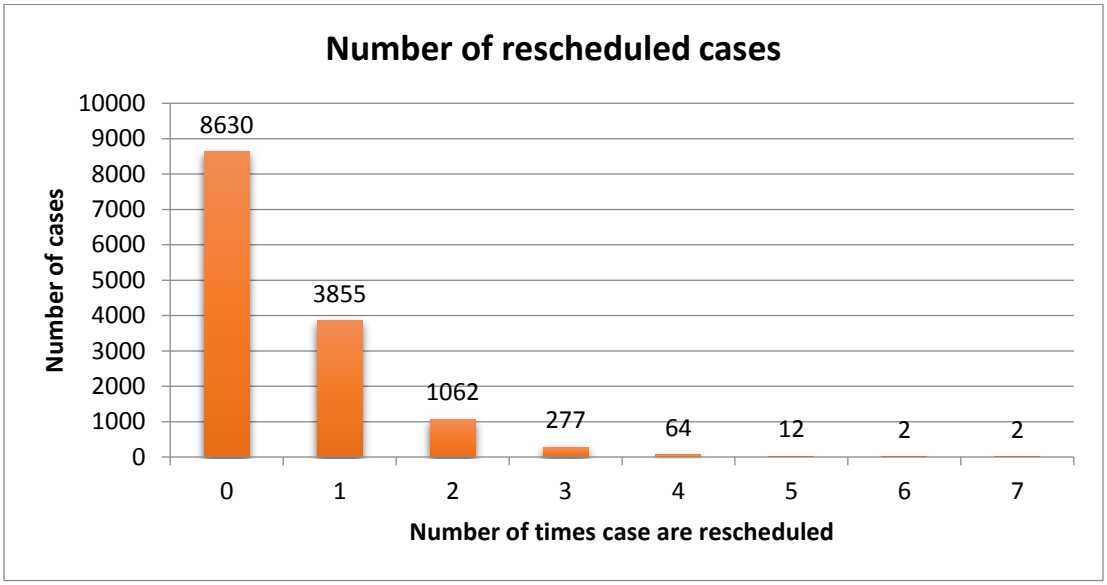

Figure 9: Histogram rescheduling of all cases (N: 13,904 T: Nov 2012-Mar 2013 Source: FCCR)

In Figure 9 we see can see the number of cases that are rescheduled. Of the 13,904, 8,630 will not be rescheduled. Adding the rescheduled cases results in 5,274 cases that are rescheduled at least once. The 5,274 cases that are rescheduled, result in a total number of 7,152 rescheduled instances (some cases are rescheduled more than once).

The histogram in Figure 9 clearly shows that the majority of the cases are not rescheduled within 14 days of the surgery (0 bar on the x-axis), although there are in total 5274 cases rescheduled. This means that 62% of the cases do not get rescheduled before the surgery, 38% is rescheduled, either to a different day or moved around on the day of surgery. The snapshot takes only into account the 14 days before surgery, which means this number might be higher, if the system would capture longer in advanced to the DoS, e.g, 30 days instead of 14.

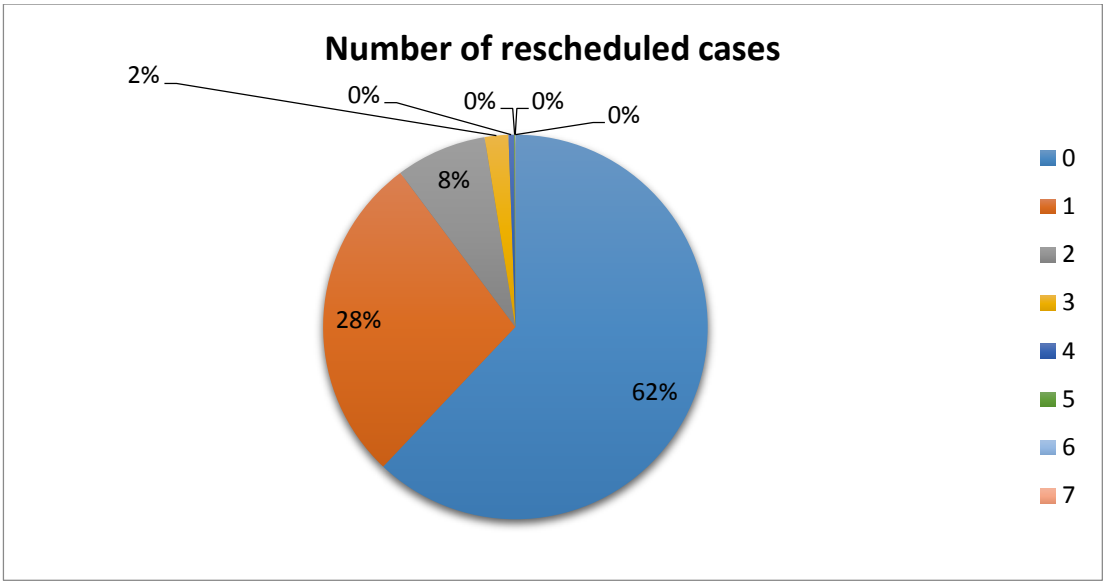

Figure 10: Pie chart of the number of rescheduling cases (N: 13,904 T: Nov 2012-Mar 2013 Source: FCCR)

Figure 10 shows the numbers in Figure 9 in a better visualized way to see that 62% of the cases are not rescheduled. The numbers in Figure 10 correspond with Figure 9. The difference is that Figure 9 shows the absolute numbers where Figure 10 shows the share of the rescheduled cases.

Since the FCCR takes a snapshot only once per day, the number of reschedules can be larger than this number; this is because multiple reschedules on one day can happen. We assume that when a case gets rescheduled multiple times on one day, the patient is only notified once. Assuming the case sometimes had to be moved a couple of times before the surgeon scheduler, or the charge nurse in charge of the on-stage scheduling, can find the right fit for all of the surgeries, to be performed in the right room, with availability of the right equipment.

Table 3: All cases, rescheduling to different date and same date. Source: FCCR.

Different date:						
	Same time		**Different time**		**Total**	
Same room	**86**	**(0.6%)**	**243**	**(1.7%)**	329	(2.4%)
Different room	**79**	**(0.6%)**	**312**	**(2.2%)**	391	(2.8%)
Total	165	(1.2%)	555	(4.0%)	720	(5.2%)
Same date:						
	Same time		**Different time**		**Total**	
Same room			**1464**	**(10.5%)**	1464	(10.5%)
Different room	**2294**	**(16.5%)**	**1917**	**(13.8%)**	4211	(30.3%)
Total	2294	(16.5%)	3381	(24.3%)	5675	(40.8%)

Table 3 shows the distinction between the number of cases that, get rescheduled to a different day, and rescheduled only on the planned day. We can see that, with a total of 720 cases, the number of rescheduling to a different day, is almost 8 times lower than the number of rescheduled cases on the day of surgery. Every reschedule means quite some work. The perioperative scheduling team, the charge nurse, and the surgeon scheduler are all contacted and notified of changes, and have to make changes in their own systems. Also the patient has to be notified about the changes.

This section showed the total overview of the rescheduled cases, in the next sections we will explain the distinction we made based on the assumptions noted Section 3.3.1.1.

3.3.1.4 Rescheduled On-stage cases – including heuristic

In Table 4 we show the results of the number of rescheduled on-stage cases, including the cases we marked as on-stage via the heuristic (see Section 3.3.1.1). So we include, the cases that show up in de data in one of the virtual rooms, and the cases marked via the heuristic. We combine the two in the results shown in this section.

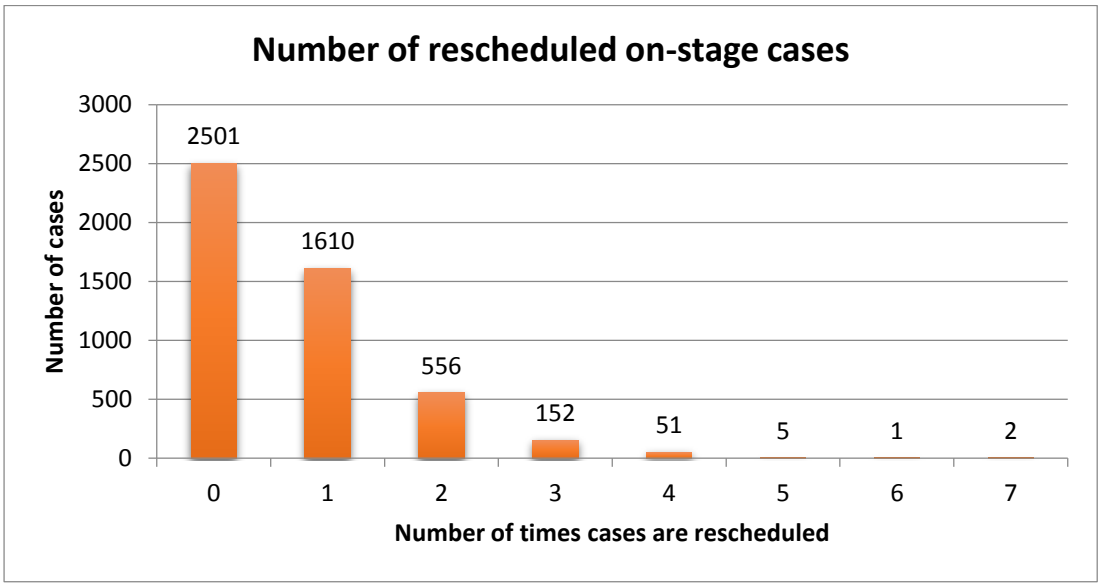

Figure 11: Histogram of rescheduled on-stage cases. (N: 4878 T: Nov 2012-Mar 2013 Source: FCCR)

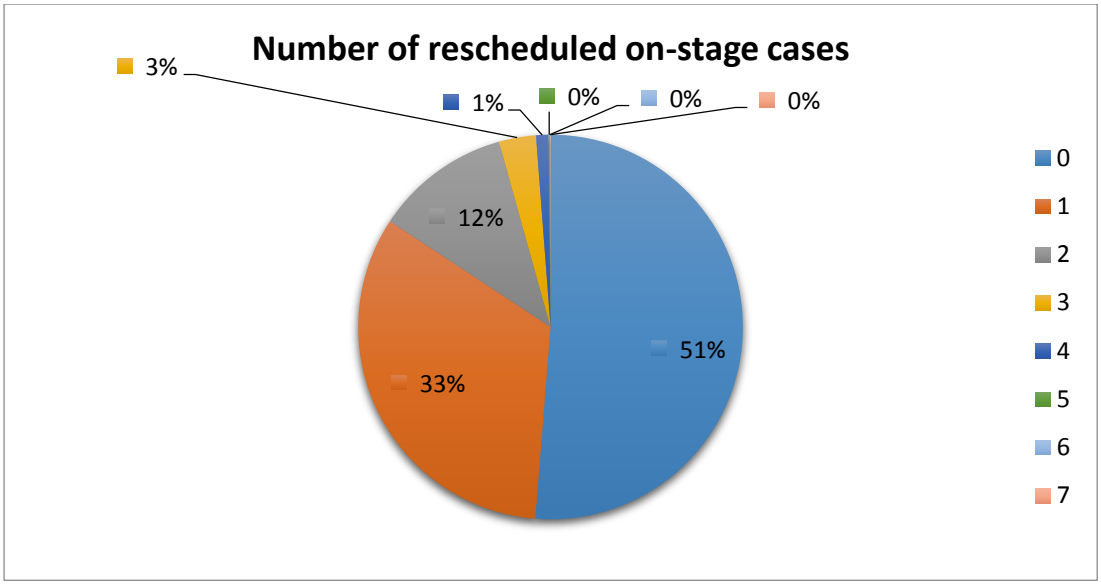

Figure 12: Pie chart of the percentage of rescheduled on-stage cases (N: 4878 T: Nov 2012-Mar 2013 Source: FCCR)

In Figure 11 and Figure 12, we can see that 51% of the on stage cases are not rescheduled. The 51% is not surprising, since we capture quite a lot with the heuristic, and the 33% is also not surprising since all the cases, that are not captured by the heuristic, need to be scheduled from the virtual rooms into real rooms.

Table 4: on-stage cases via heuristic & virtual rooms. (N: 4878 T: Nov 2012-Mar 2013 Source: FCCR)

Different date:						
	Same time		**Different time**		**Total**	
Same room	**17**	**(0.3%)**	**58**	**(1.2%)**	75	(1.5%)
Different room	**50**	**(1.0%)**	**163**	**(3.3%)**	213	(4.4%)
Total	67	(1.4%)	221	(4.5%)	288	(5.9%)
Same date:						
	Same time		**Different time**		**Total**	
Same room			**317**	**(6.5%)**	317	(6.5%)
Different room	**849**	**(17.4%)**	**1565**	**(32.1%)**	2414	(49.5%)
Total	849	(17.4%)	1882	(38.6%)	2731	(56.0%)

In Table 4 we can see that of the staged cases 5.9% get rescheduled to a different date, and 56.0% gets rescheduled within the day of surgery, of the on-stage cases. The 56% sounds alarming although all the cases that are placed in a virtual room should be rescheduled into a real OR. This is only a virtual reschedule and expected to happen and therefore less alarming than at first sight. Although the reschedule of 5.9% to a different date is alarming. Whether the 5.9% is patient driven rescheduling or surgeon initiated rescheduling remains unknown.

3.3.1.5 Rescheduled non-staged cases (regular elective cases)

In this section the results on the non-staged rescheduled cases (so regular elective cases) are shown. In Table 5 we can see that cases are rescheduled 2,944 times on the same date, and 432 times to a different date. Figure 13 and Figure 14 show the number of cases affected by the reschedule.

Table 5: percentage of rescheduled elective cases. (N: 9026 T: Nov 2012-Mar 2013 Source: FCCR)

Different date:						
	Same time		**Different time**		**Total**	
Same room	**69**	**(0.8%)**	**185**	**(2.0%)**	254	(2.8%)
Different room	**29**	**(0.3%)**	**149**	**(1.7%)**	178	(2.0%)
Total	98	(1.1%)	334	(3.7%)	432	(4.8%)
Same date:						
	Same time		**Different time**		**Total**	
Same room			**1147**	**(12.7%)**	1147	(12.7%)
Different room	**1445**	**(16.0%)**	**352**	**(3.9%)**	1797	(19.9%)
Total	1445	(16.0%)	1499	(16.6%)	2944	(32.6%)

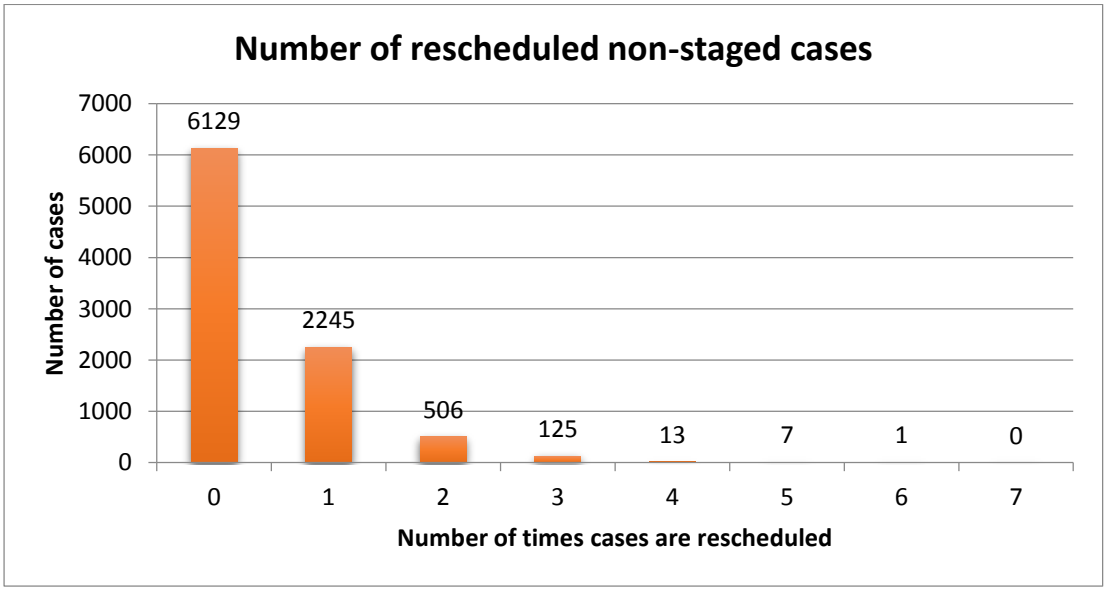

Figure 13: Histogram of rescheduled elective cases. (N: 9026 T: Nov 2012-Mar 2013 Source: FCCR)

From Figure 13 and Figure 14 we can see that 68% of the cases do not need to be rescheduled, whereas 32% of the cases need one or more reschedules.

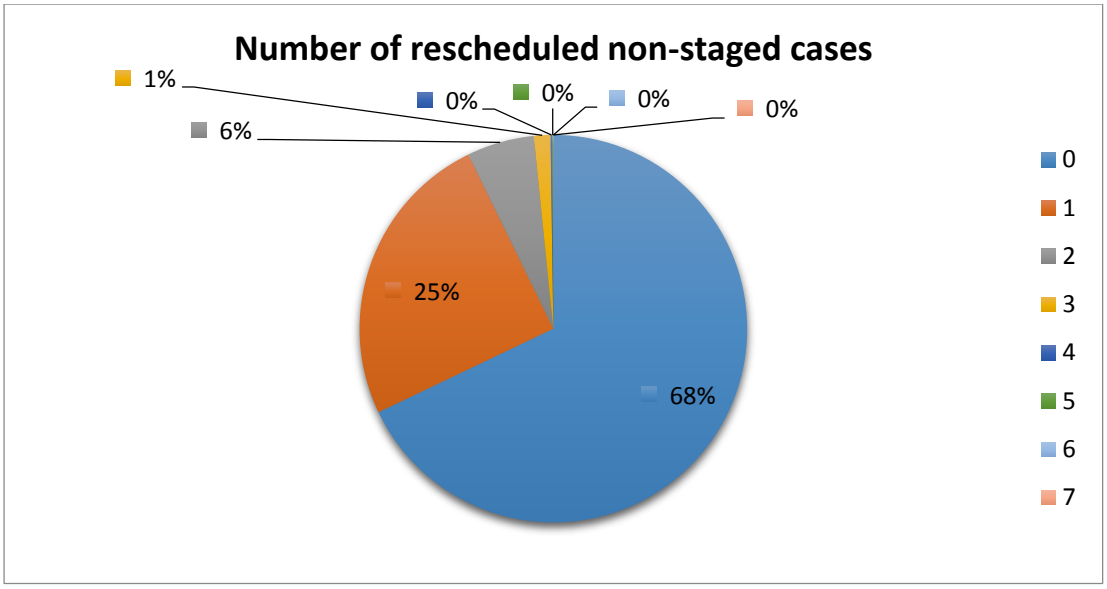

Figure 14: Pie chart of the percentage of rescheduled elective cases. (N: 9026 T: Nov 2012-Mar 2013 Source: FCCR)

3.3.1.6 Overall view of rescheduled surgeries

In order to compare the data we made one overall graph where we combine: all rescheduled cases, the on-stage rescheduled cases, and the non-staged rescheduled cases, see Figure 15. Where the number of rescheduled surgeries is shown as percentage of the total number of cases (all elective, non-staged, and on-stage cases).

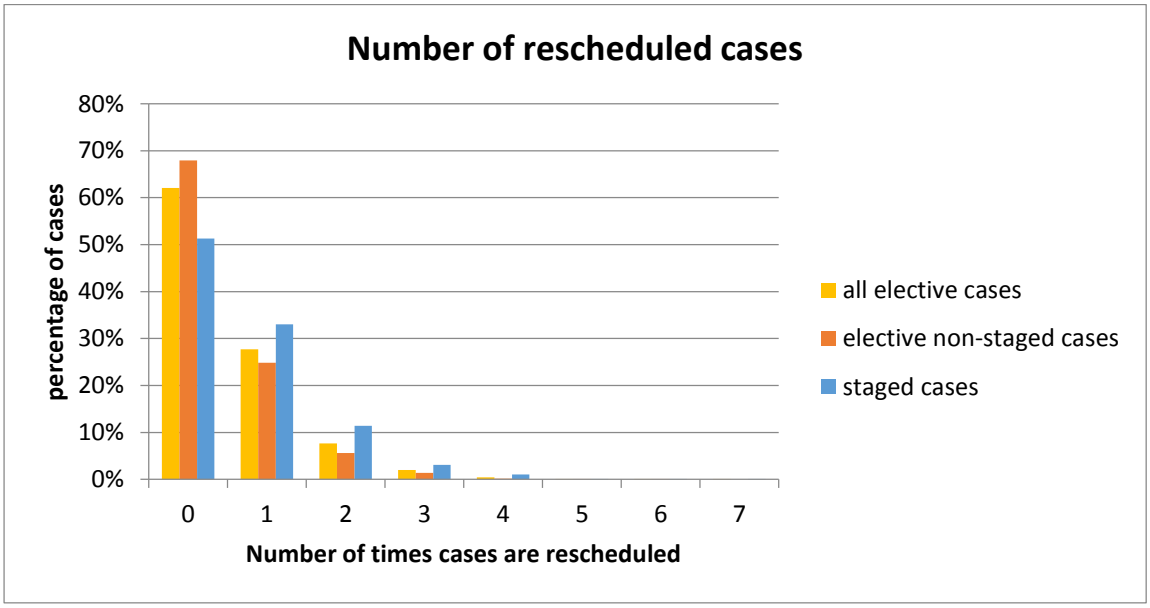

Figure 15: Histogram of the number of rescheduled cases. (N: 13904 T: Nov 2012-Mar 2013 Source: FCCR)

In Figure 15 we can see that there is not a large difference in percentage between the on-stage, the non-staged elective and total of the cases (all elective), although we see a higher level in the on-stage cases that are, at least once, rescheduled. This is not surprising since on-stage cases will be placed from a virtual room into a definitive room, except those caught with the heuristic, because they bypass the reschedule from the virtual room. The combination in the on-stage cases that are rescheduled from the virtual room and those marked by the heuristic leaves this view a bit unclear. In Figure 16 we also split the on-stage cases in the ones marked via virtual room en the ones marked via the heuristic. The first three bars in Figure 16 are exactly the same as in Figure 15.

The two additional bars in Figure 16, split the on-stage cases in: on-stage via virtual rooms and on-stage via heuristic. The heuristic has a spike where the virtual rooms have a low bar, this can be explained by the fact that all the virtual cases need to be placed in a definitive room, so rescheduled at least once. The high number of non-rescheduled cases in the 'on-stage via heuristic cases' can be explained because they bypass the virtual room and are immediately placed in the definitive OR, and do not need to be rescheduled. That is why they level out, when they are combined in Figure 15.

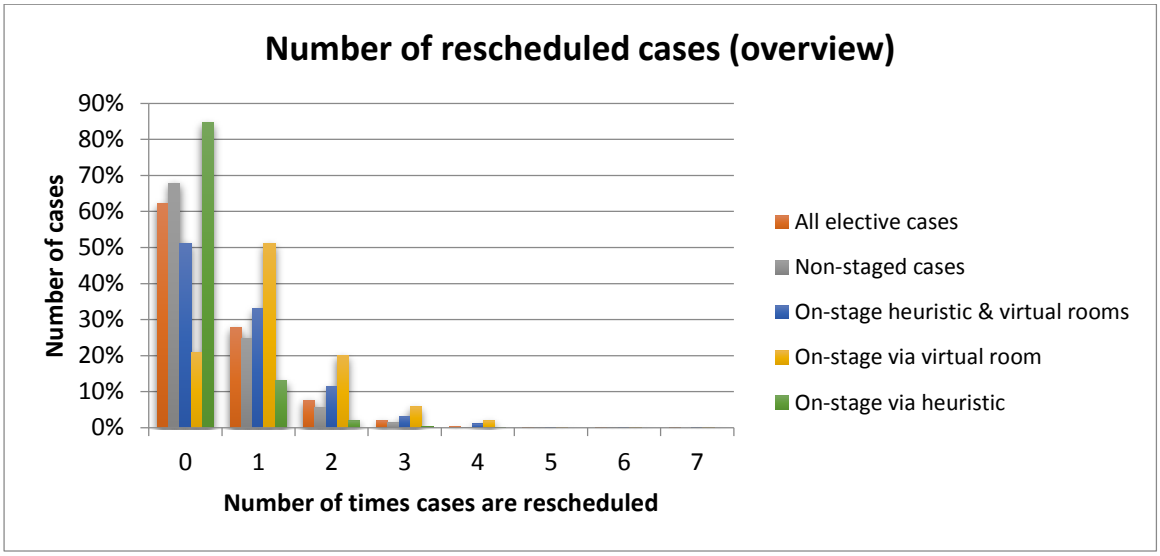

Figure 16: Rescheduling broken down. (N: 13904 T: Nov 2012-Mar 2013 Source: FCCR)

3.3.2 Number of patients positively and negatively affected by rescheduling

Table 6 shows the total number of cases for the different cases (see section 3.3.1.2) and summarizes the negative and positive scheduling events. This means only the number of reschedules is counted when the date changes. A positive reschedule is when the case is rescheduled to an earlier date, and a negative reschedule is to a later date.

Table 6: Positive and negatively affected cases per scheduling situation. (N: 13,904 T: Nov 2012-Mar 2013 Source: FCCR)

Rescheduling	# new cases	positively (for pat)	% positive	negative	%negative
Non-staged	9026	86	1,0%	366	4,1%
On-stage total	4878	64	1,3%	243	5,0%
On-stage room	2552	52	2,0%	198	7,8%
On-stage heuristic	2326	12	0,5%	45	1,9%

The patients scheduled via the on-stage room (non-heuristic) are clearly the most negatively affected by rescheduling, this is 7.8%. Also the most positively influences are found among these cases by 2.0%.

The least affected are the patients put up for surgery that are caught by the heuristic applied this is 1.9%. This is not very surprising since most of the cases put on stage have a short planning horizon, and therefore less things change in that time period.

3.3.3 Number of cancelled patients

In the data, we marked a patient as cancelled when, within the 14 days before surgery, the patient would suddenly disappear and not reappear in the rest of the time. So from October 30 to March 27. This is the same time interval as used in the Future Case Count Reports.

In total of the 13,904 cases scheduled there were 1038 cancelled cases, this results in a cancellation rate of 7.5%. This number might be lower in reality, because of two reasons. The first reason: the case numbers in ORMIS sometimes change (see Section 3.1.6), thus we might mark rescheduled cases, which received a new case number, as a cancellation. The second reason: we mark cases as cancelled when the case is

rescheduled to a date at least 14 days after March 27, since it will not reappear in the data. An example of this: when a case was scheduled for the 15th of March and would be rescheduled for the 25th of April, the Future Case Count Report does not show this case on the 27th of March, and we mark it therefore as a cancelled case, instead of a rescheduled case.

