Assessment of an innovative outpatient ward: the Lounge

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Management summary

Background

As a result of the merger between Sint Lucas Andreas Ziekenhuis and Onze Lieve Vrouwe Gasthuis, respectively OLVG West and OLVG East, a new strategy in both hospitals will be applied. Low-complexity high-volume surgeries will be allocated to OLVG West and high-complexity low-volume surgeries will be allocated to OLVG East. To adopt to this new setting, OLVG West aspires to create a modern and efficient outpatient ward; the Lounge. As the Lounge has yet to be built, question rise how it can be optimally configured and whether it will improve performance. Therefore the research objective of this thesis is:

To determine the required capacity of the Lounge and develop and assess interventions to optimize the performance of care trajectories suitable for the Lounge.

Approach

First, we analyze the current performance of the outpatient ward before introducing a solution approach to achieve the objective. Specific Lounge performance indicators are added to performance indicators of the outpatient ward, currently used by OLVG West. The reason for this is to compare future and current situation in order to create a realistic reflection of the performance of the Lounge. Patients and procedures suitable for the Lounge are selected in consultation with specialists.

To achieve the objective, a discrete event simulation (DES) model is built. In DES the system is represented as a chronologically-linked sequence of events, in order to describe flows of patients and explore the effects of changes. These features are necessary for further experiments and to create more insight for stakeholders about the way the Lounge will operate.

Advice is collected from various specialists, nurses, managers and other employees, in order to create a realistic model of the Lounge. Historical data of 2014 are used to determine distributions of several input parameters of the model. Two stages of experiments and a total of 136 experiments have been performed in which experimental factors and circumstances are altered. The experimental factors are *closing time*, *slack on registration*, *slack on preparation*, *number of Lounge spots*, *dedicated spots*, and *OR scheduling sequence*.

The first stage of the experiments aims on altering only one experimental factor, which will be compared with the 'starting point' experiment to register the effect. A combination of experimental factors will be altered in the second stage of the experiments to determine the combined optimal setting (COS). After that, experiments are conducted in order to identify the Lounge performance under different circumstances.

Results and conclusions

The settings shown in Table 1 are the combined optimal setting resulting from the second stage experiments. It shows the experimental factors that have been altered in the experiments.

Closing time	slack on registration	slack on preparation	Lounge spots	dedicated spots	Schedule
20:00	1:30	0:15	18	Flexible	Outpatients First

Table 1– Combined optimal setting

The COS is used to compare the performance of the Lounge with the performance of the outpatient ward in 2014. The performance of the current situation and the performance of the Lounge are shown in Table 2.

Performance Indicator	COS	Data 2014
Average Length of Stay	5:46:59	8:27:08
Bed Occupancy Ratio	44%	45%
Operation Room Utilization Ratio	70%	80%
Cancellation Ratio	1.8%	1.7%
Overtime Ratio	6.5%	5.5%
Average Waiting Time Before Surgery	1:06:01	1:20:11
Patients Moved to Ward	151	172
Lounge Patients Treated at Holding/Recovery	56	0
Lounge Patients Treated	4667	4596
Inpatients Treated	4465	4590

Table 2 – Performance result model and data

The Average Length of Stay decreases with 32% and the Average Waiting Time Before Surgery decreases with 18%. More experiments were performed using the COS, like more ORs and more Lounge spots. The overview of the conclusions can be found in Table 3.

Experiment	Conclusion
More Lounge spots	20 spots shows best results
More ORs	Maximum capacity of patients treated at the Lounge is 5070
Inpatients admitted at the Lounge	Performance decreases
Flexible or dedicated Lounge spots	Flexible spots show better performance
Closing time	Performance best when closing time is 20:00
Slack on registration	A slack of more than 1:30 hour does not improve performance
Slack on admission	A slack of more than 0:15 hour does not improve performance
Schedule	Outpatient First schedule shows the best results

Table 3 – Overview conclusion

Recommendations

The following recommendations are suggested according to the computational results and conclusion of this thesis. We recommend to:

- proceed developing the Lounge as it shows promising results.
- adopt the conclusions of this thesis for the initial setup of the Lounge.
- validate the simulation model used in this study to confirm the results.
- discuss the *slack on registration* with the specialties OR planner to create a uniform registration process.

Overall this study shows that introducing the Lounge will improve the performance of OLVG West creating a tranquil environment for patients and staff.

Management samenvatting

Achtergrond

Als gevolg van de fusie tussen het Sint Lucas Andreas Ziekenhuis en het Onze Lieve Vrouwe Gasthuis, respectievelijk OLVG West en OLVG Oost, wordt een nieuwe strategie gehanteerd. Laag complexe hoog volume operaties zullen naar OLVG West verplaatst worden en hoog complex laag volume operaties naar OLVG Oost. Om zich aan te passen aan deze nieuwe situatie ambieert OLVG West de bouw van een gemoderniseerde en efficiënte dagbehandelingsafdeling: de Lounge. De gemiddelde wachttijd voor de operatie en de gemiddelde ligduur zijn te lang in de huidige situatie en worden gezien als een probleem. De Lounge zou deze problemen moeten verminderen. Aangezien de Lounge nog gebouwd moet worden, is het ook de vraag hoe deze zo optimaal mogelijk ingesteld kan worden en of de prestaties zullen verbeteren. Het onderzoeksdoel van deze scriptie is dan ook:

Het bepalen van de capaciteit van de Lounge en het ontwikkelen en beoordelen van interventies om het presteren van de Lounge te optimaliseren.

Het huidige presteren van de dagbehandelingsafdeling wordt geanalyseerd alvorens een benadering voor een oplossing wordt bedacht. Specifieke Lounge indicators zijn aan de huidige gebruikte indicatoren van de dagbehandelingsafdeling toegevoegd. Reden hiervoor is om de huidige situatie met de toekomstige situatie te vergelijken en om een realistische weergave van de prestatie te krijgen. In overleg met specialisten worden patiënten en operaties geselecteerd die geschikt zijn voor de Lounge.

Om het onderzoeksdoel te behalen wordt Discrete Event Simulatie(DES) gebruikt. Bij DES wordt een systeem gerepresenteerd door een chronologische geschakelde keten van gebeurtenissen, dit om een stroming van patiënten en het gevolg van veranderingen te omschrijven. Dit is nodig voor verdere experimenten en om meer inzicht in de Lounge te creëren voor de stakeholders.

Er is advies ingewonnen bij verschillende specialisten, verpleegkundigen, managers en andere medewerkers om een zo realistisch mogelijk model van de Lounge te krijgen. Historische data van 2014 zijn gebruikt om de verdelingen van verschillende input parameters te bepalen. Twee rondes experimenten, in totaal 136 experimenten, zijn uitgevoerd waarbij experimentele factoren en omstandigheden zijn gevarieerd.

De eerste ronde experimenten heeft als doel het effect te meten van een experimentele factor op de prestatie, dit is gedaan door steeds een experimentele factor te veranderen. In de tweede ronde worden meerdere experimentele factoren tegelijk gevarieerd om de Combinatie van Optimale Setting(COS) te bepalen. Hierna zullen met de COS experimenten worden uitgevoerd om de prestatie van de Lounge onder verschillende omstandigheden te analyseren.

Resultaten en conclusie

De instellingen getoond in Tabel 1 zijn de COS die resulteren uit de tweede ronde experimenten.

Sluitingstijd	Speling op registratie	Speling op preparatie	Lounge plekken	Toegewezen plekken	Schema
20:00	1:30	0:15	18	Flexibel	Dbh. Eerst

Tabel 1 – Combinatie van Optimale Setting

De COS wordt gebruikt om de prestatie van de Lounge te vergelijken met de prestatie van de dagbehandeling in 2014. Het aantal behandelde Lounge patiënten en het aantal behandelde klinische patiënten zijn bepaald aan de hand van gesprekken met specialisten. Het overzicht is te zien in Tabel 2.

Prestatie indicator	COS	Data 2014
Gemiddelde ligduur	5:46:59	8:27:08
Bed bezettingsgraad	44%	45%
OK bezettingsgraad	70%	80%
Annulering ratio	1.8%	1.7%
Uitloop ratio	6.5%	5.5%
Gemiddelde wachttijd voor operatie	1:06:01	1:20:11
Patiënten opgenomen op afdeling	151	172
Lounge patiënten behandeld op holding/recovery	56	0
Behandelde Lounge patiënten	4667	4596
Behandelde klinische patiënten	4465	4590

Tabel 2 – Prestatie resultaten Lounge en huidig

De gemiddelde ligduur daalt met 32% en de gemiddelde wachttijd daalt met 18%. Meer experimenten zijn uitgevoerd gebruikmakende van COS zoals het gebruik van meer OKs en meerdere Lounge plekken. Een overzicht met de conclusies van alle experimenten kan in Tabel 3 gevonden worden.

Experiment	Conclusie
Meer Lounge plekken	20 plekken geeft beste resultaten
Meer Oks	Maximum aantal patiënten op de Lounge is 5070
Klinische patiënten opgenomen via Lounge	Prestatie verminderd
Flexibele of toegewezen plekken	Flexibele plekken geeft beter resultaat
Sluitingstijd	Prestatie is het beste bij 20:00
Speling op registratie	Een speling van meer dan 1:30 verbetert de prestatie niet
Speling op preparatie	Een speling van meer dan 0:15 verbetert de prestatie niet
Schema	Dagbehandeling patiënten eerst geeft beste resultaat

Tabel 3 – Overzicht conclusie

Aanbevelingen

Gebaseerd op de berekende resultaten en de conclusie van deze scriptie, beleven we de volgende punten aan:

- Het voortzetten van de ontwikkeling van de Lounge, aangezien het veelbelovende resultaten toont.
- Het overnemen van de conclusies van deze scriptie door OLVG als initiële opzet van de Lounge.
- Het valideren van het simulatie model om de resultaten te bevestigen.
- Het bespreken van de speling tijdens registratie en de manier van plannen met de OK planners van de specialismen, om tot een uniforme aanpak van het registratie proces te komen.

Afsluitend toont deze scriptie aan dat het realiseren van de Lounge de prestatie van het OLVG West zal verbeteren voor patiënten en werknemers.

Preface

I started my master thesis assignment at OLVG West in November 2015 and will finish it in May. I started studying Technical Medicine in 2008. After four years of studying and a board year I realized I was not completely grasped by the subjects but finished my bachelor in 2013. Looking for other programs, I quickly noted the Health Care Technology and Management track of the master Industrial Engineering and Management. Staying within the familiar environment of healthcare the angle changed and the choice appeared to be the right decision.

The graduation assignment described by Sint Lucas Andreas Ziekenhuis (currently OLVG West) immediately caught my attention. The merger, that was going would raise some dust as the hospital had to reinvent itself and reorganize. Doing a master assignment in such circumstances about an innovative subject as the Lounge gave me a lot of motivation. Attending meetings, visiting other hospitals, discussing hospitals operations, and discussing my research with professionals was superb.

I would like to thank Erwin Hans for his role as first supervisor and for all useful feedback. I also would like to thank Ingrid Vliegen for her feedback. Although you were second supervisor you have been more engaged in my project than that is usual, for which I am grateful.

I thank Leonoor Brouwer for her supervision at the hospital and for thinking along with my research. I enjoyed our talks and discussion about the Lounge and my research. I would also like to thank Ingeborg Wanrooij for supervising me at the start of my assignment. I enjoyed my time at 'Bureau Zorg' with all the people working there, therefore I would like to thank them too.

Finally, I would like to thank my parents for their support during my graduation project and all other study time. Last, I would like to thank my girlfriend, Kimberly, for her support.

Wouter van Zwieten

Amsterdam, May 2016

Table of content

Abbreviations, Terminology and Notation

Terminology

Inpatient – Patient planned for surgery staying at the ward for at least one night.

Outpatient – Patient planned for surgery that stays in a bed at the outpatient ward during the day and will not spend a night at the hospital.

Lounge patient – After introducing the Lounge, all in- and out patients suitable for the Lounge will be called Lounge patients. This are patients planned for surgery and stay in a chair at the Lounge during the day and will not spend a night at the hospital.

Current situation – The situation before the reallocation of specialties and before introducing the Lounge at OLVG West.

Notation

Times or durations are notated as hours:minutes:seconds, HH:MM:SS

Abbreviations

ALoS – Average Length of Stay
AWTBS – Average Waiting Time Before Surgery
BOR – Bed Occupancy Ratio
CR – Cancellation Ratio
LPT – Lounge Patients Treated
LPTaH/R – Lounge Patients Treated at Holding/Recovery
OvR – Overtime Ratio
ORUR – Operating Room Utilization Ratio
PMtW – Patients Moved to Ward
IT – Inpatient Treated

1. Introduction

The past decade we see more advanced treatments, an ageing population and a high standard of care, which led to rising costs and an enormous increase in demand for care (Van Otterdijk, 2011). Due to this ageing population in the Netherlands, the overall age of patients in hospitals is rising. Therefore the kind of surgeries that are considered high-volume low-complex will raise drastically over time (Van Otterdijk, 2011). Hospitals need to adapt themselves to be able to deal with this growing number of surgeries. This makes that health care managers face the challenging task to organize their processes more effectively and efficiently.

Patients nowadays have high standards for quality of care and share their opinions with their social environment. With the possibility for patients to go online it becomes even more accessible for patients to create a well-informed opinion about different hospitals. Many reviews are written, mostly about the negative experiences like inappropriate long waiting times on the day of surgery. This makes it even more important for hospitals to adapt to new situations and provide high quality care to remain a good reputation.

Within Onze Lieve Vrouwe Gasthuis and Sint Lucas Andreas Ziekenhuis there is a sense of urgency to change. Two hospitals merge to create new treatment possibilities and offer opportunities to execute new ideas. One of the ideas proposed is the introduction of a Lounge, to improve overall performance and obtain insight into a more effective care trajectory.

In this report the possibility of the Lounge is researched regarding the preferences of the OLVG. Chapter 1 gives a short introduction and motivation for this research. Section 1.1 provides the reader with an introduction to OLVG as well as an overview of developments in the health care sector that motivates OLVG to improve their processes. This is followed by the problem description including the core problem in Section 1.2. Section 1.3 describes the objective and Section 1.4 the scope of the research. Finally, Section 1.5 gives the underlying research questions.

1.1 Context

This section provides the context of the research. First, an introduction and characteristics of OLVG is described, followed by current developments in the health care sector and a short description of the Lounge.

1.1.1 OLVG

This research carries out in OLVG within the OR complex department. In March 2013, Sint Lucas Andreas Ziekenhuis and Onze Lieve Vrouwe Gasthuis merged to one organization in order to share expertise, improve quality and specialize by allocating specialties. The organization, after merger, is now called OLVG. As the hospitals were both located in different areas of the city, the hospitals are renamed respectively OLVG West and OLVG East as can be seen in Figure 1.

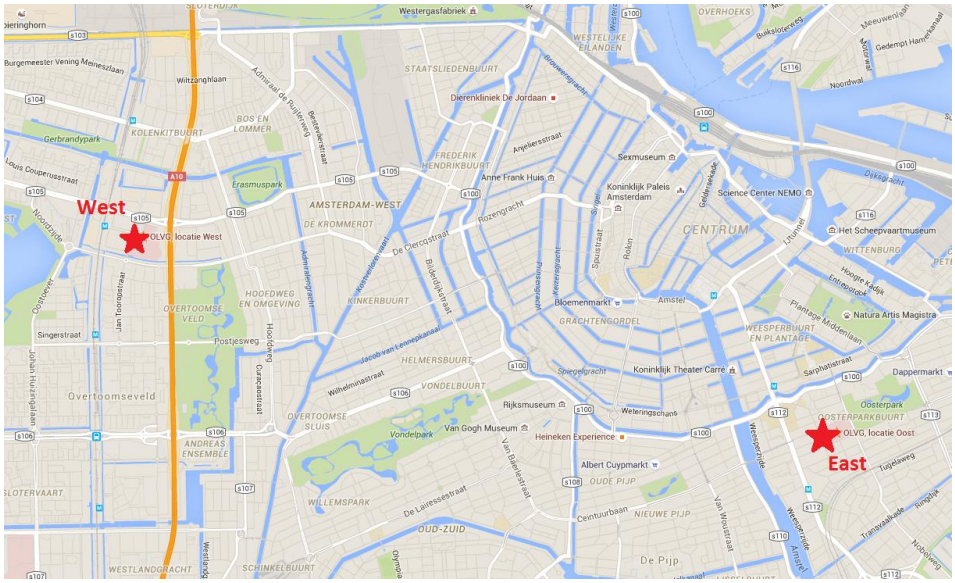


Figure 1- Map with locations of OLVG West (former Sint Lucas Andreas Ziekenhuis) and OLVG East (former Onze Lieve Vrouwe Gasthuis)

OLVG West has a total amount of 550 beds and 2.240 employees. 61 of these employees were medical specialist at the end of 2013 (AnnualReport, 2014). OLVG East has a total amount of 530 beds and 3.525 employees of which 203 medical specialist at the end of 2014 (AnnualReport, 2015).

A beneficial effect of the merger is that both hospitals can meet the volume levels that are required by health insurance companies more easily as they operate as one organization. The health insurance companies state that if the frequency of a procedure drops below the required level, a hospital is not allowed to perform this procedure anymore. Operating as one organization, the hospitals will be responsible for the care of approximately 500.000 patients each year therefore meeting the required standards.

OLVG West and OLVG East offer a wide range of specialties like urology, trauma and general surgery, orthopedics, dermatology, cardiology and neurology (AnnualReport, 2015). Both hospitals perform surgeries on similar specialties. Allocating these specialties to either one of the locations creates highly specialized centers, and a basic line of care is maintained on both locations. By merging, the hospitals can combine their resources to increase their efficiency and obtain better results.

1.1.2 Developments in the health care sector

Due to demographic ageing in the Netherlands, a relatively larger number of patients in hospitals will be considered high-volume low-complex in the future (Van Otterdijk, 2011). Hospitals need to adapt themselves to be able to deal with this increased frequency of patients and surgeries. Independent health care centers have already identified these high-volume low-complexity surgeries to be more profitable as these patients do not have to stay overnight and complications during surgery occur relatively infrequent (Castoro, 2007). These independent health care centers are considered modern and above average efficient. Even more important, these hospitals are rated above average for patient friendliness, often creating high reputations (Al-Amin & Housman, 2012).

1.1.3 The Lounge

OLVG wishes to be able to compete with these independent health care centers. They want to improve the efficiency of the hospital and develop similar modernized facilities. Therefore, they want to allocate specialties based on the volume and complexity of a specialty. Creating a focus on High-volume low-complex patients at OLVG West and low-volume high-complex patients at OLVG East. In general it is stated that high-complex surgeries take more time and are more variable compared to low-complex surgeries. A low-volume high complex surgery is for example a multiple spinal fracture; a high-volume low-complex surgery is for example a minimal invasive knee surgery.

Focusing on high-volume means that more patients will be treated. This requires a larger capacity to maintain the current performance at OLVG west. This means that the hospital needs to expand its facilities in order to maintain current performance. Therefore OLVG proposed The Lounge as a new treating facility. A Lounge is, according to OLVG West standards, a modernized surgical outpatient ward which is built in the existing OR complex. The Lounge concept is based on ideas of various departments that contain Lounge features within other hospitals, as shown in Figure 2.

Figure 2 – Lounge at VUmc

The Lounge will be part of the Admission and Day Care Center where all patients are admitted shortly before surgery. The patients will be prepared before surgery in the Lounge and will also rest after surgery at the Lounge. Therefore they will bypass the Holding/Recovery, to and from surgery. The care trajectory of patients will change as the Lounge combines the operations of the Holding/Recovery and the outpatient ward. The idea is that patients arrive fully prepared and short before surgery. With use of "fast-track" anesthetic techniques patients should be quickly recovered and be able to go home after surgery. During their stay the patient will have various facilities for a comfortable stay, like the chair they will be 'lounging' on instead of a bed. The Lounge concept will be discussed more in detail in Chapter 3.

In addition to the Lounge, short pre-surgical admission will be introduced to OLVG West. Instead of being admitted on a ward, a patient will be admitted at the Admission and Day Care Center. We included this in this thesis as it is planned to be implemented, therefore obtaining realistic results. Admitting patient shortly before surgery at the Admission and Day Care Center reduces the workload at the ward.

This thesis analyzes the possibilities of implementing the Lounge within OLVG West. It is researched whether the concept of a "Lounge" is a suitable solution for OLVG West and whether performance will improve when introducing the Lounge.

1.2 Problem statement

In this section we define the problem that is being analyzed in this thesis. For start, we give a problem description followed by a stakeholder analysis of this problem.

1.2.1 Problem description

The nursing staff of the outpatient ward at OLVG West is currently experiencing long waiting times as many patients have to wait to be admitted. Patients have to come in early, this additional time is called slack at registration. Slack is used as specialist and OR planners want to reduce the risk of ORs being vacant or surgeries being delayed. The delay of a patient is mainly caused by an unprepared patient or transport delay. Therefore patients' appointment for registration is long before the required moment of presence. In addition, after surgery the patient has to wait again, this time to be discharged. This often takes longer than needed as most of the time, this is caused because the specialist cannot leave the OR complex. This results in an unnecessary increase of the Average Length of Stay.

Long waiting times at the day of surgery is not patient friendly and might cause patients to choose for another health provider. Patients take rights in their own hand, as it is no exception that angry patients refuse to wait for the specialist and leave the ward without being formally discharged. So on one hand OR planners and specialist are afraid that reducing the *slack on registration*, increases the chance of the OR of being vacant. On the other hand patients do not want to be in the hospital longer than necessary.

In the current situation this is already a problem, but after the merger in which high-volume low-complexity patients will be allocated to OLVG West, hospital management estimates that the problems described above become obstacles even more. High-volume low-complexity patients are almost always outpatients, which means that more outpatients will be reallocated to OLVG West, which will result an increase of the problems described above.

To overcome this obstacle the hospital management came up with a Lounge concept. However this concept is still being developed and many questions still remain unanswered. Example given, questions about how the performance of the Lounge can be measured and whether the Lounge will solve the current obstacles. But even more important to what extent does the Lounge improve long waiting times and Average Length of Stay without harming the current performance. In addition, it is important to know for the OLVG how different circumstances affect the Lounge's performance, in order to support stakeholders in making a well informed decision how to setup the Lounge.

OLVG West wants to reduce the waiting time before and during admission of patients to increase patient friendliness. The core problem of this thesis can therefore be described as:

Currently patients have to wait a long time before and after surgery. In addition, after reallocation of specialties to OLVG West, it is estimated that these inefficient operations will result in a lack of bed capacity.

1.2.2 Stakeholder analysis

We conduct a stakeholder analysis in order to identify various actors, we discuss the most important stakeholders for this thesis.

1.2.2.1 Hospital management

One of the main stakeholder groups within this thesis is the hospital management. First, the **hospital board,** is considered one of the key stakeholders within the hospital management. The board is responsible for the hospital performance and focuses on strategic goals of the OLVG. The overall objective of the OLVG board is to have a financially healthy organization when providing; high quality care for patients, efficient use of resources and satisfied employees. In the OLVG the hospital board needs to approve ideas initiated by **the strategy team.** If the board identifies a problem the strategy team is assigned to bring a proper solution and deal with problems within the OLVG. Currently the strategy teams' main task is to ensure the merger of Sint Lucas Andreas Ziekenhuis and Onze Lieve Vrouwe Gasthuis is going smoothly. Therefore both groups are considered important stakeholders as they have a significant influence on the process.

1.2.2.2 Patients

Another important stakeholder group within this thesis are the patients, in which we differentiate **Inpatients and Lounge patients.** Patients demand high quality care at an affordable price. Nowadays it is easy for patients to search online to gain information about different hospitals. Therefore experiences of patients are shared and more and more patients are aware of the possibilities and demand high quality care.

It is important for hospital needs to make sure they have a good reputation, offering a patient an experience as comfortable as possible. Patients aim for the best care, but do not want to spend more time than necessary at the hospital. As the aim is to shorten the stay in the OLVG, patients are considered important stakeholders. A shorter stay will improve the recovery process of the patient and increases the comfortableness of their experience (Watkins & White, 2001). This on its turn results in faster rehabilitation, less chance of complications and a smaller chance on having another surgery (White, Rawal, Nguyen, & Watkins, 2003).

A last stakeholder group within the hospital management are **division managers**. The division manager manages a cluster of specialties and/or departments in the hospital and is therefore responsible for the long term vision of a division. One division manager will be responsible for the Lounge.

1.2.2.3 Medical personnel

Another important stakeholder group within this research is the medical personnel, including the **Medical specialists & Anesthetist**. Specialists are responsible for the treatments and choice of anesthetic. Although the board and strategy team are responsible for providing and

implementing newly constructed policy, it is without question that specialist have to agree. As the medical specialist and anesthetist are responsible for the care trajectory and anesthetic technique, they are key stakeholder to this problem. Hospital management has to make sure the medical specialists and anesthetist are involved in the process and feel problem owner as much as possible.

Nurses play an important role and are therefore considered a stakeholder, as they have direct contact with patients. There are different level of nurses which can be defined as general nurses or specialized nurses who can outperform in specific areas. The OR complex nurses are considered stakeholders because they have to adjust their work into the new setting. They will have to adjust their procedures to make sure they are compatible with the Lounge concept. Their involvement and support are important in the process of modifying care trajectories.

1.2.2.4 Department management

Next to the hospital management there are also stakeholders within the department, referred to as department management. First is the **OR complex manager**, who is responsible for the daily and strategic decisions that affect the OR complex and therefore the Lounge concept. Another stakeholder is the **Central OR planner**. As part of the OR department, the OR planner is responsible for the allocation of ORs, supporting staff and equipment.

Next is the **organizational manager**, who is responsible for one specialty and policy implementation. The organizational manager attends meetings with the specialists and functions as a link between the specialists and strategy team. Therefore it is considered as a mediating stakeholder, balancing the needs of specialist and the strategic teams. Another stakeholder is the **Ward team leader**. As the ward team leader is responsible for the daily operations on a ward, he decides how to allocate the staff on the ward to the shifts and also decides how many operational beds are available. The ward team leader is therefore also considered an important stakeholder. Last, is the **Specialty planner.** The specialty planner manages the timeslots that are assigned to a certain specialty by the central OR planner.

The follow interest of the stakeholders can be identified:

- Maximize utilization of operating rooms: surgeries should not be delayed or cause overtime.
- Maximize quality of care: Each stakeholder in the inpatient care chain demands a high quality of care.
- Minimize waiting time: Patients do not want to wait a long time at the day of surgery before they can undergo Surgery. By rearranging the process, waiting time can be reduced, which is beneficial for the patients and the hospital's reputation.
- Minimize length of stay: Patients do not want to stay unneeded long at the hospital.
- Maximize utilization of resources: All management stakeholders want to use their resources efficiently.
- Leveled workload: Optimally employees have the same workload throughout the day.

Regarding the stakeholder analysis the problem owner for this problem is the hospital management. Although the hospital board initiated the merger and the specialists are key stakeholders the problem is delegated to the strategy team. They have to analyze this concept

and eventually present a proposition for a solution. The above stakeholder analysis makes clear that there are various objectives in the patients' care trajectories. Due to all these objectives, implementing the Lounge and taking into account all objectives is considered a complex process.

1.3 Research objective

Based on the previous section we will analyze possible solutions for the problems stated before, therefore the objective of this thesis can be defined as:

To determine the required capacity of the Lounge and develop and assess interventions to optimize the performance of care trajectories suitable for the Lounge.