According to Schuster et al. (2011) has the average university hospital a higher cancellation rate than community hospitals. The numbers vary among the measured university hospitals between 4.6% and 16.5% with the average of the University hospitals having a cancellation rate of 11.8%. Therefore we conclude that Vanderbilt is on the low side of the spectrum. The article defines it as a cancellation when: surgery is cancelled after finalizing the schedule, the day before. Our data take into account all of the 14 days before surgery. Due to this we believe the found number in our dataset is an over estimation of the true number of cancelled cases.

3.3.4 Access time to OR from 7-day release and before

We can distinguish two separate time intervals in which the patient has to deal with access time. The first possible time on which the patient can be seen in the clinic, and the time in between the clinic visit and the first opportunity to schedule the surgery.

We concentrate on the access time measured from the time that the patient and surgeon want to book a surgery to the first time the OR is available for that surgery. As an indicator for this we use the time difference between the date the surgery was booked and the actual surgery date. We measured this for all services from the 19th of December 2012 until the 27th of March 2013. In total there were 8,585 elective cases scheduled.

We can see that the majority of the cases are scheduled within the last 7 days before the surgery. The average time between the booked date and the case date is 21 days. However, the median is 14 days, so the data as we also can see in Figure 17, is skewed to the left.

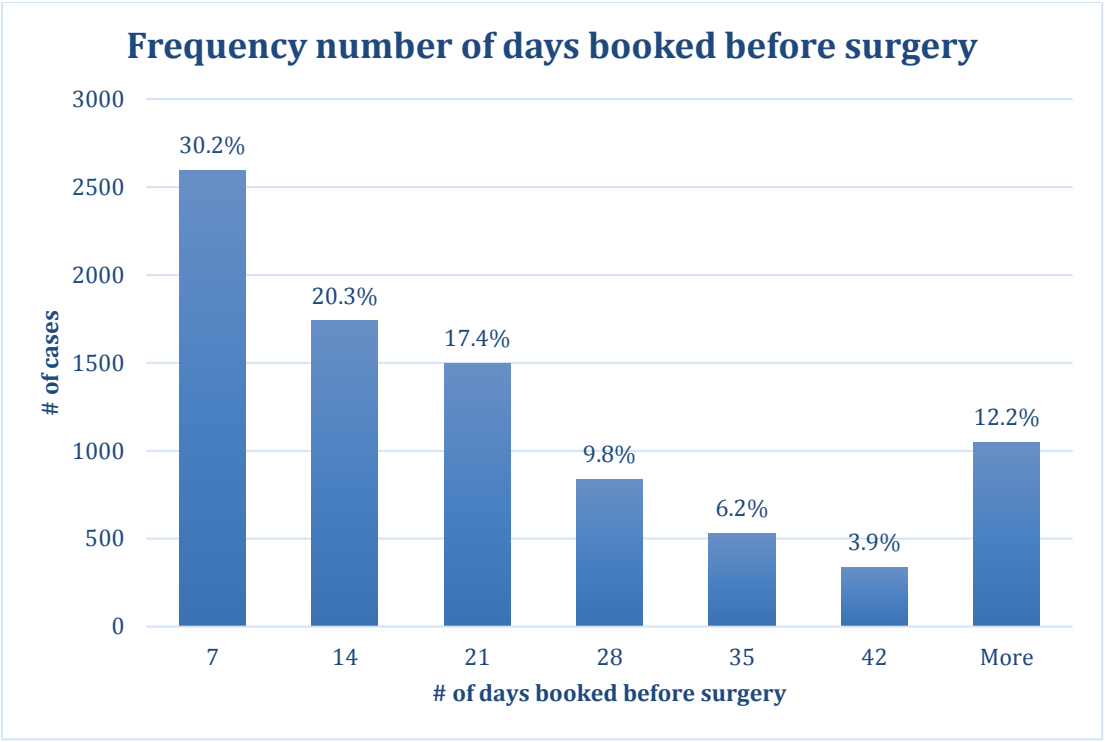

Figure 17: Access time: book date versus case scheduled date. (N: 13904 T: Nov 2012-Mar 2013 Source: FCCR)

The question is, whether the 7-day release program, had any influence on the access time. The staged cases are not logged in the systems as being staged cases. In the future case count reports (FCCR) we applied a set of rules to find staged cases. This is unfortunately not possible with the historic data. In the FCCR the change from a virtual staged room is logged, but in the historic database this information is truncated after half a year. This means that this information is not available. If the data, dating back to the introduction of the 7-day release program, would have been available, we could have analyzed, whether it contributed to the decrease in access time.

3.3.5 Utilization rate before and after introduction of 7-day release

The utilization of the ORs of VUMC is shown in four different ways: total number of surgery hours per week, number of cases per week, utilization rate without turnover time and utilization rate including turnover time. Figure 18 shows the number of cases per week. The average number of cases per week is 590 and the median is 600 cases per week. The largest number of cases performed is 701 and the least is 336, which was during the Christmas holidays. Figure 19 represents the total number of hours surgery is performed per week. The median of the total number of hours surgery per

week is 1987 hours. Figure 20 shows the utilization rate per week without taking into account the turnaround time. The median of the utilization per week without turnaround time is 70%. For the turnaround time we took 30 minutes. The 30 minutes is not the measured turnaround time, but an estimation, since also delays are measured in between surgeries, but we do not want to attribute delays to turnaround time, since it would give a too positive image of the real situation. Figure 21 shows the utilization rate with turnaround time and the median of the utilization rate of 83%.

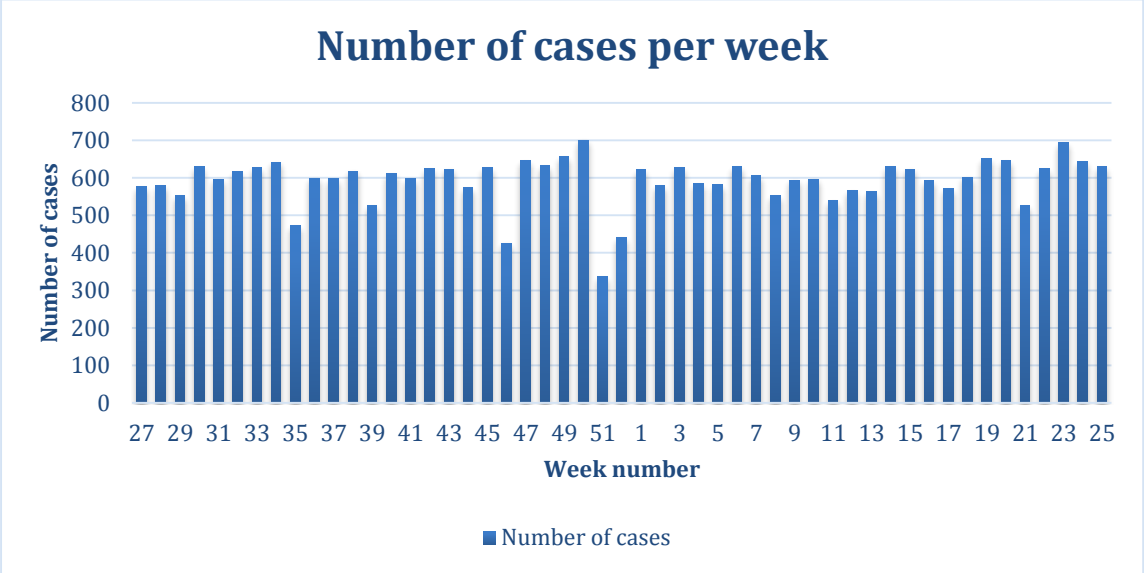

Figure 18: Number of cases per week (FY2013, Source: ORMIS)

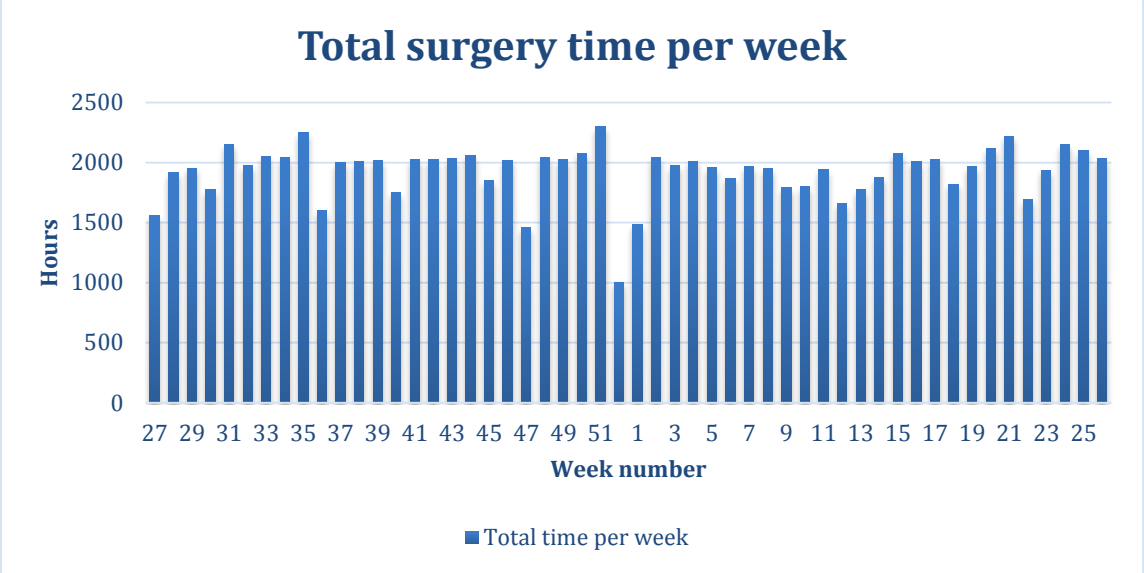

Figure 19: Total surgery time per week (FY2013, Source: ORMIS)

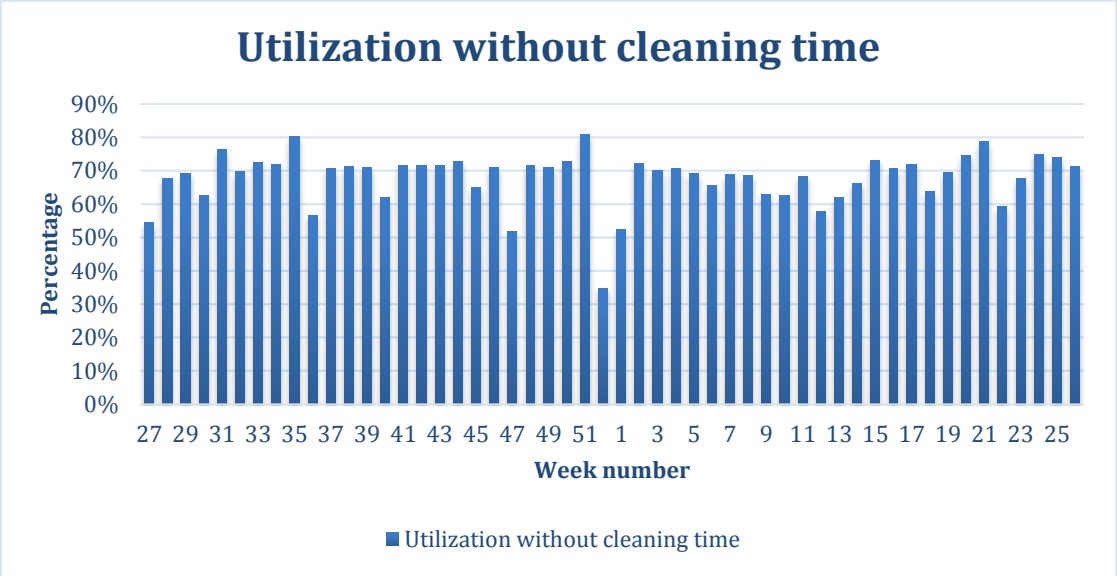

Figure 20: Utilization rate per week without turnover time (FY2013, Source: ORMIS)

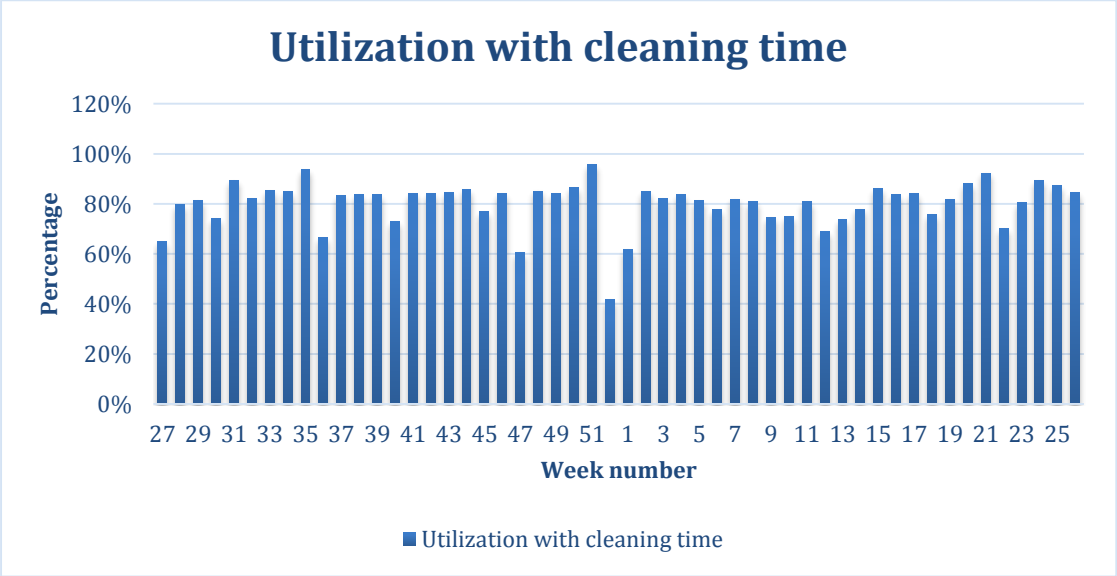

Figure 21: Utilization rate per week including turnover time (FY2013, Source: ORMIS)

The numbers show that the utilization rate is good, in relation to the access time noted earlier. As Dexter et al. (1999) describes a utilization of 100% is not possible when access time is low. The utilization of 83% is in line of what we expect, in relation to the access time of 14 days in Section 3.3.4.

3.4 Bottlenecks

In this section the root cause analysis is shown in a problem tree. This problem tree represents the causal relations between problems that are observed during our stay and deducted from the conducted interviews. Also feedback was taken into account in order to give view as complete as possible.

3.4.1 Problem tree OR related

The problem tree has two parts Figure 22 and Figure 23 and can also be found in Appendix A. We started, see Figure 22 and Figure 23, from the perspective time lost and money lost. A cause for this is the underutilization of the OR, which leads to the "time lost" that could have been used to operate patients in.

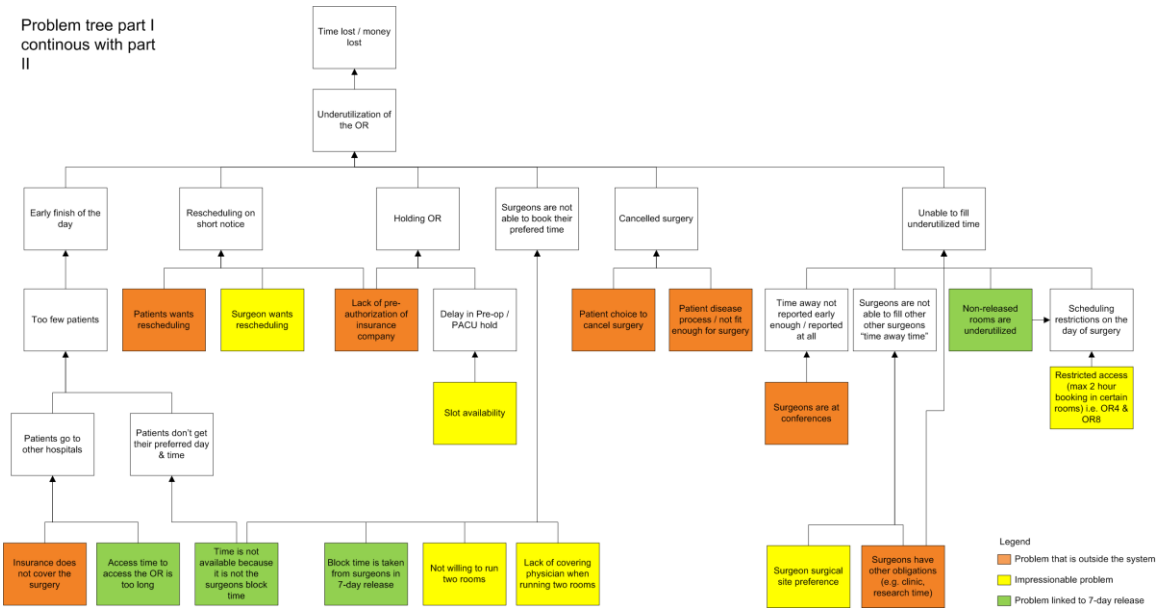

Figure 22: Problem tree part I

Underutilization has several causes, as shown in Figure 22 and Figure 23: the start time of the day is too late, an early finish of the day, rescheduling on short notice, the need to hold an OR, surgeons that are not able to book their preferred time, cancelled surgeries, unable to fill the underutilized time, incorrect predicted operating time, and too long turnover times. In the following subsections we will explain these causes and name further causes. The title of each subsection represents a cause named in Figure 22 or Figure 23

Early finish of the day

Looking at the early finish of the day, this is caused by lack of sufficient patients on the schedule. This could be caused by patients who go to other hospitals or patients who do not get their preferred day and time. The patients that leave to other hospitals can be caused by the fact that the insurance does not cover the surgery at Vanderbilt or that the access time to the OR is too long and patients choose a different hospital for this reason. The other reason is that patients do not get their preferred day or time. The cause for this can be that the preferred day and time is not the surgeon's block time. Also a cause is that surgeons may not want to operate on Friday afternoons.

Rescheduling on short notice

The rescheduling on short notice, means that there is going to be a gap in the schedule that has to be filled by another case. Otherwise it means that it is going to be unused OR time. This can be caused by the patients, they cancel or reschedule the case because they could not get transport or other arrangements ready for the surgery for example. The other cause is the surgeon who cancels or reschedules the case. Reason might be that the patient was not optimized medically, or because the clinical picture has worsened for example. Sometimes rescheduling also happens when the surgeon is convinced he needs to operate a different case because it is more urgent. Another reason for rescheduling is the lack of authorization of insurance companies. They tend to hold up surgeries when they are not convinced of the necessity. They ask for second opinions and delay the route to surgery. This means that the surgeries are delayed and need to be rescheduled if the authorization is not given in time.

Holding the OR

Holding the OR is causing delays which leads to the underutilized time. This is caused by the lack or late authorization of the insurance company. Authorization is sometimes given the last minute: for example when it is an add-on case that is semi-urgent. The emergency cases are always done; there are no restrictions on emergency cases, since there is a clear clinical need for it. Another reason for holding the OR are delays in the pre-op and PACU holding area. There are not enough beds to accommodate everyone

at once for the start of the day. But also slot availability is a cause for a delay in the PACU or Pre-op.

Surgeon not able to book preferred time

Surgeons who are not able to book their preferred time causes underutilization. One of the reasons that surgeons are not able to book their preferred time is because, they lack a covering physician when they want to cover/run two rooms at ones. Some are not willing to run two rooms, although other colleagues are doing so. But sometimes the reason that surgeons are not able to book their preferred time is due to the 7-day release program. The program blocks surgeons to book cases directly into their own block time within 7 days of the surgery date. Booking within 7 days means that surgeons are uncertain about the assignment of the requested time and room. This means that sometimes surgeons are not able to book their preferred time and reschedule the surgery. A positive way that 7 day release influences the scheduling of block time is when surgeons do not have assigned block time. In that case the surgeon has more flexibility to schedule his cases. When 7-day release would be absent these surgeons would not be able to schedule their preferred time.

Cancelled surgeries

As we can see in Section 3.3.3 there are also cancelled cases. In addition to Section 3.3.3 we explain a few extra causes. Physicians mostly look at the condition of the patient and then cancel the case. Patients who are not fit enough for surgery are not being operated. Sometimes the disease process of a patient has worsened since the last time and surgery is not possible at this point in time, which means that the patient has to recuperate, or the case is cancelled because the patient has worsened to a point where surgery is not possible any more. In some cases the clinical picture has improved to such an extent that surgery is not needed. The patient can recover in this case without the surgery, and the case will be cancelled.

Inability to fill the underutilized time

Inability to fill the underutilized time is another reason for underutilized time in the OR. There are several reasons that cause the underutilization. The provider time away

(surgeon is away) is not reported early enough, this means that the time could not be made available to the other surgeons within their service or to the surgeons outside their service. The reason that surgeons are absent during certain times is because they are for example to medical conferences, this happens since it is a university hospital, and tied to research. The reason that surgeons sometimes report their provider time away too late is because when they cancel their time away, their block has been already assigned to a different surgeon or service and is not available for themselves any more. When the surgeon is not certain about their time away, they tend to report the time away as late as possible. Also the feeling is apparent among surgeons that it is their block time, opposed to a shared resource. This thought makes it harder to give up on 'your' block time and rely on the 7-day release program when a conference or time away gets cancelled. Another reason, for not filling underutilized time, is that surgeons are not able to fill other surgeon away time. This can be due to the site preference; they prefer to operate in MCE instead of VOR, or the other way around. Also, other surgeons sometimes go to the same conferences, or have holidays the same week, which means they have other obligations. E.g., during spring break a lot of surgeons are away, and although there might be enough patients to operate, there are not enough surgeons to operate these patients. Also clinic time, or research time, are named as other obligations for not being able to fill the block time of the absent surgeon. Some rooms have a special rule that they are only released the day of surgery or that only cases shorter than two hours are allowed in their block time. Some services only fill their block the last 7 days before the surgery date. Therefore they are exempt from the 7 day release program. The downside to this is that these services also have underutilized time. Underutilized time is also caused by access restrictions on certain rooms, such as room four where only 2 hour cases are allowed to be scheduled, when from a different service.

In part two of the problem tree, see Figure 23, we continue the causal relationships with the same starting point.

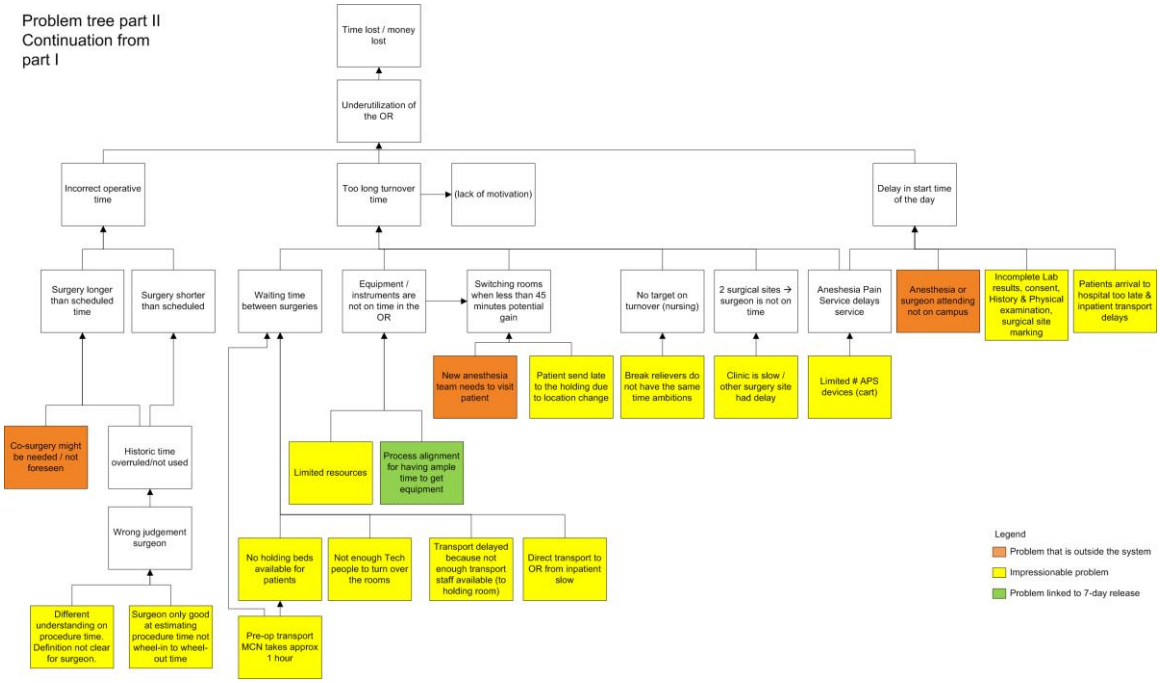

Figure 23: Problem tree part II

Incorrect operative time

Incorrect operative time leads to under or over utilization of the ORs. This is because surgery takes longer than scheduled or surgery takes shorter than scheduled. The case where it takes longer than scheduled can be caused by a couple of reasons. Most of the prolonged surgeries are caused by unforeseen issues or complications. Something that cannot be influenced and is attached to the nature or surgery. Historic timing is sometimes overruled or not used. This can be due to a wrong judgment of surgeons. This can be either because the surgeon has a different understanding on the procedure time, or because the surgeon is not good at estimating the procedure time, which is measured in wheels in wheels out. Surgeons tend to underestimate the complete procedure time, because they do not include Anesthesia time or the setup time. Although surgeons are mostly very precise in judging the time that the actual surgery will take. This is for the surgeries that are performed more often; unique procedures are harder to judge.

Too long turnover time

Too long turnover time causes underutilization. Or causes overtime when surgeries are prolonged. There are several causes for the long turnover times. Sometimes there

is waiting time between surgeries. This can happen since there are no places available in the Holding/PACU area. The cause for this is that there are no inpatient beds available to house the patient for the PACU bed, or because Pre-op transport from Medical Center North (MCN) takes approximately an hour. So when these patients are not called for in time this causes a delay. Waiting time in between surgeries is also caused by too few tech people who turn over the room. Transport can also be delayed because not enough staff is available to transport the patient. Inpatients and ICU patients are sometimes directly transported to the OR, this transport is rather slow, since the path from the ward to the OR is longer, and patients are not called for in time.

Turnover times can also be too long because of equipment and instruments that are not in the OR on time. This can be due to limited resources such as mobile X-ray machines. But sometimes the surgeries are scheduled in such a way that there is too much overlap between the surgeries, which cause a delay when the estimated time is just a little off, so scheduling ample time between surgeries will result in equipment that can be exchanged.