This research focuses on elective patient flow that is considered suitable to be treated at the Lounge at OLVG West. It will provide insight in the performance of the Lounge under different circumstances while the waiting time and Average Length of Stay are minimized. To fully grasp the effect of the reallocation of specialties and the interaction with the Lounge elective inpatients have been included as well.

A mix of strategic and tactical decisions will be evaluated to determine the best combination of settings for OLVG West. These decisions consist of capacity of the Lounge, OR planning, and process decisions. The performance used in this thesis will be analyzed and constructed.

1.4 Scope

The scope includes all elective surgical patients of OLVG West. For the Lounge it includes elective surgical patients who are now treated at the outpatient ward, and elective surgical inpatients that are considered suitable to be treated at the Lounge. For the holding/recovery it includes all other surgical inpatients that are admitted short before surgery. The scope is illustrated in Figure 3, which shows the scope after implementation of the Lounge, 'admission short before surgery' concept and after the reallocation of specialties.

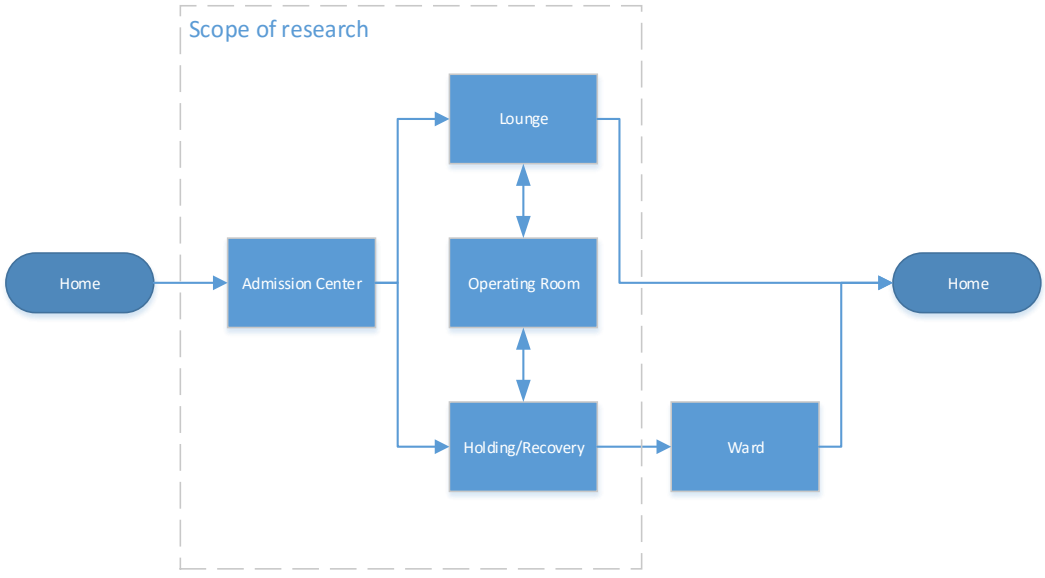


Figure 3 – Scope of research

The amount of Lounge patients depends on the decisions of specialist. Specialist assign which surgeries and which patients are suitable for the Lounge. Emergency patients, which are not planned, will be left out as only planned elective patients will be suitable to be treated in the Lounge.

1.5 Research questions

To achieve the research objective we formulate several research question, in which each question corresponds to a chapter. This provides the outline of the report. Each chapter answers corresponding sub-questions as well and the main questions are answered in the final conclusion.

Chapter 2: Content analysis

In Chapter 2, the current situation of OLVG before focusing on the Lounge is evaluated. The main question for this chapter is:

What is the current performance and how is it monitored?

This question is important to understand how performance is monitored and controlled in current situation. The sub questions are:

I. How is the current performance monitored?
II. Which performance indicators can be identified?
III. What is the current performance?
IV. What is the core problem, what are the consequences, and what factors influence the problem?

Chapter 2 therefore describes a clear overview of the current situation, so it becomes possible to analyze the opportunities for the Lounge and improvement of performance. Necessary information regarding this question is obtained by consulting professionals and annual reports of OLVG. To provide an answer to the main question, Section 2.1 describes the current care trajectory of elective surgical outpatients, Section 2.2 discusses the control of care trajectories, and Section 3 identifies which performance indicators are used to evaluate the current performance. Section 2.4 describes the core problems in the current situation. Last, Section 2.5 is a concluding paragraph that answers the sub-questions of Chapter 2.

Chapter 3: The Lounge

In Chapter 3, the proposed solution; The Lounge, will be elaborately discussed. This is based on relevant literature and best practices of The Lounge in other hospitals. The research question is:

What concepts are mentioned in literature to organize the core problem using a Lounge?

This question is important to understand how the Lounge concept can improve the performance of a hospital. The sub questions are:

I. How does the design of a Lounge improve the performance?
II. How does the characteristics of a Lounge improve the performance?
III. What are the Lounge specific performance indicators?
IV. Which patients are suitable for the Lounge?
V. What are the disadvantages of the Lounge?

Chapter 3 therefore describes the Lounge design and characteristics in Section 3.1. After that the Lounge and inpatient care trajectories are explained in Section 3.2. In Section 3.3 the care trajectory performance indicators will be analyzed. After that the requirements of the Lounge are defined in Section 3.4 which results in the reallocation of specialties which is explained in Section 3.5. As not only the profit of the Lounge should be discussed, Section 3.7 analyzes different disadvantages of the Lounge. Last Section 3.8, answers to the sub questions of Chapter 3.

Chapter 4: Analytical model of the Lounge

In Chapter 4, a literature review is done to analyze and build the best model suitable to achieve the research objective. Therefore the main question of this chapter is:

How can the Lounge be simulated to reduce waiting time and Average Length of Stay without aggravating current performance or other Lounge performance indicators?

The sub questions are:

I. How can we model the Lounge?
II. Which input parameters do we use?
III. What experimental factors do we use?

First the model selection is described in Section 4.1, analyzing which model applies best to the research objective. After the model selection, the chosen model will be motivated in Section 4.2. Thereafter the steps to build the model will be defined. Starting with Step 1: Problem definition in Section 4.3. After that Step 2: Model Construction, will be analyzed in section 4.4. The last step is Step 3: Experimental design and approach will be discussed in 4.5. After that a concluding paragraph will answer the sub questions of this chapter in Section 4.6.

Chapter 5: Results

After modelling the Lounge in Chapter 4, the results of the model will be discussed in Chapter 5. Therefore the main question of this chapter is:

How does the Lounge perform compared to the current situation and how does it perform under different circumstances?

The sub questions are:

I. What is the relationship of each experimental factor to performance?
II. What are the combined optimal settings of the Lounge based on the preferences of OLVG?
III. How is the performance of the combined optimal setting effected by various experiments?

This chapter describes the results of the experiments and is divided in two stages. After that additional experiments are done to analyze the performance of the Lounge under different circumstances. The first stage is described in Section 5.1, consisting of experiments taking into account only singular experimental factors. This is done to analyze the relationship between experimental factors and the performance. Stage two is described in Section 5.2 and consists of experiments that contain a combination of multiple experimental factors. This is done to obtain the combined optimal setting. After finding the combined optimal setting, several experiments are done to measure the Lounge performance under different circumstances, which is described in Section 5.3. Thereafter, answers to the sub questions of Chapter 5 will be provided in Section 5.4.

Chapter 6: Conclusion and recommendations

The last chapter covers the conclusions in which an answer is given of all chapter main questions. This chapter contains limitations, and recommendations for the OLVG, including suggestions for further research.

2. Context analysis

Chapter 2 describes the current situation before focusing on the Lounge. When a clear overview of the current situation is displayed, it becomes possible to look at the opportunities for the Lounge and improvement of performance. Section 2.1 describes the current care trajectory of elective surgical outpatients, in order to analyze how these are designed in the current situation. Section 2.2 discusses the control of care trajectories. Section 2.3 explains the performance indicators and the current performance and Section 2.4 describes the core problems in the current situation. Last, Section 2.5 concludes the chapter by giving answer to the sub questions of this chapter.

2.1 Current care trajectory

This section discusses logistics and information provision during the stages of the current care trajectory. The details of a general care trajectory have to be known in order to translate the current situation to the Lounge. The stages of the current in- and outpatient care trajectory are illustrated in Figure 4. Prior to the day of surgery the patient has visited the specialist and anesthetist who determined whether the patient is in- or outpatient. As can be seen in Figure 4 a patient will pass five departments during the stay in the hospital. The care trajectory for in- and outpatients are similar except for the last stage, which is longer for inpatients.

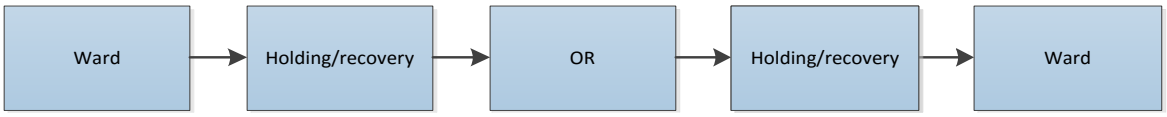


Figure 4 – Stages in- and outpatient trajectory on the day of surgery

At the day of surgery the patient registers at the admission desk of the ward. The patient and his family wait in the lobby until they are received by a nurse and accompanied to a bed. Here the patient changes into a surgical outfit and takes place in bed.

The patient is brought to the holding/recovery department after the nurse receives a call from the OR-complex. A dedicated elevator is used to transport the patient from the floor of the ward to the second floor, where the OR complex is. Once arrived at the holding/recovery the nurse hands over the patient to a specialized holding/recovery nurse. Here, the patient receives an anesthetic from the anesthetist and other medication in preparation for his surgery. The patient will wait in the holding/recovery department until the OR is ready for surgery. After being transported to the OR the patient transfers to the OR table and his bed is stored outside the OR. After surgery the patient is transferred back to his bed and brought back to the holding/recovery.

The patient stays in the recovery until he is awake and stable to be brought back to the ward. Whether the surgeon will visit the patient in the ward depends on possible complications that might have occurred during surgery, available time of the surgeon and the type of surgery. The specialist, a resident or specialized nurse decides whether a patient is ready for discharge depending on the procedure and circumstances.

It could be possible that an outpatient has to stay overnight when the patient is not stable or not feeling well. If there are any doubts about the medical status of a patient the specialist will be called for consultation. Inpatients by definition will stay at least one night.

2.2 Care trajectories control and performance indicators

This section discusses the tools and method to control the care trajectories, in which performance measurement in OLVG West is mainly conducted by using dashboards. The dashboards are self-constructed by the business intelligence department in a program called HyperSpace. The hospital board acknowledges the importance of monitoring indicators by using dashboards, as it is stated in the annual report of 2013.

The control over a process is important to achieve continue improvement, this is done by effectively adjusting the care trajectory based on retrieving feedback. The feedback, in most cases, consists of performance indicators that reflect the performance of a process (Kundler, 2008).

To know how the care trajectory is controlled and which performance indicators are used, it has to be known first who is using the dashboards. The business intelligence department customizes a dashboard for each specialty and specifically for the OR complex as can be seen in the outpatient ward dashboard in Appendix A. As the surgical outpatient is the group of interest, the care trajectory control of wards and OR complex will be discussed.

2.3 Performance indicators

In this section the performance indicators of the current situation are described. Starting with the outpatient wards, in which the performance indicators are Average Length of Stay and bed occupation ratio. After that the OR complex is being discussed which consist of the following performance indicators: OR Utilization Ratio, OR cancellations and OR Overtime Ratio.

2.3.1 Outpatient ward

An operational manager is responsible for daily operations at a ward and makes sure there are sufficient specialist, nurses, beds and other resources available. The operational manager uses dashboard to monitor performance of the ward. The most commonly used parts of the dashboard for care trajectory control will now be discussed.

2.3.1.1 Average Length of Stay

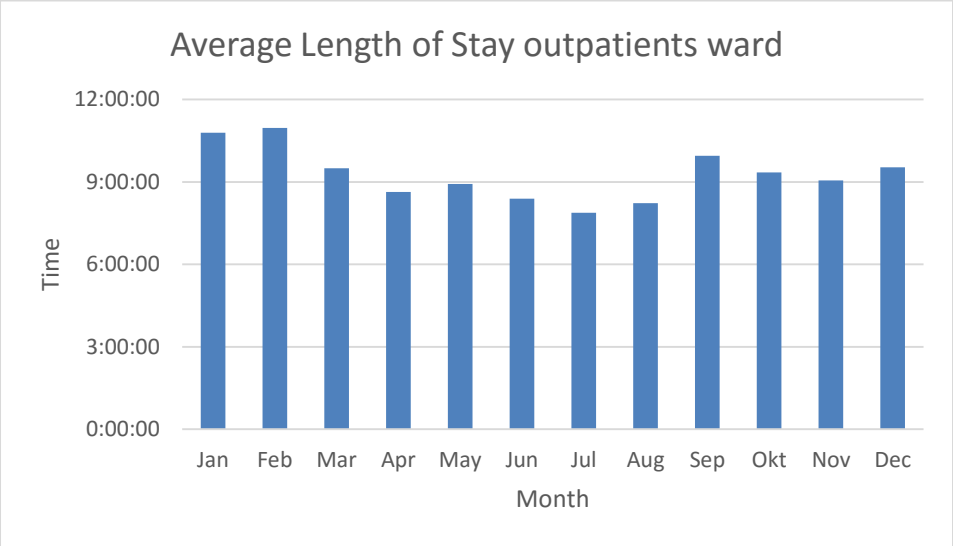


Figure 5 – Average Length of Stay Outpatient Ward(n=3041, t=2014, Business Intelligence)

Figure 5 shows a graph from the dashboard about the Average Length of Stay (ALoS). The ALoS is the average time between admission and discharge of a patient at the hospital (Veillard et al., 2005) and it is calculated using Equation 1. This performance indicator includes the stay at ward pre-surgery, holding, OR, recovery, ward post-surgery and transport times as illustrated in Figure 4. For OLVG West the ALoS for outpatients is 8:27:08.

$$Average\ Length\ of\ Stay = \frac{\sum_{All\ admissions} Time\ of\ discharge - Time\ of\ admission}{Number\ of\ admissions}$$

Equation 1 – Average Length of Stay

The ALoS is a direct indicator to measure the performance of a care trajectory. It has been decreasing over the last few decades, which shows the rapid development of technology, diagnostic and knowledge within healthcare (Borghans, Kool, Lagoe, & Westert, 2012). In this case the ALoS includes unnecessary waiting time that does affect the level of patient satisfaction.

There is evidence of a correlation between ALoS and quality of care under the condition of a well-designed care trajectory. If the ALoS shortens as a result of the reorganization of a care trajectory it does provide a higher quality of care (Kossovsky et al., 2002).

2.3.1.2 Bed Occupation Ratio

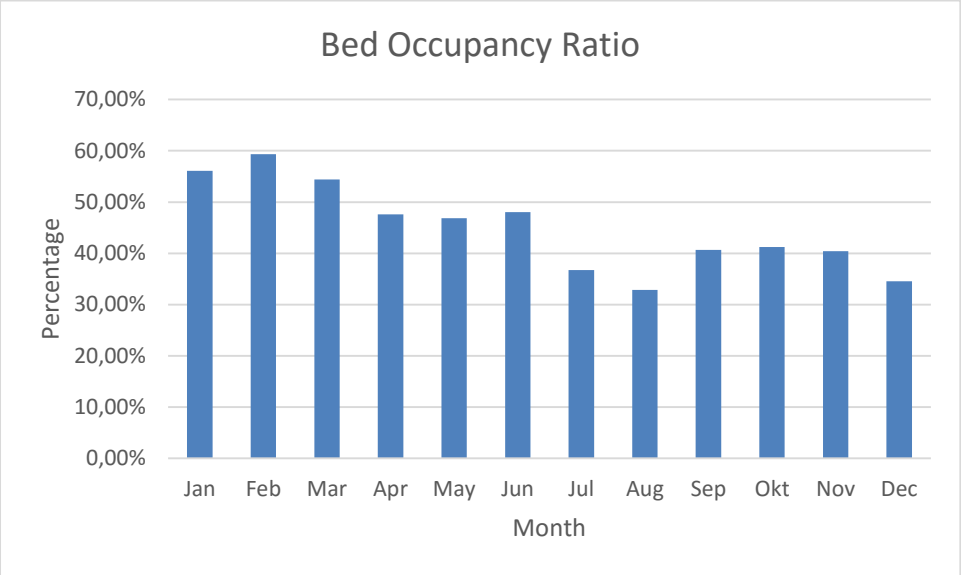


Figure 6 – Bed Occupation Ratio of outpatients ward, (n=3041, t=2014, Business Intelligence)

Figure 6 shows the graph with the Bed Occupancy Ratio (BOR). A bed can be used by a patient without a patient occupying it, if a patient is having surgery for example. The BOR is the ratio of available time beds that are used by patients and can be calculated with Equation 2.

$$Bed\ Occupancy\ Ratio = \frac{\sum_{beds} Usage\ of\ bed\ during\ opening\ hours}{Available\ number\ of\ beds * Uptime\ department}$$

Equation 2 – Bed Occupation Ratio

There are fourteen beds available for surgical outpatients at the outpatient ward which opens at 7:00 and closes at 18:00. The BOR of 2014 is 45%. The BOR is always given for a department or entire hospital instead of an individual bed. A low BOR indicates that beds are not being used optimally. On the other hand, a too high BOR can lead to an admission stop as there is no room for emergency patients (Bagust, Place, & Posnett, 1999). Although the article of Bruin, Bekker, van Zanten & koole (2010) states that most hospitals' objective is to keep the BOR on 85%, the performance is reflected by multiple performance indicators. Therefore only stating that a BOR of 85% is optimal is incomplete. It is also suspected that it influences patient outcomes (Keegan, 2010; Volpe, Magalhaes, & Rocha, 2013).

2.3.1.3 Number of patients treated

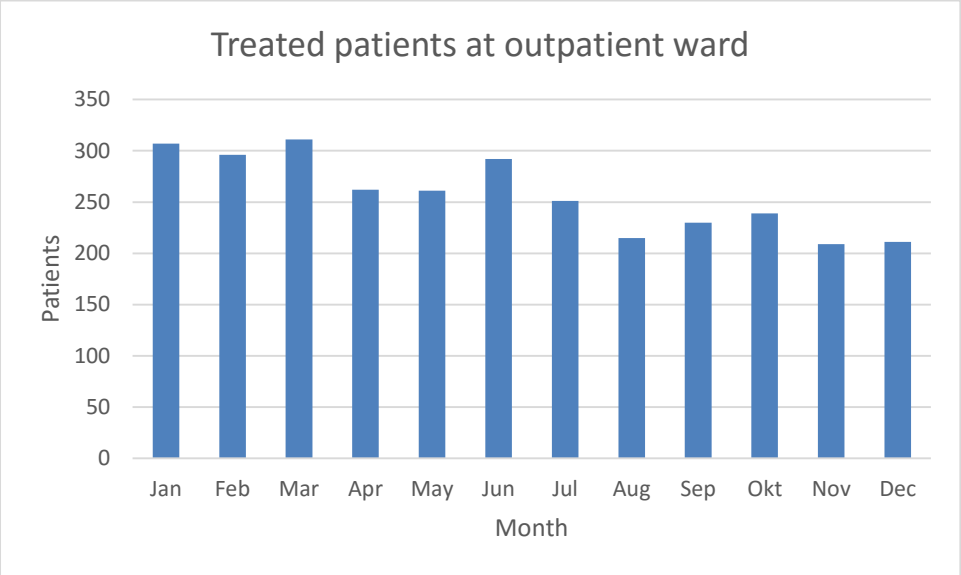


Figure 7 – Number of patients treated at outpatient ward (Year: 2014, Sample size: 3041, Source: Business Intelligence)

The number of patients or production treated does not require a lot of explanation. It shows how many patients have been treated at a specific ward of department. It is interesting to notice in Figure 7 that the number of patients treated is lower during months that contain public holidays, December, May, July and August. The total number of outpatient treated at the outpatient ward is 3041.

2.3.2 OR complex

Each specialty has a specific OR planner to schedule its surgeries, however they get permission to plan their surgeries in an assigned timeslot gained by the central OR planner. The specialty's OR planner is responsible for filling this timeslot. It depends on the patients that are available for surgery at that time and on the preferences of the specialist how the timeslots are filled. The estimated length of stay after a specific surgery is not taken into account and it does not matter for the specialties OR planner if a timeslot is filled with either five short surgeries or one long surgery. The only condition for planning a surgery is that there is sufficient OR time and also a bed on the ward for admission. The specialty's OR planner and the central OR planner receive a dashboard every month. An example of a dashboard can be found in Appendix B.

2.3.2.1 OR Utilization Ratio

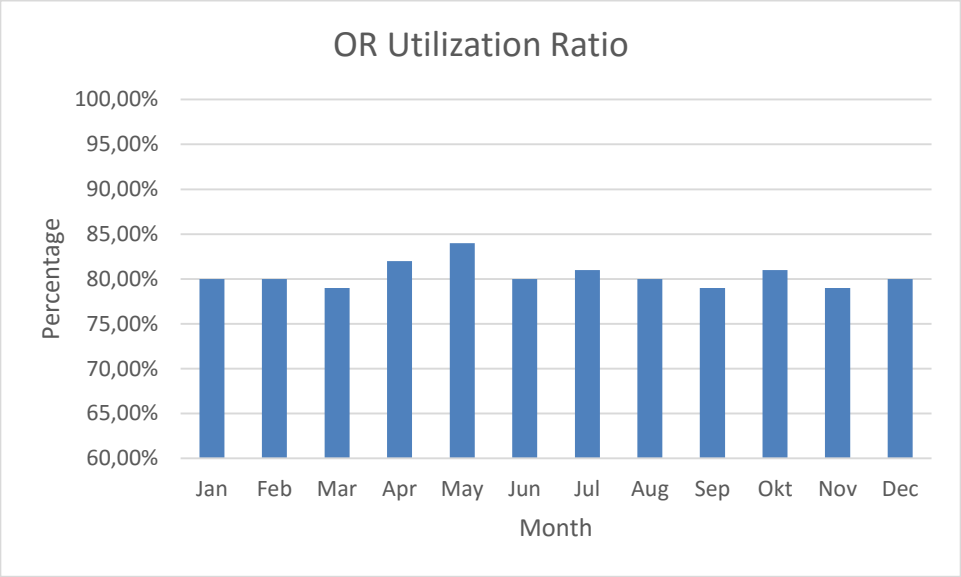


Figure 8 – Graph OR Utilization Ratio (Year: 2014, Sample size: 9985, Source: Business Intelligence)

Figure 8 shows a graph from the dashboard about the OR Utilization Ratio (ORUR). The objective of the specialty OR planner is to obtain an ORUR as high as possible. The ORUR is the percentage of available time an OR is occupied with a patient and is calculated according to Equation 3. The OR is open from 7:50 to 15:45.

$$OR\ Utilization\ Ratio = \frac{\sum_{All\ patients} Time\ patient\ leaves\ OR - Time\ patient\ enters\ OR}{Number\ of\ ORs * Opening\ hours\ duration}$$

Equation 3 – OR Utilization Ratio

As can be seen in Figure 8 the OR utilization fluctuates between 75% and 85% and was 80% on average. The hospital objective is to obtain an OR utilization rate of 85% which in this case is not achieved. An OR utilization rate of 85-90% is being considered achievable without delays and cancellations, so this means that there is space for improvement at OLVG West (Tyler, Pasquariello, & Chen, 2003).

2.3.2.2 OR cancellations

The dashboard provides insight in the number of OR cancellations (Veillard et al., 2005). This indicator provide valuable information about how well the process is organized.

Cancellations are the number of surgeries cancelled on the day of surgery. It is effected by how well a patient is informed prior to surgery but can also be affected by medical reasons in case of high blood values for example. No-shows are also included.

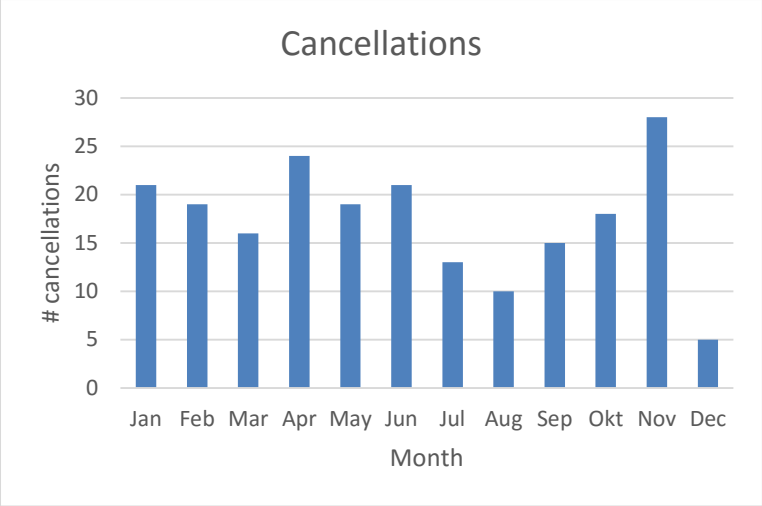


Figure 9 – Number of cancellations (Year: 2014, Sample size: 9985, Source: Business Intelligence)

2.3.2.3 OR Overtime Ratio

The Overtime Ratio is the number of surgeries that exceed the OR closing time (Tyler et al., 2003). It is an appropriate measure to evaluate the OR schedule and evaluate chosen slack on the different stages of the care trajectory.

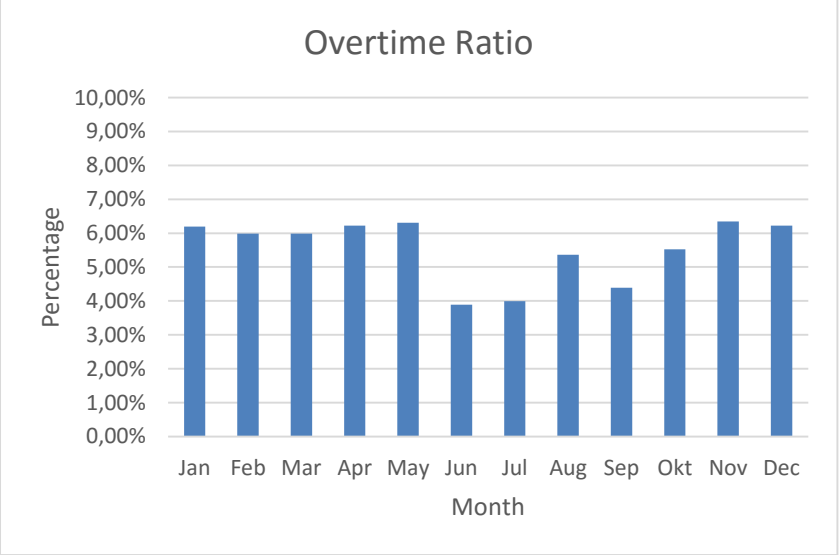


Figure 10 – Graph OR Overtime Ratio (Year: 2014, Sample size: 9985, Source: Business Intelligence)

The OR cancellation and OR Overtime Ratio are both indicators that are linked with the OR Utilization Ratio. Only using the OR Utilization Ratio would not be representative for the Ors performance, therefore the OR cancellations and OR Overtime Ratio are added.

From the conducted interviews and gathered information, it is concluded that performance control is unilateral focused on the OR Utilization Ratio. As the OR is considered one of the most expensive departments of the hospital it is a logical result that the utilization is being optimized (Archer & Macario, 2006). However practice shows, in case of OLVG West, that optimizing the OR utilization ratio as a single objective creates problems at wards. As the HER does not take the length of stay at the ward after surgery into account when a patient is

planned, it happens frequently that too many patients are planned. The ward capacity is reached, which results in an admission stop.

As the outpatient ward is filled with patients of different specialties the patients planned for surgery are being planned by the OR planner of each specialty. The outpatient ward has to deal with the patients that are separately planned by the specialty's OR planners by maintaining the restriction of 'one patient per bed' each day. A disadvantage is that even if a patient has a short surgical procedure, after which he can be quickly discharged given that the specialist can visit, the bed is registered as occupied for a full day.

2.4 Problem analysis

The core problem of this study is stated as:

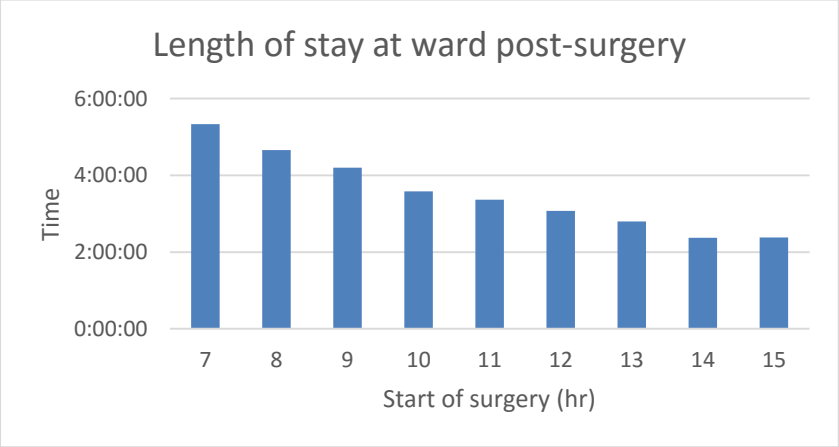
Currently patients have to wait a long time before and after surgery. In addition, after reallocation of specialties to OLVG West, it is estimated that these inefficient operations will result in a lack of bed capacity.

This problem is caused by several factors happening in the current situation, these will be discussed now.

2.4.1 Inefficient bed utilization- Specialist cannot leave OR complex

The inefficient bed utilization is caused by specialists that cannot leave the OR. It differs per procedure whether a patient can be discharged with or without the specialist. For some procedures discharge protocols are used which enables nurses to discharge patients according to protocol. However for most procedures, patients have to wait until the end of the day to wait for the specialist to finish all surgeries and visits the patient to discharge him, as the specialist cannot leave the OR complex between surgeries.

Graph 1 shows the mean length of stay at the outpatient ward post-surgery of all surgical outpatients of OLVG West (2014) excluding emergency patients and children. The hour shown on the x-axis is when the patient enters the OR. As can be seen in Graph 1, patient's waiting time for discharge is relatively long if operated early in the morning.



Graph 1 - Average Length of Stay at outpatient ward post-surgery (Year: 2014, Sample size: 3041, Source: Business Intelligence)

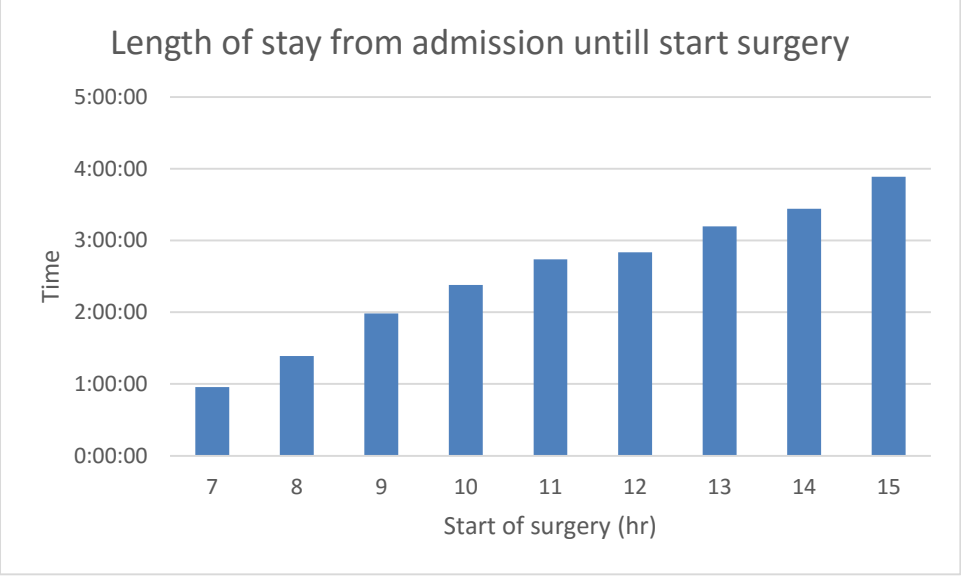
The Lounge is put forward as a suitable solution for this problem as it is located in the OR complex. Therefore it becomes possible for the specialist to visit the patient between surgeries. This way, the Lounge will decrease waiting times for discharging as it becomes possible to get discharged by the specialist between surgeries. The effect of the Lounge on discharging patients between surgeries will be analyzed later on this study.

2.4.2 Variability in transport time

The transport time from the outpatient ward to the holding/recovery creates a problem as the waiting time at the elevator varies. As outpatients have to be transported from the fourth floor to the second a dedicated care elevator is used. All surgical patients have to use this elevator and as there is only one elevator it can happen that patients have to wait for some time. The variability in transport time results in calling the patient early by the holding/recovery to make sure the patient arrives on time, which results in the patient waiting. To overcome this problem, the Lounge creates an opportunity to decrease transport times as the Lounge is built near the OR and on the same floor.

2.4.3 Average Waiting Time Before Surgery

Sometimes a patient has to wait a long time in the waiting room or at his bed in the outpatient ward, as the time of registration is long before the start of surgery. Specialist and OR planners want to make sure patients are in the hospital to reduce the risk of ORs being vacant, cancellation or delays as the hospital creates a buffer. This buffer is the slack on admission which is the additional time an OR planner has a patient come in early. If one patient is late, the next patient scheduled can have surgery first as he is already prepared and waiting. The goal of having a patient arrive early is to optimize the occupation of the OR. The patient however has the disadvantage that he has to come early and wait for his surgery and if the OR is delayed wait even longer.



Graph 2 – Length of stay between admission and start OR outpatient (Year: 2014, Sample size: 3041, Source: Business Intelligence)

As is illustrated in Graph 2, the waiting time increases as the surgery is planned later on the day. If we assume that patients of which the surgery starts at seven do not have to wait, we

can subtract that duration from the other durations to determine the waiting time. This results in an average waiting time of 1:20:11. The number of times this strategy avoided delays is not exactly known but is perceived as 'very small' for OLVG West. How much and if slack can be reduced will be analyzed later on in this study. Although OLVG West does not use the Average Waiting Time Before Surgery, this performance indicator will now be included.

2.5 Conclusion

This chapter discusses logistics and information provision during the stages of the care trajectory to create a better overview of the current situation, in order to translate the current situation to the Lounge. The following questions and corresponding answers conclude this chapter:

I. How is the current performance monitored?

The performance is monitored using dashboards. The dashboards provide valuable information about some performance indicators and are used to monitor the process Improvements or other changes are evaluated using the dashboards.

II. Which performance indicators can be identified?

The performance indicators used by OLVG West are Average Length of Stay, Bed Occupancy Ratio, Number of Patients Treated, Operating Room Utilization Ratio, Cancellation Ratio and Overtime Ratio. These performance are currently used to evaluate the performance. The Average Waiting Time Before Surgery is not considered a performance indicator at the OLVG in the current situation. However the hospital wants to measure this too when introducing the Lounge, therefore this indicator is now taken into account as well.

III. What is the current performance?

The current performance is measured by the performance indicators, the results of these measures are shown in Table 4.

Performance Indicator	Data 2014
Average Length of Stay	8:27:08
Bed Occupancy Ratio	45%
Operation Room Utilization Ratio	80%
Cancellation Ratio	1.7%
Overtime Ratio	5.5%
Average Waiting Time Before Surgery	1:20:11
Outpatients Treated at outpatient ward	3041

Table 4 – Current performance

IV. What is the core problem, what are the consequences, and what factors influence the problem?

The core problem is: *Currently, patients have to wait a long time before and after surgery. In addition, after reallocation of specialties to OLVG West, it is estimated that these inefficient operations will result in a lack of bed capacity.* The consequence is that patients have to spend

unnecessary time at the hospital, which is not patient friendly. Factors influencing the problem are:

- Specialist cannot discharge patients between surgeries
- Variability in transport time
- High slack on admission

Performance, as discussed in this chapter, is reflected by a bundle of performance indicators which will consist of the following in this thesis:

- Average Length of Stay
- Bed Occupancy Ratio
- Operation Room Utilization Ratio
- Cancellation Ratio
- Overtime Ratio
- Average Waiting Time Before Surgery

3. The Lounge

In this section the proposed solution, the Lounge, will be elaborately discussed. This is based on relevant literature and best practices of The Lounge in other hospitals. It is important to understand the Lounge concept to determine how The Lounge can improve the performance of the OLVG. Starting with Section 3.1, in this paragraph The Lounge design and characteristics will be described. After that the Lounge and inpatient care trajectories are explained in Section 3.2. After that the requirements of the Lounge are defined in Section 3.3 which results in the reallocation of specialties which is explained in Section 3.4. In Section 3.5 the care trajectory performance indicators will be analyzed. As not only the profit of the Lounge should be discussed, Section 3.6 analyzes different disadvantages of the Lounge. Last, answers to the sub questions of Chapter 3 will be provided in the concluding paragraph in Section 3.7.

3.1 Characteristics and design of the Lounge

This section discusses the design and layout of the Lounge. It will start with describing the "Healing environment" on which the design and layout of the Lounge is inspired.

3.1.1 "Healing environment"

Providing care in hospitals is not only about performing surgeries and receiving medicines anymore. The outcome of a treatment is still important, but the experience of the patient and his family become more and more important nowadays. The concept that describes the effect of the environment in which care is delivered is called "healing environment". "Healing environment" is a place where the interaction between patient and staff produces positive health outcomes within the physical environment (Jonas & Chez, 2004).

The "healing environment" concept states that the design of the environment, in which a patient is receiving care, changes a patient's state of mind and therefore is considered to be part of the treatment (La Torre, 2006). Aspects like color, daylight and Feng Shui are important as they influence the patient. The study of Ulrich (1984) compared patients looking at a brick wall and patients looking at a landscape wall painting. It showed that patients looking at the landscape recovered faster than patients looking at the brick wall.

"Healing environment" does not only have a positive effect on patients, but on nurses and specialist as well. It creates a better work environment in which they deliver better service to their patients (Huisman, Morales, van Hoof, & Kort, 2012). As the experience of a "healing environment" resulted in a faster recovery, research shows that therefore this environment decreases hospital costs (Huisman et al., 2012). As a "healing environment" is positively referred to in the literature and brings advantages to patients and specialist, this concept will be implemented in the Lounge of OLVG West to create a relaxing and restful environment in order to improve the patients' recovery process.

3.1.2 Design

The Lounge has a patient friendly design, according to the Healing Environment concept, which result in the relaxing effect caused by the colors, lights and interior. As nowadays being online is becoming a standard, Wi-Fi should be available and easy accessible for the

convenience of the patient. There is a food cart on the Lounge to make sure all patients are provided with food after surgery and if needed the nurse can help to provide care to a patient's needs. Figure 11 shows the intended design of the Lounge of OLVG West.

Figure 11 – Concept design of Lounge, adopted from OLVG West

Next to the environment of the Lounge, the chairs that will be used are an important element. The patient can be treated in a chair as illustrated in Figure 12. This chair can be used before surgery and also be converted to an operating table. The Lounge chair can change into many desirable position as this might be different for each surgery. The patient will be more comfortable and feels less like a patient when using a chair instead of a bed, as he can sit normally prior to surgery and lay down after surgery to recover.

Figure 12 – Chair of Doge Medical, adopted from Doge Medical (DogeMedical, 2015)

Another reason the Lounge will be implemented is because OLVG West wants to modernize. The Lounge concept is already used in other hospitals like ZGT hospital in Hengelo and the Oncological day care center at the VUmc. These hospital serve as best practices, for the OLVG to gain information about certain Lounge elements.

After visiting various examples of Lounge concepts, OLVG West prefers to implement a Lounge that is like a 'living room', including a TV corner, sofas, Wi-Fi, a kitchen and a food cart. The nurses that work on the Lounge should therefore be aware that their task will be adjusted, as they do not only provide care anymore but also have to provide other services.

The design and facilities at the Lounge will result in a patient friendly experience for patients according to the "Healing Environment" concept. The most important aspect is that a patient will not feel like a patient, which is a completely different experience compared to the current situation, where a patient is put in a bed in a classic ward.

3.1.3 Layout

To obtain an impression of how the layout of the Lounge will look like, a concept construction drawing is illustrated in Figure 13. As can be seen, all facilities are situated on the same floor. The Admission Center and the Lounge are part of the Admission and Day Care Center. The Lounge, ORs, and holding/recovery are part of the OR complex. Whereby as can be seen in Figure 13, the admission center, Lounge and OR complex will be located next to each other. The Lounge being implemented in the OR complex is unique for the Netherlands given the complete concept.

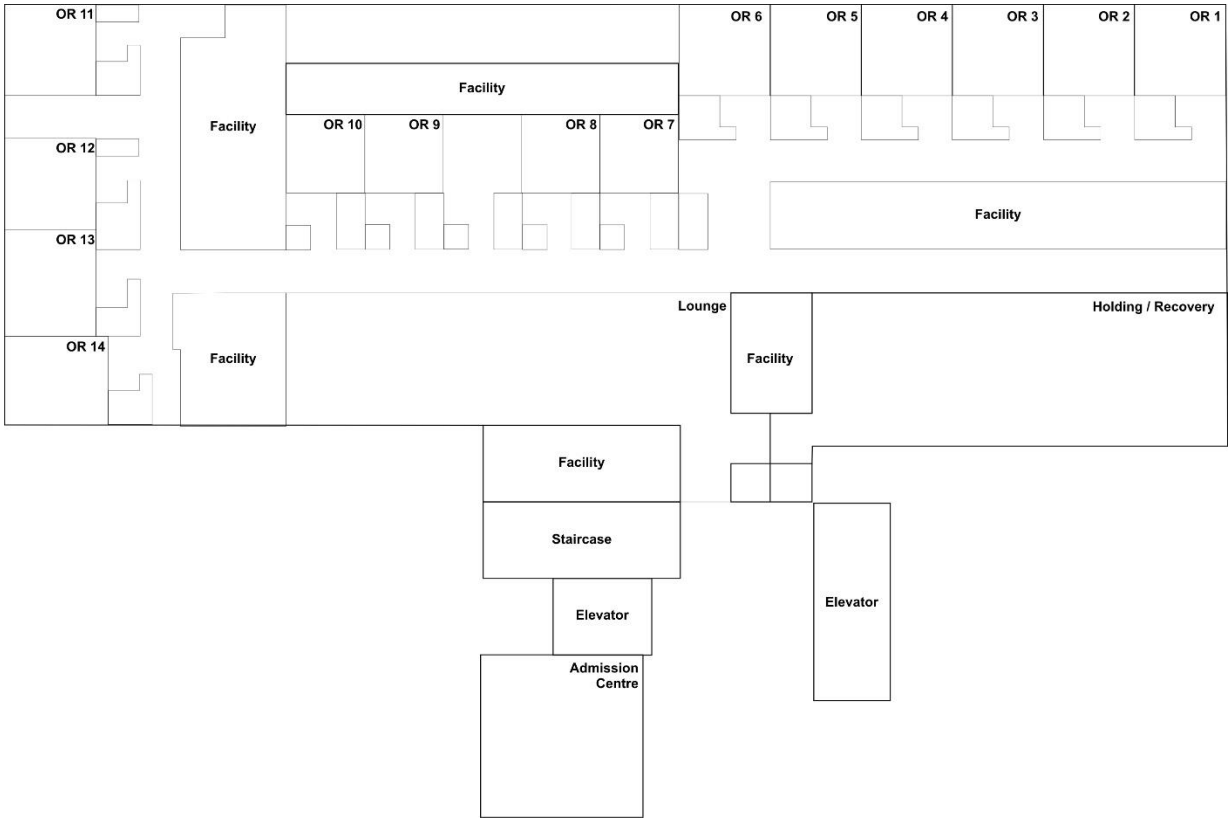


Figure 13 – Concept construction drawing

3.2 Care trajectory

Introducing the Lounge and the 'admission short before surgery' creates new care trajectories for Lounge- and inpatients. To understand which aspects are important for a well-designed

care trajectory, different stages of the care trajectory will be discussed. All stages of this new care trajectory will be explained, as shown in Figure 14.

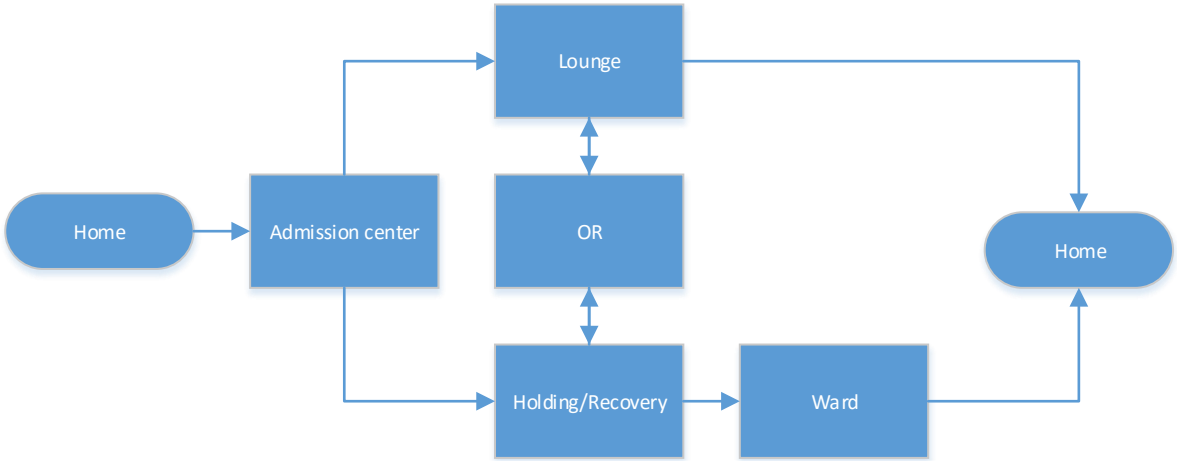


Figure 14 – Stages of the Lounge and inpatient care trajectory

Comparable with current situation, the patient registers at the admission center. However, instead of registering at the desk of a ward, the patient registers in the admission center next to the OR complex. The patient will be seated in the admission center until he is admitted.

This admission is performed by a nurse, who escorts the patient to his chair where the patient will change into a surgical outfit. After changing, the patient will put his valuables in a locker and take place in his chair. All pre-surgical preparations are conducted at the patient's chair. Inpatients will be escorted to the holding/recovery, where they will change, put their valuables in a box and receive anesthetics on a bed.

After the preparation is finished and the OR is ready, the patient will be transported to the OR. At the OR the patient will be operated in the chair if possible and will else change from the chair to an operating table. In the current situation the patient has to be moved to the operating table every time, so in the Lounge chairs it becomes possible to do surgeries when the patient is laying in the Lounge chair.

After the OR is finished, Lounge patients will be transported directly back to the Lounge. If the patient is operated on an operating table, he will be changed back to the Lounge chair first and then transported to the Lounge. Back at the Lounge, the patient will sit or lay down in his chair until he is awake and able to walk and move around. The patient can use his tablet or smart phone or even work on his laptop while recovering. If the patient feels fit enough and the nurse, resident or specialist approves the patient will be discharged. The patient changes into his own clothes and is accompanied home. An inpatient will be transported back to the holding/recovery where he recovers from surgery after which he will be moved to a ward with his box.

From this subsection, we conclude that the care trajectories of the Lounge and 'admission short before surgery' are shorter and more efficient compared to the current care trajectory described in Section 2.1 The steps for the inpatient care trajectory are similar to those of the Lounge patient trajectory. However, one major difference is that an inpatient will have a bed

instead of a chair and after surgery moves to the ward after he is recovered. Figure 14 does not include the possible trajectories of Lounge patient being admitted or recovering at the holding/recovery. Also the possibility of Lounge Patients Moved to Ward is not included as these possibilities are not considered a normal care trajectory.

3.3 Requirements of the Lounge

After discussing the design and characteristics, it is also important to know which requirements of the Lounge are needed to be able to design it that way. This section discusses requirements concerning Fast-track surgery and the patients that will be treated in the Lounge will be discussed. Last, the requirements regarding anesthetic techniques and surgeries will be discussed.

3.3.1 "Fast-track surgery"

The development of transforming inpatient surgeries into outpatient surgeries is an ongoing process. Instead of determining which inpatients could be suitable as outpatient, it should be the other way around. Every patient should be considered an outpatient, unless proven otherwise and the patients cannot be treated in day surgery (Castoro, 2007).

Patients using the Lounge will be admitted, operated and discharged the same day. Through technological advancement, surgical techniques have changed drastically, like minimal invasive surgery. New techniques decreases recovery time for patients compared to classic surgery techniques. This makes it possible to discharge the patient on the same day as the surgery takes place. This concept is called fast-track surgery and aims to optimize the postoperative outcome.

"Fast-track surgery" is the replacement of some of the traditional approaches in surgical care. It has evidence-based practices to accelerate recovery (Kehlet & Wilmore, 2008). Another definition of "fast-tracking" is bypassing the PACU after day surgery (Lubarsky, 1996). Both definitions include reduced recovery time in the hospital after surgery, which contributes to the decrease of the length of stay. The optimization of postoperative outcome means enhancing recovery. It also contributes to reduce comorbidity by implementing new techniques in the field of anesthesia, analgesia, reduction of surgical stress, fluid management, minimal invasive surgery, nutrition and ambulation (Kehlet & Wilmore, 2008).

Fast-tracking is not a new concept and has already been applied and researched by several scholars (Song, Joshi, & White, 1998). Different studies showed that the sedative can be adjusted, this makes it possible to bypass the PACU. Although one might expect that bypassing PACU decreases a nurse's workload, research shows neither the workload nor the cost decreases as the task of the nurse stays the same (Song et al., 2004).

The fast-track concept should be implemented within the care trajectories that use the Lounge. Patients will be able to regain control of their body and go home faster with the use of fast-track anesthesia techniques. Evidence shows that the Length of Stay after surgery is reduced (Rice, Muckler, Miller, & Vacchiano, 2015).

3.3.2 Patient requirements

The patient requirements discussed in this subsection result from conversations and meetings with specialist and anesthetist. There are some general requirements that are applicable to all specialties using the Lounge, however each specialty can have additional requirements as patients are different for each specialty.

The most important condition for surgical patients to be treated in the Lounge is, that the surgery is planned. Planned patients have the advantage that patients and staff are prepared at arrival. Planning makes it also possible to apply smart scheduling rules like scheduling the same type of surgery. This same surgeries require the same equipment and therefore reduce the time between ORs.

The condition of every patient should be evaluated to examine if treatment at the Lounge is possible without increasing risks. Most patients are not 'ill' like patients having a total hip replacement for example. If the risks of an 'ill' patient allows it, a patient will be treated in at the Lounge, same day-surgery, otherwise, as it is in the best interest for the patient's outcomes to become an inpatient, he will stay for at least one night.

A patient should be able to perform general daily activities prior to surgery and should require a minimum amount of support, like walking to the bed and changing into the surgical outfit. If a patient is not capable doing this independently he will not be treated in the Lounge. Indicators that can be used to determine how well daily activities are performed are age, ASA-class and BMI.

After the surgery is finished the patient will be transported back to the Lounge. If a patient is throwing up, is in pain or is just not feeling well he has to be transported to the holding/recovery instead of the Lounge. The patient will be treated at the holding/recovery until he meets all the conditions to be moved back to the Lounge. If the specialist thinks that this scenario is plausible, he will admit the patient to a ward.

Emergency patients will not use the Lounge as they will arrive at the emergency department. If emergency patients would use the Lounge as well it would disturb the relaxing atmosphere. As well minors will be excluded from the Lounge, as nurses are required to have additional education for treating them. Most hospitals have exclusive minor wards accustomed to a minor's needs and taste.

An important condition for the patient to be treated in the Lounge is that he is accompanied by another adult 24 hours after surgery. The patient will not be as mobile as normal and will need help in daily activities. The presence of a caregiver is required in the first hours after surgery to make sure the patient has everything he needs. Driving a car is prohibited for several days dependable of the surgery (Castoro, 2007).

As can be seen there are several requirements that need to be met in order to assign a patient as a Lounge patient.

3.4 Reallocation of specialties

Based on the opportunities that the Lounge brings, this section discusses the reallocation of specialties when introducing the Lounge. We will describe where the specialty is located in the current situation and how the specialties will be allocated after the merger when the Lounge is introduced. After that, the effect on the capacity Holding/Recovery department will be analyzed.

3.4.1 Reallocation of specialties after the merger

Before the merger both hospitals conducted all the specialties, however after the merger some specialties will be allocated to either OLVG West or OLVG East as shown in Table 5.

Specialty	Before reallocation	After reallocation	Specific
General surgery	Both	East	Gastroenterological surgical procedures
Trauma surgery	Both	West	Surgical procedures
Gynecology	Both	Both	
Ear-nose-throat	Both	Both	
Orthopedics	Both	West	Surgical procedures
Plastic surgery	Both	Both	
Cardiology	Both	East	Interventions
Neurology	Both	Both	
Urology	Both	East	
Eye surgery	Both	East	Standard cataracts
Neurosurgery	Both	West	

Table 5 – Specialties merged and moved to OLVG West, adopted from Lounge Business Case 2015

If at the column 'specific' a more detailed description of the procedure is given, only this group will be allocated in the new situation. If after the reallocation the specialty remains in both hospitals no significant alterations will be made.

The orthopedic specialty will be the first specialty suitable to use the Lounge, as orthopedics already ran a "pilot Lounge" in which hip replacement and knee surgeries where performed. Knowledge and experience from this pilot will be shared with other specialties, making it possible that after the orthopedic specialty, surgery, plastic and other specialties will follow too. However this is only possible if the specialties meet the conditions to use the Lounge.

3.4.2 Lounge patient volumes

As one of the goals of the mergers is to have OLVG West focused on high-volume low-complexity treatments and OLVG East on low-volume high-complexity patients. The specialties that are most likely to 'fit' in the Lounge according to the requirements mentioned in Section 3.3 are: general surgery, trauma surgery, gynecology, ear-nose-throat, orthopedic and plastic surgery.