Too long turnover times are also caused because rooms are switched, this is beneficial when a time gain is apparent. Sometimes the switching of equipment such as case carts cannot be executed as quickly as wanted. Also a different Anesthesia team needs to visit the patient, because the anesthesiologist who should be on the case is still in the room that is busy. Therefore a certain time frame should be taken into account before it is beneficial to switch rooms. Also the change in location causes sometimes that patients are sent late to the holding area, and therefore they are late for surgery. Another reason for the too long turnovers is that there is not a target on when the turnover should be done. Also break relievers do not have the same ambitions regarding turning the room over in a timely fashion compared to the team that is stationed in the room. There is no incentive of going home on time for example. Sometimes a surgeon has to travel from a different location and this causes sometimes delays. For example when an outpatient surgery is prolonged in one of the outpatient sites, it means that the surgeon is sometimes too late to start on time in the main OR.

Anesthesia Pain Service (APS) also causes delays. This is bounded mostly to the number of APS devices that are available. There are a limited number of devices available.

Delay in start time of the day

Another issue of time and money lost is the late start time on the day. This is also connected to the turnover time, but there are some extra special causes. The anesthesiologist or surgeon is not on campus and is late for work. Sometimes are labs incomplete or missing, consent is not given yet, physical examination is not done or the surgical marking is not yet applied onto the patient. These are all reasons for delays. Also patients that arrive too late to the hospital and inpatient transport that is too late are causes for a too late start of the day.

Conclusion

The areas marked orange are in our opinion out of the system and therefore cannot be influenced. The yellow causes are with-in the system and can be influenced to a certain degree. The green causes are linked to the 7 day release program and are all influenced by the 7 day release program, either in a positive or a negative way.

From the two problem trees we see that the 7-day release program has several points where it has influence on the causal relations pointed out in the two graphs.

- Access time to the OR is too long
- Time is not available because it is not the surgeon's block time
- Block time is taken from surgeons in 7-day release
- Patients requests rescheduling
- Non-released rooms are underutilized
- Process alignment for having ample time to get equipment

This means that 7-day release not only has positive influences but also negative influences. A tradeoff has to be made between the positive and negative effects. We categorize this as a multi-criteria-decision-problem. Which factors do we have to take

into account and which factors can be changed without affecting the overall score of the system negatively.

3.4.2 Challenges regarding 7-day release

The 7-day release program was developed under one major assumption. That was that there would always be enough underutilization to accommodate the cases that are put on-stage.

As noted in Section 3.2.1 when utilization is going to rise and the construction of the new ORs will stay on hold for a while, the assumption on which the system was introduced is in jeopardy. Therefore an analysis was made what would happen if utilization rate would reach its maximum, and which problems would occur with the 7-day release program.

To understand the challenges that come with the 7-day release program we made Figure 24. In Figure 24 we connect the causal relationships between the challenges and when the maximum capacity is reached.

When reaching the maximum capacity of the OR in terms of utilization rate, the 7-day release program is in jeopardy/danger. When utilization increases, more surgeries will be cancelled because the schedule will run into too much overtime. Some rooms are underutilized, but only release the day of surgery, and therefore will be underutilized.

When utilization is high, the scheduled cases can be delayed by urgent surgeries that need to happen earlier, or surgeries have to be rescheduled, because the match between the room and the surgery is not available. Causes for are: the room is too small, the room is a negative pressure room, or the room does not support the electrical requirements.

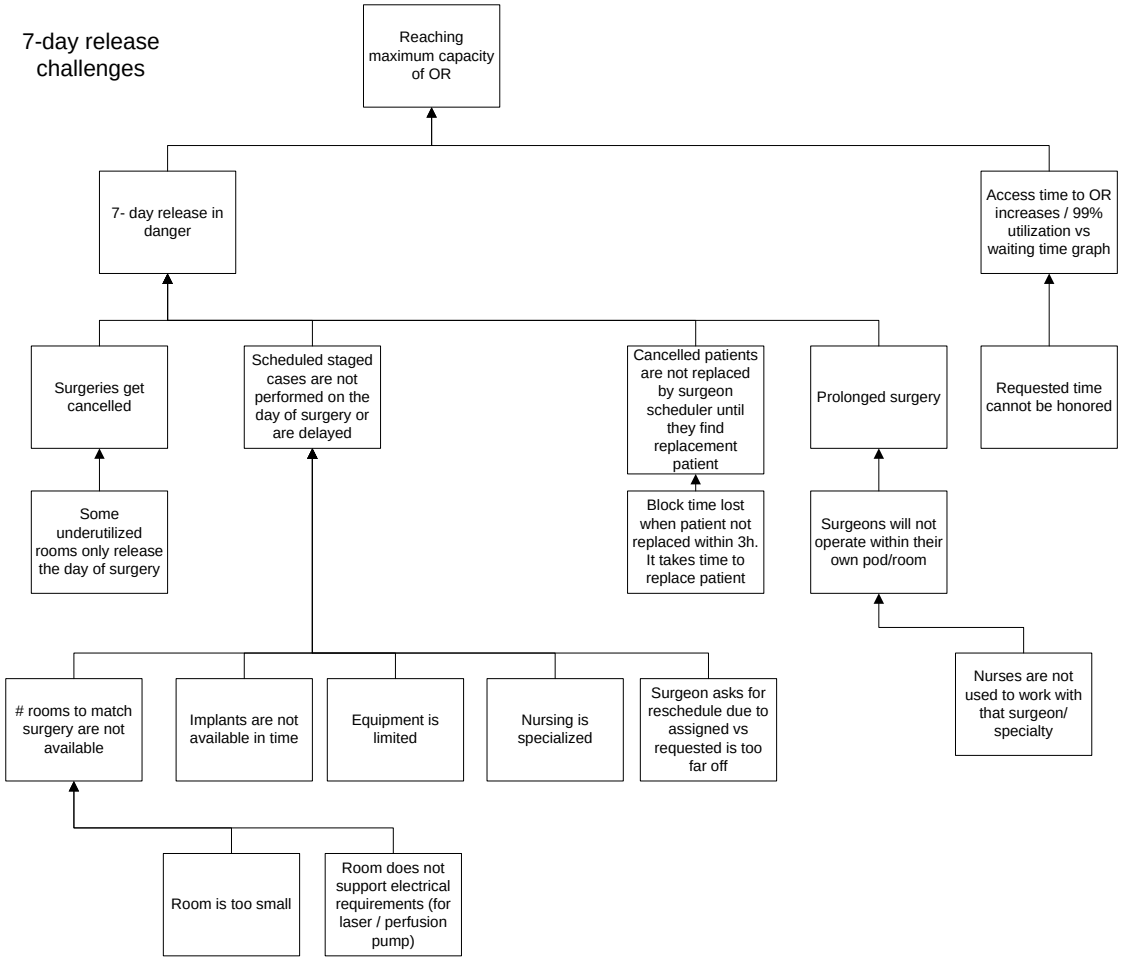

Figure 24: Challenges with the 7-day release program

Another reason why sometimes surgeries are delayed, is because implants are not available on time. Vanderbilt does not have implants in stock, and they need to be ordered before surgery. The closer to the day of surgery they get ordered, the more likely that they are not on time. Before the 7-day release program a lot of implants were ordered in a rush order. Since the time of releasing the rooms was 36 hours, and only shortly before that time the cases would appear in ORMIS en POU. The 7-day release program made a positive influence here. When uncertainty will increase again whether a surgery is going to take place on a certain day, the point in time when the implants are ordered is going to be closer to the day of surgery again. A challenge also for the 7-day release program is that equipment is limited. Robot cases for example can only be done in certain rooms, but the number of robots is also limited. The nursing staff is also specialized, in smaller hospitals most OR nurses are general OR nurses, but in bigger hospitals like Vanderbilt, there are more specialized nurses. This

has the advantage that the quality of care can be higher or more specialized surgeries can be performed. The disadvantage is that not every surgery can be performed easily in every room. This means a lack of flexibility in staff to support all surgeries. Another problem when utilization increases is that the surgeons requested time on a certain day is already given to a different surgery. When the difference between the requested and assigned time is too big, surgeons tend to reschedule the case.

Another challenge is that surgeon schedulers tend not to report when a case is cancelled until they have found a new case. This is because the time is released and therefore 'lost' if not within three hours a new case is found to replace the cancelled case. The surgeon scheduler therefore tends not to cancel the case until he has found a new one or until the day of surgery is very close. This means that when the day of surgery is close and the time is released the chance that a case of a different service will be put in that time is low. Finding a case in 24 or 36 hours is very uncommon unless it is an add-on case. The practice of not cancelling a case will be more common when the utilization rate increases, especially when not a substitution case is directly available, since the certainty that a case will and can be scheduled on the requested day within the 7-day release program is decreasing.

When utilization increases, and more surgeries are performed, the likelihood that surgeries will take place outside the POD also increases, and therefore the surgeries will take longer. The nurses are not used to work together with that surgeon or are not used to perform surgery for that service. Therefore the surgery takes longer than usual.

When the utilization increases to its maximum, on normal machines we see a sharp increase in the waiting time before the machine can be used (Cook, 2009; Winston, 2003). This is more or less also the case for operating rooms. The effect on operating rooms is that the overtime increases tremendously. Also in this case the requested times and dates cannot be honored.

3.5 Conclusion and demarcation of scope

In this section we will state the problem statement that will be solved in this research and a further demarcation in scope. In Chapter 3 we described the current situation of VUMC, with this overview in mind, we further demarcate the scope in which we have to find alternative solutions to the problem. From Chapter 3 we have to reason to believe that there is a different underlying cause that we need to address instead of looking at alternative solutions for the 7-day release program. Also taking into account the preferences VUMC posed towards the scheduling of patients.

3.5.1 Demarcation of scope

Based on the overview of the processes we described in Section 3.1, the operational performance we described in Section 3.3, and bottlenecks we described in Section 3.4, we choose to demarcate the scope further. We zoom in from the overview of looking at all of the aspects that involve the resource capacity planning, see Figure 25, to the hierarchical field of offline operational planning.

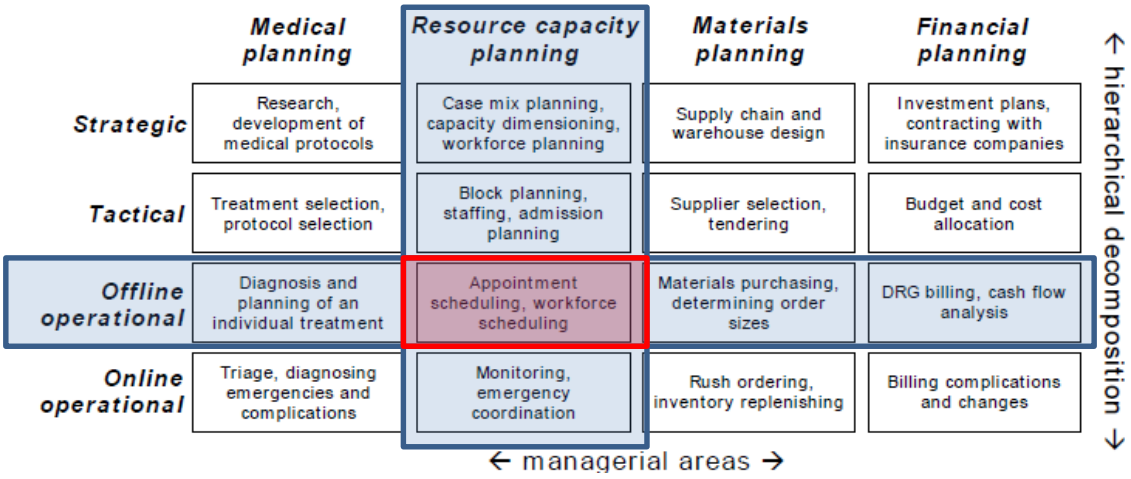

Figure 25: Demarcation of scope within the planning and control framework

3.5.2 Problem statement

The root cause analysis showed several problems and several key points where 7-day release influences the under- and overutilization of rooms. The unanswered question is what happens when demand rises. The 7-day release was introduced with the assumption that there would always be underutilization in the ORs. The demand has

risen since the program was introduced. This means that when growth continues, the ceiling of the 7-day release program will be reached in the future. To understand the behavior of the system, and the influence on the normal block scheduling, research is needed. The key is to understand whether the 7-day release program is still the appropriate method to use when we reach the maximum capacity of the ORS, with regard to: utilizing underutilized room time, and decreasing access time. Or do we have to draw the conclusion that the current 7-day release system is no longer satisfying.

3.5.2.1 Goal of the project

The goal of the project is to simulate what happens when the utilization comes closer to the maximum capacity. Here, we not only consider the utilization of the ORs, but also the capacity in the number of teams of nurses in the ORs. The goal of the research is to find the best solution to deal with scheduling when coming close to maximum capacity.

Chapter 4 Inventory of alternative solutions

From the current situation in Chapter 3 we focus on the 7-day release program scheduling of the ORs in VUMC. This chapter describes the hard and soft constraints imposed by VUMC in Section 4.1. Section 4.2 describes the possible alternative solutions. And finally in Section 4.3 we describe the key performance indicators to evaluate the alternative solutions and the non-quantitative implications for the different stakeholders.

4.1 Operating room scheduling constraints posed by Vanderbilt

The department of Anesthesiology and the department of Surgery impose a number of constraints on the scheduling of ORs. Of those constraints we categorize some as hard constraints and some as soft. Jiang, Kautz and Selman (1995) state that the hard constraints must be satisfied by any solution, and the soft constraints have a relative importance and may or may not be satisfied by a solution (Jiang et al., 1995). This means that the hard constraints imposed by VUMC define the boundaries of the solutions we take into consideration. The soft constraints are the boundaries within which we can simulate and can test various alternative solutions.

4.1.1 Hard constraints

The hard constraints described in this section are imposed by VUMC and cannot be altered for this simulation study. They are: (1) assignment and education of staff, (2) room constraints, (3) day of the week constraints, (4) safety constraints, (5) release time of the room constraints, (6) arrival of the cases, (7) location constraints, (8) opening hour constraints and (9) insurance constraints. We will discuss these in the following subsections 4.1.1.1-4.1.1.9.

4.1.1.1 Assignment and education of staff

Nurse staff and anesthesiology staff are assigned to certain rooms in the OR complex. The surgeon is able to switch between the rooms and therefore he is able to perform a surgery in a different room. The staffing though is not changed to a different room

when rescheduling of a case happens. The staff is assigned to certain rooms. This means both the nursing as well as the anesthesia staff are assigned according to rooms, not according to the cases. The ORs are physically grouped mostly per four rooms, which is also called a pod. The pod contains mostly the same or similar services. Nursing staff is trained and specialized in the services that operate in their pod. To transfer nursing staff to different rooms, education might be needed. Although on the basic level all nursing staff is able to work for a different service. We assume that the surgeries can be performed in any room. We assume that the number of rooms can be fully utilized and that staffing ORs is not an issue during regular opening hours of the ORs.

4.1.1.2 Room constraints

Certain ORs in VUMC have limitations, not every surgery can be performed in every room, for example due to size constraints. For example, pulmonary surgeries have to be performed in the negative pressure room of pulmonary surgery. The restrictions are all based on equipment, size or other requirements. The restrictions are hard, since changing them is costly, if they could be overcome by change. The soft constraints regarding the rooms can be found in Section 4.1.2.1. The hard constraints regarding the ORs are:

- Cardiac surgeries are only done in their own ORs: VOR 31, VOR 32, VOR 33 or VOR 34.
- Ophthalmology surgeries can only be performed in VOR 4.
- Neuro Interventional surgeries can only be performed in OR 8.
- Pulmonary surgeries can only be performed in VOR 28 (negative pressure room).

4.1.1.3 Day of the week

VUMC has restricted itself with the scheduling on not allowing to reschedule between different days although this is beneficial for the OR efficiency. Scheduling happens according to “Any Workday” scheduling (Dexter, Traub, et al., 2003). This means that together with the surgeon scheduler the surgery date is chosen, with the absence of a waiting list. With a waiting list there would be more possibilities to schedule with

optimization techniques in mind. The only option that remains is the rescheduling within a day to a different room or time, although this is not preferred. It is clearly a strategic choice not to schedule with a waiting list, this is done from a service to the patient perspective and because of competition with other hospitals.

The 7-day release program has the same condition, of not rescheduling to a different day, although we want to relax this constraint in the simulation to a soft constraint in order to show the difference in scheduling the cases. Vanderbilt can choose whether as not to implement this.

4.1.1.4 Safety

For safety reasons, ORs can handle a limited range of surgery type. Certain surgeries can only be performed in certain rooms. The safety constraints are also safeguarded because of the rooms constraints posed in Section 4.1.1.2. For example pulmonary surgeries can only be performed in the negative pressure room VOR 28.

4.1.1.5 Release time of the rooms

The release time of certain rooms exists because of the arrival rate or the unpredictability of the surgeries. For example Ortho Trauma has a room that only releases the day of surgery. For Ortho Trauma this release policy exist because most cases are booked in the last 48 hours before surgery. These are for example stable fractures, like a broken collarbone, that need surgery, but not immediately.

When a room has a different timeframe for releasing, this is based on the need for releasing the room at a later point in time then 7-days. A need for releasing rooms at a later point in time is the arrival rate of certain patient groups, but also the inability to schedule the cases in a different room due to equipment constraints. When a service has more ORs on the same day like Orthopedics with six rooms (orthopedic and orthopedic trauma), only the required number of rooms are released at a later point in time. Of the six rooms for orthopedics, two are released the day of surgery, the other four rooms are released in the regular 7-day release program.

4.1.1.6 Arrival rate of cases

We might be able to influence the arrival rate of the patients by organizing clinic time differently. Another way to influence the arrival of patients to the hospital is to convince a surgeon from a nearby hospital to work at Vanderbilt, usually the patient follow the surgeon. But this is outside the scope of this research. Therefore we assume that the number of patients arriving historically will continue to arrive in the same manner. We also assume that when we simulate an increase in the number of cases that this growth in the number of cases will happen equally among all specialties. This means that the share between the surgery specialties, as described in Section 3.1.2, stays the same. The rooms that do not release is partially based on the arrival rate of the patients, when patients occur frequently in the last 7 days before surgery , e.g., orthopedic trauma cases, this is a reason for not releasing that room, also described in Section 4.1.1.2.

4.1.1.7 Location constraints

The ORs are divided over three different physical locations, as described in Section 3.1.1. MCE has 11 rooms, VOR has 35 ORs, and the FEL location has three ORs. Both VOR and MCE locations are the inpatient ORs and FEL is the outpatient ambulatory site. Changing the location on the day of surgery is a problem, or at least a burden. Equipment such as the case carts need to be moved between locations and patients need to be transported longer because they are supposed to show up at a different admittance desk. Moving cases from either MCE or VOR to the FEL location is almost impossible since FEL only performs ambulatory cases. Moving cases from FEL to VOR or MCE is possible, since ambulatory cases can be performed in the inpatient ORs.

The location constraints also mean that only ambulatory cases can be done in FEL, where in VOR/VUH and MCE both ambulatory/outpatients surgeries as well as inpatient surgeries can be performed.

4.1.1.8 Opening hours constraint

VUMC does not want to extend opening hours beyond the current block schedule. The staffing, planning and scheduling of the cases is based on these opening hours. We will try to find solutions that minimize the use of overtime and come as close as possible to the imposed opening hours of the ORs.

4.1.1.9 Insurance

The insurance companies need to approve for surgery. This means that usually the case needs to be scheduled two weeks in advanced in order to get approval by the main insurance companies, this is the case for elective cases, where emergency cases are always approved. For elective cases this means that the insurance companies can ask for a second opinion, or for a less expensive procedure before approving the surgery. This can be a painstaking process in which the patient is mostly harmed instead of helped. Considering this process with the insurance companies, the only option is to take this into account when scheduling elective cases, changing this process is not possible for VUMC.

4.1.1.10 Conclusion of the hard constraints

When we take the hard constraints from Section 4.1.1.1-4.1.1.9 into account, there is no rooms for a radical new approach. We are for example not allowed to look at the rooms that are underutilized, and see whether we could alter the arrival rate of those services. Also building new ORs is out of the question, this would help the scheduling, since some of the rooms cannot handle surgeries outside their service, or the service's surgeries cannot be performed outside their specialty room.

4.1.2 Soft constraints

The soft constraints in this section can be seen as the factors which may be feasible for change in order to improve the system. The constraints are set by VUMC but can be relaxed in order to improve the current situation. The constraints can be relaxed or changed and the key performance indicators can measure the impact of these relaxations.

4.1.2.1 Room constraints

Some rooms are not released within the 7-day release schedule. One of these rooms is the Burn room (VOR25), formerly driven by one burn surgeon, and now driven by a plastic surgeon. The same surgeon has block time in the block schedule in to other blocks on the schedule (plastic surgery). As a side note, two blocks for one surgeon is not uncommon, then the surgeon supervises and his residents perform the surgery. That the surgeons name appears on three block times on the schedule also means that it is not really a different service any more, and that the two plastic surgery rooms can also be satisfactory for all of the cases. Or at least the constraint of not releasing the burn room within the 7-day release program could be relaxed. In the past this constraint was imposed because of the urgency of the burn cases and the lack of transferability to other room services.

The Ophthalmology cases can only be done in the Ophthalmology room but other cases could be done there. The restriction is that only cases shorter than 2 hours are allowed to be planned there until the day of surgery. We will further discuss the other room constraints under 4.1.2.4.

4.1.2.2 Days constraints

The staged cases in the 7-day release program always have a request day. It is not allowed to schedule the case on a different day when this would be beneficial for the overtime for example. We also want to consider the scheduling on two different request days to optimize the outcomes on the key performance indicators.

4.1.2.3 General Release day constraint

The general release constraint is 7 days before the day of service. This can be relaxed to 5 days or even 10 if needed. The question is what the effect would be on the key performance indicators in changing this number of days. Would this influence the number of surgeries put on stage, or would this influence the number of surgeries scheduled earlier to avoid the 7 day release scheduling?

4.1.2.4 Specific release constraints

The specific release constraints account for a few services or even a few rooms on a few days. The rooms with the services:

- VOR 4 Ophthalmology
- VOR 8 Neuro Interventional
- VOR 31, VOR 32, VOR 33, VOR 34 Cardiac surgery
- VOR21 Neurosurgery
- VOR25 Burn (Monday Wednesday & Friday)
- VOR 12 & VOR 13 Orthopedic Trauma

The surgeries of the services of the first three items: ophthalmology, neuro interventional and cardiac surgery, can only be performed in the mentioned ORs, as mentioned in the hard constraint Section 4.1.1.2, but other services could make use of these ORs. This is not allowed at the moment. What happens if we relax this constraint?

All of the mentioned rooms release their time 7 day prior to the DoS to their own service, and at the day of service to the rest of the services. This is done to ensure that when a case is booked there is a room available for these surgeries. For the first three items, the cases of these services can only be performed in the room of the service. For the other items, it is due to the uncertainty in arrival rate of the cases. The question is whether releasing the rooms to other services at 7-day release would harm the services.

4.2 Alternative solutions

In this section we describe the alternative solutions that we will consider. In Sections 4.2.1.1 - 4.2.1.5 we will discuss the alternative solutions regarding the relaxation of constraints and different strategies for scheduling the releasing of rooms. Recalling the problem statement of Section 1.2:

> *"Should VUMC maintain the 7-day release program in the future, when demand is expected to increase?"*

To answer this problem statement we created the following relaxations of constraints and alternative solutions:

1. Vary the volume / total number of cases scheduled
2. Alter the release day
3. Vary the request day constraint
4. Relaxation of the soft constraints of the rooms
5. Change the scheduling policy.

4.2.1.1 Vary the volume / total number of cases scheduled

One of the major questions is what the maximum capacity is with the 7-day release program and when the assumption of *"we are always able to schedule the staged cases on the requested day"* will be in distress. Distress would mean that the requested day cannot be honored, due to for example resource constraints such as room availability without scheduling in overtime.

We will increase the number of surgeries per week in steps of 10 patients. The current number of patients per week is 600 as noted in Section 3.3.5. We will evaluate the performance based on the in Section 4.3 named key performance indicators.

4.2.1.2 Alter the release day

One of the questions was whether releasing rooms 7 days before surgery is the best. Should the release day be seven days prior to the day or service, or would 5 or 10 days

for example be a better solution? Is there a difference in performance? One of the alternatives to simulate therefore is to change the number of days for the releasing of rooms from 7 to: 5 days, 6 days, 8 and 9 days before the day of service. With changing the number of days on which to release the rooms, also the number of cases will change that is scheduled according to the release policy and the number of cases scheduled according to the regular elective scheduling. We can deduct the number of cases based on the release policy by combining the information from Sections 3.3.1.4, 3.3.1.6 and 3.3.4.

To change the day on which the surgery is scheduled we need to change the share between the cases that is scheduled in the simulation program. Table 7 shows the share between x-day release patients and regular elective patients.

Table 7: x-day release: patient share between x-day and elective (Nov 2012-Mar 2013, Source: FCCR; FY2013, Source: ORMIS)

x-day release	Share x-day release cases	Share regular elective patients
5-day release	29,4%	70,6%
6-day release	32,1%	67,9%
7-day release (current situation)	35,1%	64,9%
8-day release	38,6%	61,4%
9-day release	40,7%	59,3%

Assumptions:

We assume that the surgeon scheduler does not change the way we schedule the surgeries, or can influence the number of surgeries that will go through the release policy or the regular scheduling policy. We assume that the arrival rate of the patients stays the same, and therefore that the calculated difference is the appropriate ratio. When the surgeon scheduler would have a backlog this could change, but we are not aware of such a backlog.

Dexter and Macario (2004) recommend to postpone the release of ORs to the morning before the day of services, but also simulated 5 days ahead of the day of service, and state that the longest time given their dataset was 5 days, but this might be longer in different hospitals.

4.2.1.3 Vary the request day constraint

All staged cases have a requested day on which they need to be scheduled. In the current situation, deviation from the requested day is not possible. Deviation from the requested day is one of the options to consider. This can influence for example the key performance indicator overtime. There are different options to consider. In the simulation we will consider one day before and after the preferred day of surgery. The second option is to consider the simulation of request day +1, so request day and the day after as second option. The third is to simulate the request day +2, so the request day and two days after. The fourth option is to allow to schedule in all of the 7-day release options. This means that there are three variants of the 7-day release program (Table 8).

Table 8: Deviation alternatives from request day

Alternative:	deviation from request day
Current situation	Only the requested day
One day deviation	One day before and after the requested day
One day after	One day after the requested day
Two days after	Two days after the requested day
All days	All days within the 7-day release

4.2.1.4 Relaxation of the soft constraints of the rooms

As described in Section 4.1.2.1 there are some soft constraints that can be relaxed in the simulation. VOR 25 is one of the rooms that is considered redundant since the surgeon also has two other block times on the same days. The other rooms named in Section 4.1.2.1 could be opened to other services at 7 day release. When a service cannot book the case in the desired time frame it has the choice to book the cases through the 7-day release program in an OR with time available, but this is not possible for the services named in Section 4.1.2.1 because they can only be performed in these rooms. Opening these rooms to other services is possible though, but we have to ensure this does not harm the services, since they do not have the possibility to go anywhere else than their own rooms.