Interviews with specialist have been conducted to discover which surgeries and how many patients are suitable for the Lounge combined with data of 2014. As the specialist is responsible for the treatment of the patient, he will have to determine which type of surgery can be treated in the Lounge. The specialist judges per surgery whether it can be performed

in the Lounge, under the condition that all requirements discussed in 3.3 are met. The number of patients is calculated based on the following inclusion criteria:

- Patients are admitted in 2014
- Patients are regular, no emergency patients are included
- Patients are adults (18 years and older)
- Patients are ASA class 1, 2 or 3
- Specialty/procedure that the patients need is performed in OLVG West after reallocation
- Patients are selected as suitable for Lounge by specialist

Based on this inclusion criteria, the following Table 6 can be created using the data set of Electric Health Record (EHR in OLVG West and OLVG East. Therefore, it is concluded that 4596 patients who had surgery in 2014 are considered suitable for the Lounge.

Specialties	OLVG East	OLVG West	Total
Orthopedics	1260	592	1852
General Surgery	300	994	1294
Gynecology		639	639
Ear, Nose and Throat		473	473
Plastic Surgery		235	235
Eye Surgery		89	89
Neurosurgery		14	14
Total	**1560**	**3036**	**4596**

Table 6 – Number of patients suitable for Lounge 2014

3.4.3 Inpatient volumes

The patients suitable for the Lounge have to be carefully selected. All other patients will be treated as inpatients and will be admitted shortly before surgery in the admission center. According to (Keranen & Keranen, 2011) it is possible to admit all patients shortly before surgery and even let them walk to the operating table.

Inclusion criteria for this group are:

- Patients are admitted in 2014
- Patients are regular, no emergency patients are included
- Patients are children and adults
- Patients are ASA class 1, 2, 3, 4 or 5
- Specialty/procedure that the patients need is performed in OLVG West after reallocation
- Patients are not selected as suitable for Lounge by specialist

Based on this inclusion criteria, the following Table, Table 7, can be created using the data set of surgeries in 2014 in OLVG West and OLVG East. Therefore it is concluded that 4590 patients who had surgery in 2014 are considered inpatients.

Specialties	OLVG East	OLVG West	Total
Orthopedics	844	377	1221
General Surgery	22	844	866
Neurosurgery		728	728
Eye Surgery		695	695
Gynecology	6	424	430
Plastic Surgery	5	338	343
Ear, Nose and Throat	4	303	307
Total	**881**	**3709**	**4590**

Table 7 – Number of inpatients assumed suitable for admission short before surgery

3.5 Performance indicators

Based on the performance indicators of the current situation, some Lounge specific indicators are added, as they together bundle all performance indicators of the new situation. The introduction of the Lounge will change operation, therefore it will change the way performance is measured.

3.5.1 Patients Moved to Ward

The first performance indicator added is the Patients Moved to Ward. All patients still present when the outpatient ward closes will be moved to a ward. Patients that cannot be discharged when the outpatient ward closes will be staying for a night at the hospital. Although the number of patients moved to a ward is not being registered in dashboards it is an important performance indicator for the process of the Lounge. The number of Patients Moved to Ward mainly depends on the *closing time* of a department. When a department closes earlier, more patients have to be admitted as they have not finished their recovery.

3.5.2 Patients treated at holding/recovery

A second Lounge performance indicator is the patients treated at holding/recovery. As stated in the objective of this thesis the capacity of the Lounge has yet to be determined. Therefore if the Lounge's capacity limit is reached, patients will be admitted or recovering at the holding/recovery instead. As these patients have been treated at holding/recovery they will be counted as such. The number of patients treated at holding/recovery mainly depends on the capacity of the Lounge and the number of Lounge patients that have to be treated.

3.5.3 Overview of all performance indicators

In Figure 15 an overview of all the performance indicators is displayed. Within this figure it is also shown where in the care trajectory this performance indicator is measured.

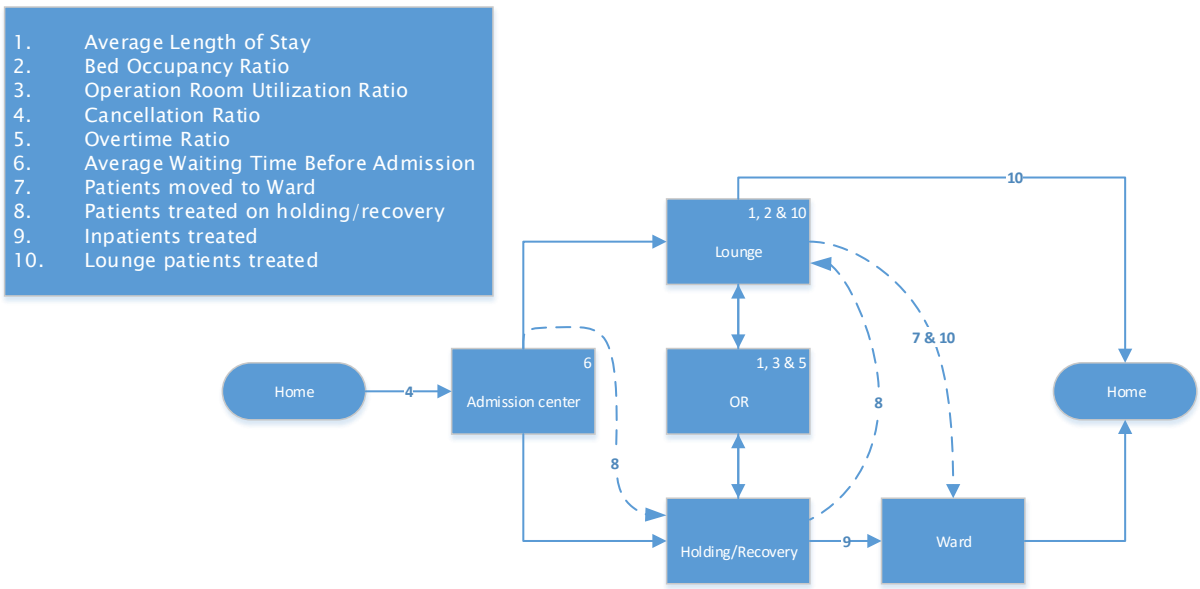


Figure 15 – Location of 'measurement' performance indicators

An overview of the performance indicators and their performance based on historical data and the patient group sizes after reallocation is given in Table 8.

Performance Indicator	Data 2014
Average Length of Stay	8:27:08
Bed Occupancy Ratio	45%
Operation Room Utilization Ratio	80%
Cancellation Ratio	1.7%
Overtime Ratio	5.5%
Average Waiting Time Before Surgery	1:20:11
Patients Moved to Ward	172
Lounge Patients Treated at Holding/Recovery	0
Lounge Patients Treated	4596
Inpatients Treated	4590

Table 8 – Performance data

The number of Lounge Patients and Inpatients Treated are determined after reallocation of specialties. The other performance indicators are of the outpatient ward of OLVG West in 2014 with sample size 3041.

3.6 Disadvantages of the Lounge

This section discusses the disadvantages of the Lounge compared to the current situation of OLVG West. Although the Lounge seems to be a suitable solution for all problems in the problem statement the Lounge also has its downsides.

As patients change at their bedside patients might experience a lack of privacy according to outpatient ward nurses. Even though curtains will be used to create a separated area, patients

might feel an absence of privacy as there is no private room to turn to. Privacy is a very sensitive subject and can be more important for patients with non-western cultural backgrounds. If a patient feels the need to have some privacy there is no other option than to close the curtain.

Second, coherent to the lack of privacy when changing, patients might experience a lack of privacy when staying in a room with all other patients. As for example some cultures do not allow men and women lying in the same room, it is "impossible" for them to have their treatment in the Lounge, as all beds in the Lounge are in the same room.

Third, although the Lounge should have a relaxing atmosphere patients that just had surgery will be brought back which can cause disturbance. Also in case of post-surgical bleeding or other medical discrepancies a hectic situation can exist. The Lounge causes higher concentrations of patients within the OR complex. This might cause disturbances in the general flow of processes within the OR complex, more employees using the breakroom for example. The patient will be transported to the Lounge straight after surgery instead of a recovering at the holding/recovery first. This might scare or cause inconvenience for other patients that are waiting to have surgery.

Next, the patients might feel like not having their own space if it is decided that the Lounge will have flexible chair spaces instead of dedicated ones. This might cause the patient feeling uncomfortable as he sees another patient sitting at the spot where he was admitted.

In addition, patients are not allowed to bring family to the Lounge because it will become too busy otherwise. This can be a disadvantage for both patient and his family and/or partner as they both have to wait alone. Some patients prefer having their family with them for comfort and distraction but that will not be possible at the Lounge.

However, despite the disadvantages the Lounge is still considered to be a good option as the advantages are overruling the disadvantages as the Lounge makes it possible to solve the prescribed problem statement of this study.

3.7 Conclusion

This chapter describes the characteristics of the proposed Lounge based on literature and best practices within other hospitals using elements of the Lounge. The following questions and corresponding answers conclude this chapter:

I. How does the design of the Lounge improve the performance?

It is most likely that the design of the Lounge increases patient friendliness, although it is not included in the performance. The healing environment appears to have a positive effect on the recovery time of patients which improve the performance. The introduction of a Lounge chair instead of a bed improves performance as it might be used as surgery table as well.

II. How does the layout of the Lounge improve the performance?

The layout of the Lounge will improve the performance as it will be located in the OR complex. The variability on transport time will be eliminated as the patients will already be in the OR complex. It is possible for the specialist to discharge patients between surgeries which will reduce the Average Length of Stay. New control rules have to be introduced to decrease the Average Waiting Time Before Surgery.

III. Which patients are suitable for the Lounge?

Specialists have determined whether a procedure is suitable for the Lounge or not. General conditions for patients to use the Lounge are elective, adults and ASA class 1, 2 and 3. Exceptions can be made as it is the specialist his responsibility to determine whether a patient will be suitable for the Lounge.

IV. What are the Lounge specific performance indicators?

There are two additional Lounge performance indicators added in this chapter; Patients Moved to Ward and Outpatients treated on holding/recovery

1. Average Length of Stay
2. Bed Occupancy Ratio
3. Operation Room Utilization Ratio
4. Cancellation Ratio
5. Overtime Ratio
6. Average Waiting Time Before Surgery
7. Patients Moved to Ward
8. Lounge Patients Treated at Holding/Recovery
9. Inpatients treated
10. Lounge Patients Treated

V. What are the disadvantages of the Lounge?

There are some issues that need attention in the development process of the Lounge. The main issues are privacy, disturbances and no visitors. Although these issues need attention they can be solved by having patients properly informed and taking them into account in the design of the Lounge.

Based on these conclusions the Lounge is analyzed as a suitable option in literature and other hospitals, therefore a model of the Lounge can create more insight in the opportunities the Lounge can bring to OLVG West.

4. Analytical model of the Lounge

In this section the process of modeling The Lounge will be explained. Starting with a model selection in Section 4.1, in which it is analyzed which model applies best to the research objective. Section 4.2 describes the theoretical framework for the chosen model, thereafter the steps to build the model will be explained. Starting with Step 1: Problem definition in Section 4.3. After that Step 2: Model Construction, will be analyzed in section 4.4. The last step is Step 3: Experimental design and approach and will be discussed in 4.5. After that a concluding paragraph will answer the sub questions of this chapter in Section 4.6.

4.1 Model selection

This section discusses the selection for a model and corresponding arguments. Literature provides numerous options for the application of models. These options are now analyzed to discuss which model fits this study best.

Assessing modeling options, the objective of this thesis regarding the model has to be kept in mind: "*To determine the required capacity of the Lounge and develop and assess interventions to optimize the performance of care trajectories suitable for the Lounge.*"

All desired factors should be able to model, to create an accurate reflection of reality. As otherwise the model might be incomplete and does not meet the demands of the stakeholders. The level of detail of the output requires the model to include not only system interactions, but also detailed answers on changes, to prevent minimal insight and trend analysis. The level of insight should be at operational level as this shows how the system responds to different circumstances. Also the availability of historical data plays an important role when choosing a model.

As modeling has already been frequently done in health care, key groups of model types can be distinguished (Brailsford, Harper, Patel, & Pitt, 2009). There are three categories; qualitative models, mathematical models and simulation models. (Naseer, Eldabi, & Young, 2010) All three models will be discussed in order to decide which suits best with this study.

4.1.1 Qualitative models

Qualitative models like cognitive models and process mapping are analyzed. These models are used to determine the origin of a problem or to understand how a specific process can be optimized, in which it analyzes processes or methods to determine what can be improved. Taking the main objective in mind, the Lounge has yet to be built. Therefore it would be hard to use qualitative models to determine the capacity and develop and assess interventions for optimization.

4.1.2 Mathematical models

Mathematical models, like linear programming, would be a suitable technique to determine the capacity of the Lounge. Although some experiments could be performed and optimization techniques can be applied, it does not meet the level of detail that is preferred in this study (Naseer et al., 2010). In addition, mathematical models are used for the optimization of 'simple' flows where an interacting effect between departments cannot be taken into account.

Taking in mind the objective this is considered a method that can be used. However as the Lounge does not yet exist a drawback is that the 'what-if' scenarios and additional information of interaction between scenarios cannot be analyzed using this model.

A specific mathematical approach called Queuing theory, shows some promising features to fit this study. Describing the model for this study in short, will show the motivation not to use the model. First, in terms of production scheduling, we can identify the Lounge and patients as a multi-stage, multi-machine and multi-product system. Thereby the stages are Lounge and OR. The machines are the Lounge chairs and ORs, and the products are patients. However instead of having a flow through the system, as is normal within queuing theory, the patients of this study return to the first stage without having to wait. Back in first stage, the processing time is different. As the input for the system is deterministic, it is already known how many patients will arrive. Because the Lounge opens and closes with no patients present, no steady state is achieved. Therefore queuing theory will not be a suitable method for this study.

4.1.3 Simulation

The last model of interest that is discussed is Simulation modeling. As one of the key findings Bailsford (2009) states that; "Simulation methods are prominent in planning and system/resource utilization."(Brailsford et al., 2009). To invigorate this statement Jun, Jacobson & Swicher (1999) define simulation as the most appropriate tool to make a capacity calculation. The designed simulation tool allows a more accurate interpretation of the current usage of hospital resources. This is achieved by a flow model of the patient routing through the hospital. Simulation provides two important aspects for hospital management one is to create insight in the complex hospital system and another important aspect is to apply 'What-if'-scenarios without interrupting daily operations (Jun, Jacobson, & Swisher, 1999). Therefore, we think that the best suitable modeling choice for this case and the OLVG would be simulation.

As there are various types of simulation Naseer et al. (2010) developed a tool kit to determine which model fits best given certain in- and outputs. An example is stochastic simulation, a specified model of stochastic simulation is Monte Carlo Simulation. This model does not fit our needs as this simulation model lacks a level of detail according to Naseer et al. (2010). Our model needs to provide high level of insight and detail outputs, therefore we find that only three types of simulation models meeting these requirements; Agent Based Simulation, Hybrid Simulation and Discrete Event Simulation.

Agent Based Simulation (ABS) contains an autonomous agent that adjust its behavior according to its environment. An application could be the simulation of an OR planner that adjust its scheduling rule according to past experience. This is not the type of simulation we are looking for as within this study it is not about the OR planner, or any other agent, but about the process. Next is the Hybrid Simulation, this is a mix of discrete event and continuous simulation. This could be a suitable model as it can meet all the modeling needs. However the continuous simulation is not asked for in this study and would therefore unnecessarily increase of the model's complexity. This leaves Discrete Event Simulation (DES), the type of modeling we think would suit best with this study.

4.1.4 Discrete Event Simulation

DES is a high appreciated modeling method and numerous examples of DES can be found in healthcare (Vissers, 1995; Groothuis & van Merode, 2000; Shahani, 2002; Bailford et al., 2009). In DES the operation of a system is represented as a chronologically-linked sequence of events, in order to describe flows of people and/or material and explore the effects of any changes. DES is best suited when it analyzes systems modelled as a series of queues and activities, a clinic for example. Individual patients are modelled as they pass through the system, allowing variability and uncertainty in behavior. This allows potential impacts to the system or patients to be estimated, it can help answer 'what-if' questions, before changes are made to the real system.

DES can be used for (re)designing a system at operational or strategic levels. Other applications of DES that are useful for this study: scheduling, resource allocation, waiting list management and patient pathway design. The output of DES consists of a quantitative estimation of the system performance. These applications correspond with the objective of this thesis. We are dealing with a new system design, with new constructed patient pathways, and newly constructed patient groups of which a detailed performance analysis is required. The level of detail and insight required are high which is why DES is the best suitable model. In addition, the circumstances that are to be analyzed can be experimented as 'what-if' scenarios. To create a sound DES model a proper theoretical framework has to be obtained.

4.2 Discrete Event Simulation

This subsection discusses the theoretical framework of a Discrete Event Simulation (DES). A widely known way to create a DES model is the approach of Law and Kelton (2000). "Discrete-events simulation concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at spate points in time." (Law & Kelton, 2000). The steps to create a sound DES are shown in Figure 16. These steps will be performed to construct a discrete event simulation model for the Lounge and will be discussed respectively in the coming section.

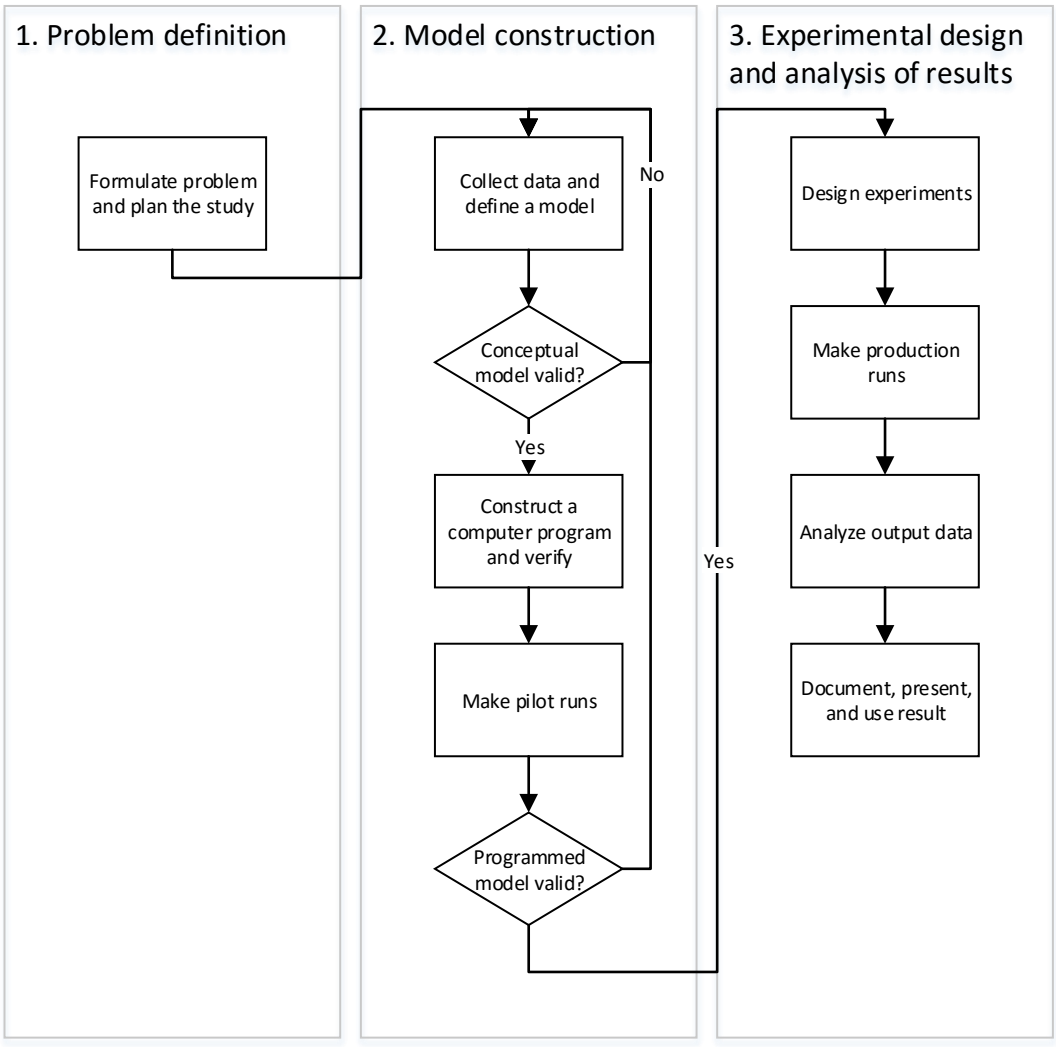


Figure 16 – Steps of a sound simulation study, adopted from (Law & Kelton, 2000)

4.3 Step 1 of DES: Problem definition

The objective of this simulation study is: "*To determine the required capacity of the Lounge and develop and assess interventions to optimize the performance of care trajectories suitable for the Lounge.*" in accordance with the objective of this study.

The performance of the Lounge depends on a variety of performance indicators as discussed in Section 3.5

4.4 Step 2 of DES: Model construction

4.4.1 Input parameters

Based on Section 3.3 it is concluded how many, but also which, patients will be using the Lounge. Historical data of 2014 is extracted from the Electric Health Record (EHR) and the operational aspects of the model are obtained through Lounge project group meeting.

4.4.1.1 Determine theoretical distribution

Theoretical distributions can be determined based on historical data in case of surgery durations, transport duration and inter OR duration. In Appendix F the method Pearson's Chi Square Test is explained. According to (May, Strum, & Vargas, 2000) a lognormal distribution can be expected in case of surgeries. A positive fit with the lognormal was found as well for transport duration and inter OR duration. Reason for the lognormal distribution for transport and inter OR durations could be because of all durations are associated.

4.4.1.2 Changing clothes and admission Processing Time

The patient has to change into surgical outfit after he is admitted. The changing time is determined by consulting nurses and is estimated at approximately five minutes. As the patient has to put his clothes and valuables in a locker and move to his chair the duration of this process is estimated at approximately fifteen minutes. As it has yet to be determined whether a patient will change at his bed or in a changing room, where the lockers might be situated, the fifteen minutes will be used as time the patients spends in the changing room.

4.4.1.3 Surgery Processing Time

There are many procedures, as can be seen in Table 9. As there are several different types of surgeries most of the procedures occur too few to determine a significant theoretical distribution.

Specialties	Types of surgeries
Orthopedics	350
General Surgery	276
Gynecology	95
Ear, Nose and Throat	39
Plastic Surgery	76
Eye Surgery	29
Neurosurgery	22
Total	**887**

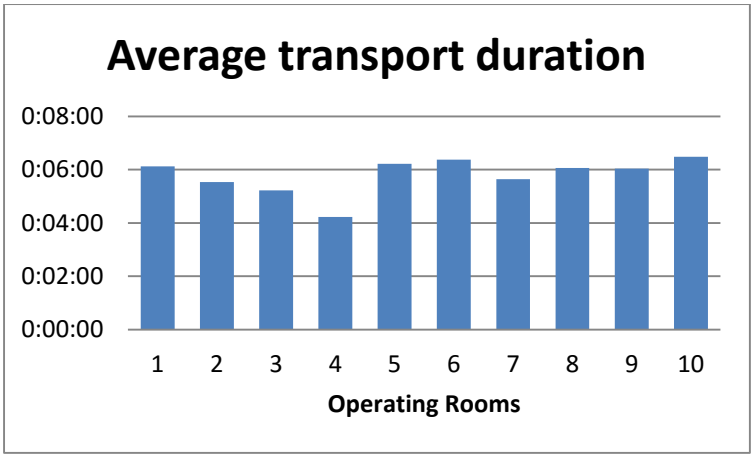
Table 9 – Types of surgeries per specialty suitable for Lounge 2014

To solve this problem the surgery processing times will be clustered. Clustering surgeries is necessary to have a realistic reflection of reality. The most frequent occurring surgeries with sample sizes between 60 and 70 times, can be fitted to their own distribution to keep as much detail as possible.

All other distribution are clustered according to their total length of stay which indicates the intensity of a surgery and the duration accordingly. Each specialty has a collection of clusters which can be found in Appendix C. These clusters apply for surgery processing times but will be used for other purposes as well.

4.4.1.4 Transport times

The transport time from OR to Lounge can be determined using the current transport time from OR to holding/recovery. The distance between holding/recovery and ORs and Lounge and ORs is similar as is illustrated in the concept construction drawing in Figure 13. In 2014 ten ORs are operational. The distribution of the transport times will be determined.



Graph 3 – Average transport time from OR to Holding/Recovery

As can be seen in Appendix C it was not possible to determine a significant fitted distribution for operating room eight. A realistic distribution is estimated using the distributions of operating room seven and nine which are located next to nine on each side. The mu and sigma are interpolated and are respectively 1.61 and 0.56.

4.4.1.5 Preparation processing time

The processing time for preparation at the Lounge pre-surgery depends on the type of anesthetic that is used. Table 10 is obtained by consulting anesthetists, in which the duration for administering anesthetic and how long it takes to create the desired effect is listed. Note, this is the minimum duration a patient will need to be seated in his Lounge chair for his preparation.

Anesthetic	Duration
Narcosis	0:05:00
Plexus	0:30:00
Spinal	0:15:00
Sedation	0:05:00
Local	0:05:00
Block	0:30:00

Table 10 – Duration for administering anesthetic and taking effect

4.4.1.6 Lounge post-surgery processing time

The Lounge post-surgery processing time is constructed combining the stay of a patient at the recovery and at the outpatient ward. A patient is entitled to a recovery duration of at least half the time of his surgery as this is legally defined. A document is provided containing the estimate duration of stay at the outpatient ward for each procedure. This document is constructed in collaboration with nurses at the outpatient ward. The formula for the minimum length of stay at the Lounge post-surgery is shown in Equation 4.

$$Length\ of\ Stay\ Lounge\ post-surgery = \frac{1}{2} * duration\ surgery + \ stay\ outpatient\ ward$$

Equation 4 – Length of Stay Lounge post-surgery

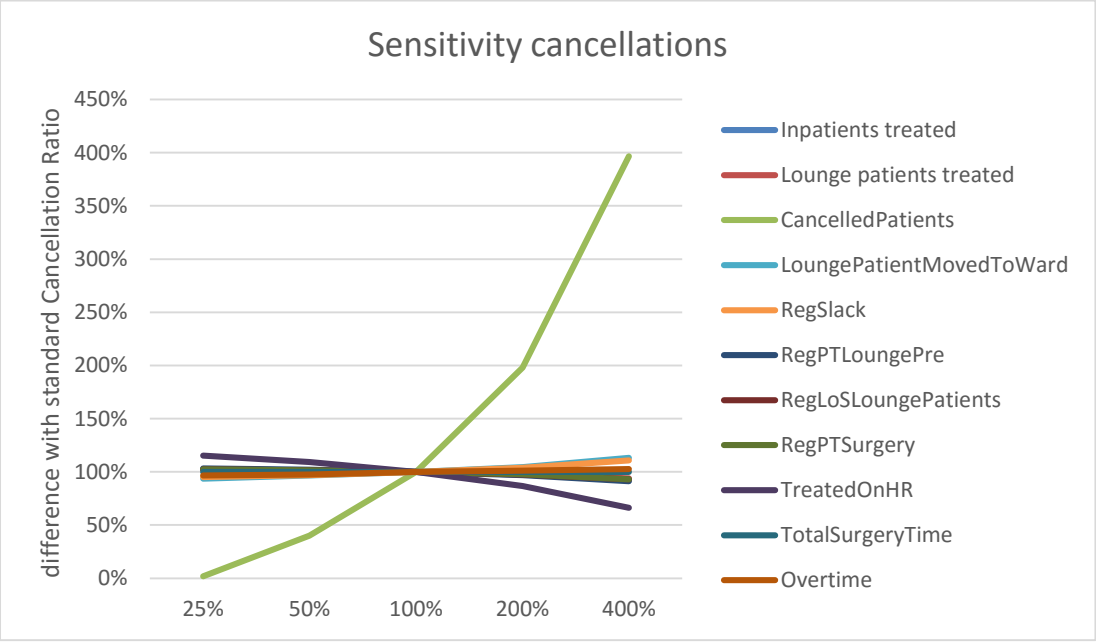
4.4.1.7 Cancellation Ratio

The Cancellation Ratio is the percentage a patient cancels surgery at the start of the day after being scheduled. Reasons for cancellations are patients that have eaten short before surgery, patients not showing up or other negative indications for surgery. Table 11 shows the Cancellation Ratio per specialty.

Specialty	# cancellations	# of patients	Cancellation Ratio
Eye Surgery	16	811	1,97%
Ear, Nose and Throat	14	908	1,54%
General Surgery	38	3011	1,26%
Plastic Surgery	8	634	1,26%
Orthopedics	22	1051	2,09%
Gynecology	30	1814	1,65%
Neurosurgery	24	778	3,08%

Table 11 – Cancellation Ratio per specialty

The ratio is calculated dividing the number of cancellation per specialty by all surgical patients of OLVG West in 2014. We assume that the Cancellation Ratio for the Lounge patients will be similar to the Cancellation Ratio of all surgeries. As it is not registered if a cancellation is of an outpatient or inpatient it is not possible to obtain a more detail ratio. It is also assumed that the patient's surgery is rescheduled on another day. To understand the importance of the accuracy of the Cancellation Ratio a sensitivity analysis is performed of which is shown in Graph 4



Graph 4 – Cancellation Ratio sensitivity analysis

The Cancellation Ratio is positively correlated whit the cancelled patients. It is negatively correlated with the patients not treated on holding/recovery which is logical as if more patients are cancelled less Lounge patients have to move to the Lounge.

If the Cancellation Ratio would be higher than calculated, 200% for example than it would result in an error for patients treated on holding/recovery. The difference between 100% and 200% is significant (a=0.05) with a mean of 30 patients fewer treated on holding/recovery in case of 200%. If however the Cancellation Ratio would be lower, 50% for example there would be no significant difference with the number of patients treated on holding/recovery. There is no difference for the other outputs not mentioned in this paragraph.

From this sensitivity analysis is concluded that the Cancellation Ratio would only affect the number of patients treated at holding/recovery.

4.4.1.8 Inter-surgery time

The inter-surgery time is the time between surgeries that is used for cleaning and preparation. The OR cannot be occupied during inter-surgery time as it has to be cleaned and prepared for the next surgery. The inter-surgery time depends on type of specialty and on having two different consecutive type of surgeries or the same. In Appendix C the inter-surgery times are elaborated. These average inter-surgery times are verified by the OR complex manager as realistic.

4.4.1.9 Recovery time inpatients

For inpatients the recovery time is determined using historical data. As the recovery time for inpatient is similar to the times in the past the surgery cluster distributions will be used. This way it is also possible to assign a recovery time to patients being allocated from East to West. The distribution can be found in Appendix C.

4.4.2 OR schedule

The *OR schedule* is constructed at start of the day. There are three experimental schedules: random, outpatient first, and outpatient and longest recovery time first.

First the number of ORs required for each specialty is estimated using the theoretical distributions of each surgery and quantity of each cluster. These calculation are made based on the article of (Hans, 2012). A surgery slack factor of 0.84 is used to determine the number of required ORs after reallocation of specialties. The division of ORs is shown in Table 12.

	Monday	Tuesday	Wednesday	Thursday	Friday	Total
CHI	2	2	2	2	2	**10**
GYN	1	1	1	1	1	**5**
ENT	1	1	0	0	0	**2**
NEU	1	1	1	1	0	**4**
EYE	0	0	1	0	1	**2**
ORT	4	4	3	3	3	**17**
PLA	0	0	1	1	1	**3**
Total	**9**	**9**	**9**	**8**	**8**	**43**

Table 12 – Division of ORs

Now the number of ORs is known the input for the scheduling program will be created using Excels Visual Basic Application. As the main objective of this thesis is to determine the capacity of the Lounge, the sample sizes of the clusters are important because they should be equal to the sample sizes from historical data.

To obtain an equally distributed division of procedure the random function will used and will pick the frequency of a cluster. Having created similar sample sizes the next Step is determining the anesthetic and recovery time. This will be determined similar to previous procedure using the historical frequencies of division with the random function. The in- and outpatient, type of anesthetic and recovery duration are similar to the data of 2014. Appendix D shows the constructed sample sizes compared to the historical sample sizes. Results show that 11 clusters have a difference of more than 10% which account for 18% of the patients. The majority of clusters are within range.

Besides having a positive fit according to the Pearson's chi square test an additional test is performed. For all clusters the sum of surgery processing times will be compared with that of fifty runs for each patient in a cluster. For all clusters, the average of the fifty runs of each patient is summed. If the distribution is correct the simulated value is similar to the actual sum. The results are shown in Appendix D. As the total number of patients is a 100% match to those of 2014 and total expected surgery time a 97% match, these clusters and quantities will be used for simulation.

A Borland Delphi project file "RobustSurgeryLoading.dpr" constructed by E.W. Hans is used to create *OR schedule sequences*. The constructed sample can be uploaded in the program after which scheduling rules can be applied. The day and OR on which patients are operated and the sequence in which patients are operated, are determined for the three types of schedules. This schedule will be used as input for the Lounge simulation model.

As only a sequence is known, the OR, admission, and registration schedule is constructed at the start of the day. Similar to the current situation the first patients scheduled for surgery are registered at 7:00 in the admission center and the second patients at 7:15. The first patients will be admitted at 7:15 after which his surgery starts at 7:50. The surgery times of the other patients depend on the expected surgery and inter surgery time. The admission time depends on the type of anesthetic and chosen anesthetic slack and the registration time on the chosen slack for registration.

4.4.3 Model description

This subsection discusses the model description. The upper layer of the model consist of the Lounge, Holding/Recovery, Admission Center, Home, Operating Rooms, OR Complex Manager and basic configuration tools and methods. The model is shown in Figure 17 and is attached to the thesis.

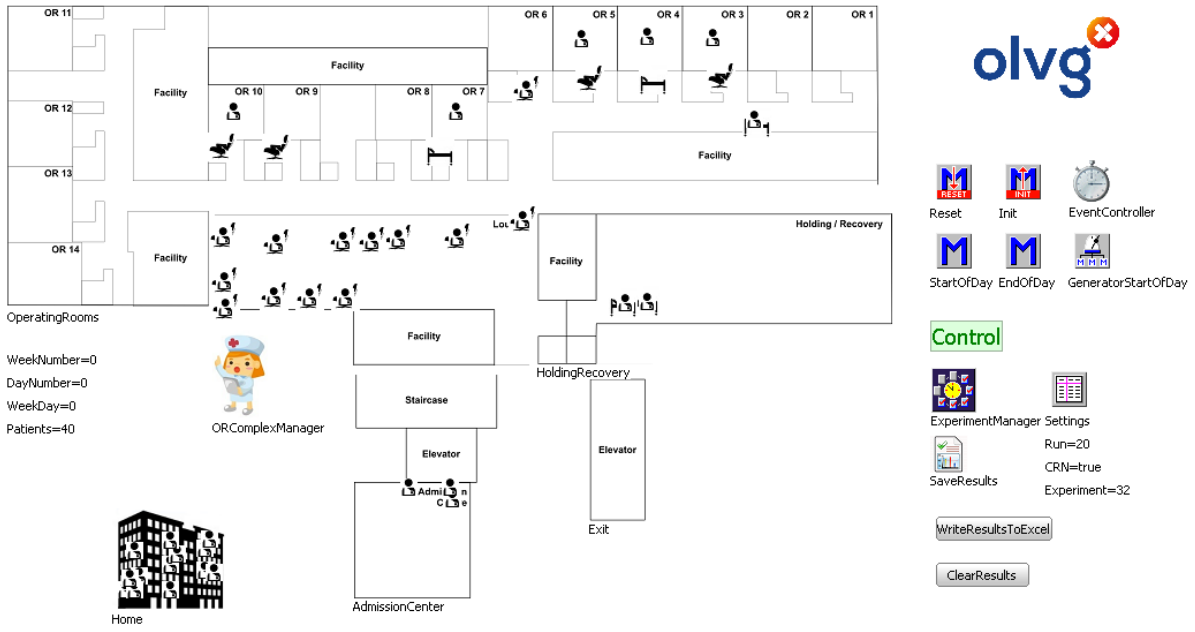


Figure 17 – Lounge simulation model

The patient will start at home and registers at the admission center at the time of registration according to schedule. Cancelled patients will not enter the admission center as they are unfit for admission. The patient is admitted either to Lounge or holding/recovery according to schedule. When the OR is ready and empty, and the patient's preparation is finished he will be transported to the OR. After surgery the patient is brought back to the Lounge or holding/recovery. If the Lounge is full patients prior to surgery will be admitted at the holding/recovery. Lounge patients that had surgery will be brought to the holding/recovery if the Lounge is full. They will be moved to the Lounge is there is space available.

An overview of the departments and methods can be found in Appendix G.

4.4.4 Assumptions

This subsection discusses assumptions that are used in the model. All assumptions are verified with stakeholders.

- Special emergency OR so no interference with elective program.
- Patient will always be treated in the planned OR.
- No outpatient become inpatients because of a medical reasons.
- All patients will be moved to ward if department, Lounge or holding/recovery, closes
- Patients will not be sent to surgery after 15:45.

4.4.5 Outputs

- Total number of patients in the model
- Number of inpatients treated
- Number of Lounge Patients Treated
- Number of cancelled patients
- Patients Moved to Ward
- Time slack, waiting time in admission center
- Time at Lounge pre surgery
- Length of Stay
- Number of Lounge Patients Treated at Holding/Recovery
- Total surgery time
- Number of surgeries overtime

The number of patients present will be saved as well to know how many patients are present at a specific time of the day. This is monitored for the admission center, Lounge and holding/recovery from the start of the day at 7:00 till closing time of the department.

These outputs are used to obtain results for the performance indicators as discussed in Section 2.2.

4.4.6 Validation

This subsection discusses the validation of the model. The face validity of the model is tested by showing and discussing the model with stakeholders. As the face validity indicates the extent in which the model does what it supposed to do, the stakeholders have a leading role in this. By showing the model to the stakeholders and explaining how the duration, numbers and flow have been constructed they can validate if the model is realistic.

As the Lounge is not built and operational yet, it cannot be compared to a real-life situation. This makes it harder to know whether the model is valid but in according to the stakeholders the validity is sufficient.

4.5 Step 3 of DES: Experimental approach and design

4.5.1 Terminating simulation

The simulation model can be classified as a terminating simulation, meaning that at the end of the day the work stops after which the system is cleared of all content. The end of the day is marked when the Lounge and holding/recovery are closed. There is no steady state in a terminating simulation therefore no warmup period has to be determined.

4.5.2 Experimental factors

Experiments are performed in order to assess interventions to optimize the performance of the Lounge. These interventions are performed altering the experimental factors discussed with stakeholders to make sure the results will be useful.

4.5.2.1 Number of Lounge spots

A Lounge spot is where a patient will receive preparation before surgery and where he will recover after surgery. The *number of Lounge spots* indicates the maximum number of patients that can be present at the Lounge.

4.5.2.2 OR schedule sequence

Three type of OR schedules are used for experiments: Random, Longest Recovery First (OFLRF) and Outpatient First (OF). Outpatients and inpatients are scheduled randomly in the Random schedule. In the OF schedule outpatients are scheduled first in the OR sequence. In the OFLRF schedule outpatients with the longest expected recovery time are scheduled first in the OR sequence.

4.5.2.3 Closing time Lounge

When the Lounge is closed all Lounge patients still present will be moved to a ward. If Lounge patients are still having surgery they will be moved to the holding/recovery.

4.5.2.4 Flexible or dedicated spots

Within the model it is possible to use *dedicated* or *flexible Lounge spots*. The patient will return to the same spots as before surgery, in case of dedicated Lounge spots. The spot is not used for other patients during surgery of the patient. In case of flexible spots, The Lounge spot will become available for another patient when the patient goes into surgery, in case of flexible spots. After surgery the patient can be assigned to another Lounge spot.

4.5.2.5 Slack on registration

The *slack on registration* is the additional time OR planners use to make sure a patient is already present, in case the OR schedule is brought forward or to replace a cancelled patient. Figure 18 illustrates the position in a patient's time schedule of the *slack on registration*.

4.5.2.6 Slack on preparation

The *slack on preparation* is the additional time OR planners use to make sure a patient is already prepared, in case the OR schedule is brought forward. Figure 18 illustrates the position in a patient's time schedule of the *slack on preparation*.

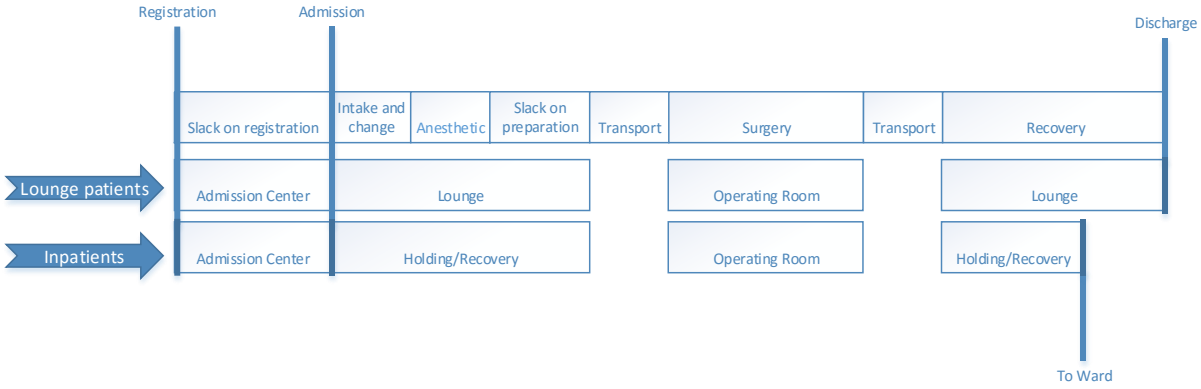


Figure 18 – Overview time schedule patient process

4.5.3 Starting point

Before experiments are performed a 'starting point' has to be determined. The patient group as described in Appendix D will be used as input. The starting point settings are shown in Table 13.

Experimental factor	Setting
Number of Lounge spots	12
OR planning sequence	Random
Closing time Lounge	18:00
Chair spaces	Dedicated
Slack on registration	0:30 hour
Slack on preparation	0:15 hour

Table 13 – Starting point

4.5.3.1 Significant number of runs

The starting point is used to determine the significant number of runs. The significant number of runs is determined using the method described by (Law & Kelton, 2000). 20 runs per experiment is sufficient to make sure the results are significant, a more detailed method explanation is given in Appendix F.

4.5.4 Optimal setting

During the optimal setting experiment only one experimental factor at a time is altered. An overview of the experimental factors that will be altered is shown in Table 14. The effect of each experimental factor on the performance will be analyzed and an impression of the optimal setting (OS) will be obtained.

Experimental factor	Setting
Number of Lounge spots	12/14/16/18
OR schedule sequence	Random/ OF/ OFLRF
Closing time Lounge	18:00/18:30/19:00/19:30/20:00/20:30/21:00
Chair spaces	Dedicated/Flexible
Slack on registration	2/1:30/1/0:30 hour
Slack on preparation	1/0:45/0:30/0:15 hour

Table 14 – First stage experiments

4.5.5 Combined optimal setting

In this experiment the impression of the optimal settings obtained in the first stage as is shown in Table 15 will be combined. As the experimental factors affect each other, the combined optimal setting (COS) is found by varying the factors in a small range around the value found in the first stage. According to the stakeholders the maximum *number of Lounge spots* possible is 18.

Experimental factors	Setting	Fixed/variable
Number of Lounge spots	18	Variable
OR schedule sequence	OF/OFLRF	Fixed
Closing time Lounge	19:30/20:00/20:30	Variable
Chair spaces	Flexible	Fixed
Slack on registration	1/1:15/1:30	Variable
Slack on preparation	0:05/0:10/0:15	Variable

Table 15 – Second stage experiments

4.5.6 Increased number of ORs

This experiment will create insight in the performance while it deals with more patients. The COS, found in the combined optimal setting experiment, is used as shown in Table 16.

Input/control rule	Setting
Number of Lounge spots	18
OR schedule sequence	Outpatient first
Closing time Lounge	20:00
Chair spaces	Flexible
Slack on registration	1:30 hour before admission
Slack on preparation	0.15 hour before surgery

Table 16 – Combined Optimal Setting

As an expansion of ORs is planned at OLVG West, it is interesting to examine how this would affect Lounge performance. A new patient sample group is constructed based on three additional ORs and can be found in Appendix E. One of these ORs will be used for emergency patients and one as buffer for all other specialties leaving twelve ORs for the newly constructed patient group.

4.5.7 Without Lounge

The goal of this experiment is to analyze how the performance changes if the Lounge is closed. The Lounge will be closed during this experiment and all surgical patients will be admitted short before surgery at the holding/recovery. The COS is used for the *slack on registration* and *preparation*.

4.5.8 Number of Lounge spots

The goal of this experiment is to examine at what the optimal *number of Lounge spots* is. Using the COS, the *number of Lounge spots* will be increased to analyze at which point the performance does not improve anymore. The *number of Lounge spots* will be altered between twelve and twenty-six, with two spots at a time.

4.5.9 Inpatients admitted at Lounge

The goal of this experiment is to analyze how the performance is affected if all inpatient are admitted at the Lounge. During the development of the Lounge concept in OLVG West, questions rise whether it is an appropriate idea to admit inpatients at the holding/recovery.

After admission inpatients will be prepared for surgery and wait for their surgery at the Lounge. After having surgery inpatients are brought to the holding/recovery. The *closing time*

is altered and a new schedule is made: Inpatient First schedule. The configurations are shown in Table 17.

Input/control rule	Setting
Number of Lounge spots	18
OR schedule sequence	Inpatient first
Closing time Lounge	19:00–23:00 (0:30 interval)
Chair spaces	Flexible
Slack on registration	1:30 hour before admission
Slack on preparation	0.15 hour before surgery

Table 17 – Experiment setting: inpatients admitted at Lounge

4.5.10 Closing times with COS

The goal of this experiment is to examine how the performance is affected, by *altering the closing time* of the Lounge under combined optimal settings.

Input/control rule	Setting
Number of Lounge spots	18
OR schedule sequence	Outpatient first
Closing time Lounge	18:00/19:00/20:00
Chair spaces	Flexible
Slack on registration	1:30 hour before admission
Slack on preparation	0.15 hour before surgery

Table 18 – Experiment setting: closing times with COS

4.5.11 Slack on registration with COS

The goal of this experiment is to analyze how the *slack on registration* of 1:00 and 1:30 affects the performance under combined optimal setting.

Input/control rule	Setting
Number of Lounge spots	18
OR schedule sequence	Outpatient first
Closing time Lounge	20:00
Chair spaces	Flexible
Slack on registration	1:00/1:30 hour
Slack on preparation	0:05 hour

Table 19 – Experiment setting: slack on registration with COS

4.5.12 COS with slacks on 0:05

The goal of this experiment is to examine how the performance is effected by a *slack on registration* of 0:05 and *slack on preparation* of 0:05.

Input/control rule	Setting
Number of Lounge spots	18
OR schedule sequence	Outpatient first
Closing time Lounge	20:00
Chair spaces	Flexible
Slack on registration	0:05 hour
Slack on preparation	0:05 hour

Table 20 – Experiment setting: slacks on 0:05 with COS

4.5.13 COS with random schedule

The goal of this experiment is to analyze how the performance is effected by using a random OR schedule.

Input/control rule	Setting
Number of Lounge spots	18
OR schedule sequence	Random
Closing time Lounge	20:00
Chair spaces	Flexible
Slack on registration	0:05 hour
Slack on preparation	0:05 hour

Table 21 – Experiment setting: random schedule with COS

4.6 Conclusion

This chapter describes a motivation of the chosen model for this study, as well a specified analyzation of the model is given. The following questions and corresponding answers conclude this chapter:

I. How can we model the Lounge?

The Lounge can be modeled using Discrete Event Simulation. In DES the operation of a system is represented as a chronologically-linked sequence of events, in order to describe flows of people and/or material and explore the effects of any changes. In addition, 'What if' scenarios can be performed to evaluate the effect of specific circumstances.

II. Which input parameters do we use?

Input parameters used is the model are: changing clothes and admission processing time, pre-surgery processing time, transport time, surgery processing time, post-surgery processing time, Cancellation Ratio, inter-surgery time and recovery time inpatients. A patient group similar to the suitable group described in previous chapter is used to create an OR schedule.

III. What experimental factors do we use?

Experimental factors used in this thesis are: *number of Lounge spots*, *OR scheduling sequence*, *closing time* of the Lounge, *flexible or dedicated spots*, *slack on registration* and *slack on preparation*. These experimental factors will be altered to find the Combined Optimal Setting(COS). Using the COS additional experiments are performed.

This chapter gives an overview of the modelling possibilities of the Lounge, the experiments done and the results will be discussed in Chapter 5.

5. Results

This chapter describes the results of the experiments and is divided in two stages to find the combined optimal setting and additional experiments to analyze the performance of the Lounge under different circumstances. The first stage is described in Section 5.1. This stage consists of experiments taking into account only singular experimental factors, to analyze the relationship between experimental factors and the performance. Stage two is described in Section 5.2 and consists of experiments that contain a combination of multiple experimental factors. This is to obtain the combined optimal setting. After finding the combined optimal setting, several experiments are done to measure the Lounge performance under different circumstances in Section 5.3. Thereafter, answers to the sub questions of Chapter 5 will be provided in Section 5.4.

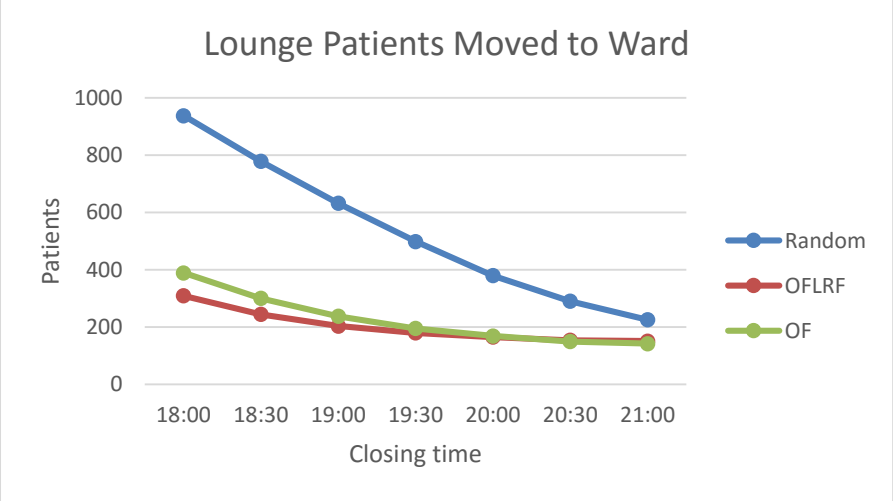
5.1 First stage results

The first stage initially included 54 experiment. The simulation model blocked doing the experiment with an hour *slack on preparation*, therefore this experiment is excluded, as inpatients that had surgery could not return to the holding/recovery because it was full. This situation is undesirable therefore the maximum *slack on preparation* will be forty-five minutes. Excluding this experiment brings the total number of experiment to 51. Only outcomes that differ are discussed during the first stage.

Goal of the first stage is to determine how the experimental factors affect the performance indicators, therefore all results are discussed according to experimental factors. Only the performance indicators that were affected by experimental factors are discussed. A full overview of all results can be found in Appendix E. The range of interest of experimental factors is determined as input for the second stage.

5.1.1 Closing time

As can be seen in Graph 5, the *closing time* has more impact on the number of patients that move to a ward in case of the Random schedule than the OF or OFLRF schedule. Both the OF and OFLRF schedule flatten from 20:00.

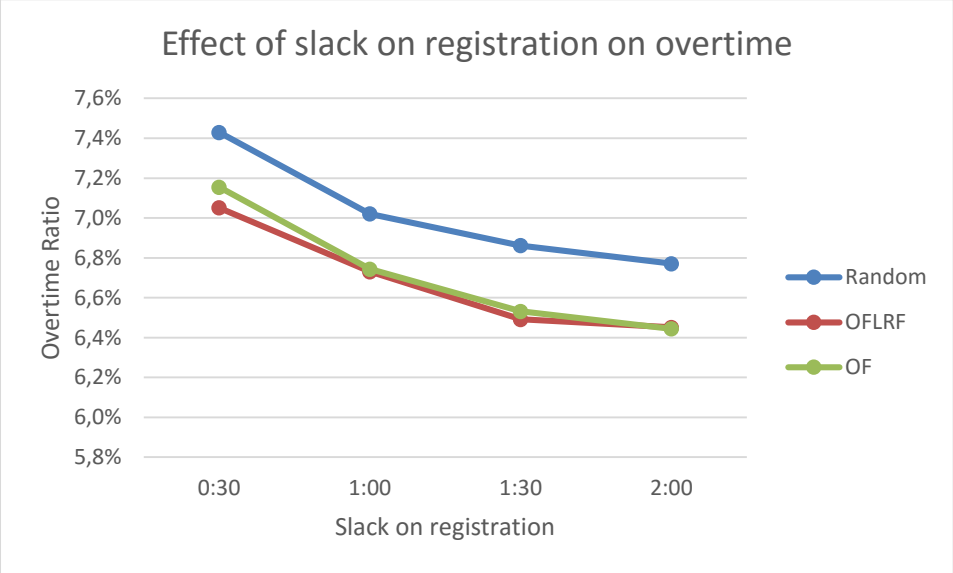


Graph 5 – Closing time and Lounge Patients Moved to Ward

For the OFLRF schedule there is a significant (a=0.05) difference between 19:00 and 19:30 with 24 patients, but no significant differences between the following periods. For OF there is a significant (a=0.05) difference between periods till 20:00 and 20:30 with nineteen patients, but no significant (a=0.05) difference between the following periods. The period between 19:30 and 20:30 will be further researched in the second stage of the experiments as from 20:30 there is no significant improvement for OFLRF and OF. The random schedule performs remarkably bad for this experimental factor, although it will perform similar to the other two schedules as the *closing time* is high.

5.1.2 Slack on registration

The *slack on registration* shows a positive effect on the Overtime Ratio, as can be seen in Graph 6. The higher the *slack on registration*, the lower the Overtime Ratio became. This effect is equal for all schedules. For Random, OF and OFLRF schedule there is a significant (a=0.05) difference between 1:00 and 1:30 hours, but not between 1:30 and 2:00 hours.