The question for this alternative: which room constraints can we relax, with an increase in the number of patients, compared to the current number, without harming the dedicated services ability to schedule patients?

4.2.1.5 Change the scheduling policy

Currently the Any Workday (Dexter, Traub, et al., 2003) scheduling principle is applied. When 7-day release scheduling is applied, the cases that are put on stage are scheduled FCFS. One of the alternatives could be to completely eliminate the 7-day release program. What would the performance of the ORs be? Would the performance be better or worse?

Another alternative could be to create a waiting list, which could be scheduled with an optimization policy to increase the performance of the key performance indicators. Dexter, Macario, Traub, et al. (1999) state that it is unrealistic for OR suites to aim at an utilization rate larger than 90% when the access time or waiting time is less than two weeks. The number of possibilities increase when the waiting time increases, and a better match can be found to increase utilization (Dexter et al., 1999). When there is a waiting list of patients there are numerous techniques and algorithms to consider and simulate. As also described in Section 2.3.3.1, Hans et al. (2008) propose to plan with slack time to reduce the risk of overtime, applying a first fit rule for the base solution, and performing constructive and local search methods to evaluate the tradeoff between overtime and utilization rate.

Considering the various alternative scheduling approaches, we will simulate the absence of the 7-day release program and compare the results with the current situation. We will not consider the alternative with the waiting list, because there are five surrounding hospitals, which leads to lost patients (Baugh & Li, 2012).

4.3 Key performance indicators

The key performance indicators are used to evaluate the alternatives proposed in Section 4.2. The key performance indicators, introduced in Section 2.3, are:

- Utilization rate
- OR efficiency: overtime & unused OR time
- Access time

In addition to these key performance indicators we have also analyzed the number of rescheduled surgeries in Section 3.3.1. For the simulation study we will also include the rescheduling of surgeries, when a request day cannot be honored in the release program. This is measured in deviation in days from the requested day or the denial of the surgery to be scheduled. It means that the surgery will end up not being scheduled or being scheduled on a different day.

The key performance indicators are all numeric and can be optimized accordingly. The question remains what the consequences are for the different stakeholders. A good score on the key performance indicators is beneficial for the hospital, like utilization rate and overtime. The patient will not benefit from a high or low utilization rate directly. The one outcome measure that is directly beneficial for the patient is access time. For the different alternatives we consider also the non-quantitative measurements, that cannot be measured directly in the simulation study, but that can be deducted from the impact certain policies have. Section 3.3.1 shows that although patients received a date and time immediately in the clinic for their surgery. This often changes because the schedule cannot be put together based on resource constraints or due to a cancellation.

In order to make a trade-off for these non-quantitative outcomes we identify as the main stakeholders: Patient, Surgeon Scheduler/schedulers, Surgeon & OR staff and the hospital. Questions we need to consider in order to answer the non-quantitative implications for the different stakeholders:

The patient: Do the patients want to schedule their surgery together with the surgeon/surgeon scheduler/scheduler? How many days is the patient willing to wait before the surgery can take place (access time)? If a waiting list means shorter access time or more certainty, does the patient prefer that above scheduling together with the surgeon scheduler?

Surgeon, scheduler or surgeon scheduler: Does the surgeon prefer the flexibility of being able to schedule outside BT? How many days before the surgery is acceptable for the surgeon to have their BT released? When scheduling with a waiting list increases the certainty of the schedule, is that preferred above "Any Workday" scheduling?

Surgeon and OR staff: When other surgeons perform surgery in other services ORs has this consequences for OR staff or the surgeon? Does the flexibility of performing a case outside of BT mean that surgeons are neglecting clinical duties (Gupta, 2007)? When a release policy reduces overtime, what sacrifices is staff willing to make for this reduction in overtime? Does a release policy create too much anxiety or stress for staff, or extra work?

The hospital: Does a release policy increase the efficiency of the ORs? Does having a (short) waiting list mean fewer patients? Does having a waiting list increase OR efficiency? Is overtime reduced with a release policy? Does a release policy lower the access time for patients? Is staff more satisfied after or before introducing a release policy? Does a release policy increase the utilization rate? What is the effect of a release policy on the downstream resources (Gupta, 2007)?

4.4 Conclusion

In this chapter we formulated the hard constraints and the soft constraints imposed by VUMC within we have to find solutions to the problem. We formulated various alternative solutions that can be simulated and the key performance indicators on which to judge the alternative solutions. Also the non-quantitative aspects are named that we need to take into consideration for the alternatives posed in Section 4.2. In the next chapter we describe how to simulate the alternatives and how to measure the key performance indicators.

Chapter 5 Simulation study

This chapter discusses how the simulation model is constructed. Section 5.1 discusses the simulation study, and the approach. Section 5.2 gives the conceptual model design of the simulation and the program used. Section 5.3 describes the construction of the simulation model and the data used in the simulation. Section 5.4 describes how the different alternative solutions, introduced in Section 4.2, are modelled in the simulation program.

5.1 Simulation study

Simulation can be used to model situations or evaluate intervention,s that are impossible in practice, too costly or too time consuming to try, or situations that are risky or unethical (Lagergren, 1998). Discrete Event Simulation (DES) has proven itself as an effective tool to aid the decision making in healthcare settings (Günal & Pidd, 2010; Mes & Bruens, 2012). These arguments are also applicable for Vanderbilt. Implementing a new strategy for the scheduling on a trial and error basis is not desirable, this would be also to time consuming to collect the data of all the possible alternatives to evaluate which alternative would be the best.

5.1.1 Simulation model to approach problem

For the simulation we will adapt a program developed by E.W. Hans of the University of Twente. This is a simulation program that is specifically designed to model operating theaters. The program is uses the Delphi compiler and is written in the programming language Pascal.

The program is capable of modelling:

- All the ORs with their opening hours
- The case mix of inpatients and outpatients
- Statistical distribution per surgery (to ensure the simulation is close enough to reality)

Figure 26: Screenshot of the Operating Room Manager

The program consists of five different parts with different functions. The foundation of the program is based on the scientific work conducted by E.W. Hans (Hans, 2013).

5.2 Conceptual Model design

To adept the simulation program we made a conceptual model of the scheduling of the 7-day release program. The setup of the model is inspired by Mes & Bruens (2012). We start with listing the events that can trigger decisions and processes. We distinguish the following triggers: New Patient, End Task, End Delay and New Day (Mes & Bruens, 2012). The processes in Figure 27 are connected with solid lines, when processes communicate or consult with the two databases a dotted line is used. The conceptual model describes the processes from a new patient arriving until the patient leaves the hospital. We will describe in the following subsections the four event triggers. We describe what happens when a new patient arrives to the hospital. A New Patient triggers all the processes involved in the scheduling of the surgery and the triggers End Task, End Delay and New Day, trigger the decisions and processes that are involved in the simulation of the surgery.

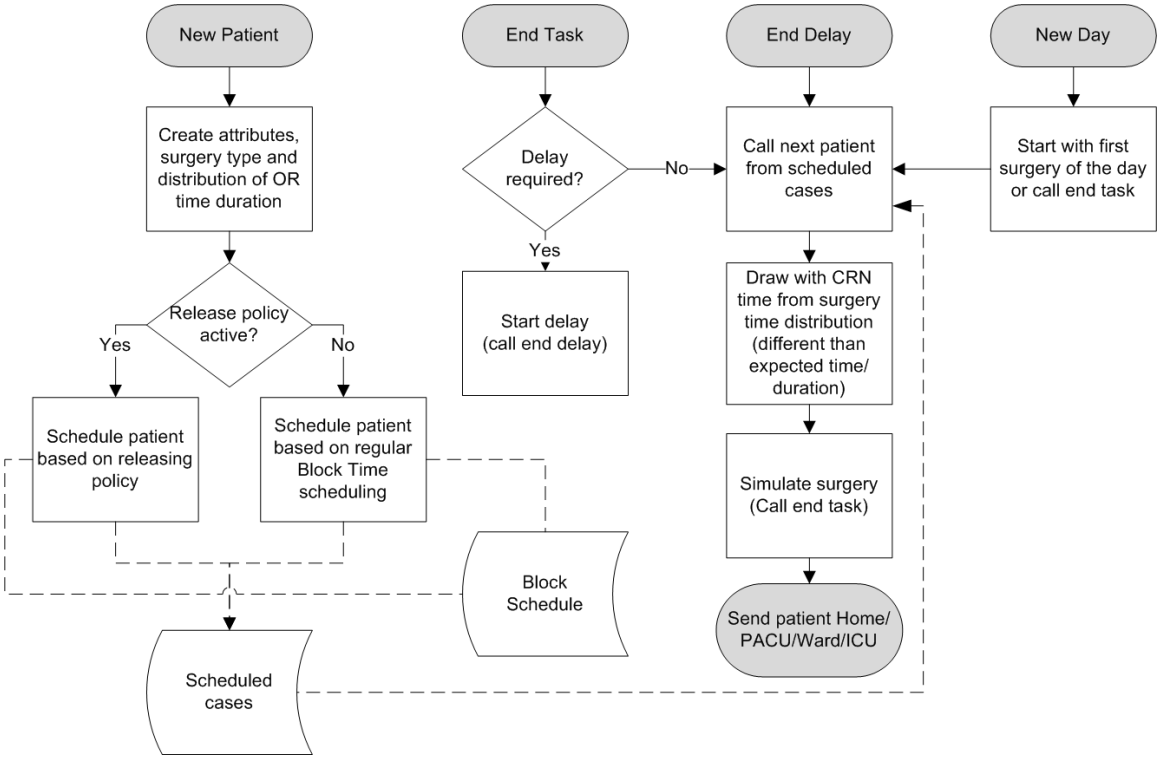

Figure 27: Conceptual simulation model x-day release

New Patient event

The New Patient event, in Figure 27, triggers the creation a new patient and will assign all of the needed attributes to the patient in order to make the simulation possible. The decision is made whether the release policy is active, and therefore whether the patient needs to be scheduled according to the release policy or whether the patient is scheduled as a regular elective patient and is scheduled in the regular block time.

New Day event

When a new day starts, the New Day event is triggered, which will trigger the first surgery of the day. When we start a new day we could also trigger the End Task event, and call up the next patient from scheduled surgeries. The only difference is that also a delay could occur before the first surgery when we would trigger the End Task.

End Task event

The End Task event is triggered after the first surgery until the last surgery. The End Task event prompts the decision whether a delay is required. Delays happen frequently in hospitals, sometimes the room is not prepared yet, the surgeon might

not be in the building or the patient has not arrived yet. The decision in the Figure 27 triggers either the delay or the next patients is called up from the scheduled cases. After finishing the delay the End Delay event is triggered.

End Delay event

The End Delay triggers the process of calling up the next patient for surgery from the scheduled cases list. Then a time is drawn from the distributions attributed to surgery type, this is a different value than the expected duration. And then the simulation of the surgery is performed with the drawn duration. After the surgery the patient is send home, to the Post Anesthesia Care Unit (PACU), ward or ICU. Where most of the cases are sent to the PACU, even the ambulatory cases. If after the surgery it is not the end of the day, the End Task event is triggered, to continue to process of delay or new surgery.

The 'Block Schedule', and 'Scheduled Cases' boxes in Figure 27 are aid lists that help to schedule the patients and store them. When scheduling a case, the Block Schedule list allows to check whether the case can be scheduled in the desired OR. The dotted lines represent that only information is transferred and stored, whereas the solid lines represent also a physical change in processes.

5.3 Construction of the model & simulation of current situation

Section 5.3.1 describes the construction of how we put the conceptual simulation model described in 5.2 into the simulation program. Section 5.3.2 describes which historic information we used and modelled, to create a representation of the current situation. In Section 5.3.3 we describe how we modelled the current situation in VUMC. Section 5.3.4 describes the validation and verification of the current situation.

5.3.1 Construction in simulation program

The simulation program consists of five steps. 1: initialization, 2: strategic management, 3: tactical management, 4: operational management, 5: simulation. For more information on the data structure behind the program see Figure 38 in Appendix I. In Section 5.3.2

Initialization

In the initialization phase all the basic settings are loaded into the simulation program. The different specialties as described in Section 3.1.2 with their case mix share is loaded into the program. Also the share of the 7-day release patients can be defined per specialty. This means that for example cardiac surgery can be attributed zero 7-day release patients since they all need to be performed in the ORs of the service. In the initialization step also the different surgeries that are performed by the different services are loaded. The surgeries have the following attributes: specialty, duration (distribution), cleaning time (distribution), case mix share within the specialty, the patient type (inpatient or outpatient), and the name and number of the surgery (CPT). In the initialization tab also the distributions of the surgery types and the cleaning distributions.

Strategic & tactical management

In the strategic management the number of operating rooms is set. The tactical management tab is also linked to this, because it contains the Block Schedule. In this Tab the ORs can be assigned to the different services. This tab represents the whole schedule that is used by VUMC as partially shown in Section 3.2.2. In this tab a different schedule can be made for all the different periods, but this is not necessary for VUMC because the schedule is the same every week.

Operational management

The operational management tab contains the scheduling approaches for the surgeries. The scheduling approach can be defined, but also whether overtime is allowed for scheduling the surgeries. How many patients are generated to schedule is also defined in this tab. The x-day release sub-tab is also situated in this tab, in this sub-tab the number of release days can be set. Which OR selection rule to apply with scheduling, and what the exact number of days should be used to release the rooms. When the patients are generated there are a number of attributes that are connected to the patient, such as whether it is a regular elective patient or an x-day release patient. Also the surgery type and service are attributed to the patient in order to schedule the patient.

Simulation

In the simulation tab we can define the number of warm-up periods which should be used. In this tab we also determine when a case needs to be cancelled during the simulation and whether patients are available at the start of a day for example. Also rescheduling on the day of service can be considered when this would be beneficial, for example when there is a huge delay in one of the surgeries and another OR is already available.

5.3.2 Used historic data

For the simulation we analyzed data and deducted the needed parameters, e.g., case mix share and specialties. The case mix share and the specialties as described in Section 3.1.2. This data are the base for the case mix share of the first initialization tab in the simulation program as described in Section 5.3.1. We analyzed the same data from ORMIS with 80,813 records from July 2010 to January 2013 to extract the different surgery types that are possible for the different services. The different surgery types also have different surgery distributions. We first checked whether we were able to fit a lognormal or three parameter lognormal statistical distribution on the surgery types. According to Strum, May & Vargas (2000) lognormal distribution is the best distribution to use when modelling surgery time or according to Stepaniak, Heij, Mannaerts, de Quelerij, & de Vries (2009) 3-parameter lognormal is even better at modelling surgery time. In order to fit a statistical distribution on the surgery time, at least five surgeries of one type has to be performed. Unfortunately not all surgery types were performed five times or more. For those performed more than five times we checked with the Kolmogorov-Smirnov goodness of fit whether a fit was found (α=0,05). The surgeries that produced more than 50% standard deviation from the expected value were rejected. The rejected surgeries, and the surgery types that performed less than five times, are then grouped by Clinical Classifications Software (CCS) groups (Healthcare Cost and Utilization Project (HCUP), 2012). These groups have clinical similarities and are used to make data usable for analysis. The fitting of the distributions was done with the statistical software package SAS 9.2 and the goodness of fit was checked manually in Excel for verification. If after grouping in CCS

groups there was no statistical fit, these surgery types were excluded from the data modelling. This concerned less than 1% of the available data.

The surgical BT schedule is deducted from the scheme shown in Appendix E. This scheme shows the different services with the different ORs and the opening hours of the ORs.

In order to know how many cases are scheduled through the 7-day release program we analyzed the FCCR, as described in Section 3.3.1 and Appendix C. We created a share between the patients that are generated. So part of the patients is 7-day release patient and others generated are regular elective cases. The share can be found also in Table 7.

This historic information and the interviews were sufficient to combine and model the data into the simulation program. Some settings such as not scheduling into overtime, are given in the constraints posed in 4.1.1.8.

5.3.3 Simulate current situation

In this section we describe how we simulated the current situation and which assumptions we made to represent the current situation as described throughout Chapter 3. In step 4 of the simulation, as described in Section 5.3, we generate the patients to be scheduled divided in two groups. The two groups are divided into the 7-day release program cases, and the regular elective cases. The scheduling of regular elective cases happens according to the any workday scheduling method (Dexter, Traub, et al., 2003). This is represented in the simulation program by rule selected for OR selection (see Section 5.3), namely the first fit algorithm (Hans et al., 2008) or Next fit (Dexter et al., 1999), which is the same. With the 'first fit' algorithm we assume that the patient wants to have the surgery as soon as possible, and we assume that the surgeon scheduler does not optimize the schedule by looking at the case duration to decide whether the case is a good fit in the schedule. We assume the surgeon scheduler suggests the first available date to the patient. The 'first fit' algorithm searches the first available room that is suitable for performing the surgery.

For the 7-day release patient, we assume that the surgeon scheduler suggest a day that is both suitable for the surgeon and the patient. This is the requested day in the simulation study. In the simulation program we randomly draw a day within the next seven days (since it is a 7-day release case), and we assume this represents the requested day. The scheduling of the cases happens according the arrival of patients, in the simulation we do the scheduling at the end of every day for the patients that arrived that day. Optimization is possible since there is a list of patients at the end of the day that need scheduling. Sorting this list of patients, for example on case duration, before scheduling, could yield better results, but does not represent the current situation in VUMC. The scheduling is done according to the 'first come first serve' principle.

We assume that the best suitable OR is always chosen, by the scheduler, for the scheduling of the 7-day release case. In the simulation we modelled this by first looking at the specialty room on the request day. We apply a first fit again in the first available OR suitable for this case. So when an orthopedic room is available for an orthopedic case, this surgery is scheduled in first available orthopedic room. When there is no suitable OR of the specialty for the 7-day release case, we look outside the specialty OR/BT and apply the 'worst fit' (Dexter et al., 1999) OR selection rule. Worst fit is the OR in the set of available ORs that leaves the most underutilized time available after scheduling the surgery. Worst fit is applied without the condition of having at least one case scheduled in the OR (Dexter et al., 1999), allowing services the most time available as possible in their own BT. For example, for an orthopedic case, first is checked whether the case will fit in one of the ORs of orthopedics, thereafter all the available ORs are checked and the case is scheduled in the least used suitable OR, like Dexter, Traub, et al. (2003) suggest.

When the regular elective cases cannot be scheduled until the end of the planning horizon (a year) the cases are cancelled and noted as unable to schedule. We mark a 7-day release cases as cancelled when there cannot be fount a suitable OR on the requested day. Cancellations should not happen in the current situation when we take

into account the main assumption of 7-day release scheduling, namely that there is always enough underutilization to perform the case on the request day.

For the arrival rate of the patients we made the assumption that there are no patients that arrive during the weekend. Most of the cases are scheduled during clinic hours, and the clinic hours do not occur during weekends. The same holds for the requested day, the ORs are closed during weekends, except for two orthopedic trauma rooms. Therefore, we decided that the request day could not be in a weekend. Bounded to the clinic scheduled during weekdays, we also assumed that the arrival of new patients happens deterministically (Swartzman, 1970). According to Swartzman (1970) is the arrival of emergency patients a stochastic arrival process, but when the patients arrive in the clinic and they schedule their surgery, due to the clinic visit, the arrival process became deterministically. The distribution of the patients in the simulation program are therefore divided equally over all the periods (weeks). We randomly draw an origin day on which the patients arrive in the system.

Summary of the assumptions

- Two groups: 7-day/x-day release patients and regular elective cases
- First group scheduled is regular elective then 7-day release patients
- Surgeon scheduler assigns first available date to patient
- Scheduling according to 'first come first serve' principle
- OR selection rule for regular elective cases is 'first fit'
- OR selection rule for the 7-day release patients is first fit for specialty rooms, otherwise 'worst fit'
- Request day randomly drawn for 7-day release
- Cancel regular elective case when end of simulation horizon is reached without finding suitable OR
- Cancel x-day release case when the request day cannot be fulfilled
- Arrival of cases deterministically
- No arrivals in the weekends

5.3.4 Validation & Verification

In order to validate the model we created a base model to represent the current situation. This situation is verified with the historic information and analyzed to see where differences occur and why this could be the case. The data analyzed and presented in Chapter 3 is used as verification information. In Appendix H the time per specialty and the number of cases per specialty are analyzed for the historic information and the simulation of the current situation. The overall measurements are shown in Table 9. The base solution of the number of scheduled cases is output, since the total number of scheduled surgeries is not the same as the number of generated patients. The total number of performed cases is the number of generated cases minus the cancelled cases, minus the warm-up period and generated based on the case mix share. Therefore we represent this as one of the outcomes of the simulation. The total simulated duration is based on the generation of the patients, with the case mix share of the specialties, the statistical distributions tied to the surgery type and the number of surgeries generated in the case mix share. So this is a highly stochastic number. The simulated duration is also different than the expected duration while scheduling. This because during the scheduling the expected duration of the (3-parameter) lognormal distribution is taken and during the simulation a random number within the distribution is drawn. This also represents the real life situation in hospitals

Table 9: Compare historic information with current simulated situation

Parameter	Historic information FY2013	Base solution in the simulation	Difference in %
Number of cases	32788	32733	-0.2%
Number of cases per week	631	629	
Total simulated duration (in minutes)	5,354,303	5,187,042	-3.1%
Utilization rate	71.4%	69.2%	-2.2%
Average case duration	163 minutes	158 minutes	-3.1%

We explain the difference in less utilization, and the average case duration, by the way how the distributions are chosen. The CCS grouping caused extra variance that does

not occur in practice. Because of the lack of cases in the data we could not fit every surgery by surgery type, we also needed to group by CCS to allow for sufficient data entries to fit distributions on the data. This leads to a bigger variance than would occur in practice, therefore we limited the standard deviation of the simulated times in the simulation. This leads to a reduction of on average 5 minutes per surgery. We will take this into consideration when interpreting the results. We accept the simulation difference of 5 minutes per case. Limiting the distributions of the cases that needed to be grouped by CCS is still a better representation than leaving the data behind. The only thing we limit is the variance that occurs, and that also would not occur in practice. For example: a surgery with an expected duration of three hours does not at once take nine hours, this only occurs in very rare cases. Given this example we believe that this is a best representation given the available data.

For the simulation we determined a warm-up period of five weeks. The first five weeks were taken as the warm-up period. The first two weeks the first patients arrive in the hospital and less surgeries are scheduled. After five weeks the number of scheduled surgeries remains the same, and a steady state in the simulation is reached. In this data the warm-up period is already excluded. We excluded the first five weeks of the simulation data. We simulate a year, plus the five weeks we took as warm-up period. So in total we schedule and simulate data in 52 weeks. From the cancellations we exclude the first three weeks and the last two weeks, which results in a 3 week warm-up and two week cool-down period. This because a case is generated and the access time of the cases is 7 days, and the first possible day to schedule on is 7, which results in a 14 days cool-down period.

We do not do replications and only use average numbers in the results. We also note that the reliability of the results depend heavily on the share between the 7-day release cases and the regular elective patients, determined based on FCCR. Since in the data analysis we had to make assumptions we would recommend logging in the data systems when a case is a 7-day release case or not. Then we would be able to conclude with more reliability what the exact share is between the 7-day release cases and the regular elective cases.

5.4 Experiments in the simulation

We described the base solution to represent the current situation in Section 5.3.3 and compared this to the historic data in Section 5.3.3. From this point we continue to simulate the alternatives proposed in Sections 4.2.1.1 - 4.2.1.5. In the following sections we describe how we implemented the proposed alternatives in the simulation.

5.4.1 Increase the number of cases scheduled

For this alternative we increase the number of cases scheduled per week by 10 every simulation run and look at the outcome measures. We increase the number from 600 cases scheduled per week to 750, which represents an increase of 25% compared to the current situation. This would be reached after four years in case of an annual growth of 6. A time horizon of four years is long enough, and a lot can change in the meanwhile, also on the demand side. When no change in the current system would occur and demand would grow with six percent annually we can at least predict when the current system will reach its maximum capacity.

One of the assumptions we make is that when growth occurs this happens equally among all the services. Foremost the simulation shows when the system is fully utilized and when the maximum capacity of the 7-day release program is reached with the current constraints.

5.4.2 Alter the release day

The effect of altering the release day can be modelled by changing the day that the rooms are released to the other services. The current situation is 7 days before the day of service, but this can be changed to 5, 6 ,8 9 or 10 days as described in Section 4.2.1.2. We changed this in the simulation program and kept the other constraints the same to show the difference. Since there is an arrival rate of the patients we also have to alter the two groups of patients that are generated, this is done according to Table 7. We did not have to make further assumptions. We only allowed to schedule on the requested day as in the current situation.

5.4.3 Vary the request day constraint

The requested day is always honored is the current motto. When the number of cases increase this motto is going to be harder to achieve without scheduling in overtime. In the simulation program we followed the scheduling approach of the current situation. When the case could not be scheduled this alternative is put into effect. So first we try to schedule according to the current situation, and thereafter instead of cancelling the case, the simulation program tries to schedule the case with the options given in Table 8. When the option of one day before and after is scheduled we first look at the day before and thereafter we look at the day after the requested day. With the option of all of the days within the 7-day release program, we look at all of the consecutive days, starting with the first one, when the requested day could not be honored.

5.4.4 Relaxation of the soft constraints of the rooms

In order to show the difference between the different room constraints we ease up these constraints one by one and show the difference per room(s). There might be a difference in the outcomes since the case mix is different for the different ORs/services. The rooms for which we erase the constraint of **not** releasing the rooms to other services (so we release the rooms). We will do this for the following ORs:

- VOR 4 Ophthalmology
- VOR 8 Neuro Interventional
- VOR 31, VOR 32, VOR 33, VOR 34 Cardiac surgery
- VOR21 Neurosurgery
- VOR25 Burn (Monday Wednesday & Friday)
- VOR 12 & VOR 13 Orthopedic Trauma

The restriction will still remain that ophthalmology, neuro interventional, cardiac surgery, neurosurgery, and burn can only schedule in their own rooms. Where orthopedic trauma can also be performed in a different OR. We hard coded this in the Block Schedule in the simulation program or hard coded the options in the scheduling algorithm. We did not change the scheduling procedure described in Section 5.3.3.

5.4.5 Change the scheduling policy

For the different scheduling options we consider to sort the patients every day by case duration before scheduling them. This should lead to a better fit. This is done for both the regular elective cases as for the staged cases.

The other option is to schedule according to the four options for the selection of the best suitable OR, namely: Best Fit (Dexter et al., 1999), First Fit (Hans et al., 2008), Level Fit, and Random Fit. Where Best Fit means the suitable OR with the least time available after the surgery, but not allowing overtime. First Fit, is the first available suitable OR. Level Fit tries to schedule the cases evenly over the ORs to create a utilization of the rooms that is as even as possible among the rooms. The Random Fit, randomly draws a room, and when it fits it is scheduled in this room, otherwise a new room is randomly drawn. We will not simulate the best fit, level fit and random fit last option. Since with the time horizon of a year to schedule the surgeries, this would yield an access time that is worse than the current access time.