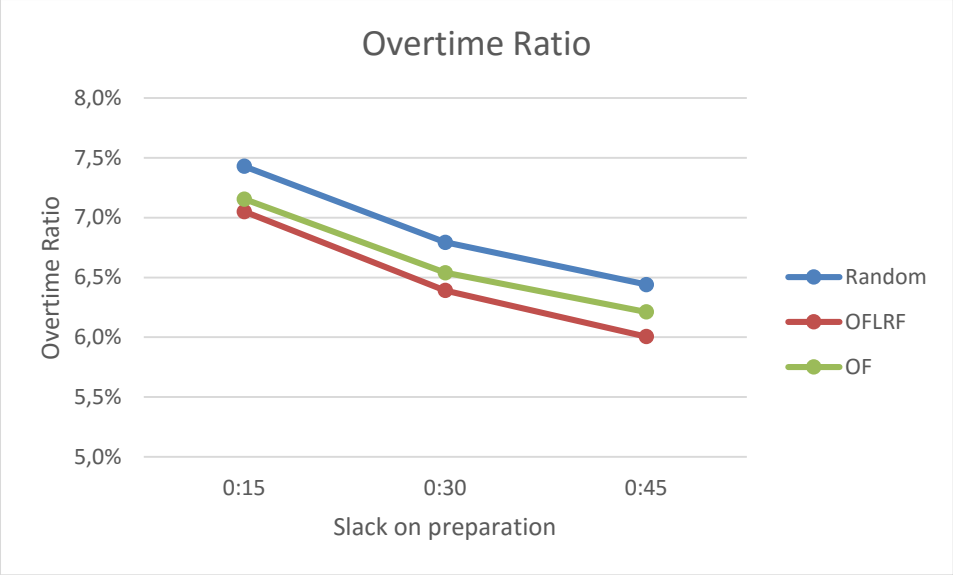


Graph 6 – Effect of slack on registration on overtime

As the *slack on registration* has similar effects on every type of schedule, it can be noted that flattens after 1:30 hour. This means that having a *slack on registration* of more than 1:30 hour does not improve the overtime probability significantly. The largest difference can be observed between 0:30 and 1:00 hour and shows that the Overtime Ratio is negatively affected by a decreasing *slack on registration*. As the Overtime Ratio and *slack on registration* are preferably small, the *slack on registration* between 1:00 and 1:30 will be further researched in the second stage of the experiments.

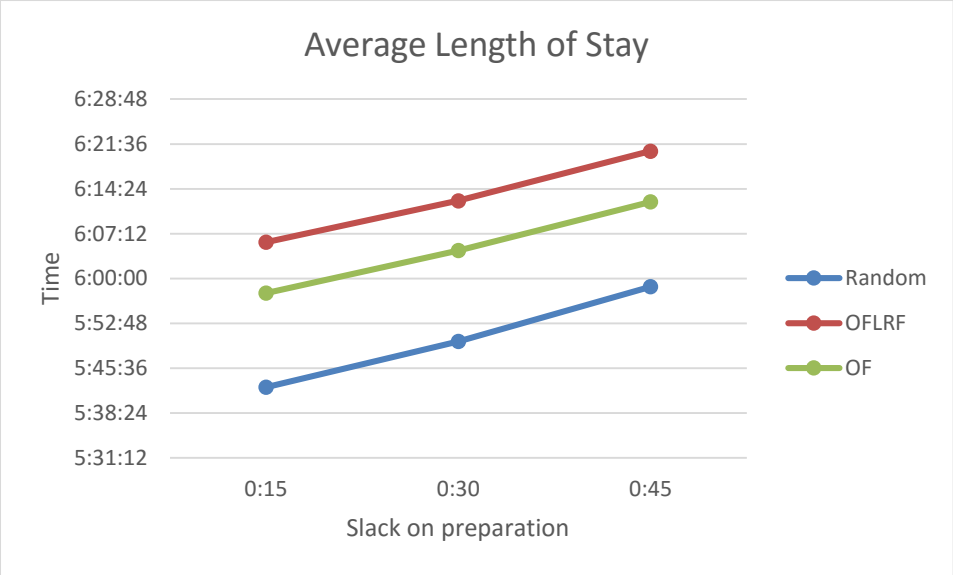
5.1.3 Slack on preparations

The *slack on preparation* registration has a positive effect on the Overtime Ratio: the higher the *slack on preparation* is, the lower the Overtime Ratio. This effect is equal for all schedules as can be seen in Graph 7.



Graph 7 – Relation between slack on preparation and overtime

On the other hand, patients will spend more time at the Lounge pre-surgery as the *slack on preparation* increases. This results in a long Average Length of Stay for all schedules, as can be seen in Graph 8.

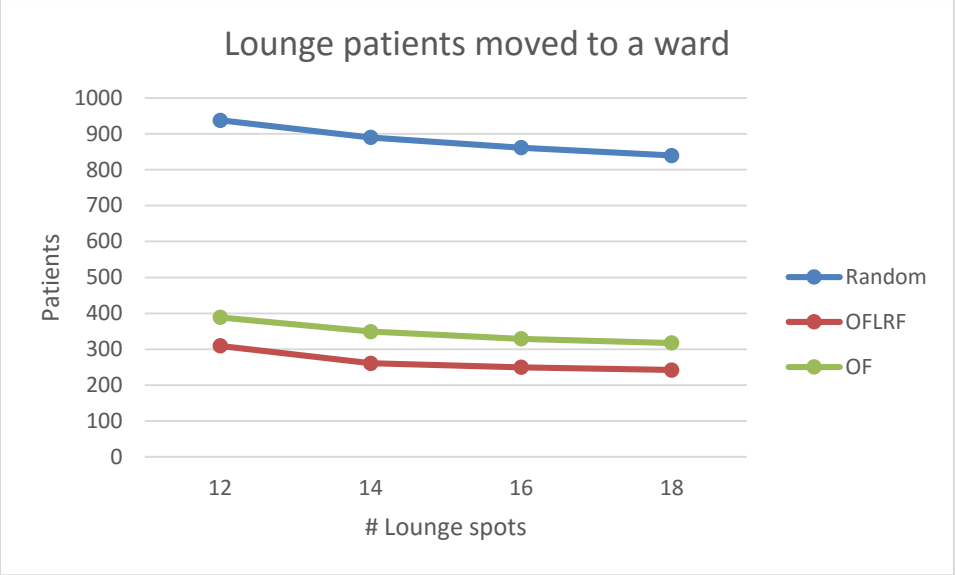


Graph 8 – Relation between slack on registration and Average Length of Stay

Because the Average Length of Stay should be minimized, the range in which the *slack on preparation* will be varied in the second stage experiment is between 0:05 and 0:15 hour.

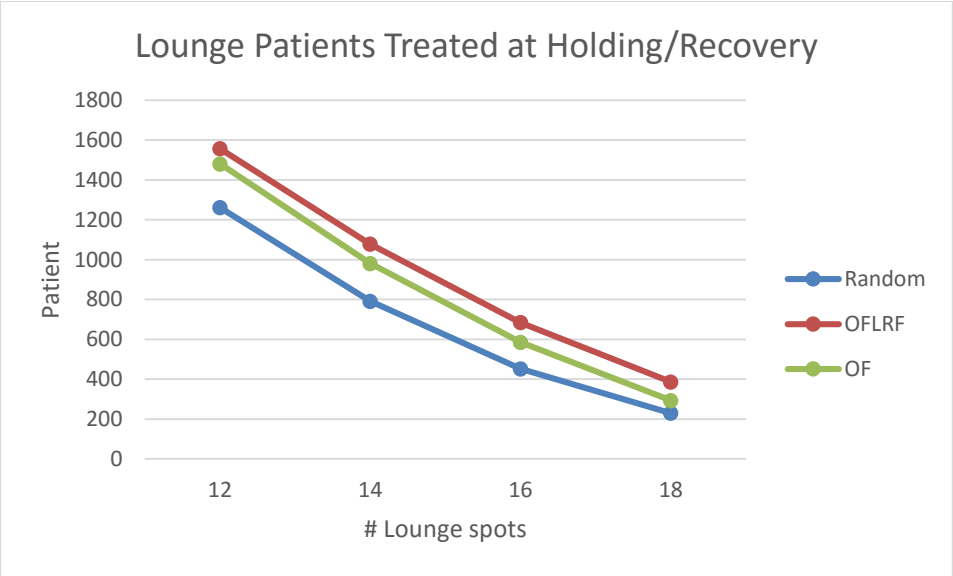
5.1.4 Number of Lounge spots

The *number of Lounge spots* does not influence the Number of Patients Moved to a Ward as the holding/recovery deals with all the patients from the Lounge. Obviously the idea is to treat all Lounge patients at the Lounge, in which eighteen is the optimal number of chairs.



Graph 9 – Relation between Lounge spots and Lounge patients moved to a ward

Graph 9 shows the relation between the *number of Lounge spots* and Number of Patients Moved to a Ward. It shows that the Number of Patients Moved to a Ward is not affected by the *number of Lounge spots*. Graph 10 shows how the Number of Lounge Patients Treated on the Holding/Recovery is affected by the *number of Lounge spots*.

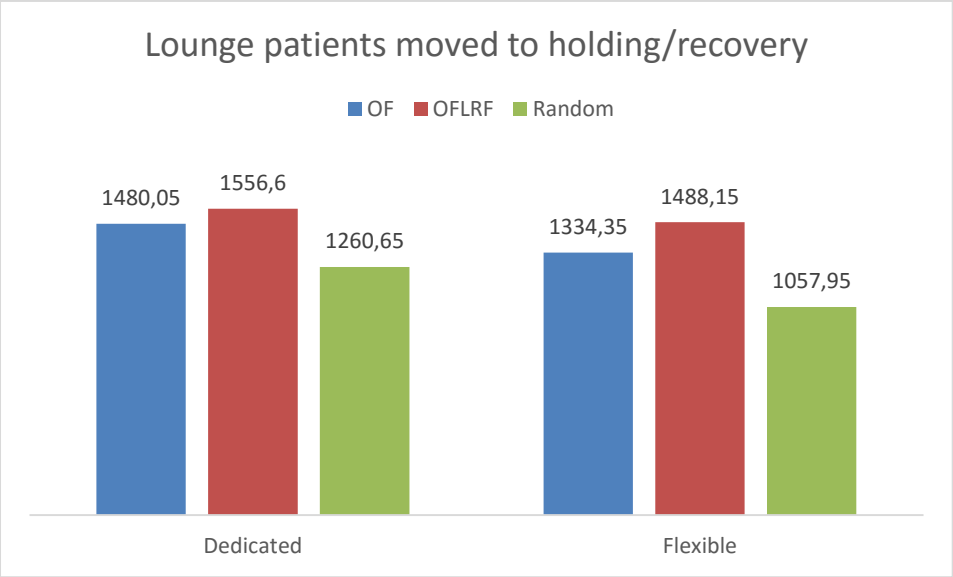


Graph 10 – Relation between number of Lounge spots and patients treated on holding/recovery

As the *number of Lounge spots* increase, the Number of Lounge Patients Treated on the Holding/Recovery decreases, as does the Number of Patient Moved to a Ward after closing the Lounge.

5.1.5 Flexible or dedicated spots

The flexible Lounge spot setting shows promising results regarding the number of patients treated on the holding/recovery.

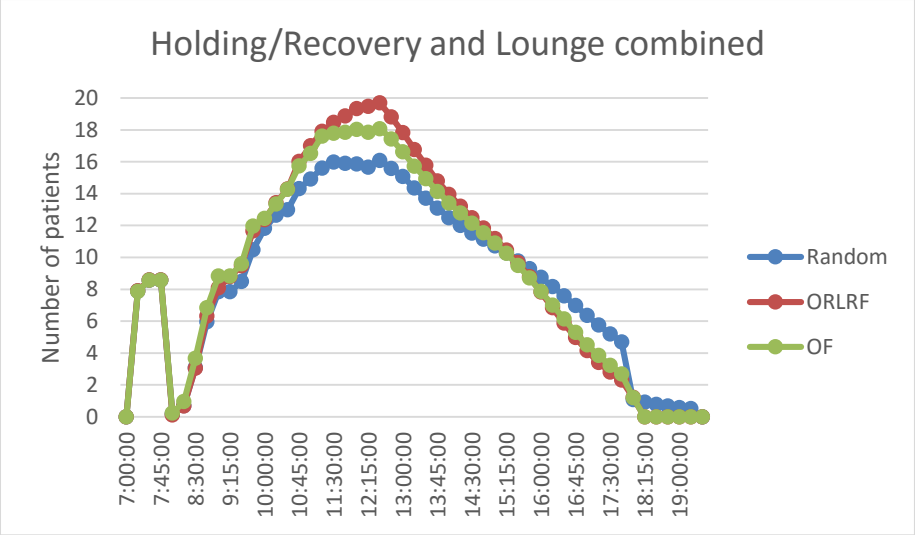


Graph 11 – Relation between dedicated Lounge spots and moved to holding/recovery

As is illustrated in Graph 11, there is a significant (a=0.05) difference between *dedicated and flexible Lounge spots*. In case of a random schedule there is an average difference of 203 patients. In case of an OFLRF schedule there is a difference of 68 patients and in case of an OF schedule there is a difference of 146 patients on average. Flexible spots result in fewer patients being treated at the holding/recovery for all three schedules. The Random schedule performs best in both cases as Lounge patients are more equally distributed during the day, which reduces the chance of a shortage of spots.

5.1.6 Number of patients present

Graph 12 shows the average number of patients present in the Lounge and holding/recovery during the day for the three schedules. Because of interchangeable personnel, it is interesting to analyze the number of patients present in Lounge and holding/recovery combined. The drop in patients between 7:45 and 8:00 is caused by the first group of patients transported to the OR leaving the Lounge and holding/recovery empty in most cases.



Graph 12 – Relation between time and number of patients present at Lounge and holding/recovery combined

There is a significant (a=0.05) difference between 11:00 and 13:00. Between the random and ORLFR schedule there is a difference of three patients and between the random and OF schedule there is a difference of two patients.

The maximum number of patients present using a random schedule is around sixteen patients between 11:00 and 13:00. In case of the OF schedule there are eighteen patients in on average during this period and for the OFLRF schedule the number of patients is twenty. It is concluded that the random schedule shows the best results considering the number of patients present during the day.

5.1.7 Schedules

The results of the three types of schedules are shown in Table 22.

Performance Indicator	Random	OF	OFLRF
Average Length of Stay	5:42:33	5:57:40	6:05:51
Bed Occupancy Ratio	52%	54%	55%
Operation Room Utilization Ratio	70%	70%	70%
Cancellation Ratio	1.8%	1.9%	1.8%
Overtime Ratio	7.4%	7.2%	7.1%
Average Waiting Time Before Surgery	0:41:35	0:39:20	0:40:11
Patients Moved to Ward	938	389	309
Lounge Patients Treated at Holding/Recovery	1261	1480	1557
Lounge Patients Treated	4649	4666	4656
Inpatients Treated	4461	4455	4429

Table 22 – Results of the three types of schedules

Remarkable is that the Average Length of Stay is smallest with Random schedule. This is caused by the reduced number of Lounge Patients Treated at Holding/Recovery that are not taken into account for the ALoS. Lounge Patients Treated at Holding/Recovery include patients that have a shorter length of stay which result in a shorter ALoS.

The Random schedule has the least number of Lounge Patients Treated at Holding/Recovery because Lounge patients are more equally distributed during the day. On the other hand, more Lounge patients have to be moved to a ward as Lounge patients can be scheduled for surgery at the end of the day. This excessive difference of 549 and 629 between the Random and respectively OF and OFLRF schedule, causes two or more patients a day to be admitted at a ward. As this would be a major disturbance in ward planning, the random schedule is excluded at the second stage of experiments.

5.2 Second stage results

The results in the second stage are analyzed using factor analysis described in Appendix E.

5.2.1 Schedule

Remarkable for the OF and OFLRF schedule is the difference in number of Patients Treated at the Holding/Recovery. Except for the experiments with a *closing time* of 20:30, 1:30 *slack on registration* and ten or fifteen minutes *slack on preparation*, all other differences are significant (a=0.05) with a mean difference of 171 patients. This means that on average 171 less patients are treated at the holding/recovery for the OF schedule compared to the OFLRF schedule.

5.2.2 Closing time

The effect that the *closing time* had on Patients Moved to Ward was significantly different between 19:30 and 20:00, as thirteen less patients were moved to ward was having a *closing time* of 20:00 instead of 19:30. However there was not much change between 20:00 and 20:30.

Another significant difference noted between a *closing time* of 20:00 and 20:30, was in case of OFLRF schedule with a *slack on registration* of 1:30. A significant difference of 189 fewer patients treated on holding/recovery was noted, in case of a *closing time* of 20:30.

5.2.3 Slack on registration

The effect of the *slack on registration* on overtime is significant between 1:00 and 1:15 and in some cases between 1:15 and 1:30. If a *slack on registration* of 1:15 is chosen then there were twelve less cases of overtime compared to 1:00. The difference between 1:15 and 1:30 was significant with nine less cases of overtime if the *slack on registration* is 1:30 except in case of OFLRF schedule with a *slack on preparation* of ten and fifteen minutes.

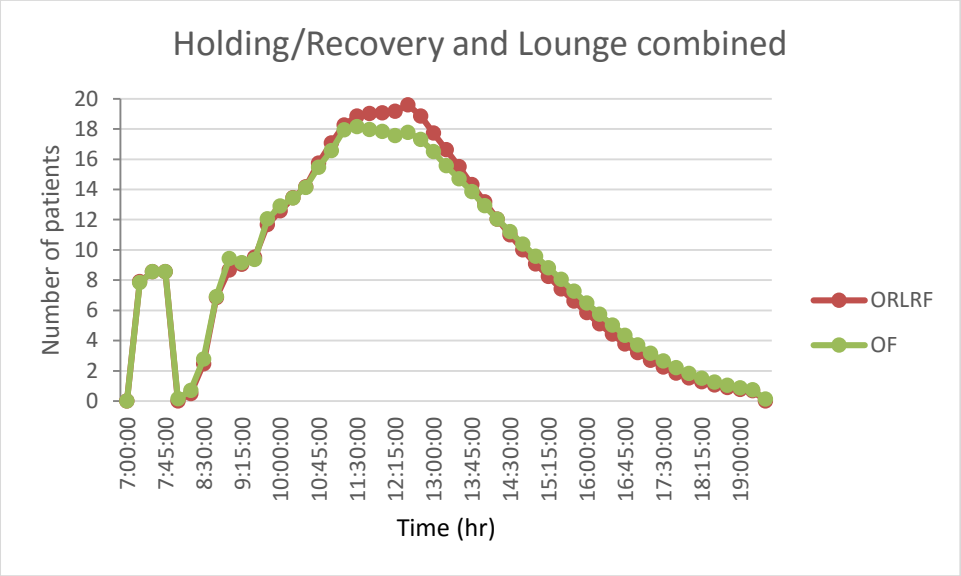
5.2.4 Slack on preparation

The effect of *slack on preparation* on overtime is significant between 0:05 and 0:10 with an average of 23 fewer surgeries in case of an overtime of 0:10. There was no significant (a=0.05) difference in case of OFLRF schedule with *closing time* 20:30, *slack on registration* 1:30, between 0:05 and 0:10. Between 0:10 and 0:15 on average 22 less cases of overtime occurred in case of 0:15.

As the *slack on preparation* decreases the Overtime Ratio it increases the number of patients treated on holding/recovery increases.

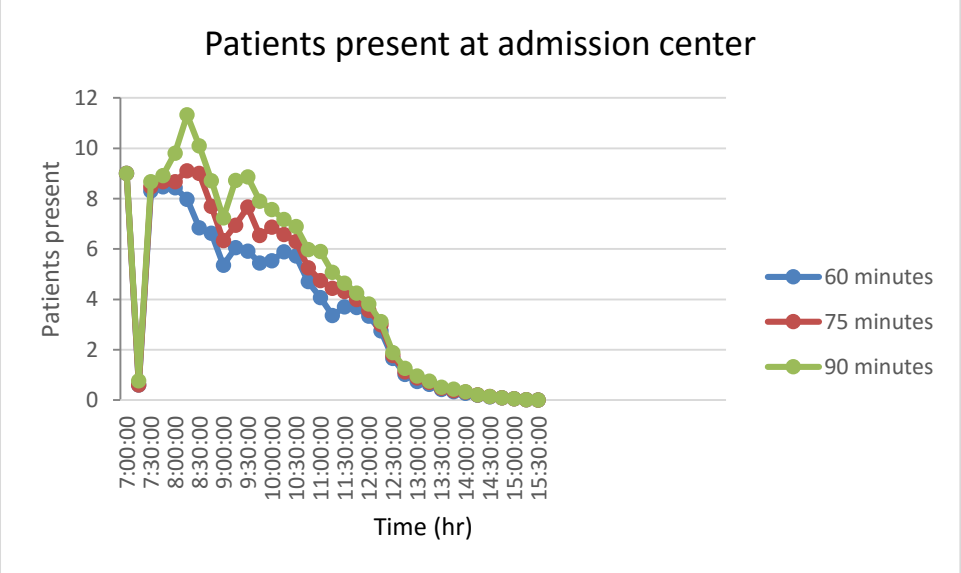
5.2.5 Number of patients present

Similar to stage one the combined number of patients present at Lounge and holding/recovery is significantly different on the 11:00–13:00 interval compared to the rest of the day. This is illustrated in Graph 13.



Graph 13 – Number of patients at holding/recovery and Lounge

As illustrated in Graph 14 the required capacity of the admission center depends on the *slack on registration*. The number of patients at the admission center is shown for a *slack on registration* of 60, 75 and 90 minutes. It is concluded that an increase of the *slack on registration* causes more patients to be present. The sudden drop in patients present at 7:15 is caused by the first group of patients that are moved to Lounge or holding/recovery.



Graph 14 – Number of patients at admission center

5.2.6 Combined optimal setting

The combined optimal setting found in stage two experiments and the current settings are shown in Table 23.

	Closing time	slack on registration	slack on preparation	Lounge spots	dedicated spots	Schedule
COS	**20:00**	1:30	0:15	18	Flexible	OF
2014	**18:00**	Various	Various	17	Dedicated	OF

Table 23 – Combined optimal setting and current setting

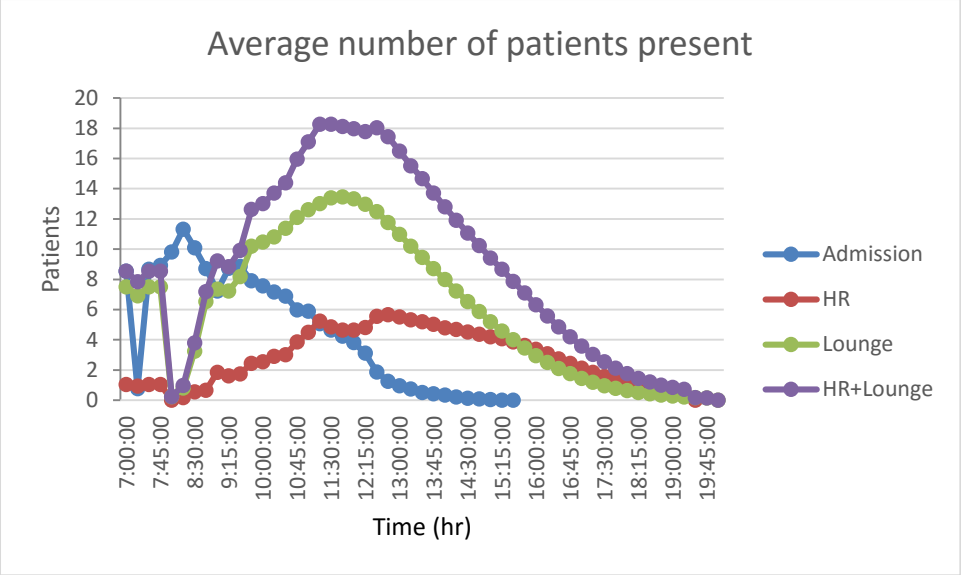
Now the combined optimal setting is known, it is possible to compare the results with data from 2014. The chosen performance indicators can be determined using these results and are shown in Table 24.

Performance Indicator	COS	Data 2014
Average Length of Stay	5:46:59	8:27:08
Bed Occupancy Ratio	44%	45%
Operation Room Utilization Ratio	70%	80%
Cancellation Ratio	1.8%	1.7%
Overtime Ratio	6.5%	5.5%
Average Waiting Time Before Surgery	1:06:01	1:20:11
Patients Moved to Ward	151	172
Lounge Patients Treated at Holding/Recovery	56	0
Lounge Patients Treated	4667	4596
Inpatients Treated	4465	4590

Table 24 – Performance result model and data

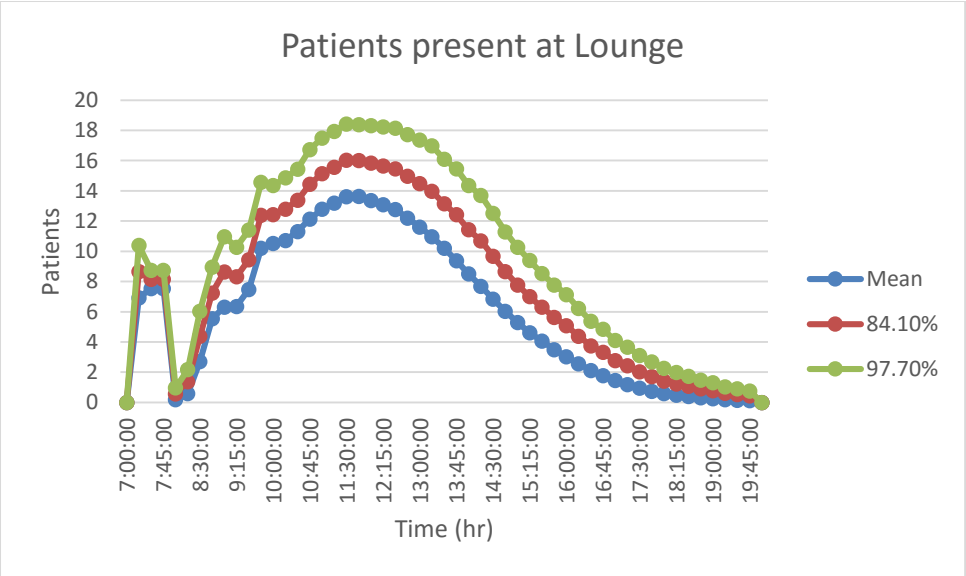
The ALoS of the model is remarkably shorter than the ALoS of the data and shows a decrease of 32%. The ORUR of the model is 10% lower compared to historical data of 2014. This is caused by the constructed OR schedule for the model which is mainly focused on the frequency of the clusters. Therefore it is possible that some timeslots cannot be completely filled. The Average Waiting Time Before Surgery decreases with 18%.

As can be seen in Graph 15 the maximum average number of patients present at the Lounge and holding recovery is 18.3 and the maximum average number of patients present at the admission center is 11.3.



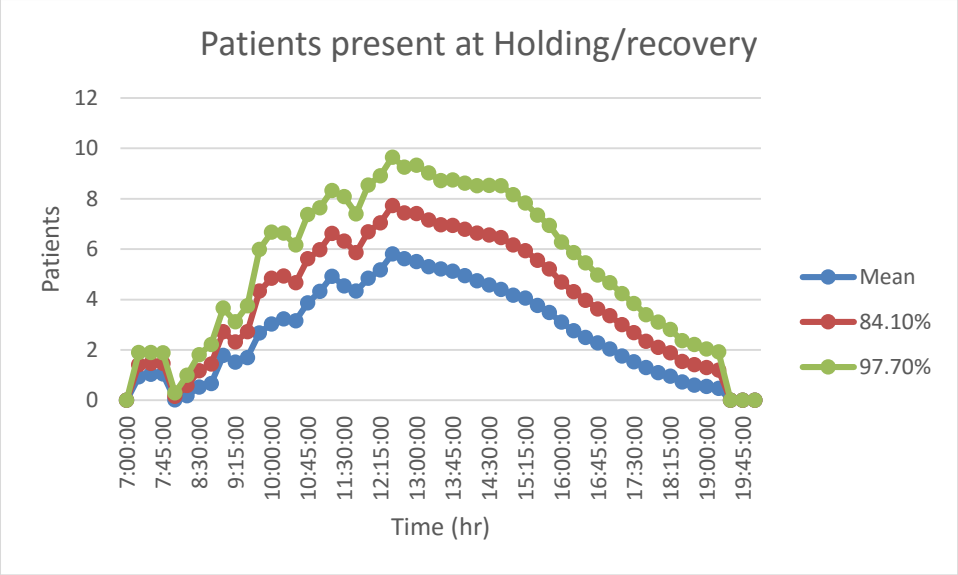
Graph 15 – Number of patients present with combined optimal setting

As all values of Graph 15 are the average number of patients it does not provide insight in the variability. Graph 16 shows the number of patients present at the Lounge with variability. This shows how often there would be a lack of spots. The 97.7% line indicates that there are just a few cases in which the capacity of eighteen is not sufficient.



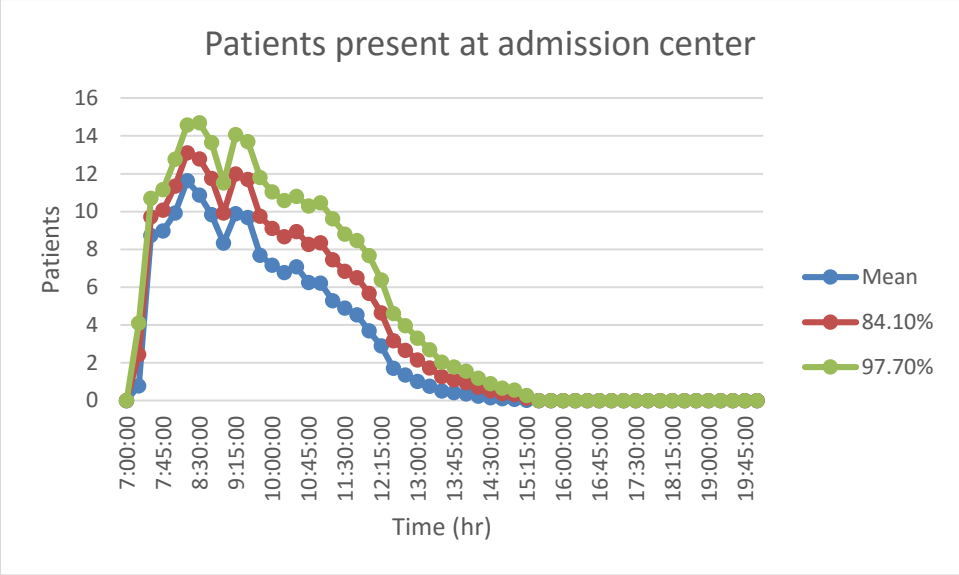
Graph 16 – Number of patients present at Lounge with COS

Graph 17 shows the variability of the number of patients present during the day at the holding/recovery. This graph shows that for the specialties included in this thesis no more than ten chairs will be used.



Graph 17 – Number of patients present at the holding/recovery with COS

Graph 18 shows the variability in the number of patients present at the Lounge. The admission center is empty from 15:15 hour.



Graph 18 – Number of patients present at the admission center with COS

Table 25 shows the required capacity of the admission center assuming that every patient brings 1.5 person as company with him. As stated earlier, it is assumed that the patient's company will leave the admission center after the patient is admitted.

	mean	84.1%	97.7%
Admission center	29	32.75	36.75

Table 25 – Required capacity of admission center

5.3 Lounge performance under various circumstances

From this point on the COS is used to perform further experiments. Various circumstances are simulated to determine how it affects the performance.

5.3.1 Increased number of ORs

The number of ORs in the model is increased from 9 to 12 and corresponding the number of patients to fill the schedule for these additional ORs. From this experiment, it is determined how the Lounge will perform when more ORs are used.

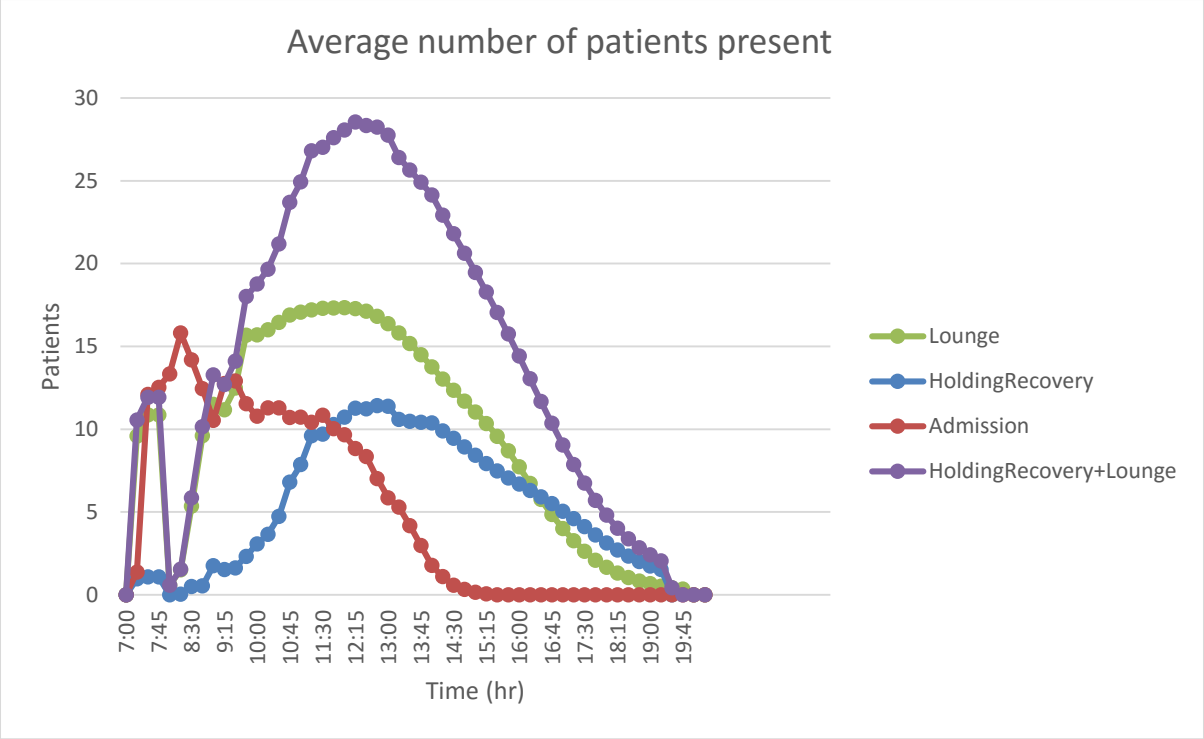
Table 26 shows the results of performance indicators of the combined optimal setting compared with the experiment with more ORs. Both the ORUR and BOR improve, but Overtime Ratio increases. The ALoS, Cancellation Ratio, and Average Waiting Time Before Surgery are the same.

Performance Indicator	COS	More ORs
Average Length of Stay	5:46:59	5:57:54
Bed Occupancy Ratio	44%	75%
Operation Room Utilization Ratio	70%	83%
Cancellation Ratio	1.8%	1.8%
Overtime Ratio	6.5%	11.1%
Average Waiting Time Before Surgery	1:06:01	1:08:45
Patients Moved to Ward	151	425
Lounge Patients Treated at Holding/Recovery	56	2532
Lounge Patients Treated	4667	7601
Inpatients Treated	4465	6858

Table 26 – Performance indicators COS and more ORs

The total number of patients treated is 14.459 with more ORs as can be seen in Table 26. Remarkable is the high number of patients treated on holding/recovery. The high number of patients treated on holding/recovery indicate that the Lounge capacity is not sufficient to handle the increase in Lounge patients. As more Lounge patients have to move to the holding/recovery, it obstructs inpatients from being admitted which results in less treated inpatients and more patients not treated. The number of treated Lounge patients that are not treated on holding recovery is 5070, which is only 110% more compared to the combined optimal setting.

As more ORs are used and more patients are having surgery the number of patients present will increase as can be seen in Graph 19.



Graph 19 – Average number of patients present during day

5.3.2 Without Lounge

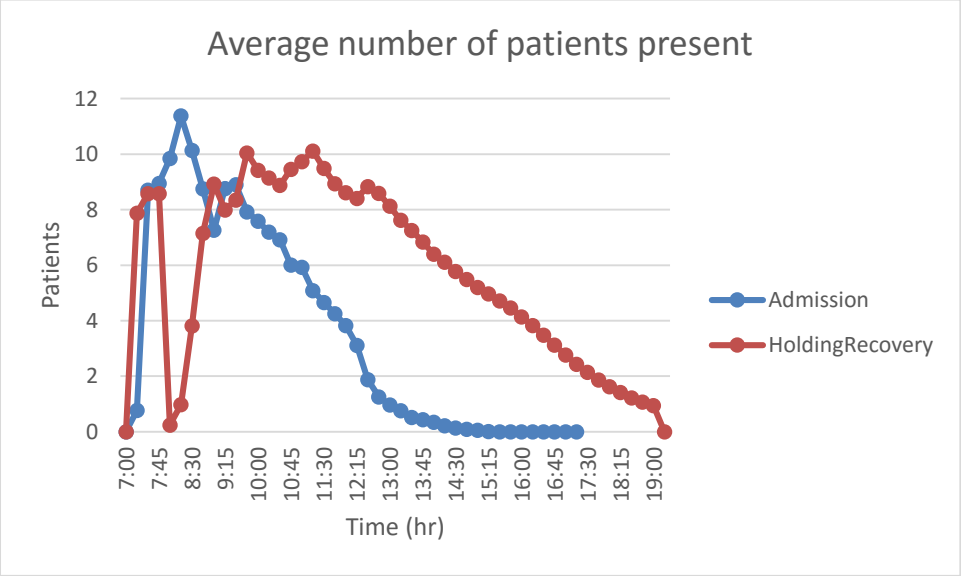
For this experiment the same *slack on registration*, *slack on preparation* and schedule is used as with COS, but the Lounge itself is closed. All patients will be treated at the 17 holding/recovery beds but all Lounge patients will be transferred to a ward just like the inpatients. The recovery time of Lounge patients are according to the recovery times of inpatient half of surgery time. The number of Patients Moved to Ward in are the patients still present at the holding recovery at *closing time*.

Table 27 shows the results of the experiment with no Lounge compared to the COS. The ALoS in this case is the time a Lounge patient spends in the OR complex. As the patient will recover at the ward, the ALoS will be less compared to the situation with Lounge with a difference of 2:32:35.

Performance Indicator	COS	No Lounge
Average Length of Stay	5:46:59	-
Bed Occupancy Ratio	44.4%	-
Operation Room Utilization Ratio	70.3%	70.3%
Cancellation Ratio	1.8%	1.8%
Overtime Ratio	6.5%	6.5%
Average Waiting Time Before Surgery	1:06:01	1:05:58
Patients Moved to Ward	151	211
Lounge Patients Treated at Holding/Recovery	56	4632
Lounge Patients Treated	4667	4659
Inpatients Treated	4465	4453

Table 27 – Performance indicators no Lounge experiment and combined optimal setting

All patients are treated at the holding/recovery as can be seen in Graph 20.

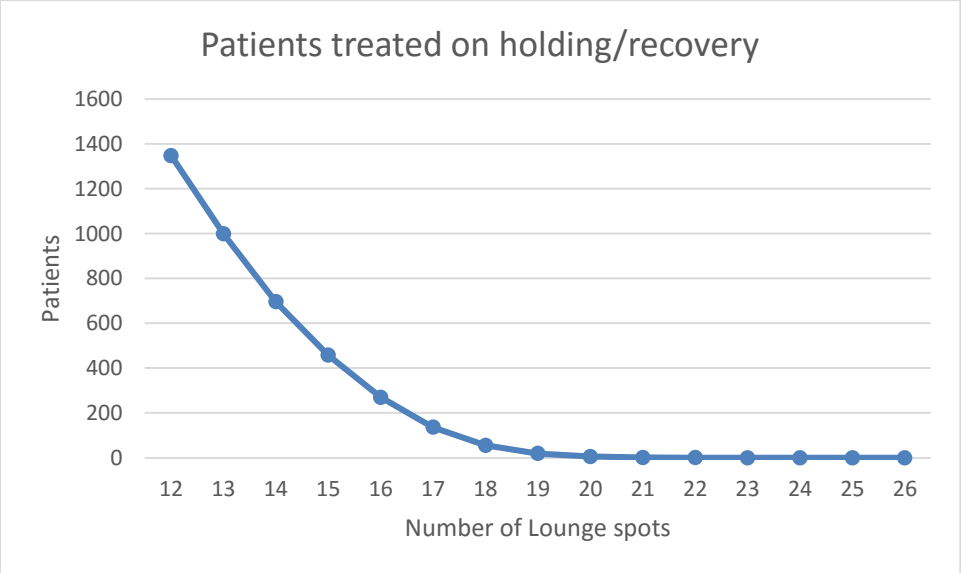


Graph 20 – Number of patients present without Lounge

Although these results suggest that the holding/recovery has sufficient capacity to deal with the allocation it has to be kept in mind that emergency and some minor specialties are excluded.

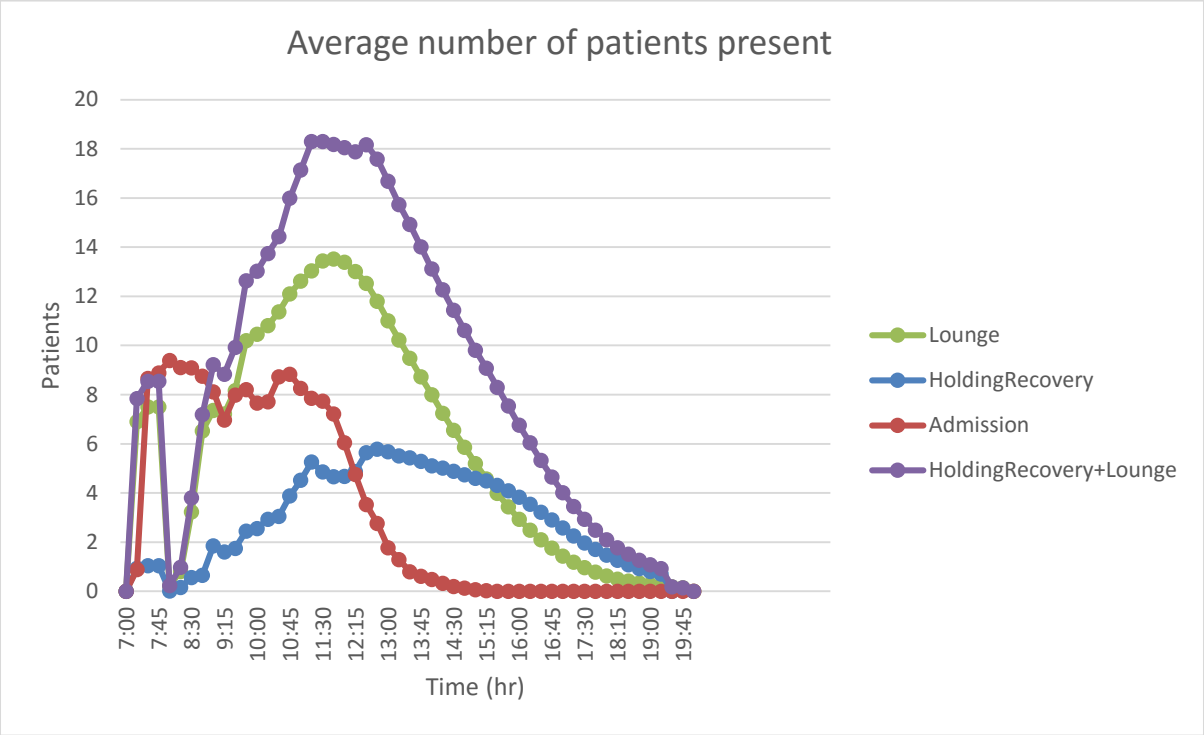
5.3.3 Number of Lounge spots

In this experiment the *number of Lounge spots* is varied using COS to see whether the performance improves. Graph 21 shows how the number of Lounge patients being treated on holding/recovery drops as the *number of Lounge spots* increases. From twenty spots, no significant difference of improvement is observed between additional spots. All other outcomes do not change as the *number of Lounge spots* increases.



Graph 21 – Relation of number of patients treated on holding/recovery with number of Lounge spots

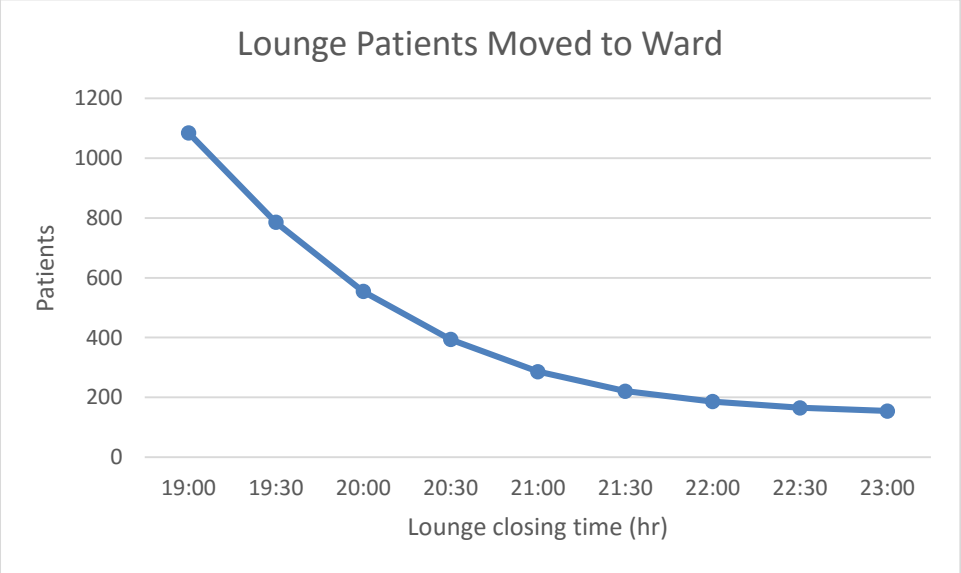
A full comparison of performance indicators can be found in Appendix E. Graph 22 shows the average number of patient present at each department. No more than six holding/recovery spots are required on average.



Graph 22 – Number of patients present with 20 Lounge spots

5.3.4 Inpatients admitted at the Lounge

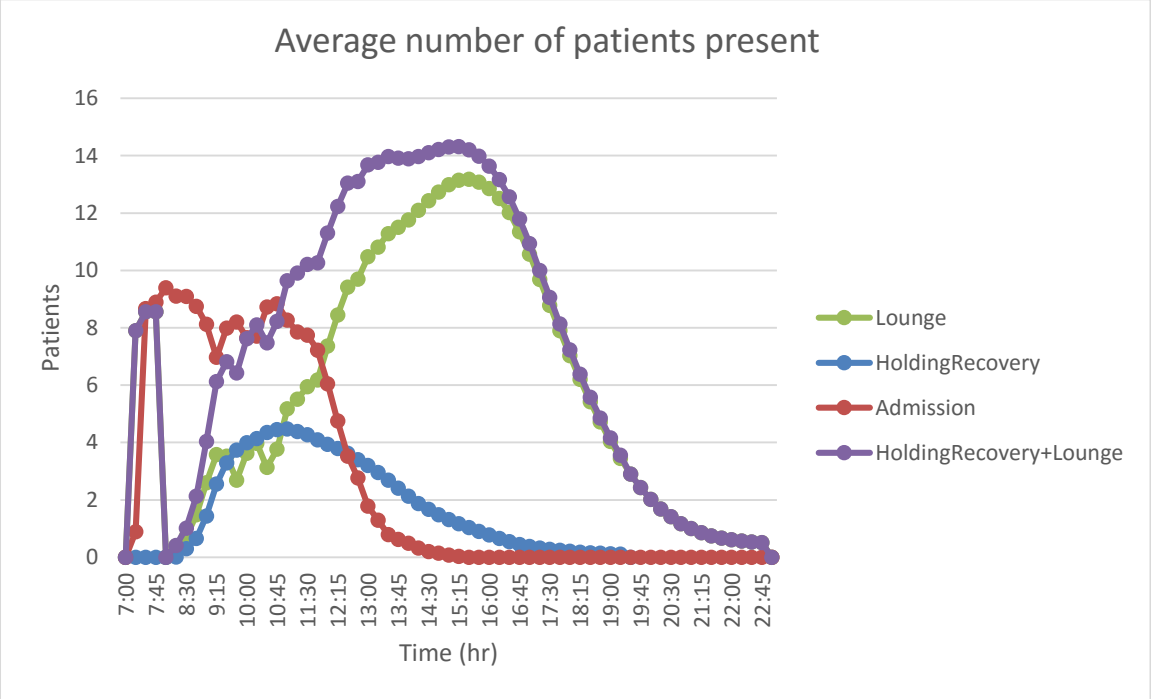
Inpatients are admitted at the Lounge in this experiment and will only stay at the holding/recovery to recover after surgery. Graph 23 shows the relation between Lounge Patients Moved to Ward and the *closing time*.



Graph 23 – Relation between Lounge Patients Moved to Ward and closing time

Graph 24 shows the relation between the number of patient present and the time. Comparing this graph with the graph of the combined optimal setting it can be seen that more patients are present at the holding/recovery in the morning instead of afternoon. Also it can be seen that more patients are present at the Lounge in the afternoon instead of the morning, this was also expected with an IF schedule.

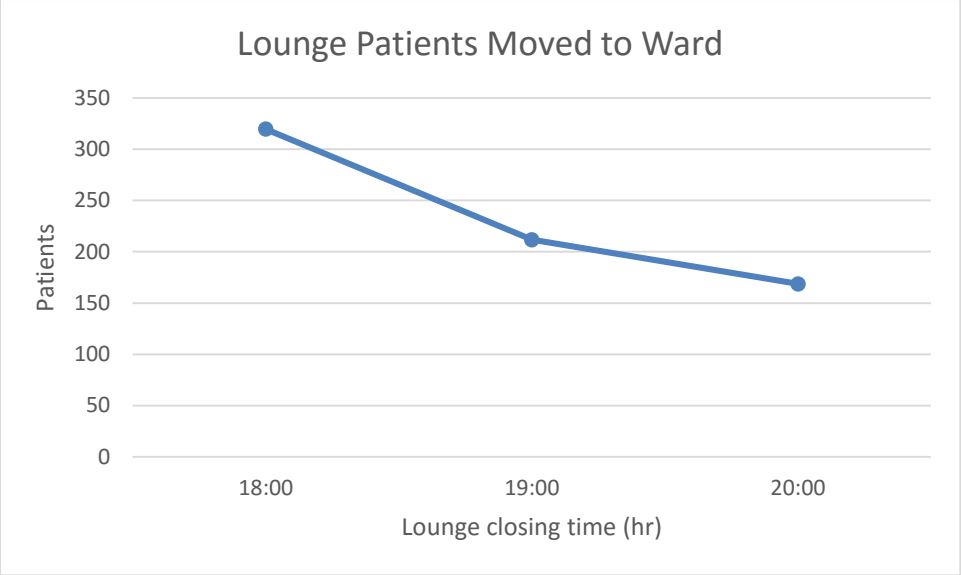
In comparison to Graph 15, which shows the number of patient present for the combined optimal setting, a difference of four patients is found. Less nurses might be required as the patients are more equally divided.



Graph 24 – Number of patients present with closing time of 23:00

5.3.5 Difference between closing times with the COS

In this experiment the *closing time* is varied using the COS. Less patients have to be moved to a ward as was already seen in the first stage of the experiment. A significant (a=0.05) difference of 37 patients is found between a *closing time* of 19:00 and 20:00. A significant (a=0.05) difference of 92 patients is found between a *closing time* of 18:00 and 19:00.



Graph 25 – Relation between the closing time and lounge patients moved to ward

5.3.6 Difference between slack on registration with COS

The *slack on registration* is varied in this experiment. There is a difference of fourteen minutes between an Average Waiting Time Before Surgery with a *slack on registration* of 1:00 hour and 1:30 hour. The Overtime Ratio increases as the *slack on registration* is reduced, which results in a 0.3% difference.

5.3.7 Slacks minimal 0:05 both

The *slack on registration* and *slack on preparation* are both set on 0:05 in this experiment. The ALoS is reduced with three minutes from 5:46:59 to 5:43:42 hour. The Overtime Ratio is increased with 1.8% from 6.5 to 8.3%. The Average Waiting Time Before Surgery is reduced with 33:55 from 1:06:01 to 0:32:06 hour. Number of patients moved to a ward increases as the slacks are reduced with 38 patients, from 149 to 187. The number of Lounge Patients Treated at Holding/Recovery decreases with nine patients. The number of Lounge patient treated and number of inpatient treated, both decrease with respectively 5 and 48 patients.

5.3.8 COS with random

The random schedule is used with COS in this experiment. The Overtime Ratio is increased with 0.4% from 6.5 to 6.9%. The number of Patients Moved to Ward is increased with 132 from 149 patients to 281 patients. The number of Lounge Patients Treated decreases with seventeen and the number of Inpatient treated increases with four patients.

5.4 Conclusion

Overall, this chapter describes the results of the two stage experiments as well as a measurement of the Lounge performance under different circumstances. The following questions and corresponding answers conclude this chapter:

I. What is the relationship of each experimental factor to performance?

The effect of a later *closing time* is that less patient are moved to a ward. A longer *slack on registration* decreases the Overtime Ratio. The *slack on preparation* causes the Overtime Ratio

to decrease, but also increases the Average Length of Stay. As the *number of Lounge spots* increases, the number of Lounge Patients Treated at the holding/recovery and Patients Moved to Ward decreases. Less patients are treated at holding/recovery with flexible Lounge spots. Random schedule performs worse on Patients Moved to Ward, but has a more equally distributed patients present. OF and OFLRF schedule have less Patients Moved to Ward but less equally distributed patients.

II. What are the combined optimal settings of the Lounge based on the preferences of OLVG?

The combined optimal setting is:

Closing time	slack on registration	slack on preparation	Lounge spots	dedicated spots	Schedule
20:00	1:30	0:15	18	Flexible	OF

Table 28 – Combined optimal setting

These settings show the best performance according to the preferences of OLVG West. The performance according to the COS is shown in Table 29.