As described in Section 4.2.1.5 we also eliminate the 7-day release schedule and don't allow to schedule the cases outside the dedicated Block Time schedule. This means that in the simulation program we use the first fit schedule and only generate regular elective patients and do not release the rooms to any other service.

Due to time constraints we will not simulate the option of having a waiting list of for example two weeks, although this might be beneficial to VUMC, besides the time constraint we think this would harm the satisfaction of the patient. Because the patient would walk out of the clinic not knowing exactly on which day the surgery is going to be scheduled.

5.5 Conclusion

This chapter describes the conceptual model and how this conceptual model is translated in the simulation program. We demonstrated that with the assumptions ade to model the date we are able to simulate the current situation adequately. The next chapter shows how the alternative solutions are simulated and the results from the simulated current situation and alternative solutions.

Chapter 6 Simulation outcomes

This chapter describes the results of the alternative solutions. Section 6.1 discusses the results regarding the alternative prospective solutions. In Section 6.2 we will draw conclusions on the simulated alternative solutions.

6.1 Results of the alternative solutions

This section describes the results on the alternative solutions named in Section 4.2, and which are explained in more detail in Section 5.4, regarding the performance measures described in Section 4.3.

6.1.1 Increase the number of cases scheduled

This section describes the scenario of an increase in the number of cases. Section 6.1.1.1 shows the results on the quantitative outcome measures. Section 6.1.1.2 describes the non-quantitative implications. In Section 6.1.1.3 we draw conclusions on this scenario.

6.1.1.1 Quantitative outcome measures scenario increasing number of patients

In the simulation we increased the number of scheduled cases per week, from 600 to 760. The current situation is 630 cases per week, which is underlined in Table 10. Looking at the results in Table 10 and Figure 28, we see that the difference between the number of generated patients, and the number of patient surgeries performed is increasing when the number of scheduled patients per week is increased. The difference is caused by a twofold, (1) the number of patients in the warm-up period is increasing, and (2) the number of unscheduled surgeries is increasing, we can also see this in Table 10.

Table 10: Results simulation increased number of patients

Volume (cases per week):	**600**	**610**	**620**	***630***	**640**	**650**
Number of generated patients	34389	34896	35414	36165	36687	37206
Number of elective surgeries performed	31284	31666	32221	32855	33363	33775
Utilization rate (%) without turnover	66%	67%	68%	69%	70%	71%
Utilization rate (%) with turnover	78%	79%	81%	82%	84%	84%
Overtime (% of available time)	10%	10%	11%	11%	12%	11%
Undertime (% of available time)	23%	22%	21%	20%	19%	18%
Access time (days) 7-day release patients	3,5	3,5	3,5	3,5	3,5	3,5
Access time (days) regular elective patients	7,0	7,0	7,1	7,1	7,2	7,5
Number of unscheduled surgeries	82	103	109	169	149	146
Number of unscheduled 7-day release cases	68	78	89	139	128	124
Average duration unscheduled surgeries (hours)	9,0	9,3	8,9	8,4	7,7	8,2
Volume (cases per week):	***660***	***670***	***680***	***690***	***700***	***710***
Number of generated patients	37762	38479	39000	39522	40053	40889
Number of elective surgeries performed	34255	34805	35364	35773	36225	36790
Utilization rate (%) without turnover	72%	73%	74%	75%	76%	78%
Utilization rate (%) with turnover	86%	87%	88%	89%	91%	92%
Overtime (% of available time)	12%	12%	12%	13%	13%	14%
Undertime (% of available time)	18%	17%	16%	15%	14%	13%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,5	3,5	3,6
Access time (days) regular elective patients	7,3	7,5	7,4	7,5	7,6	7,3
Number of unscheduled surgeries	206	244	272	314	372	483
Number of unscheduled 7-day release cases	181	230	249	291	341	461
Average duration unscheduled surgeries (hours)	7,1	7,0	6,8	6,6	6,4	6,0
Volume (cases per week):	**720**	**730**	**740**	**750**	**760**	
Number of generated patients	41670	42456	43199	43793	44327	
Number of elective surgeries performed	37477	38055	38603	39057	39406	
Utilization rate (%) without turnover	78%	79%	80%	81%	82%	
Utilization rate (%) with turnover	93%	95%	95%	97%	98%	
Overtime (% of available time)	14%	15%	15%	15%	15%	
Undertime (% of available time)	12%	12%	11%	10%	10%	
Access time (days) 7-day release patients	3,6	3,6	3,6	3,6	3,6	
Access time (days) regular elective patients	7,8	7,9	7,9	7,8	8,2	
Number of unscheduled surgeries	553	654	810	904	952	
Number of unscheduled 7-day release cases	521	640	784	876	921	
Average duration unscheduled surgeries (hours)	5,5	5,4	5,3	5,0	5,1	

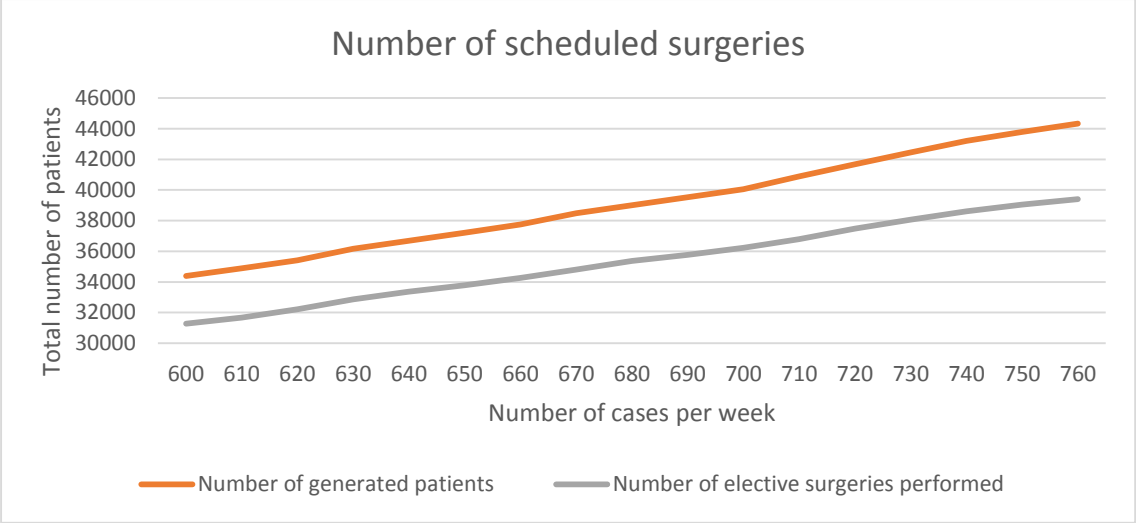

Figure 28: Number of generated and performed cases

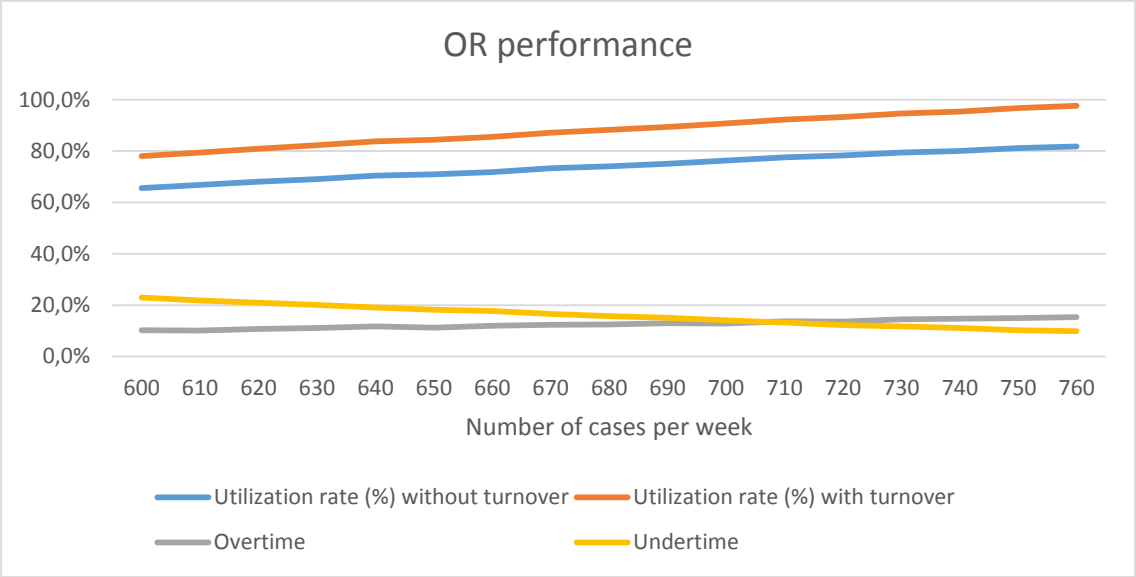

Figure 29: OR performance results increasing number of cases

Table 10 and Figure 29 show that with the increasing number of patients the utilization also increases, from 66% (without turnover) to 82% (without turnover), and 78% (with turnover) to 98% (with turnover), respectively. The undertime decreases more rapidly compared to the overtime, which is a positive effect, and due to the way of scheduling.

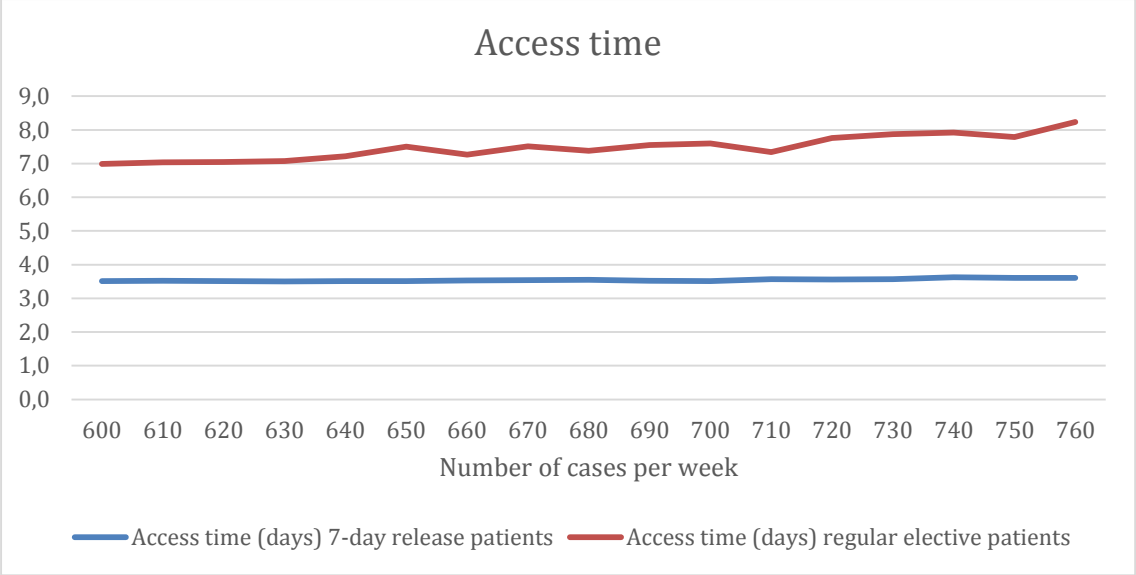

Figure 30: Access time increasing number of patients

Table 10 and Figure 30 show the access time. The access time for the regular elective cases increase by a small number, which is almost negligible. The reason why this number is not increasing more rapidly is because the regular elective cases are planned before the 7-day release program is effectuated. By scheduling the regular elective patients earlier, the available time in the OR is not utilized to its maximum capacity, and the cases can be accommodated in a relative short time period after the first possible day. This leads to the average access time of in between 7 to 8 days. Where the first day the regular elective cases allowed to be scheduled is the 7 days from the release day (8 days from arrival of the case). An access time of 7 or 8 days means that the case can be scheduled on the first or second day that they are allowed to be scheduled on. Example given, a regular elective gynecology case needs to be scheduled, the case arrives today, since regular elective case, the first 7 days are not allowed to be scheduled in, the 8^{th} day from arrival and 7^{th} day from release (release one day after patient arrival), the case can be scheduled and will be scheduled. From the numbers in Table 10 and Figure 30 we can see that access time is effectively one to two days for regular elective cases.

When we look at the access time of the 7-day release cases in Table 10 and Figure 30, we see that the number stays the same. The reason for the flat line is that the cases all have a request day on which they are scheduled, and therefore the average of the

request days is 3.5 (7 possible request days). The line stays flat since the cases are marked as unscheduled when they cannot be accommodated on the request day.

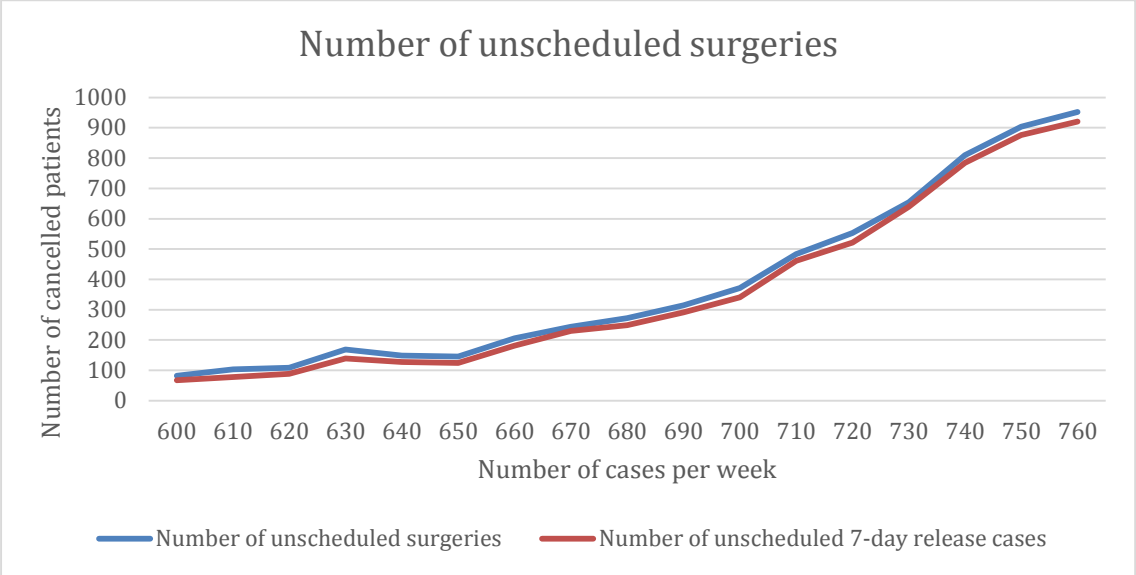

Figure 31: Number unscheduled surgeries scenario increasing number of patients

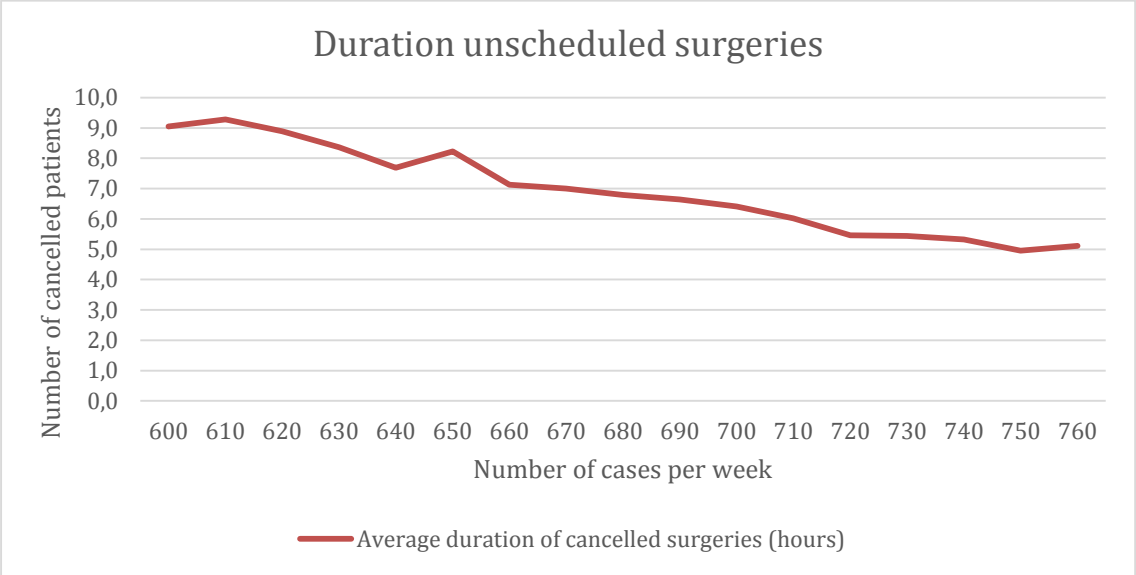

Figure 32: Average duration unscheduled surgeries

The number of unscheduled surgeries are shown in Figure 31, the largest portion of the unscheduled surgeries consist of 7-day release cases. Where the regular elective cases can be scheduled on the next day, the 7-day release program cases are cancelled, because they have a request day. The difference in scheduling means that the 7-day release patients remain unscheduled where the regular elective cases see an increase in access time.

Figure 31 shows the number of unscheduled surgeries, and Figure 32 shows the average duration of the unscheduled surgeries. Table 10 shows that with 600 cases a week on a yearly basis 82 patients are cancelled. The average duration of these cases is 9 hours. Seems to us as not a surprising number of patients that cannot be fit, if we strictly apply the first come first served rule.

6.1.1.2 Non-quantitative implications increasing number of patients

In this section we describe the non-quantitative implications, as described in Section 4.3, for the different stakeholders.

The patient: Implication for the patient is that, when the 7-day release is kept above 730 cases is, that the patient will be send home with a request date and that the patient has at least 1.6% (640 cases not scheduled / 38055 cases performed) chance of not getting the surgery scheduled on that DoS. In the case of an unscheduled surgery, the case will be rescheduled to a later date. This is inconvenient for the patient that might have to arrange care at home and transport.

Scheduler or surgeon scheduler: The implication for the scheduler or surgeon scheduler is that with the increase in the number of cases the uncertainty of whether the case is scheduled in the 7-day release is going to increase. This might have the effect that the schedulers are going to schedule the case in regular elective time, which leads to an increase in access time for the patient.

Surgeon and OR staff: For the surgeon and the OR staff there is not to be a big change except for more busy OR days. The effect on the surgeon might be that some patients decide to have the surgery in a different hospital when the access time increases.

The hospital: For the hospital an increase in the number of cases is beneficial when they can be performed with the outcomes presented in Section 6.1.1.1. The staff might be less satisfied with an increase of patients, because they have to work more, and overtime is also increasing. VUMC needs to make a trade-off between how satisfied the patients are, how satisfied the staff is, and when the costs of paying overtime is worth the costs of building a new OR, or changing the scheduling policy.

6.1.1.3 Conclusion increasing number of patients

In Section 1.2 we posed the question: *"What is the maximum demand for which the 7-day release program still suitable"*. VUMC has to decide how many patients they want to deny service in the 7-day release program, but when more than 700 cases are scheduled per week, one patient per day is left unscheduled. When the number of scheduled cases increase to 730, 640 cases are left unscheduled. This means that 1.6% of the cases arriving in the hospital is left unscheduled. In practice this means that the patient is rescheduled to a later point in time, something we also measured in Section 3.3.1. We would advise VUMC not to continue with the current scheduling policy beyond 730 cases.

6.1.2 Alter the release day

The in Section 4.2.1.2 and Section 5.4.2 described alternative solution of altering the 7-day release program to let the day differ is discussed in this section. Section 6.1.2.1 describes the quantitative outcomes with the alternative solution of altering the 7-day release program. Section 6.1.2.2 describes the non-quantitative impact of the alternative solution of altering the release day. Section 6.1.2.3 gives the conclusion on the alternative of altering the release day.

6.1.2.1 Quantitative outcome measures

One of the alternative solutions is to alter the release day. Not releasing rooms 7 days ahead of the DoS, but: 5, 6, 8 or 9 days. We simulated these x-day release scenarios in accordance with the arrival rate of the patients, described in Section 4.2.1.2. The x stands for the day the ORs are released. In Table 11 surprisingly we see that releasing on another day than 7, performs worse. The utilization does not increase and the number of x-day release patients that are unscheduled, increases in all of the scenarios. Therefore we suggest that releasing the rooms 7-day ahead of the DoS is the best.

The explanation for this outcome could lie in the input we calculated. In Section 4.2.1.2 we described and calculated the share between x-day release patients and regular

elective cases, see Table 7. We had to make some assumptions, to calculate the share between regular elective and the x-day patients for the other scenarios. Since we already made assumption with marking the 7-day release patients in de FCCR, we think this might be the cause for the unexpected outcome in this section.

Table 11: Results of the scenario of altering the release day

x-day release:	5-day	6-day	7-day (current)	8-day	9-day
Utilization rate (%) without turnover	69%	69%	69%	68%	67%
Utilization rate (%) with turnover	82%	82%	82%	81%	80%
Overtime (% of available time)	12%	11%	11%	12%	13%
Undertime (% of available time)	21%	20%	20%	22%	23%
Access time (days) 7-day release patients	2,4	2,9	3,5	4,2	4,8
Access time (days) regular elective patients	5,9	6,1	7,1	7,9	8,7
Number of unscheduled surgeries	324	187	117	488	891
Number of unscheduled x-day release cases	309	168	99	465	867
Average duration unscheduled surgeries (hours)	5,6	7,2	8,6	5,0	4,3

6.1.2.2 Non-quantitative implications

According to the quantitative measurement in Section 6.1.2.1, we can be short on the non-quantitative implications. An increase in the number of unscheduled cases is negative from the patient perspective. The surgeon and schedulers might want to have a 5-day or 6-day release to have longer certainty on “their own” BT, but this influences the performance negatively, and more patients will be unsatisfied with their scheduling of the case. The hospital also does not benefit in any way from changing the policy.

6.1.2.3 Conclusion alter the release day

Looking at the quantitative outcome measures in 6.1.2.1 we advise VUMC *not* to change the 7-day release program to a different day. The current case mix, and the assumptions we had to make in calculating the case mix for the 5- to 9-day release program delivered this result. See also Section 3.3.1.1 for the assumptions in marking the 7-day release patients and Section 4.2.1.2 for the calculation of the share. When we would have more exact data on which cases are staged cases we could rerun this simulation. But with the current assumptions we would advise VUMC to leave the 7 in the 7-day release program.

6.1.3 Vary the request day constraint

The in Section 4.2.1.3 and Section 5.4.3 described alternative solution to vary the request day in the 7-day release program is discussed in this section. Section 6.1.3.1 describes the quantitative outcomes regarding the alternative solution of altering the request day. Section 6.1.3.2 describes the non-quantitative impact of the alternative solution of altering the request day. Section 6.1.3.3 gives the conclusion on the alternative solution of altering the request day.

6.1.3.1 Quantitative outcome measures

For the variation of the request day, we added extra days. Currently cases are labeled as unscheduled when on the request day the case cannot be scheduled. We choose to alter this approach and simulate other possibilities. The possibilities, described in Section 4.2.1.3, we choose: extend the request day with the day after, extend with one day before and one day after, extend with 2 days after, and all of the release days are allowed.

The results in Table 12 show that one day, one day before and after and two days after have almost the same performance. The all days approach gives a boost to the number of unscheduled surgeries.

We also tested the different scenarios in the case of 730 scheduled surgeries per week. From Table 12 we can see that even in the case of 730 scheduled surgeries, the one day after, the one day before and after and the two days approaches deliver around the same result, where the all days approach is clearly delivering better results. Scheduling the volume of 730 cases according to the current scheduling policy deliver 654 unscheduled cases, where the all days approach delivers 42 unscheduled surgeries. This means instead of having to deny the patient access twice a day, the number drops to a patient every eight days. In the case of 630 patients a week, the 1 day after option reduces the denial from one patient every two days, to denying a patient almost every four days. In the case of 730 cases, the denial drops from two patients a day to one patient per day.

Table 12: results scenario: Vary the request day

Variation from request day:	**630 Current**	**1 day after**	**1 day before and after**	**2 days after**	**all days**
Utilization rate (%) without turnover	69%	69%	70%	70%	69%
Utilization rate (%) with turnover	82%	82%	83%	83%	82%
Overtime (% of available time)	11%	11%	11%	11%	11%
Undertime (% of available time)	20%	20%	20%	20%	20%
Access time (days) 7-day release patients	3,5	3,5	3,5	3,5	3,6
Access time (days) regular elective patients	7,1	7,2	7,1	7,1	7,4
# of unscheduled surgeries	169	96	94	93	35
# of unscheduled 7-day release cases	139	78	73	71	14
Avg. duration unscheduled surgeries	8,4	8,7	8,4	8,2	11,6
Variation from request day:	730 cases	1 day after	1 day before and after	2 days after	all days
Utilization rate (%) without turnover	79%	80%	81%	81%	82%
Utilization rate (%) with turnover	95%	96%	96%	96%	97%
Overtime (% of available time)	15%	15%	15%	15%	15%
Undertime (% of available time)	12%	11%	11%	11%	10%
Access time (days) 7-day release patients	3,6	3,6	3,6	3,6	3,9
Access time (days) regular elective patients	7,9	8,2	7,7	7,8	8,0
# of unscheduled surgeries	654	363	351	479	42
# of unscheduled 7-day release cases	640	336	327	451	17
Avg. duration unscheduled surgeries	5,4	5,9	6,1	5,4	11,4

6.1.3.2 Non-quantitative implications

In this section we describe the non-quantitative implications, as described in Section 4.3, for the different stakeholders.

The patient: The impact of the 1 day after release might be accpetable for the patient. This means that when the patient leaves the hospital, the patient knows that on two possible dates the patient is getting surgery. The option of a request day and then all of the other days creates a lot of uncertainty for the patient. The trade-off for the patient is that the extra uncertainty by nog knowing when the surgery is going to take place, decreases the uncertainty of whether the case is going to happen in the first place. This means that the trade-off is that more cases can be scheduled, which is also beneficial for the patients, but at the cost of more uncertainty when the surgery is going to take place.

Scheduler or surgeon scheduler: for the schedulers the uncertainty is also increasing. They give a request day to schedule the patient on, but are not certain whether this day is going to be honored in the schedule.

Surgeon: the surgeon is the one who is affected the most by a change in this policy. The surgeon might have clinic the day after the request day. The likelihood of this happing is apparent when we look at the schedule in which all of the surgeons are names (not in this report due to privacy). The surgery could possibly be performed by one of the other surgeons who is performing surgery on the day after the request day, but patients want to be operated by the surgeon whom they have seen in the clinic, although other another surgeon might be just as good or better, this is a trust issue.

In the case of scheduling the surgery to any other day than the request day, when this is not possible, leaves the same objections as described before, and the likelihood of the surgeon having clinic even increases.

The hospital: from the hospital perspective, we want to point out that when changing the scheduling policy to 1 day after or all days, the satisfaction of the surgeon can be affected negatively. Also the satisfaction of the patient can be negatively affected. On the other hand, the hospital is left with less unscheduled surgeries, which is a benefit, also revenue wise.

6.1.3.3 Conclusion alter the request day

We would advise VUMC to put the policy only into effect when needed, in the current situation almost no patients are left unscheduled. The one day after performs similar to the one day before and after and better than the 2 days after prospective solutions. Since the solution has the least impact on the patient or the surgeon, we would advise to opt for this approach when the need for it is apparent. Only when the number of cases is going to be near the 730 cases a week, we would advise VUMC to take the most drastic approach. Namely allowing all of the days within the 7-day release program. The downside to this might be that surgeon and patient satisfaction can decrease.

6.1.4 Relaxation of the soft constraints of the rooms

The in Section 4.2.1.4 and Section 5.4.4 described alternative solution to relax some of the room constraints in the 7-day release program is discussed in this section. Section 6.1.4.1 describes the quantitative outcomes regarding the relaxation of the room constraints. Section 6.1.4.2 describes the non-quantitative impact of the alternative solution of the relaxation of the room constraints. Section 6.1.4.3 gives the conclusion on relaxing the room constraints.

6.1.4.1 Quantitative outcome measures

We simulated the rooms (VOR4, VOR8, VOR31-34, VOR21, VOR25, and VOR12-13) that are not released in the 7-day release program, and erased the constraint that other services are not allowed to schedule in those rooms. We assumed that when we would release the rooms to other services, the same restrictions count for the specialty, which means that when the specialty is bounded to a certain room this remains. Although other services now have the ability to schedule their cases in the newly released room(s). To judge whether releasing these rooms has a negative impact on the service we looked at the total number of unscheduled cases and at the number of unscheduled cases of the service. Table 13 compares the current situation to the room that is released, for the volume of 630 cases per week and 730 cases per week.

Table 13: Results relaxing room constraints

Scenario:	**630 current**	**VOR4 (630)**	**730 current**	**VOR4 (730)**
Utilization rate (%) without turnover	69%	69%	79%	80%
Utilization rate (%) with turnover	82%	82%	95%	95%
Overtime (% of available time)	11%	11%	15%	14%
Undertime (% of available time)	20%	20%	12%	11%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	7,1	7,6	7,9	8,3
Number of unscheduled surgeries	169	116	654	578
Number of unscheduled Ophthalmology cases	0	0	0	0
Average duration of cancelled surgeries (hours)	8,4	8,4	5,4	5,5

Scenario:	*630 current*	*VOR8 (630)*	*730 current*	*VOR8 (730)*
Utilization rate (%) without turnover	69%	69%	79%	80%
Utilization rate (%) with turnover	82%	83%	95%	95%
Overtime (% of available time)	11%	11%	15%	14%
Undertime (% of available time)	20%	20%	12%	11%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	7,1	7,2	7,9	7,9
Number of unscheduled surgeries	169	111	654	556
Number of unscheduled Neuro Interventional cases	0	0	0	0
Average duration of cancelled surgeries (hours)	8,4	8,9	5,4	5,7
Scenario:	**630 current**	**VOR 31-34 (630)**	**730 current**	**VOR 31-34 (730)**
Utilization rate (%) without turnover	69%	69%	79%	80%
Utilization rate (%) with turnover	82%	82%	95%	95%
Overtime (% of available time)	11%	11%	15%	14%
Undertime (% of available time)	20%	20%	12%	11%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	7,1	7,7	7,9	8,3
Number of unscheduled surgeries	169	124	654	548
Number of unscheduled Cardiac cases	0	0	0	0
Average duration of cancelled surgeries (hours)	8,4	8,8	5,4	5,9
Scenario:	**630 current**	**VOR21 (630)**	**730 current**	**VOR21 (730)**
Utilization rate (%) without turnover	69%	69%	79%	79%
Utilization rate (%) with turnover	82%	83%	95%	95%
Overtime (% of available time)	11%	11%	15%	14%
Undertime (% of available time)	20%	20%	12%	11%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	7,1	7,2	7,9	8,1
Number of unscheduled surgeries	169	152	654	615
Number of unscheduled Neurosurgery cases	32	30	81	113
Average duration of cancelled surgeries (hours)	8,4	8,7	5,4	5,7
Scenario:	**630 current**	**VOR25 (630)**	**730 current**	**VOR25 (730)**
Utilization rate (%) without turnover	69%	69%	79%	80%
Utilization rate (%) with turnover	82%	82%	95%	95%
Overtime (% of available time)	11%	11%	15%	14%
Undertime (% of available time)	20%	20%	12%	11%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	7,1	7,3	7,9	8,0
Number of unscheduled surgeries	169	115	654	573
Number of unscheduled Burn cases	0	0	0	0
Average duration of cancelled surgeries (hours)	8,4	8,8	5,4	5,7

Scenario:	*630 current*	*VOR 12,13 (630)*	*730 current*	*VOR 12,13 (730)*
Utilization rate (%) without turnover	69%	69%	79%	79%
Utilization rate (%) with turnover	82%	82%	95%	95%
Overtime (% of available time)	11%	11%	15%	14%
Undertime (% of available time)	20%	20%	12%	12%
Access time (days) 7-day release patients	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	7,1	7,6	7,9	8,2
Number of unscheduled surgeries	169	136	654	663
Number of unscheduled Orthopedic Trauma cases	6	9	48	61
Average duration of cancelled surgeries (hours)	8,4	7,6	5,4	5,3

From Table 13 we can see that we should not release the following rooms:

- VOR 21 Neurosurgery
- VOR 12&13 Orthopedic Trauma

We explain this because the case mix share and the utilization of the specific rooms is higher than the other services, and therefore scheduling other cases in these ORs will yield negative results.

The rooms that are not negatively impacted by a release are the following rooms:

- VOR 4 Ophthalmology
- VOR 8 Neuro Interventional
- VOR 31 – 34 Cardiac Surgery
- VOR 25 Burn

The ORs are not negatively impacted, which means that the surgeries of their own specialty are not denied, the situation for these specialties stays neutral. There is not a positive impact because the specialty does not benefit of releasing their OR in the 7-day release schedule, but we showed that it is also not negatively impacted.

All of these rooms don't have unscheduled surgeries in the current scheduling method, and also with the release of these rooms no additional unscheduled cases occur of these services. For all of the scenario's we see that the total number of unscheduled surgeries also decreases.

6.1.4.2 Non-quantitative implications

In this section we describe the non-quantitative implications, as described in Section 4.3, for the different stakeholders.

The patient: The patient is positively influenced when the rooms that can be released are released. The chance of having the surgery scheduled increases.

Scheduler or surgeon scheduler: For the services of which the rooms can be released there should not be an impact, since none of the cases is denied to be scheduled.

Surgeon and OR staff: Also for the surgeon and the OR staff there should not be a difference, since the same amount of surgeries can be performed.

The hospital: For the hospital, the release of these rooms leads to an improved schedule without harming the services in the number of cases they can schedule in their rooms.

6.1.4.3 Conclusion on the relaxation of the soft constraints of the rooms

We would recommend that VUMC allows that VOR4, VOR8, VOR 31-34 and VOR 25 are released at the 7-day mark. This is not going to affect the services negatively, and is beneficial for the hospital and the patient.

6.1.5 Change the scheduling policy

The results of the in Section 4.2.1.5 and Section 5.4.5 described alternative solution: change the scheduling policy, are discussed in this section. Section 6.1.5.1 describes the quantitative outcomes regarding the alternative solution of changing the scheduling policy. Section 6.1.5.2 describes the non-quantitative impact of the alternative solution of changing the scheduling policy. And finally Section 6.1.5.3 gives the conclusion on the alternative solution of changing the scheduling policy.

6.1.5.1 Quantitative outcome measures

In order to show the impact of the 7-day release policy for VUMC we scheduled the surgeries without a releasing policy in place. Table 14 shows that scheduling with-out the 7-day release policy does not lead to an improvement, it is with 3738 unscheduled cases performing rather poorly. Also the other key performance indicators show a decrease in performance.

Table 14: Results different scheduling strategies

Scenario:	**no 7-day**	**Current**	**Current descending**	**730 current**	**730 descending**
Utilization rate (%) without turnover	62%	69%	69%	79%	80%
Utilization rate (%) with turnover	74%	82%	82%	95%	95%
Overtime (% of available time)	12%	11%	12%	15%	15%
Undertime (% of available time)	23%	20%	20%	12%	11%
Access time (days) 7-day release patients	0,0	3,5	3,5	3,6	3,6
Access time (days) regular elective patients	8,4	7,1	7,2	7,9	8,0
Number of unscheduled surgeries	3738	169	77	654	449
Number of unscheduled x-day release cases	0	139	57	640	432
Average duration unscheduled surgeries (hours)	2,9	8,4	9,5	5,4	5,2

Besides scheduling without the 7-day release program, we schedule the cases with the 7-day release program, but with a waiting list of one day. We sorted the cases on this waiting list on decreasing expected duration. We then applied the same heuristics described in Section 5.3.3. Recalling the scheduling heuristics: first fit for the regular elective cases, then a first fit in the specialty rooms for the 7-day release cases, and then a worst fit for the 7-day release case scheduled outside the OR of the specialty.

Table 14 shows that using a waiting list of only one day and sorting on decreasing order of expected surgery duration leads to an increased performance. The number of unscheduled cases drops from 169 to 77 and in the case of 730 scheduled cases a week, it drops from 640 to 449.

6.1.5.2 Non-quantitative implications

In this section we describe the non-quantitative implications, as described in Section 4.3, for the different stakeholders.

The patient: The impact on the patient is that the number of unscheduled patients is decreased in the case of sorting the waiting list per day. There is no difference in when the patients is called to confirm when the surgery is scheduled, since the cases are already collected on a day and scheduled by the end of the day. The only way the patient is negatively affected is when he is the first on the list, but there is no place to accommodate the surgery. Where in other situations this surgery would have found a spot in the schedule. It is hard to trace these instances in the OR manager, and we find the decrease in unscheduled surgeries more important also from the patient perspective.

Considering the absence of the 7-day release program, this would have a negative effect from the patient perspective. The access time increases and the number of unscheduled surgeries also increases, which are all negative effects for the patient.

Scheduler or surgeon scheduler: from the perspective of the surgeon scheduler or the scheduler, the extra step they have to take is to sort the cases on expected case duration before they start to schedule the cases. Usually when scheduling cases they are shuffled around quite frequently in order to create a feasible fit with-out scheduling in overtime. Sorting the cases per day on duration will decrease the number of reschedules, and leave less cases unscheduled. Therefore we see the sorting on case duration as a positive solution.

Erasing the 7-day release program would be beneficial to the surgeon scheduler because they have more power again on their BT. At the 7-day mark before the DoS, the service and therefore the surgeon scheduler would remain “owner” of the BT. This means that when the service has enough BT, they can more easily schedule their cases. When there is not enough BT for the service of when the surgeon wants to operate on a different day or run two rooms, then the absence of the 7-day release program is a negative effect. Foremost from the interviews conducted in VUMC the

surgeon schedulers are positive about the program, and see the benefits as greater than the downsides. The extra flexibility is more required than the ownership in the last week before the DoS.

Surgeon and OR staff: the surgeon perspective is already highlighted partially in under the surgeon scheduler part. The flexibility that is created with the 7-day release program is more valuable than the ownership of the BT. Regarding the sorting of the patients, this has no effect on the surgeon. Regarding the OR staff it is hard to say whether the 7-day release program is a blessing or not. The positive to the 7-day release for the OR staff is that they are able to operate different cases, and not only cases from their pod. Whether this is received as something positive or negative remains unknown to the researcher.

The hospital: from the hospital perspective the absence of the 7-day release program is clear: that is hard negative. The option of sorting the patients per day, has is a positive solution from the hospital perspective since more cases can be scheduled in the ORs with-out harming the surgeon or surgeon scheduler. The patient even benefits from this sorting, because the likelihood that their case is getting scheduled increases.

6.1.5.3 Conclusion on changing the scheduling policy

We would advise VUMC to implement the sorting of cases based on their expected duration. This leads to less unscheduled patients, with a slight increase in performance.

6.2 Conclusion & recommendation

In this chapter we showed how to simulate the various alternative solutions as shown in Section 5.4. We presented the results of the alternative solutions in Section 6.1.

From Section 5.4.1 we can conclude that when nothing is changed in the current system the maximum capacity is reached for the 7-day release program when 730 cases are scheduled per week. Scheduling 730 cases a week means denying two patients service every day when they are put on staged to be scheduled as a 7-day

release patient. The assumption with which the 7-day release program was introduced, see Sections 1.2 and 3.4.2, will no longer hold. The underutilization is low and the longer cases are denied access and need to be rescheduled to a later point in time.

The alternative solution, to alter the release day in Section 5.4.2 is performing worse than the current situation, and therefore we discard this prospective solution immediately.

The prospective solution of Section 6.1.3 to vary the request day constraint gives from a quantitative point of view improvements, but regarding the non-quantitative implications we would only advise VUMC to introduce a second request day, in Section 5.4.3 simulated as the day after, only above, the in Section 5.4.1 simulated, 730 cases a week. The other simulated variants in Section 5.4.3 have unwanted extra non-quantitative implications that cannot be justified.

The prospective solution to relax the soft constraints shown in Section 5.4.4 give mixed results. We advise to ease the constraint of not releasing certain rooms, but not for all rooms. The rooms that can release in the 7-day release program with-out impacting the performance are: VOR4, VOR8, VOR 31-34 and VOR 25. We would advise to gradually ease the constraints of these rooms one by one.

Regarding the prospective solution of changing the scheduling policy in Section 5.4.5, we can conclude that eliminating the 7-day release program leads to a performance which is worse, and therefore we should keep the 7-day release program. Regarding the prospective solution of sorting the 7-day release patients on decreasing expected duration per day, we would advise VUMC to implement this change. The solution gives an improvement without impacting the patient in a negative way. The surgeon scheduler and scheduler are impacted in a small way, because they need to sort on expected duration instead of following the first come first serve rule. We foresee that when this policy is implemented that the scheduler has less work, since it is easier to find a small spot later on in the list of surgeries than to find a large spot when already a number of patients is planned.

To conclude, we advise VUMC to combine the solutions of Section 6.1.4 (ease the room constraints) and 6.1.5 (scheduling the 7-day release patient with a waiting list of one day) and conduct an evaluation of the performance thereafter before opting for the solution proposed in Section 6.1.3 (to add an extra request day). We want to emphasize again that the option of the waiting list of one day does not impact the patient. The surgeries in the current situation are already collected and scheduled by the end of the day. We only suggest to change the priority rule in scheduling the patient.

Chapter 7 Implementation & evaluation

This chapter describes a proposal for implementation and the evaluation of the proposed solutions of Chapter 6. Section 7.1 we describe how to implement the proposed changes. In Section 7.2 the setup for the evaluation is given. And finally in Section 7.3 we draw conclusions.

7.1 How to implement the changes

First of all, one of the most important parts in order for changes to be effective is to communicate to the staff. When staff is not informed properly they will resent the changes immediately. The changes we propose for are not drastic, but can call resentment with the surgeons and the surgeon schedulers who still “own” their BT.

The simulation showed that the release of rooms does not affect the services negatively. This is the most important message to get across. The simulation is based on the historic cases mix and the performance. Prospective growth is not taken into account and will probably be used as an argument that the simulation cannot predict whether the service is affected or not. In our opinion there should be very strong indicators brought across the table to justify this argument, like we bring justification to the argument of releasing the rooms in the 7-day release program.

The second prospective solution, to schedule with a one day waiting list, is not regarded as a hard solution to implement. We think that the schedulers are willing to accept this policy change without great reservations.

We propose seven phases for VUMC to implement the changes:

Phase 1: Communicate to surgeon schedulers, surgeons & anesthesiologists

- Communicate to staff.
- Ask feedback.
- Explain where it will help the performance of the hospital.
- Explain where staff will benefit from the change.

    - Explain also where more insecurity will arise, but that the benefits outperform the negatives.
    - Explain that there will be an evaluation and that the outcomes will be communicated to the staff.
    - Ask staff which indicators they would like to have included in the baseline measurement and the evaluation.
    - Ask for a voluntary service to start the policy change.
- Phase 2: Write policy for change & baseline measurement
    - Write a policy which states the changes and let staff comment on the policy.
    - Perform a baseline measurement on the criteria that are going to be used for the evaluation of the pilot. For performance measurements see the results section of the simulations (Sections 6.1.4 and 6.1.5). For evaluation also see Section 7.2.
- Phase 3: Pilot
    - Start with one service that voluntary starts the change and implements the alternative solutions.
    - We suggest a Pilot of 3 months (based on the data analysis we performed).
    - First three weeks are excluded from the data for evaluation, because of start-up problems.
- Phase 4: Evaluate Pilot
    - Adjust the policy where problems occurred during the pilot.
    - Give outcomes of the pilot compared to the baseline measurement.
    - Evaluate whether new performance measurements should be included, that were unforeseen in the baseline measurement.
- Phase 5: Roll-out to all services
    - Roll-out the policy to all services.
- Phase 6: Evaluate
    - We recommend to evaluate 6 month after introduction and at least to not include the first two month of data.
    - Evaluate and communicate the outcomes with the staff
- Phase 7: Adjust where needed
    - Adjust the policy where needed after the evaluation has taken place to optimize the outcomes.

These 7 steps lead to a successful implementation of the proposed solutions in our opinion. We tried to address as many points as possible addressed by van Lent, VanBerkel & van Harten (2012) who discuss the points for implementation of simulation studies.

7.2 How to evaluate the changes & projected outcomes

To evaluate the proposed solutions we recommend to collect data in such a way that analysis of the data is kept to a minimum. Analysis is time consuming, and when collection can be done in such a way that it is automated by a report, this would be very helpful for VUMC. We propose to measure the following performance measurements and data logging:

- Access time per service divided in:
    - 7-day release patients
    - Regular elective patients
- Unscheduled surgeries
    - The number of surgeries that cannot be scheduled on the requested day when the 7-day release program is active. Measured **per service**.
- Overtime per room and per service, measured in hours.
- Mark the patients in the database as 7-day release patient or not, in order to evaluate exactly which patients are 7-day release and which are regular elective.
- We recommend to keep logging the regular ORMIS data regarding time, place, surgeons, case number, anesthesia number etc.
- Collect data regarding the rescheduling of cases and the reason for rescheduling a case.
    - Surgeon initiative
        - Urgent other case gets priority
        - Worsened condition of the patient/ patient not fit for surgery
        - Surgeon unavailable / surgeon time away
    - Patient initiative
- Staff satisfaction

- Interview surgeons, surgeon schedulers and anesthesiologists how the system is performing and what should change in order to let the system improve.

With this data we can clearly distinguish between 7-day release program cases and regular elective cases. The systems currently do not log whether a case is a 7-day release case or a regular elective case.

With the above measurements we compare the baseline measurement with the outcomes. As main performance measurements for the baseline and evaluation we would recommend the following:

- Utilization rate
- Overtime
- Underutilization
- Access time
- Patient satisfaction on time and service before and after implementing changes.
- Staff satisfaction
- Number of unscheduled 7-day release cases

We recommend that these measurements are done at the service level to create insight into the performance of the different services. Also an overview should be given of all of the services together.

7.3 Conclusion

In summary of this chapter, we propose that the seven steps in Section 7.1 for implementing the proposed alternative solutions. Section 7.2 describes the measurement that should be taken to evaluate the proposed solutions and also to perform a proper baseline measurement.

Chapter 8 Conclusion & recommendation

This chapter draws conclusions and recommendations in Section **Error! Reference source not found.**. In Section 8.2 we will discuss and reflect on the literature. Section 8.3 will give ideas for further research.

8.1 Recommendations

Based on the simulation outcomes we conclude that VUMC should continue with the 7-day release program. We also conclude that with the current scheduling policy, the system starts to deny access to more than two patients a day beyond 730 cases per week. The number of cases that will have to be rescheduled is increasing to a point where it is more than two per day. This gives the answer to the posed problem statement in Section 1.2. What is the suited approach when nearing the 730 cases?

There are two prospective solutions we recommend VUMC to implement, namely to relax the constraints on some of the rooms that are not released. The services are not negatively affected by this change as showed in the simulation. We also recommend VUMC to implement a different strategy for scheduling the rooms. Where at the moment the first come first serve strategy is used, we recommend to use a waiting list of one day, and at the end of the day, sort the collected patients based on their expected duration and schedule them accordingly. This leads to fewer unscheduled surgeries, and is only a small change for the schedulers. We also recommend VUMC to implement the changes by following the implementation guideline. This should cause less resistance and ease the implementation.

During our research we had to make a number of assumptions, some of the assumptions were directly tied to distinguish between regular elective cases and 7-day release cases. We would recommend VUMC to log, whether the scheduled cases is a 7-day release case, or not. This would make the data analysis a lot easier and more reliable.

In conclusion, we believe that the 7-day release program is a good trade-off between the OR efficiency and flexibility on the one side and the safety and convenience on the

other side. Normally, to create a sound schedule we would need to allocate the BT exactly in accordance with the case mix to create an efficient solution. Furthermore we would need a pool of patients (waiting list) to choose from in order to get the best solution.

When scheduling according to a Block Schedule without the ability to release the ORs, this means that the surgeon can follow himself on the day of service, which is good for the efficiency and the quality of care. The 7-day release program shows a good trade-off in our opinion, where up to 7 days ahead of the DoS the surgeon can schedule case and can follow himself. After the 7-day release is put into effect OR efficiency is going to play a larger role, because we want to optimize the schedule, and have fewer unscheduled surgeries. We believe that the 7-day release program shows that this is the case. See also Section 6.1.5 on when the 7-day release program is 'erased'.

The 7-day release program is the best suited approach for the current case mix in VUMC, with the best trade-off between access time for the patients, flexibility for the surgeons and OR efficiency.

8.1.1 Other recommendations

During the research in VUMC we came across other things that did not affect the study directly. We want to point these out to VUMC to help them to improve the organization, or giving them subjects for additional research.

During the observations and the interviews we found out that patients lack the ability to check their latest status of the surgery. The patients sometimes showed up with an outdated paper given to them in the clinic with their surgery time, although the scheduled surgery time had changed in the meanwhile. We would propose a phone line or a web-site where they can enter their information and that the latest surgery time is shown to them, with the indication whether this is a change or not and when they know for certain (for example one day ahead of the surgery) when they are receiving their surgery.

We recommend to schedule based on expected duration when this is possible. A commonly heard complaint of the surgeon schedulers and board nurses is that some rooms run into overtime, where based on historic times they could already have foreseen this was going to happen. The surgeon overruled them in these cases, and noted a shorter time in order to get the timeslot in the OR on the desired day. In the category: “how to cheat the system”.

We also recommend that VUMC makes a clear schedule of when and which data is transferred between databases. There is not a good scheme of when databases communicate and what the effect of the different systems working together is. For this research, this leads to the decision to use only one database as the source for the data. Reliability of data when using data from two databases is an issue in our opinion. We also discussed this in Section 3.1.6.

We recommend VUMC to take a close look at waiting time before and after admittance and recovery. During the interviews conducted this was told as one of the issues where extra waiting time arises. We could not get data on this subject and it was out of the scope of this research, but we recommend investigating this further.

8.2 Discussion

Regarding the literature found and described in Section 2.2, we think that this report shows that there is more to take into account than OR efficiency. Dexter, Macario, et al. (2003) pointed out that for services with low volume, BT allocation based on utilization rate is not a good measurement due to variance. Dexter and Macario (2004) state that releasing OR time has a negligible effect on the OR efficiency, and that OR allocation is far more important. Where Dexter, Macario, et al. (2003) state that for low volume specialties OR allocation based on utilization leads to too much variance, we think this is a contradiction in the literature. This is exactly why we think the 7-day release program shows its value. On the one hand it optimizes the OR efficiency and on the other hand it creates flexibility without having to discuss the OR allocation every half a year, with the utilization as point of view to judge the performance of

services and to justify the OR allocation. Therefore we believe that the 7-day release program has more potential than stated in the literature.

Simulations are always a simplification of reality. One of the issues not addressed in this simulation study is the exact resource constraints based on equipment such as x-ray machines. Also the dedication of the surgeon to the case instead of the room is not taken into account in this simulation study. We believe that for the regular elective cases this has no effect. Furthermore, for the 7-day release patients we assume that when the request day is generated, the surgeon is available for that day. This might not be true for some instances, but with the number of surgeons performing surgery in VUMC, and the number of residents, the likelihood of not operating on the request day is left behind, since it would mean an extra constraint. Also we show only the difference between the simulated current situation and the simulated improved situation. We do not compare the improved simulated results to the historic information. The issue of not simulating all of the equipment is a recommendation for further research.

We propose a change in the policy of scheduling the surgeries in this report. People have to be willing to change, we can change the program or the policy, but as long as staff does not accept the change, it is not going to happen. Also when we considered alternative solutions in Chapter 4, we thought about how differently hospitals are organized in the US compared to Europe and also in particular in the Netherlands. Where it is very common in the Netherlands to have a waiting list for surgery of a couple of weeks, if not longer, this is differently in the US. Patients do not accept a long waiting list in the US, they will go to the next nearby hospital. Although a waiting list could be beneficial to improve the performance of the scheduling in the hospital and decrease cost, patients will have to be educated and also be willing to accept this change. We do not see this happening any time soon in the US, where it is just common in Europe to have this practice.

8.3 Further research

For further research we would want to address the issue of modelling equipment in the simulation and to assign a surgeon to the surgeries and see whether the same results are achieved. By modelling equipment we mean, for example x-ray machines, or surgery robots.

As described by Dexter, Traub, et al. (2003) rooms should be released based on the expected least utilized OR. We release based on the 7-day release program, this is on a given day, and we think that this is a clear policy that is understandable for everyone. Further research could look at the improvement of based on the *predicted* least utilized room, instead of the least utilized room (worst fit), and whether this yields improvement. This can be done based on the Future Case Count Reports that we also used in Section 3.3.1, which predict the number of cases in the coming 14 days ahead of the DoS.

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For those who consider going abroad and going to the US, I can tell you that you need good funding to be able to live in the US. It appears like things come cheap in the US, but don't be fooled. Food for example is expensive, and housing is not cheap either. Regarding housing, try to find a home, not just housing. I had a lot of fun and a lot is easily accessible as long as you try and ask. Dutch people are known to "deal and wheel" and that is a very good way to approach the US. The south is very friendly, but be aware that starting the talk about politics and in particular democrats might get you into trouble, unless you live in the "Vanderbubble". Something that we could learn from the US is maybe their resilience. I believe that they can still have a crisis and come back stronger with new ideas and products. The US would not be my home country, but it gave me inspiration on how to organize certain processes and certain perspectives. One thing I found remarkable is how open armed people are. I became a member of a yacht club and engaged in two fleets, going sailing and racing. The open-minded people I met were very encouraging and that is something I will miss!

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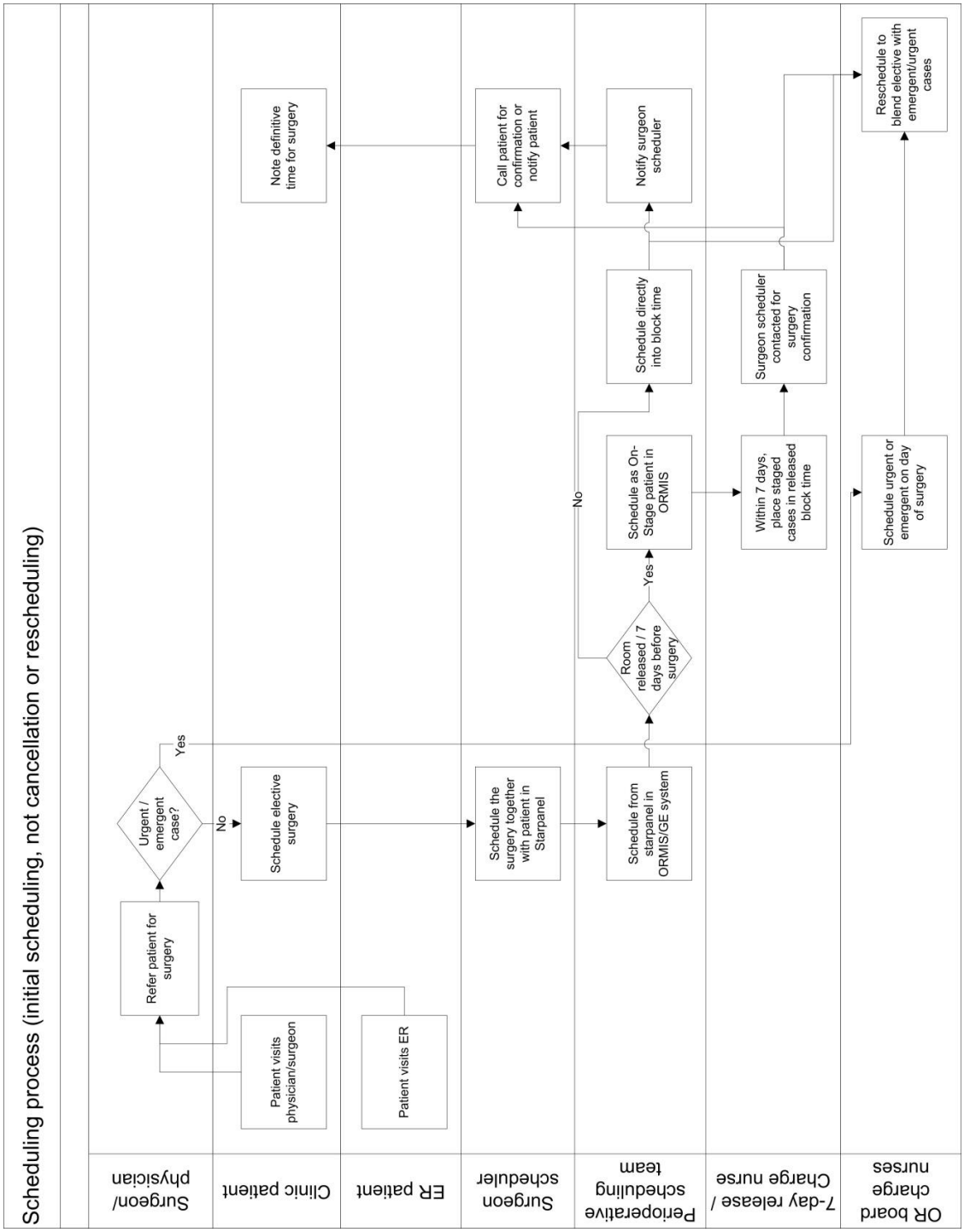
Rimmert van der Kooij

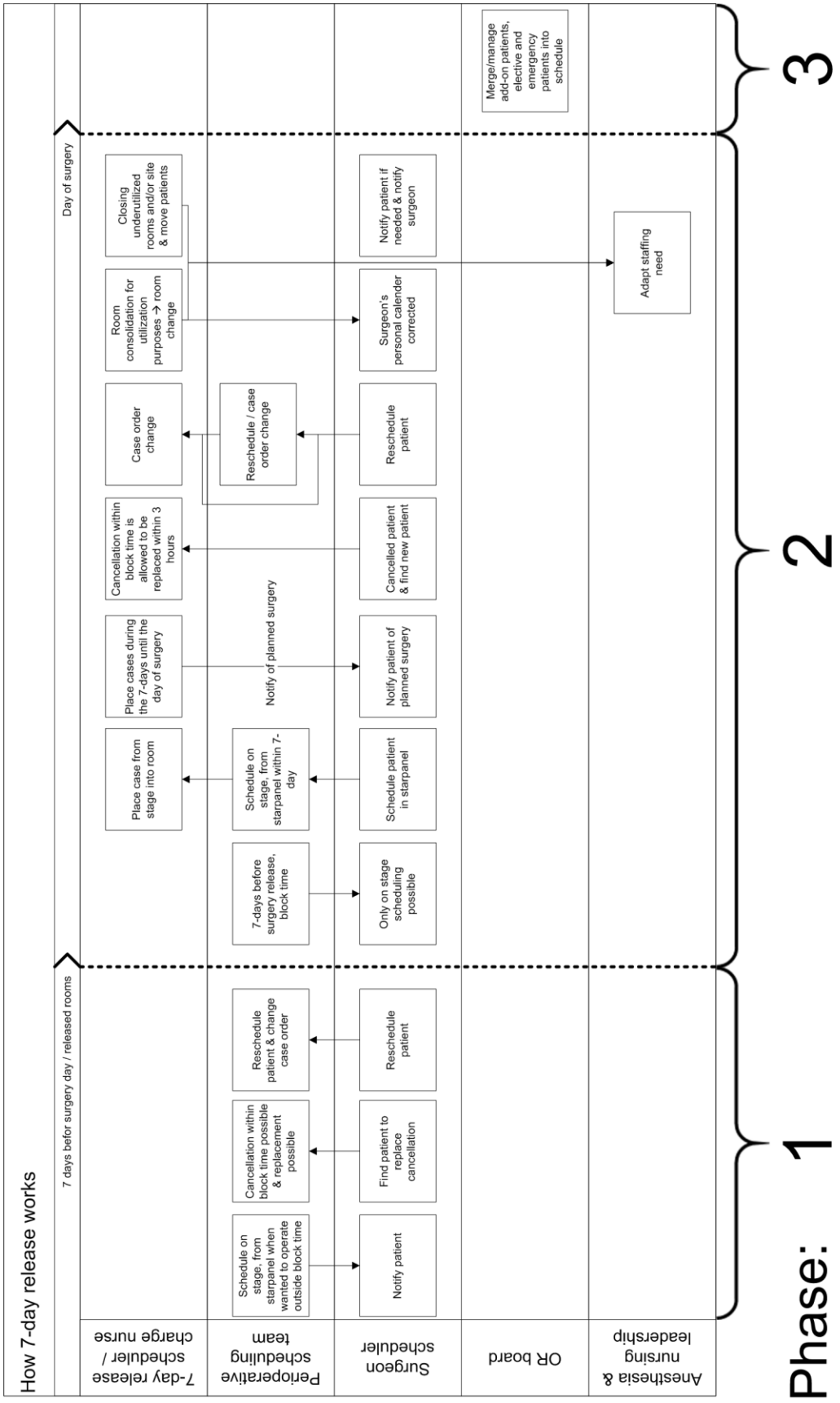
March 16, 2014

Appendix A Visio graphs

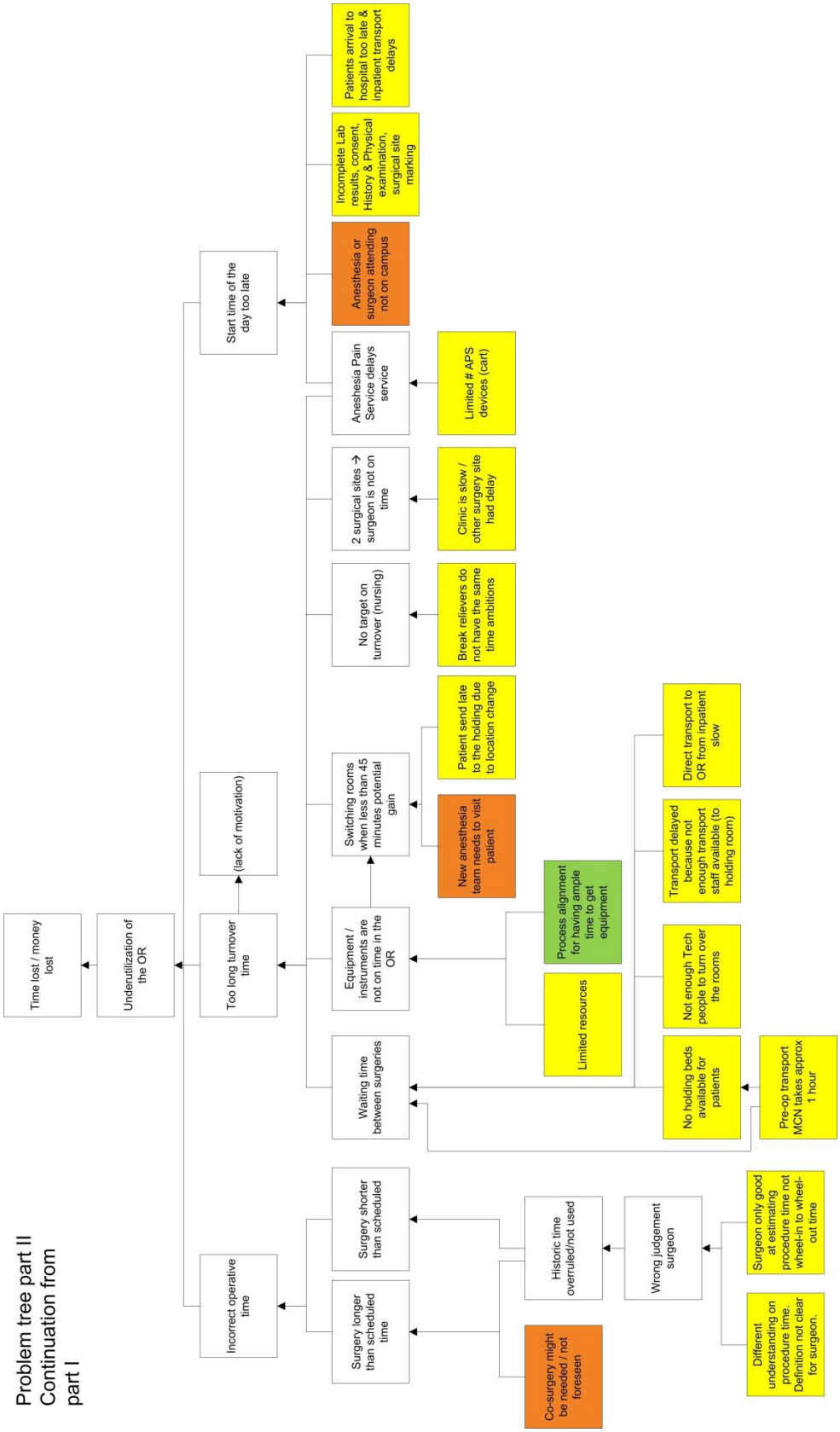
Scheduling process of elective surgery per stakeholder

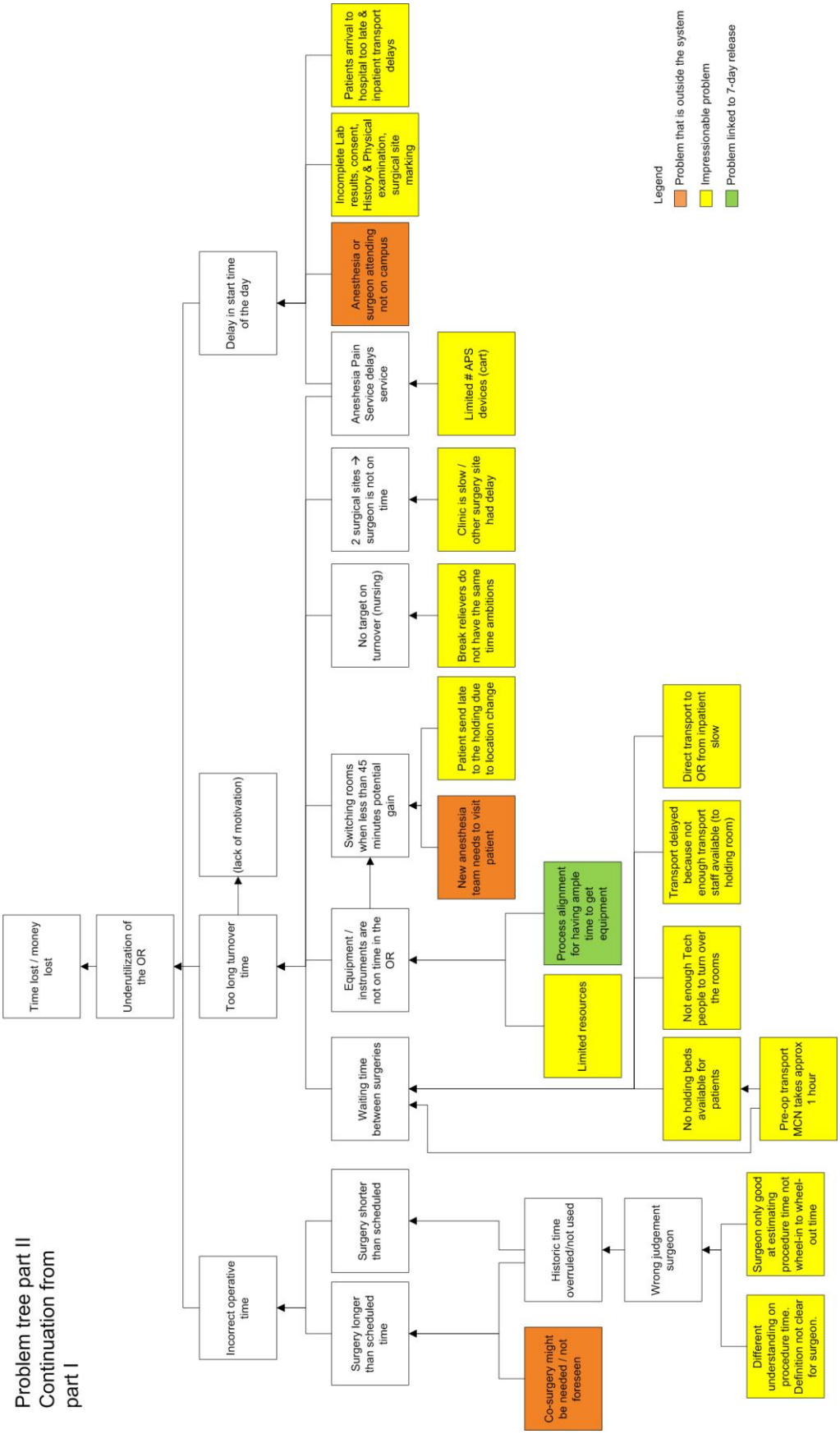


Distinction in time & involved stakeholders in the 7-day release program



Problem tree OR related




Problem tree part II
Continuation from part I
Time lost / money lost
Underutilization of the OR
Too long turnover time
(lack of motivation)
Incorrect operative time
Surgery longer than scheduled time
Surgery shorter than scheduled
Co-surgery might be needed / not foreseen
Historic time overruled/not used
Different understanding on procedure time. Definition not clear for surgeon.
Wrong judgement surgeon
Surgeon only good at estimating procedure time not wheel-in to wheel-out time
Waiting time between surgeries
Equipment / instruments are not on time in the OR
Switching rooms when less than 45 minutes potential gain
New anesthesia team needs to visit patient
Patient send late to the holding due to location change
Process alignment for having ample time to get equipment
Limited resources
No holding beds available for patients
Not enough Tech people to turn over the rooms
Transport delayed because not enough transport staff available (to holding room)
Direct transport to OR from inpatient slow
Pre-op transport MCN takes approx 1 hour
Delay in start time of the day
No target on turnover (nursing)
Break relievers do not have the same time ambitions
2 surgical sites → surgeon is not on time
Clinic is slow / other surgery site had delay
Anesthesia Pain Service delays service
Limited # APS devices (cart)
Anesthesia or surgeon attending not on campus
Incomplete Lab results, consent, History & Physical examination, surgical site marking
Patients arrival to hospital too late & inpatient transport delays
Legend
Problem that is outside the system
Impressionable problem
Problem linked to 7-day release

Appendix B Map physical locations VUMC

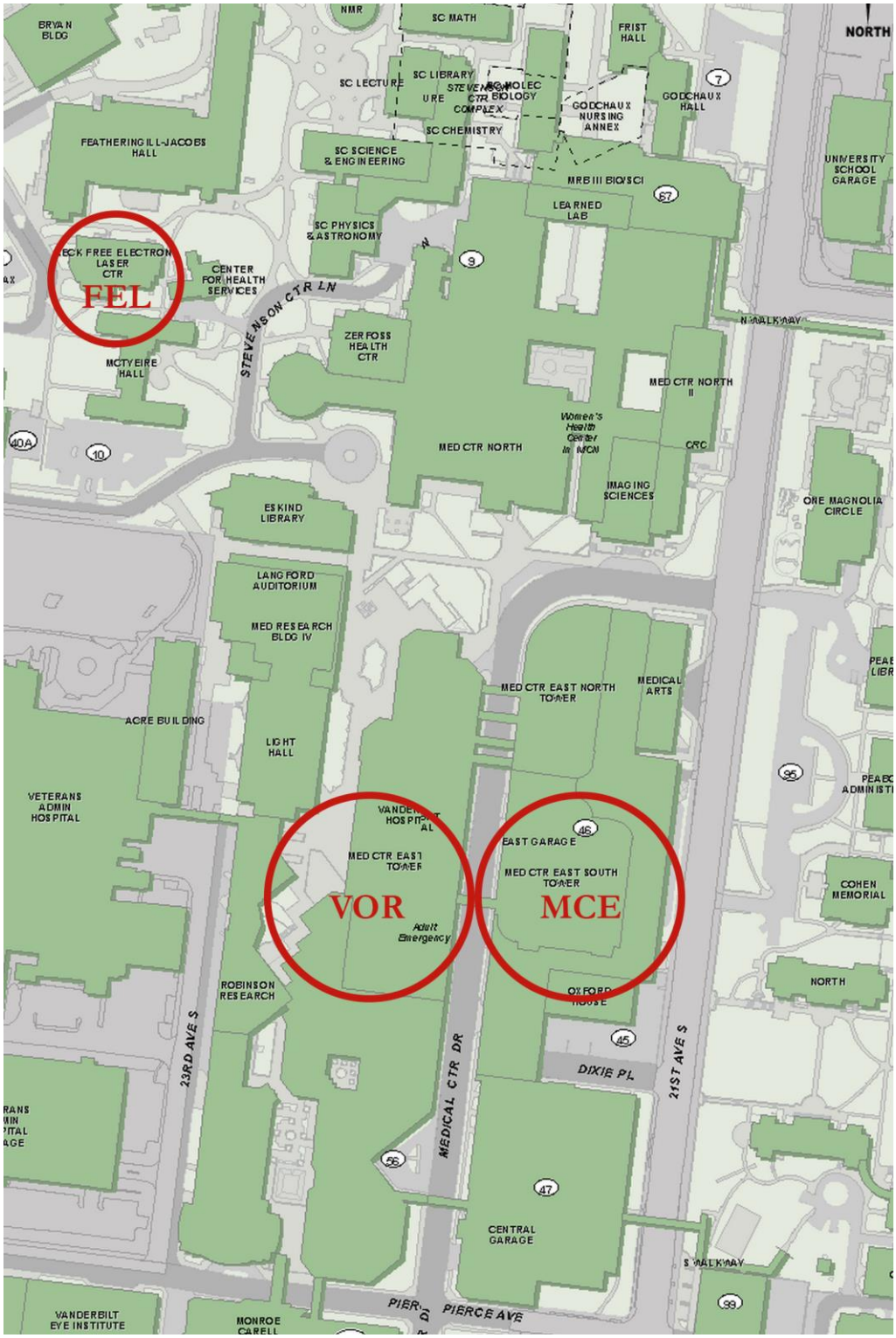


Figure 33: Map of the physical locations of VOR, MCE and FEL

Appendix C Assumption analyzing Future Case Count Reports

- Future case count report makes a snapshot of the scheduled cases on a run-date 14 days into the future.
- Future case count report does not record the changes and actual surgeries on the day of surgery

Excel alterations to the data:

Excluded OR-rooms:

- VUH1 AC4
- MCE3 RR-07 to MCE3 RR-12
- VBJS RM 01 to VBJS RM 03
- VOR3 RM 15
- VOR3 RM 16

Staged cases:

- All cases which were put in "staged" named rooms (FEL4 STAGE, MCE3 STAGE, VOR3 ST 01&02, VUH4 STAGE)
- All cases 7 days out, which first appeared in the data within 7 days of day of surgery, but which were not captured as in one of the "staged rooms"
    - Except cases in Rooms: VOR 8, 12, 13, 21, 25 (MWF), 26 (MTWF), 32, 33
        - These rooms release 6 am the day of surgery
    - First 10 run-dates are not included in staged heuristic

Cancellations do not occur on the last run-date and not on 3/22/2013 (missed run)

Not captured in the data:

All changes where new case numbers are generated: e.g., reschedule after hard close 4:30 PM day before surgery (POU database) or on the day of surgery.

The service NSC is not captured in the snapshots.

Wrongly captured

For the heuristic which is applied to capture cases which are not first boarded into a room we also capture another phenomenon. Cases which are scheduled in an OR during regular block time which are cancelled within the 7 days release program can be replaced by the same service without boarding the cases on stage.

So when case A of 3 hours in room 22 gets cancelled it might be replaced by the service for a case B of 3 hours or less in room 22. These cases will show up directly in the room within the 7 days and this happens also quite frequently according to Beth Adame.

Legend to the columns in Excel: (Future case count report)

ID#	generated ID in Excel for checking purposes
SITE	FEL4, VUH1, VUH4, MCE3 or VOR3
CASE DATE	Date the case will take place
BOOKED DATE	Date the first time the case was booked on
CASE #	Unique ORMIS case number
SERVICE	The service (Recorded since 12/13/2012 (changed in reporting))
SURGEON	Surgeon # (Recorded since 12/13/2012 (changed in reporting))
CPT #1	CPT number (Recorded since 12/13/2012 (changed in reporting))
ROOM	OR Room of the surgery coded as e.g., VOR3 RM 01
START TIME	Scheduled start time

STOP TIME	Scheduled stop time
Run Date	Date on which the 14 day snapshot is taken

Auxilary procedures:

Difference between run and surgery date: Difference between rundate and scheduled surgery date

# days booked before surgery	# days it occurs the first time in the snapshot
MJ_StagedRoom	Check whether Surgery was once placed in 1 of the 5 stage rooms: VOR3 ST 01, VOR3 ST 01, VUH4 STAGE, MCE3 STAGE, FEL4 STAGE (SQL)
Staged v2 heur.	Not captured in the "staged" rooms but occurred for the first time within 7 days of planned surgery. (if statement to detect)
StagedCase_MJ_HEURISTIC	SQL output to find all case numbers corresponding to heuristic
Staged total	Total of heuristic (auxiliary for if statements e.g., if total etc)
Difference	
cancelledcase / move	Records cases which have as last day >1 (snapshot should capture until 1 day before surgery)
Days change	Measures rebooking/moving of case in days difference
Time difference in min minutes	When a case is rescheduled this captures the difference in
case if	Checks whether it is a new case, same case same day or same case different day
room if	Checks with whether the case is scheduled in a different room or the same room
Time if	Captures whether there is a change in time
Total if occurrences)	Combines the three former ones into 1. (all 18 possible
Elective non-staged cases	Selects "total if" when the cases were elective non-staged
Staged cases total if	Selects "total if" when the cases were staged
Staged dif. Day different day	Checks whether the staged cases were rescheduled to a
Positive change numbers)	Displays only the positive changes in rescheduling (negative
Negative change numbers)	Displays only the negative changes in rescheduling (positive
_Number of occurrences	

Data sorting method excel

The cases are sorted as follows:

- Case #
- Rundate
- Room (exta sorting, should not be possible)
- Start time (exta sorting, should not be possible)

Appendix D 7-day release scheduling

Author: Beth Adame
Date made/date received: Mai 10.

Cases are selected from the add-on elective stage and placed in released block by the following criteria:

1. Numeric selection via case number
2. Attending availability/request start time
3. Patient availability
4. Appropriate in room staffing resources
5. Access to sterile instruments (basic sets/implants)
6. Availability of equipment (OR tables/Jackson Flat/Jackson Sling/Stealth/Microscopes/Tourniquets/etc…)
7. Available room size for cases requiring excessive equipment (robot, 2 c-arms, c-arm and microscope, etc…)

Case length (avoid placing cases outside of scheduled block time (10 or 12 hour) or avoiding to bump elective cases previously scheduled prior to block release greater than 30 min to an hour.
Verification of all case placements must be communicated to either the attending surgeon or his/her surgery scheduler to ensure direct communication and/or verification with the patient regarding the updated allocation of surgery time for each patient. When cases are placed in release block outside of the POD, email communication is sent to the receiving POD service line charge nurse and the service line charge nurse of the service being placed outside of the POD.
All locations which participate in the 7Day release process, release the rooms to case placement for surgical patients with limited exceptions and are evaluated by the same above criteria for placement by the POCN.

When surgeons continue to add cases as the DoS gets closer, case order may be rearranged due to cancellations, alteration in surgeon availability, realignment to get surgeon who may have previously been spread in multiple location into one room if time availability works out for all participants to maintain their original requested start times and the above criteria is not violated. Keep in mind, the day of service (DoS) scheduled times can be interrupted by transplant cases, urgent/emergent cases, extensive case lengths due to unforeseen issues (wrong guestimate of surgical case length, surgical complications, etc.) lack of surgeon availability due to multiple sites.

Appendix E The complete Block Schedule

The Block schedule represents which room is for which service and also the opening hours of the different ORs. The abbreviations for the surgical sites, services can be found below Figure 34. The numbers in Figure 34 after the abbreviation of the services are the opening hours. So 10 means the OR is open for 10 hours on that day.

4/1/2012							
ROOM	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	VOR3	VOR3	VOR3	VOR3	VOR3	VOR3	VOR3
VOR1	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-10		
VOR2	Plastic-12	Plastic-10	Oto-HN-10	Oto-HN-10	Plastic-10		
VOR3	Oto-HN-10	Plastic-10	Oral-10	Plastic-10	Oto-HN-10		
VOR4	Ophtho-12	Ophtho-10	Ophtho-12	Ophtho-10	Ophtho-12		
VOR5	Oto-HN-12	Oto-HN-12	Oto-HN-12	Oto-HN-12	Oto-HN-12		
VOR6	Plastic-10	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-8		
VOR7	Neuro-10	Neuro-12	Neuro-10	Neuro-10	Neuro-10		
VOR8	NeuroInv-12	NeuroInv-12	NeuroInv-12	NeuroInv-12	NeuroInv-12		
VOR9	Vascular-12	Vascular-10	Vascular-12	Vascular-12	Vascular-10		
VOR10	Neuro-12	Neuro-10	Neuro-12	Neuro-12	Neuro-12		
VOR11	Ortho-12	Ortho-12	Ortho-10	Ortho-10	Ortho-12		
VOR12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12
VOR13	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-10	Ortho Trauma-10
VOR14	Ortho-12	Ortho Sports-10	Ortho-10	Ortho Sports-12	Ortho-10		
VOR15	EP-	EP-	EP-	EP-	EP-		
VOR16	EP-	EP-	EP-	EP-	EP-		
VOR17	Ortho-12	Ortho-10	Ortho-12	Ortho-10	Ortho-10		
VOR18	Ortho-10	Ortho-10	Ortho-10	Ortho Sports-12	Ortho Sports-10		
VOR19	Neuro-10	Neuro-10	Neuro-10	Neuro-10	Neuro-10		
VOR20	Neuro-10	Neuro-10	Neuro-10	Neuro-10	Neuro-10		
VOR21	Neuro-10	Neuro-10	Neuro-10	Neuro-10	Neuro-10		
VOR22	Open-10	Open-10	Ortho-10	Oral-10	Open-10		
VOR23	Hepatobil-8	Hepatobil-8	General-10	Hepatobil-8	Trauma/EGS-10		
VOR24	Open-12	Renal-10	Trauma/EGS-10	Renal-10	General-10		
VOR25	Burn-10	Renal-10	Burn-10	Renal-10	Burn-8		
VOR26	Open-12	Open-12	Open-8	Thoracic-10	Open-12		
VOR27	Gen Onc-10	Oral-10	Plastic-10	Oto-HN-8	Plastic-8	(moved from 29)	
VOR28	Bronch-8	Bronch-8	Bronch-8	Bronch-8	Bronch-8		
VOR29	Closed-	Closed-	Closed-	Closed-	Closed-		
VOR30	Closed-	Open-12	Open-12	Plastic-10	Closed-		
VOR31	Cardiac-10	Cardiac-10	Cardiac-10	Cardiac-10	Cardiac-10		
VOR32	Cardiac-12	Cardiac-12	Cardiac-12	Cardiac-12	Cardiac-12		
VOR33	Cardiac-12	Cardiac-12	Cardiac-12	Cardiac-12	Cardiac-12		
VOR34	Thoracic-12	Thoracic-12	Thoracic-10	Thoracic-12	Thoracic-10		
VOR35	Ortho Trauma-12	Ortho Trauma-12	Ortho Trauma-10	Ortho Trauma-12	Ortho Trauma-10		
VUH1	HYBRID	HYBRID	HYBRID	HYBRID	HYBRID		
	Cardiac-10	EP-	EP-	EP-	EP-		
	MCE	MCE	MCE	MCE	MCE		
MCEI	Urology-10	General-10	Urology-10	Urology-12	General-10		
MCE2	Urology-10	General-10	Urology-12	General-10	Urology-10 1st/3rd Ophtho-10 2nd/4th		
MCE3	Urology-12	Gen Onc-10	General-10	Gen Onc-10	Gen Onc-10		
MCE4	General-10	General-10	Gen Onc-10	Gen Onc-10	General-10		
MCE5	Gen Onc-10	Urology-10	Urology-12	Urology-10	Gen Onc-10		
MCE6	Gen Onc-10	Urology-10	Gen Onc-10	General-10	Gen Onc-10		
MCE7 ®	Gen Onc-10	Urology-10	Urology-10	Urology-12	Urology-10		
MCE8 ®	Open-10	Urology-12	Urology-10	Urology-10	Urology-10		
MCE9 ®	General-10	Urology-10	Urology-10	Urology-10	Urology-10		
MCE10	General-12	General-10	General-10	General-10	General-10		
MCE11 ®	Gyn-10	Urology-12	General-10	Urology-10	Urology-12		
	FEL	FEL	FEL	FEL	FEL		
FEL1	Oto-HN-8	Oto-HN-10	Oto-HN-8	Oto-HN-8	Oto-HN-8		
FEL2	Open-8 1st/3rd Neuro-8 2nd/4th	Oto-HN-10	Oto-HN-10	Oto-HN-10	Plastic-8		
FEL3	Oto-HN-10	Oto-HN-10	Oto-HN-10	Oto-HN-10	Plastic-8		

Figure 34: Block Schedule

Abbreviations rooms:

VOR: **V**anverbilt **O**perating **R**oom
MCE: **M**edical **C**enter **E**ast
FEL: **F**ree **E**lectron **L**aser
VUH: **V**anderbilt **U**niversity **H**ospital

Abbreviations services:

Bronch: Pulmonary
Burn: Burn
Cardiac: Cardiology
EGS: Emergency General Surgery
Gen Onc: General Oncology Surgery
General: General Surgery

Gyn: Gynecology
Hepatobil: Hepatobiliary/Liver Transplant
Neuro: Neurosurgery
NeuroInv: Neuro Interventional
Ophto Ophthalmology
Oral: Oral & Maxillofacial
Ortho Sports: Orthopedics
Ortho Trauma: Orthopedic Trauma
Ortho: Orthopedics
Oto: Otolaryngology
Plastic: Plastic Surgery
Renal: Renal Surgery
Thoracic: Thoracic
Trauma: Trauma
Urology: Urology Surgery
Vascular: Vascular Surgery

Closing times of the VOR location

Date	Monday	Date	Tuesday	Date	Wednesday	Date	Thursday	Date	Friday
VOR 1	5p	VOR 1	5p	VOR 1	5p	VOR 1	5p	VOR 1	5p
VOR 2	7p	VOR 2	5p	VOR 2	5p	VOR 2	5p	VOR 2	5p
VOR 3	5p	VOR 3	5p	VOR 3	5p	VOR 3	5p	VOR 3	5p
VOR 4	7p	VOR 4	5p	VOR 4	7p	VOR 4	5p	VOR 4	7p
VOR 5	7p	VOR 5	7p	VOR 5	7p	VOR 5	7p	VOR 5	7p
VOR 6	5p	VOR 6	5p	VOR 6	5p	VOR 6	5p	VOR 6	3p
VOR 7	5p	VOR 7	7p	VOR 7	5p	VOR 7	5p	VOR 7	5p
VOR 8	7p	VOR 8	7p	VOR 8	7p	VOR 8	7p	VOR 8	7p
VOR 9	7p	VOR 9	5p	VOR 9	7p	VOR 9	7p	VOR 9	5p
VOR 10	7p	VOR 10	5p	VOR 10	7p	VOR 10	7p	VOR 10	7p
VOR 11	7p	VOR 11	7p	VOR 11	5p	VOR 11	5p	VOR 11	7p
VOR 12	9p	VOR 12	9p	VOR 12	9p	VOR 12	9p	VOR 12	9p
VOR 13	7p	VOR 13	7p	VOR 13	7p	VOR 13	7p	VOR 13	7p
VOR 14	7p	VOR 14	5p	VOR 14	5p	VOR 14	7p	VOR 14	5p
VOR 15	7p	VOR 15	7p	VOR 15	7p	VOR 15	7p	VOR 15	7p
VOR 16	7p	VOR 16	7p	VOR 16	7p	VOR 16	7p	VOR 1	7p
VOR 17	7p	VOR 17	5p	VOR 17	7p	VOR 17	5p	VOR 17	5p
VOR 18	5p	VOR 18	5p	VOR 18	5p	VOR 18	7p	VOR 18	5p
VOR 19	5p	VOR 19	5p	VOR 19	5p	VOR 19	5p	VOR 19	5p
VOR 20	5p	VOR 20	5p	VOR 20	5p	VOR 20	5p	VOR 20	5p
VOR 21	5p	VOR 21	5p	VOR 21	5p	VOR 21	5p	VOR 21	5p
VOR 22	7p	VOR 22	7p	VOR 22	5p	VOR 22	5p	VOR 22	7p
VOR 23	3p	VOR 23	3p	VOR 23	5p	VOR 23	3p	VOR 23	5p
VOR 24	7p	VOR 24	5p	VOR 24	5p	VOR 24	5p	VOR 24	5p
VOR 25	5p	VOR 25	5p	VOR 25	5p	VOR 25	5p	VOR 25	3p
VOR 28	3p	VOR 28	3p	VOR 28	3p	VOR 28	3p	VOR 28	3p
VOR 29	5p	VOR 29	5p	VOR 29	5p	VOR 29	5p	VOR 29	3p
VOR 30	7p	VOR 30	7p	VOR 30	7p	VOR 30	7p	VOR 30	7p
VOR 31	5p	VOR 31	7p	VOR 31	5p	VOR 31	5p	VOR 31	5p
VOR 32	7p	VOR 32	7p	VOR 32	7p	VOR 32	7p	VOR 32	7p
VOR 33	5p	VOR 33	5p	VOR 33	5p	VOR 33	5p	VOR 33	5p
VOR 34	7p	VOR 34	7p	VOR 34	5p	VOR 34	7p	VOR 34	5p
VOR 35	7p	VOR 35	7p	VOR 35	5p	VOR 35	7p	VOR 35	5p

Figure 35: Closing time of the VOR location

The closing time per day per OR are mentioned in Figure 35. The times are stated as PM hours, so 5p means closing at 5PM. Downside of Figure 35 is that this was last updated in March 2011. The opening hours in Figure 34 give a more accurate interpretation than the closing hours in Figure 35. Figure 35 clarifies when am 8 hour day is terminated, namely at 3PM and a 12 hour day is terminated at 7pm. Although the first surgery start is scheduled for 7:30AM.

The different services divide the block time within their service to the different surgeons.

Appendix F Information for patient -surgery

Figure 36 and Figure 37 show the paper the patient receives when they leave the surgeon schedulers office after scheduling their appointment.

VANDERBILT UNIVERSITY

MEDICAL CENTER

YOUR SURGERY ROAD MAP

Date: March 22, 2013

Patient Name: Unknown Medical Record #:

YOUR APPOINTMENTS

(For various reasons, dates and times may need to be changed. Ask your surgery coordinator if you have questions.)

Patient Teaching and Surgery consent forms is on
Friday, April 5, 2013 at 1:00pm with Teresa Prentice, LPN

Comprehensive Spine Center, One Hundred Oaks, 719 Thompson Lane, Suite 23108, Nashville, TN 37204; 615-875-5100(phone)

Vanderbilt Preoperative Evaluation Center (VPEC) appointment is on
Friday, April 5, 2013 at 1:35pm

One Hundred Oaks, 719 Thompson Lane, Suite 21100, Nashville, TN 37204, 615-343-3030 (phone)

"For more information of your VPEC appointment please see page 6 of "Your Guide to Surgery".

You may need other appointments before your surgery. If so, they are listed below:

Your **Pre-operative Imaging** is on
None Requested at

One Hundred Oaks, 719 Thompson Lane, Suite 23300, Nashville, TN 37204, 615-936-3606 (phone)

Your surgery is scheduled on **Wednesday, April 10, 2013 at 08:00am**

You will need to arrive for surgery at 06:00am

Vanderbilt Hospital, 1st Floor Lobby, 1211 Medical Center Drive, Nashville, TN 37232; 615-343-0179(phone)

After your surgery you will have a **Post-op appointment** on
Tuesday, May 28, 2013 at 1:15pm with Oran Aaronson, MD

The Comprehensive Spine Center, One hundred Oaks, 719 Thompson Lane, Suite 23108, Nashville, TN 37204; 615-875-5100(phone)

Figure 36: Paper patient receives when leaving the surgeon schedulers office 1/2

Please do not eat or drink anything after midnight the night before your surgery. If you need to take a specific medication(s) that morning, drink just enough water (a sip) to swallow your medicine.

If you are taking any type of Anticoagulants (blood thinners) including ASPRIN please contact your prescribing physician to discuss your upcoming surgery.

YOUR SURGERY COORDINATOR

Your surgery coordinator:

- Is your one-stop contact for all your questions or concerns.
- Helps you manage all of your appointments, from now until the day of your surgery.
- Makes sure your surgeon has all of the test results, forms, and other paperwork you will need for your surgery.

Contact your coordinator if you:

- Have any questions about the surgery.
- Feel that your condition is getting worse.
- Get a cold or the flu.
- Decide not to have surgery at Vanderbilt.
- Want to confirm the time and place of your surgery.

Your surgery coordinator is

Kamecia Morrow
615-343-4602 (Phone)
615-343-9553 (Fax)

You can reach your surgery coordinator by phone or email, Monday through Friday, from 09:00am to 4:30pm.

For medication or medical questions please contact your surgeons nurse at 615-875-5100.

Figure 37: Paper patient receives when leaving the surgeon schedulers office 2/2

Appendix G Legend of the eOR-board

This is the legend of the eOR-board. A number of steps can be followed

Case start

Early case start
Late case start
Long case

Case status

Not here
Inpatient on floor
Reception
Admitted
Preop
Ready to go to OR
Intraop
Closing
Procedure stop
Postop
ERR
Discharged

Alert Flags

A – Add-on case
D – Direct to OR
I – Isolation precautions
L – Level case (Trauma)
P – Research patient
S – Patient sent for

Other indicators

- Patient not ready to proceed to OR
- Patient ready for OR team in Holding
- Patient ready to proceed to OR
- Surgeon ready
- Surgeon not ready
- No anesthesia required

Appendix H Verification simulation model

Case duration and number of cases per specialty

Table 15: Historic information cases Fiscal Year 2013 (July 2012-June 2013, Source: ORMIS N:32788)

Case service	Tot time (min)	Number of cases	Average duration (min)
ANES	4161	32	130
BMT	2028	12	169
BURN	31018	269	115
CARD	807	7	115
CT	356925	1138	314
DEN	390	2	195
EGS	135169	975	139
GAS	3536	48	74
GEN	344972	2439	141
GENO	374143	2303	162
GYN	291539	2115	138
HEP	93184	324	288
HN	239847	1254	191
NEU	519165	2360	220
NI	65206	479	136
OPH	104372	1138	92
ORA	90887	521	174
ORT	381755	1953	195
ORTH	450140	2346	192
OSH	194274	1224	159
OTO	335785	2250	149
PLA	282354	1835	154
PUL	56314	1148	49
RA	733	4	183
REN	91398	570	160
TDS	8024	32	251
THOR	147784	707	209
TRA	87832	646	136
URO	512041	3551	144
VAS	148520	1106	134
TOTAL	5354303	32788	
Average total			163,30

Table 16: Simulated current situation (Source: OR Manager, N: 32733)

Case service	Tot time (min)	Number of cases	Average duration (min)
ANES	4259	33	129
BMT	1892	12	158
BURN	35380	273	130
CARD	1577	7	225
CT	360733	1152	313
DEN	172	2	86
EGS	129727	970	134
GAS	4016	49	82
GEN	357933	2442	147
GENO	346026	2300	150
GYN	296292	2111	140
HEP	81456	320	255
HN	217879	1225	178
NEU	521823	2342	223
NI	65059	486	134
OPH	113074	1151	98
ORA	83094	520	160
ORT	282105	1941	145
ORTH	468898	2374	198
OSH	194299	1224	159
OTO	300263	2235	134
PLA	263163	1827	144
PUL	61884	1159	53
RA	757	4	189
REN	92326	571	162
THOR	144262	712	203
TRA	91467	641	143
URO	512627	3545	145
VAS	154599	1105	140
TOTAL	5187042	32733	
Average total			159

Table 17: Difference between Table 15 & Table 16

Case service	Difference in avg. case duration	Number of cases FY2013	Number of cases Simulation	Difference in #cases (pro rato)
ANES	-2	32	33	-1
BMT	-14	12	12	-11
BURN	8	269	273	14
CARD	120	7	7	110
CT	3	1138	1152	-1
DEN	-138	2	2	-109
EGS	-4	975	970	-5
GAS	-2	48	49	8
GEN	3	2439	2442	5
GENO	-11	2303	2300	-12
GYN	4	2115	2111	3
HEP	-40	324	320	-33
HN	-18	1254	1225	-13
NEU	-1	2360	2342	3
NI	1	479	486	-2
OPH	5	1138	1151	7
ORA	-13	521	520	-15
ORT	-49	1953	1941	-50
ORTH	8	2346	2374	6
OSH	1	1224	1224	0
OTO	-13	2250	2235	-15
PLA	-7	1835	1827	-10
PUL	4	1148	1159	4
RA	-72	4	4	6
REN	5	570	571	1
THOR	-12	707	712	-6
TRA	6	646	641	7
URO	2	3551	3545	0
VAS	2	1106	1105	6
TOTAL		32788	32733	
Average				1

The difference in case duration is large for some cases, but the number of cases is also rather low. On average the difference with the historic information is 5 minutes in case duration. The cases are performed on average 5 minutes shorter in the simulation than in practice. This is also due to the boundaries set in the simulation for the surgery types that were grouped according to CCS grouping. This was to reduce variability that is not there in practice, but the lack of historic information to estimate based on only CPT type.

For duration differences between years we also should be surprised. Table 18 shows the year over year number of cases of the Fiscal years 2011, 2012 and 2013, where the numbers differ each year, in both number of cases as the average duration of the case length.

Table 18: Total cases per specialty and per fiscal year with average duration

FY11,12,13:				FY11:			
Case service	Total duration	total case count	average case duration	Case service	Total duration	total case count	average case duration
ANES	10970	80	137	ANES	440	3	146,67
BMT	5301	32	166	BMT	2194	13	168,77
BURN	130778	1006	130	BURN	59023	440	134,14
CARD	3107	20	155	CARD	865	7	123,57
CT	1094333	3507	312	CT	310854	1011	307,47
DEN	2132	15	142	DEN	662	5	132,40
EGS	369812	2674	138	EGS	112226	827	135,70
GAS	6462	96	67	GAS	689	11	62,64
GEN	1024601	7350	139	GEN	327596	2417	135,54
GENO	1026766	6184	166	GENO	315242	1878	167,86
GYN	873089	6208	141	GYN	270164	1884	143,40
HEP	293096	1116	263	HEP	99120	414	239,42
HN	763787	3899	196	HN	269268	1326	203,07
NEU	1520648	6872	221	NEU	502901	2254	223,11
NI	184181	1312	140	NI	63094	400	157,74
OBS	331	4	83				
OPH	319407	3303	97	OPH	113289	1090	103,93
ORA	298937	1748	171	ORA	106631	629	169,52
ORT	1067958	5535	193	ORT	345354	1799	191,97
ORTH	1349905	6926	195	ORTH	442297	2277	194,25
OSH	550378	3369	163	OSH	172557	1026	168,18
OTO	830975	5829	143	OTO	229348	1645	139,42
PLA	768105	5314	145	PLA	226666	1644	137,87
PUL	148559	2945	50	PUL	41921	792	52,93
RA	1443	7	206	RA	78	1	78,00
REN	272916	1716	159	REN	86133	543	158,62
TDS	13921	60	232	TDS	2843	12	236,92
THOR	438025	2111	207	THOR	149612	725	206,36
TRA	311795	2224	140	TRA	111101	788	140,99
URO	1558240	10363	150	URO	516656	3182	162,37
VAS	458264	3357	137	VAS	154219	1135	135,88

FY12: Case service	Total duration	total case count	average case duration	Year over year duration	FY13: Case service	Total duration	total case count	average case duration	Year over year duration
ANES	6369	45	141,53	-5,13	ANES	4161	32	130,03	-11,50
BMT	1079	7	154,14	-14,63	BMT	2028	12	169,00	14,86
BURN	40737	297	137,16	3,02	BURN	31018	269	115,31	-21,85
CARD	1435	6	239,17	115,60	CARD	807	7	115,29	-123,88
CT	384028	1228	312,73	5,25	CT	399451	1268	315,02	2,30
DEN	1080	8	135,00	2,60	DEN	390	2	195,00	60,00
EGS	122417	872	140,39	4,68	EGS	135169	975	138,63	-1,75
GAS	2237	37	60,46	-2,18	GAS	3536	48	73,67	13,21
GEN	352033	2494	141,15	5,61	GEN	344972	2439	141,44	0,29
GENO	337381	2003	168,44	0,58	GENO	374143	2303	162,46	-5,98
GYN	311386	2209	140,96	-2,44	GYN	291539	2115	137,84	-3,12
HEP	100792	378	266,65	27,23	HEP	93184	324	287,60	20,96
HN	254672	1319	193,08	-9,99	HN	239847	1254	191,27	-1,81
NEU	498582	2258	220,81	-2,31	NEU	519165	2360	219,99	-0,82
NI	55881	433	129,06	-28,68	NI	65206	479	136,13	7,07
OPH	101746	1075	94,65	94,65	OBS	331	4	82,75	-11,90
ORA	101419	598	169,60	65,66	OPH	104372	1138	91,72	-77,88
ORT	340849	1783	191,17	21,64	ORA	90887	521	174,45	-16,72
ORTH	457468	2303	198,64	6,67	ORT	381755	1953	195,47	-3,17
OSH	183547	1119	164,03	-30,22	ORTH	450140	2346	191,88	27,85
OTO	265842	1934	137,46	-30,73	OSH	194274	1224	158,72	21,26
PLA	259085	1835	141,19	1,77	OTO	335785	2250	149,24	8,05
PSY	84	1	84,00	-53,87	PLA	282354	1835	153,87	69,87
PUL	50324	1005	50,07	-2,86	PUL	56314	1148	49,05	-1,02
RA	632	2	316,00	238,00	RA	733	4	183,25	-132,75
REN	95385	603	158,18	-0,44	REN	91398	570	160,35	2,16
TDS	3054	16	190,88	-46,04	TDS	8024	32	250,75	59,88
THOR	140629	679	207,11	0,75	THOR	147784	707	209,03	1,92
TRA	112862	790	142,86	1,87	TRA	87832	646	135,96	-6,90
URO	529543	3630	145,88	-16,49	URO	512041	3551	144,20	-1,68
VAS	155525	1116	139,36	3,48	VAS	148520	1106	134,29	-5,07

Table 18 shows also that cases fluctuate with average case duration. The column year over year duration compares the average case duration with the former year. All of the numbers are in minutes except the cases, those are in number of cases.

Appendix I Diagram data structure OR manager

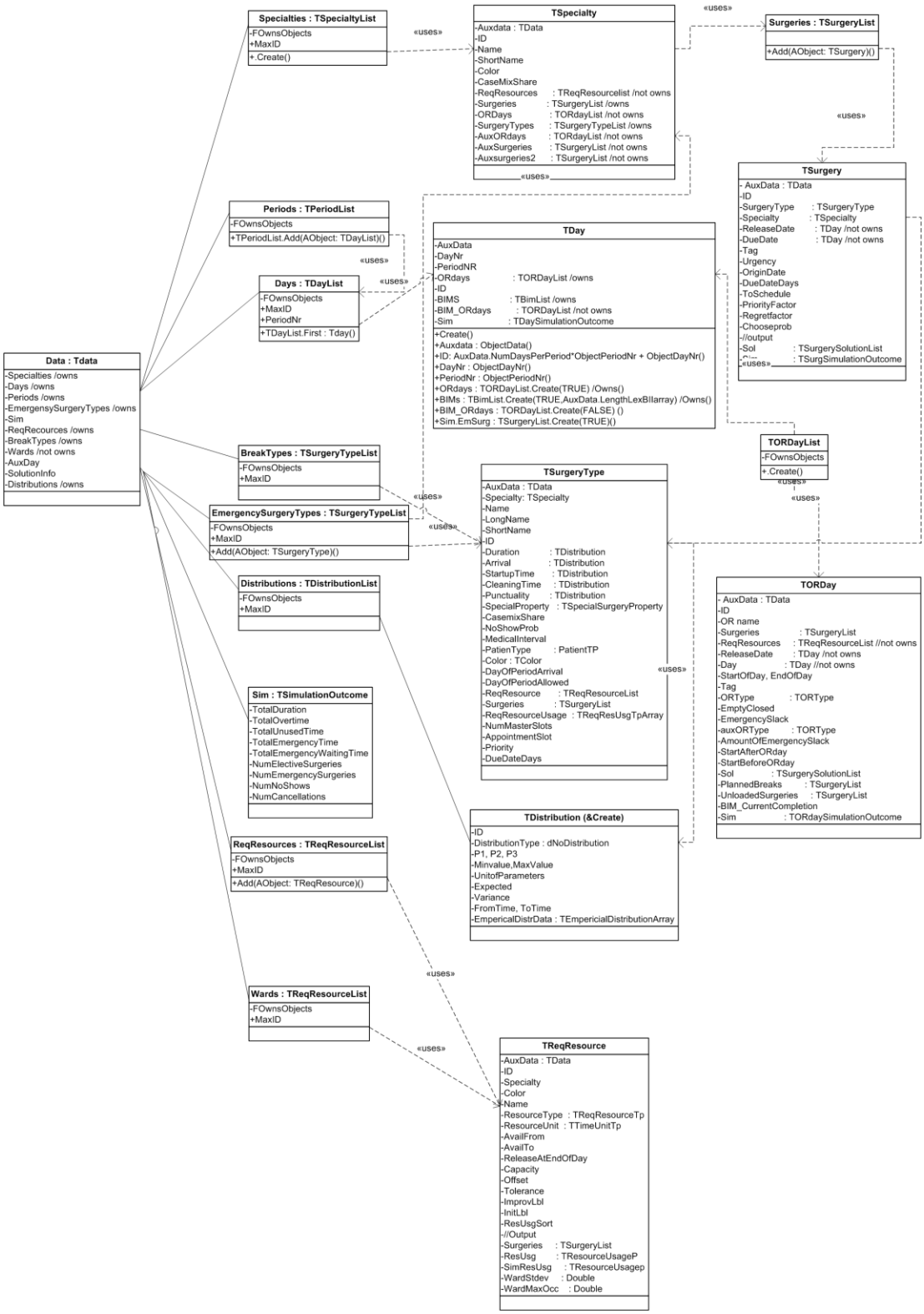


Figure 38: Visio diagram data structure of the OR manager