Performance Indicator	COS
Average Length of Stay	5:46:59
Bed Occupancy Ratio	44%
Operation Room Utilization Ratio	70%
Cancellation Ratio	1.8%
Overtime Ratio	6.5%
Average Waiting Time Before Surgery	1:06:01
Patients Moved to Ward	151
Lounge Patients Treated at Holding/Recovery	56
Lounge Patients Treated	4667
Inpatients Treated	4465

Table 29 – Current performance (Year: 2014 Sample size: 3041 Source: Business Intelligence)

III. How is the performance of the combined optimal setting effected by various experiments?

Using more ORs, which increases the patients suitable for the Lounge, indicates that only a 10% increase of patients is possible. Closing the Lounge shows that the capacity of the holding/recovery is sufficient for the patient group after reallocation. Increasing the *number of Lounge spots* to twenty, reduces the number of patients treated at holding/recovery. Using an IF schedule results in an increase of Patients Moved to Ward, but has a more equally division of patients present. Using earlier *closing times* increases the number of Patients Moved to Ward. Reducing the *slack on registration* reduces the waiting time before surgery with fourteen minutes, but increases the Overtime Ratio with 0.3%. Having slack of both 0:05 hour decreases the Average Length of Stay 5:43:42 and Average Waiting Time Before Surgery 0:32:06, but increases the Overtime Ratio to 8.3%. Using Random schedule increases the Overtime Ratio, Patients Moved to Ward and decreases the number of patients treated.

6. Conclusions & Recommendations

In this chapter we conclude this thesis in Section 6.1, in Section 6.2 we will provide recommendations for the OLVG West and in Section 6.3 suggestion for further research are given. Last, Section 6.4 provides the discussion and limitations of this thesis.

6.1 Conclusion

The objective of this thesis is:

To determine the required capacity of the Lounge and develop and assess interventions to optimize the performance of care trajectories suitable for the Lounge.

The merger of Onze Lieve Vrouwe Gasthuis and Sint Lucas Andreas Ziekenhuis created new possibilities for the new OLVG. However also problems occurred caused by the merger, as currently patients have to wait a long time before and after surgery, after reallocation of specialties to OLVG West, it is estimated that these inefficient operations will result in a lack of bed capacity.

Analyzing the current situation we identified factors that influence the core problem, like for example specialists that are unable to discharge patients between surgeries, high *slack on registration* and variability in transport time.

The current performance is monitored using dashboard for each department. We noticed that hospital management is dissatisfied about the Average Length of Stay and Average Waiting Time Before Surgery of outpatients at the outpatient ward. As the Average Waiting Time Before Surgery is not included in the dashboards at this moment, but stakeholders do experience this as a problem, this is added as a performance indicator in this thesis. Other performance indicators in the current situation are Bed Occupancy Ratio, Operation Room Utilization Ratio, Cancellation Ratio, Overtime Ratio and Outpatient Treated at the Outpatient ward. Overall, stakeholders are satisfied with those results and like to keep them similar to the current situation.

OLVG came up with a possibility to overcome the problem by introducing the Lounge, and opportunities concerning the Lounge. According to literature, the Lounge will reduce the recovery duration of patients as the 'healing environment' has a positive effect on the recovery. The problem of variability on transport time is solved as the Lounge is located in the OR complex. In addition, specialist are able to discharge patients between surgeries. To obtain a full overview of the performance of the Lounge additional performance indicators have to be added. The Number of Patients Moved to Ward and Number of Patients Treated at Holding/Recovery are both indicators that reflect the performance of the Lounge.

Together with specialists and anesthetists, it has been determined which type of procedures and patients are suitable to use the Lounge. In general surgeries that are suitable for 'fast-track' are also suitable for the Lounge. Conditions for patients are that patients should be elective, an adult and considered ASA class 1, 2 or 3.

To analyze the opportunities of the Lounge, we modeled the Lounge using Discrete Event Simulation (DES). In DES the operation of a system is represented as a chronologically-linked sequence of events, in order to describe flows of people and/or material and explore the effects of any changes. We performed 'What if' scenarios to evaluate the effect of specific circumstances. We used input parameters based on historical data in order to obtain a model that reflects reality best. First, we determined the Combined Optimal Settings (COS) which are the best setting according to the preferences of OLVG West. Second, we performed experiments to analyze how different circumstances affect the Lounge.

Based on this experiments, it became possible to measure the Lounge performance compared to the current performance as can be seen in Table 30.

Performance Indicator	COS	Data 2014
Average Length of Stay	5:46:59	8:27:08
Bed Occupancy Ratio	44%	45%
Operation Room Utilization Ratio	70%	80%
Cancellation Ratio	1.8%	1.7%
Overtime Ratio	6.5%	5.5%
Average Waiting Time Before Surgery	1:06:01	1:20:11
Patients Moved to Ward	151	172
Lounge Patients Treated at Holding/Recovery	56	0
Lounge Patients Treated	4667	4596
Inpatients Treated	4465	4590

Table 30 - Performance result model and data

Comparing the results with the data from 2014, the Lounge reduces the Average Length of Stay with 32% from 8:27:08 currently to 5:46:59. The waiting time before admission is also reduced as patients currently have to wait on average 1:20:11 until admission and when introducing the Lounge only 1:06:01 on average. This is an 18% reduction using a *slack on registration* of 1:30 hour compared to the current situation. These results proof that the Lounge will improve the performance of the Average Length of Stay and the Average Waiting Time Before Surgery. Improving these performance indicators will increase patient friendliness as patients do not have to wait for a long time anymore.

Based on the results it can be said that the capacity of the admission center depends foremost on the length of *slack on registration*. The longer the *slack on registration*, the longer a patient has to wait. The maximum number of patients present at the admission center when using the Lounge is 11.3 patients. Taking into account a patient brings on average 1.5 person as company with him, according to nurses of OLVG West, we determined that the capacity of the admission center should be at least 33.

Regarding our experiments, the *number of Lounge spots* directly affect the number of patients treated on the holding/recovery, but the experiment with additional Lounge spots shows that results only improve up to 20 spots. From the experiment in which we included more ORs, we concluded that the number of patients treated at the Lounge can grow with 10%. However, treating more patients at the Lounge will deteriorate the performance. According to our

results the maximum number of Lounge patients per year that can be treated given the COS is 5070.

Comparing the experiments of dedicated and flexible chair spaces, the flexible chair spaces show significant better results regarding the number of patients treated on the holding/recovery. The *slack on preparation* affects the Overtime Ratio and shows an interacting effect in case of OFLRF schedule with the *slack on registration*. Optimal *closing time* of the Lounge is determined 20:00. It is considered optimal when there is no significant improvement if the *closing time* is increased. An overview of all experiments is given in Table 31.

Experiment	Conclusion
More Lounge spots	20 spots shows best results
More ORs	Maximum capacity of patients treated at the Lounge is 5070
Inpatients admitted at the Lounge	Performance decreases under realistic circumstances
Flexible or dedicated Lounge spots	Flexible spots show better performance
Closing time	Performance best when closing time is 20:00
Slack on registration	A slack of more than 1:30 hour does not improve performance
Slack on admission	A slack of more than 0:15 hour does not improve performance
Schedule	Outpatient First schedule shows the best results

Table 31 – Overview conclusion

In this study we developed a model which determines the performance of the Lounge under different circumstances. We have made it possible to find the best combination of Lounge specific performance indicators. Therefore we can conclude that the Lounge would be a suitable option for the OLVG to perform better than the current situation when using the Lounge.

6.2 Recommendations

Based on this study we can provide some recommendations for the OLVG, concerning the realization of the Lounge, validation of the model, registration process and the implementation using the Combined Optimal Settings.

Starting with the realization of the Lounge. We recommend to proceed realizing the Lounge, as the concept will be beneficial for both, patient and hospital. The Lounge will reduce the unnecessary hours a patient has to spend in the hospital.

Second, the model used in this thesis should be validated as soon as the Lounge is operational. When realizing the Lounge, all inputs, assumptions and operational features have to be checked to make sure that the results are still applicable. The usage of the Lounge by specialties will be phased, therefore the actual validation can be done when all specialties, used in this thesis, are using the Lounge.

Third, the registration process within OLVG West has to be more structured, as patients have to wait long before having surgery. To achieve this goal, we recommend that this subject is discussed with the specialties OR planners. Creating a more uniform registration process approach will decrease the Average Waiting Time Before Surgery. Therefore we recommend implementing the slacks found in this thesis.

Fourth, we recommend the OLVG to take into account the Combined Optimal Setting of the results when implementing the Lounge. This thesis shows that the Lounge will perform better with 20 Lounge spots, instead of the 18 Lounge spots that were proposed by OLVG West. We recommend to analyze whether it is possible to increase the *number of Lounge spots* to 20 given the surface on which the Lounge has to be built. Also no patients should be admitted at the Lounge as this decreases the performance under realistic circumstances. Thereby we recommend Outpatient First scheduling and flexible Lounge spots according to the COS. In which we conclude that the best *closing time* will be at 20:00.

Overall we can conclude based on this recommendations that OLVG West should continue to build the Lounge as based on the result of this thesis, it will create a patient and staff friendlier environment. Using the model it becomes possible for them to configure the Lounge in most optimal way, making them prepared for the moment that the Lounge will be operational.

6.3 Further research

Next to recommendations for the OLVG also some recommendations for scholars are done, providing possibilities for future research.

First, as we have focused on the Lounge and analyzed it in the chain of the care trajectory future research should be directed at the OR schedule. The OR schedule used in this thesis did not take equipment or personnel restrictions into account. A more realistic OR schedule should be made in future research that includes these restrictions.

Second, an interesting addition to this research would be to optimize the performance using linear programming. Only linear programming would lack a level of detail, however performance will most likely be improved using a combination of linear programming and DES.

6.4 Discussion & Limitation

As with every study this thesis encloses limitations and a discussion, to explain circumstances that might influence the results in the study, they will be briefly explained in this section. In this study we divided them in four groups; results, OR schedule, Experiments and the model.

6.4.1 Results

Starting with the results, the time a patient is waiting before admission at the ward was not available in the historical data. Therefore the *Average Waiting Time Before Surgery* of 2014 is calculated taking the time between admission and entering the holding/recovery and subtract the average transport time from ward to holding/recovery and fifteen minutes for intake and changing. As most patients also wait before admission the current *Average Waiting Time Before Surgery* is longer and the reduction of 18% is more.

Results from the experiment without Lounge show no significant difference with the number of patients treated compared to the situation with Lounge. However, it cannot be concluded that the capacity of the holding/recovery is sufficient after reallocation of specialties. The reason for this is that not all patients using the holding/recovery are included, emergency patients and patients of excluded specialties for example. Therefore no conclusion can be drawn on the capacity of the holding/recovery.

6.4.2 OR Schedule

Second the OR Schedule will be discussed. It is hard to take into account all scheduling rules of the hospital, as this depends on the specialty, specialist and time of the year how the OR schedule is designed. Therefore it is not possible to copy the schedule of 2014 as procedures will be reallocated to East and West.

Because of simplification a week schedule is constructed which is used for all 52 weeks. In reality every week will be different therefore as the means have to serve the purpose this simplified schedule is used. An example of a seasonal depending circumstance that is not included is the 'reduction schedule' during holidays in which only 75% of the ORs are operational.

As doing this research we did not take into account the equipment that is required for surgeries. For example, the C-arc X-ray machine that is used for frequent of orthopedic and trauma surgeries. Currently there are just enough C-arcs to perform surgeries, therefore it is important for OR planners to check the availability while planning a surgery. The reallocations will result in an increase of orthopedic and trauma surgery at OLVG West, therefore it is expected that more C-arcs will be required or moved from OLVG East, however this is not included in this research.

Next, the number of surgeons is not taken into account. As there are numerous individual preferences, like on which day a surgeon works or which type of surgeries he prefers, however it is impossible to implement these preferences in the model. To make sure that the schedule is realistic the dedicated specialty slots are divided equally over the days of the week.

Last, the model does not send any patient to surgery after 15:45. This rule is discussed and verified with the central OR planner. A comment was made however that the specialist decides whether a patient will have surgery and therefore exceptions are possible.

6.4.3 Experiments

A third point of discussion is concerning the experiments. We consider additional experiments with the OR schedule interesting, for example the use of dedicated in- and outpatient ORs or generic ORs in which all surgeries could operate. Although this experiment would most likely have provided positive results the specialists in OLVG West hold on to having their own OR. Therefore these possibilities are not further researched.

6.4.4 Model

Last, the model will be discussed. Within this research we did not include the flow of Lounge patients that need transferring to the ward because of medical reasons. As based on the historical data, it is impossible to know how many patients are being admitted because of medical reasons this flow is excluded from this research. Specialist also confirm that it's exceptional that a patient has to be admitted because of medical reasons.

Another model element is that there will always be elective patients that are admitted at a ward instead of the admission center. Elderly or disabled patients that bring aiding devices for example will most likely prefer to put their things at their ward bed. As it is assumed that all surgical patients will be admitted through the admission center the capacity of the Lounge can be affected by this.

Next, the transport times from Lounge to OR can be different than the transport times of the holding/recovery to OR that are used. The Lounge will be located next to the holding/recovery therefore the times will be similar. As the location of the Lounge doors to the ORs effect the transport times are not known yet the current method is sufficient.

Last, fast-track can have a positive effect on the recovery times. The current recovery times of outpatients on the ward is used but they may change if new anesthetic techniques are used. Although this limitations, this study can be used as a guideline when implement the Lounge.

Despite the points of discussion we are convinced that this research will help OLVG West to setup the Lounge in an optimal way, taking into account all indicators that are considered important for OLVG West.

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Appendix A – Dashboard B4 2014

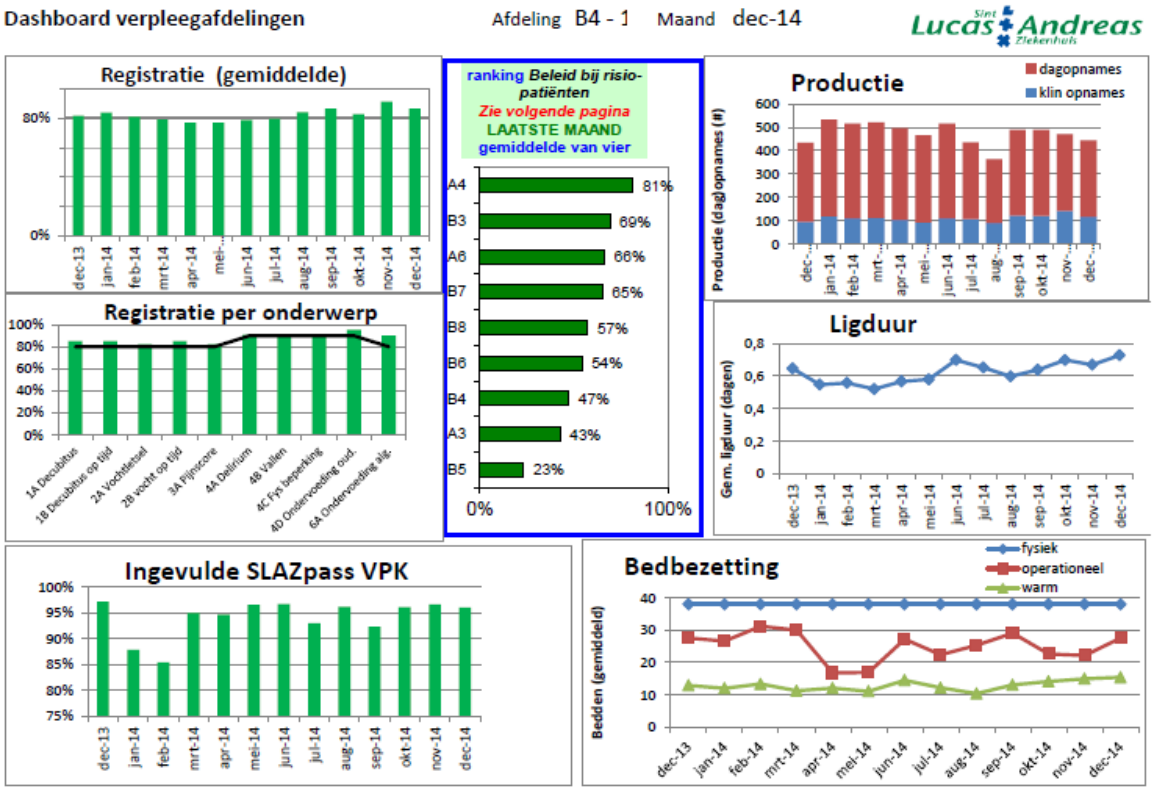


Figure 19 – Dashboard B4 outpatient ward 2014

Appendix B – Dashboard OR 2014

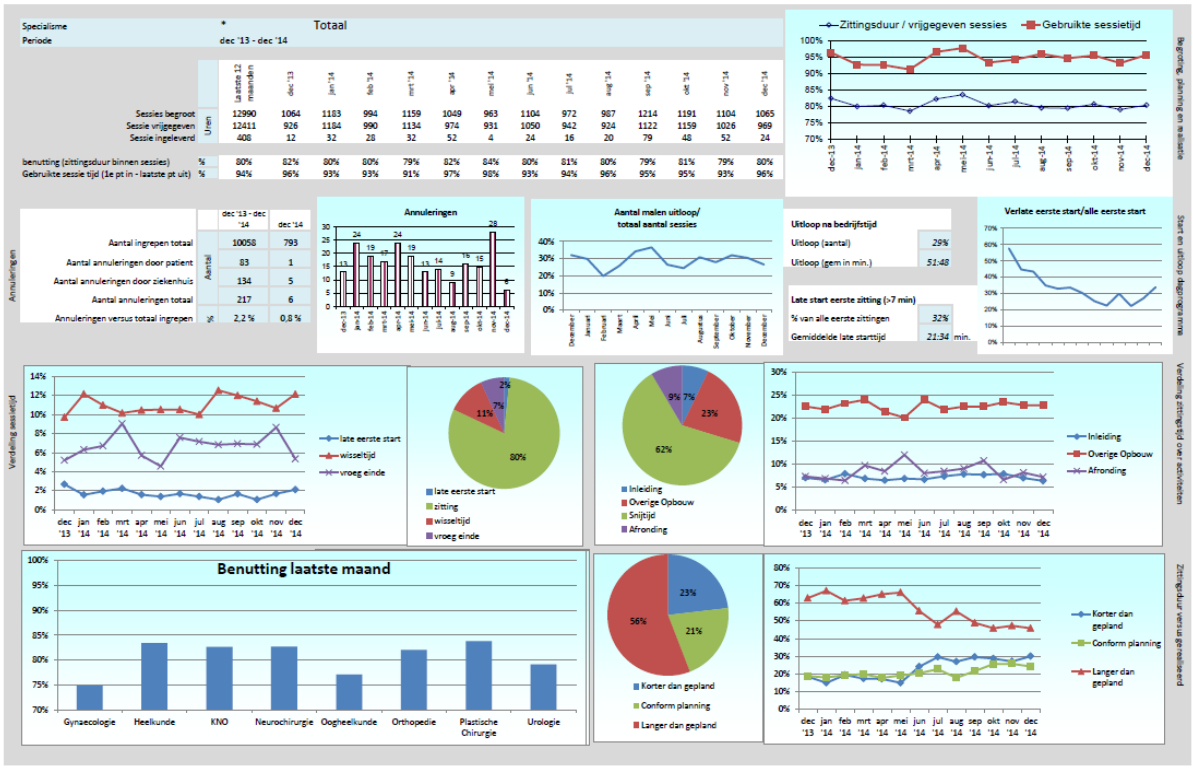


Figure 20 – OR dashboard 2014

Appendix C – Input distributions

Surgical distributions

	Mu	Sigma	n	Test statistic	Chi square	Significant?
CHI1	3.94	0.51	1104	46.19	37.13	Significant
CHI2	4.37	0.46	191	21.03	12.44	Significant
CHI3	4.44	0.29	101	16.92	8.21	Significant
CHI4	4.00	0.34	97	15.51	5.71	Significant
CHI5	4.23	0.35	57	12.59	9.19	Significant
CHI6	4.55	0.53	463	31.41	19.46	Significant
CHI7	4.51	0.34	458	31.41	29.13	Significant
ENT1	2.70	0.22	85	15.51	6.80	Significant
ENT2	3.96	0.53	279	25.00	2.47	Significant
ENT3	3.74	0.30	114	16.92	11.44	Significant
ENT4	4.16	0.29	54	12.59	3.81	Significant
ENT5	3.72	0.27	156	19.68	12.46	Significant
ENT6	4.04	0.64	146	19.68	18.55	Significant
EYE1	3.85	0.20	35	9.49	3.14	Significant
EYE2	4.27	0.38	54	12.59	11.07	Significant
EYE3	3.43	0.21	517	32.67	26.45	Significant
EYE4	3.50	0.18	67	14.07	3.57	Significant
EYE5	3.63	0.33	89	15.51	8.38	Significant
GYN1	3.89	0.38	115	16.92	3.35	Significant
GYN2	4.08	0.36	298	26.30	19.30	Significant
GYN3	4.79	0.57	97	15.51	7.75	Significant
GYN4	3.52	0.24	91	15.51	8.20	Significant
GYN5	4.14	0.19	143	18.31	9.54	Significant
GYN6	4.28	0.16	61	12.59	6.59	Significant
GYN7	5.33	0.24	29	9.49	2.55	Significant
GYN8	4.69	0.68	184	21.03	16.65	Significant
NEU1	4.27	0.28	189	21.03	18.79	Significant
NEU2	4.19	0.28	106	16.92	0.79	Significant
NEU3	4.74	0.16	94	15.51	4.23	Significant
NEU4	4.33	0.23	61	12.59	4.75	Significant
NEU5	4.74	0.52	283	25.00	9.92	Significant
ORT1	4.16	0.49	497	32.67	27.86	Significant
ORT10	4.91	0.15	158	19.68	10.00	Significant
ORT11	4.91	0.16	155	19.68	6.73	Significant
ORT12	4.57	0.17	65	14.07	4.29	Significant
ORT13	5.18	0.31	46	11.07	10.19	Significant
ORT14	4.45	0.57	193	21.03	11.97	Significant
ORT15	4.93	0.28	123	18.31	17.50	Significant
ORT16	5.36	0.47	106	16.92	11.74	Significant
ORT17	4.91	0.41	217	22.36	16.10	Significant
ORT2	3.96	0.26	167	19.68	13.86	Significant

ORT3	3.71	0.28	113	16.92	6.73	Significant
ORT4	4.72	0.19	101	16.92	15.34	Significant
ORT5	3.99	0.31	82	15.51	6.24	Significant
ORT6	4.00	0.23	70	14.07	4.06	Significant
ORT7	4.37	0.26	67	14.07	3.57	Significant
ORT8	4.34	0.41	216	22.36	9.94	Significant
ORT9	4.79	0.27	692	37.65	22.17	Significant
PLA1	3.80	0.40	81	15.51	4.89	Significant
PLA2	4.39	0.40	100	16.92	9.80	Significant
PLA3	4.21	0.17	106	16.92	3.43	Significant
PLA4	4.91	0.20	70	14.07	6.57	Significant
PLA5	4.73	0.49	159	19.68	13.15	Significant

Table 32 – Distribution surgery duration per cluster

Inter surgery duration distributions

	Specialty	mu	sigma	Exp. 84%	n	Test statistics	Chi Square	
Same procedure	**Ort**	2.42	0.48	18.06	116	16.92	15.03	Significant
	Chi	2.14	0.38	12.41	275	25.00	12.24	Significant
	Ent	1.83	0.42	9.41	169	21.03	12.62	Significant
	Neu	2.13	0.39	12.46	73	14.07	1.41	Significant
	Eye	1.07	0.22	3.63	176	21.03	20.63	Significant
	Gyn	2.30	0.44	15.34	54	12.59	7.19	Significant
	Pla	1.93	0.45	10.81	69	14.07	7.41	Significant
Other procedure	**Ort**	2.55	0.39	18.96	396	28.87	21.33	Significant
	Chi	2.27	0.41	14.63	967	43.77	41.00	Significant
	Ent	1.84	0.47	9.99	384	28.87	20.84	Significant
	Neu	2.33	0.39	15.11	356	27.59	22.61	Significant
	Eye	1.67	0.59	9.55	162	19.68	16.07	Significant
	Gyn	2.33	0.39	15.26	451	31.41	28.74	Significant
	Pla	2.12	0.41	12.60	296	26.30	19.30	Significant

Table 33 – Inter-surgery duration distribution

Recovery duration distribution

	Mu	Sigma	n	Test statistic	Chi square	Significant?
EYE	-	-	4	-	-	-
ENT	3.8051	0.5577	146	19.68	7.69863	Significant
CHIrest	3.9456	0.4728	42	11.07	2.285714	Significant
CHI7	4.3738	0.3497	235	23.68	7.361702	Significant
CHI6	3.9890	0.8391	221	22.36	18.90045	Significant
PLA	4.1034	0.4874	253	23.68	12.19763	Significant
ORT	4.0987	0.6379	243	23.68	22.8642	Significant
GYN	3.7550	0.8834	204	22.36	20.13725	Significant
NEU5	4.2156	0.5094	192	21.03	10.85417	Significant
NEUrest	3.9908	0.4604	356	27.59	16.74157	Significant

Table 34 – Recovery duration distribution per cluster of specialty

Transport duration distribution

	Mu	Sigma	n	Test statistics	Chi Square	Significant?
OR1	1.62	0.65	567	33.92	22.85	Significant
OR2	1.52	0.65	785	40.11	39.56	Significant
OR3	1.44	0.65	1043	44.99	38.65	Significant
OR4	1.00	0.94	230	23.68	13.00	Significant
OR5	1.74	0.62	301	26.30	23.69	Significant
OR6	1.68	0.59	663	36.42	35.30	Significant
OR7	1.58	0.55	707	37.65	30.52	Significant
OR8	1.64	0.59	922	42.56	55.11	Not Significant
OR9	1.65	0.56	834	40.11	16.34	Significant
OR10	1.73	0.54	892	41.34	36.46	Significant

Table 35 – Transport duration distribution per OR

Appendix D – Sample size

Cluster	Sample	Data	freq
CHI1	1110	1188	0.934343
CHI2	150	162	0.925926
CHI3	112	101	1.108911
CHI4	98	106	0.924528
CHI5	49	58	0.844828
CHI6	390	378	1.031746
CHI7	503	485	1.037113
ENT1	91	96	0.947917
ENT2	332	289	1.148789
ENT3	140	118	1.186441
ENT4	65	57	1.140351
ENT5	171	158	1.082278
ENT6	160	138	1.15942
EYE1	42	37	1.135135
EYE2	62	71	0.873239
EYE3	599	534	1.121723
EYE4	66	70	0.942857
EYE5	99	94	1.053191
GYN1	105	100	1.05
GYN2	280	288	0.972222
GYN3	109	98	1.112245
GYN4	91	92	0.98913
GYN5	141	144	0.979167
GYN6	58	62	0.935484
GYN7	27	29	0.931034
GYN8	185	187	0.989305
NEU1	205	195	1.051282
NEU2	102	107	0.953271
NEU3	78	95	0.821053
NEU4	62	62	1
NEU5	254	265	0.958491
ORT1	523	523	1
ORT10	172	160	1.075
ORT11	166	157	1.057325
ORT12	73	66	1.106061
ORT13	48	46	1.043478
ORT14	217	194	1.118557
ORT15	116	124	0.935484
ORT16	108	108	1
ORT17	249	228	1.092105
ORT2	177	169	1.047337
ORT3	114	122	0.934426

ORT4	96	106	0.90566
ORT5	79	84	0.940476
ORT6	68	70	0.971429
ORT7	68	70	0.971429
ORT8	265	254	1.043307
ORT9	834	790	1.055696
PLA1	101	98	1.030612
PLA2	163	142	1.147887
PLA3	110	108	1.018519
PLA4	81	71	1.140845
PLA5	119	112	1.0625
Total	9883	9666	

Table 36 – Samples per cluster from data and in constructed sample

Row Labels	Data in days	Sample in days	ratio
CHI1	47.64079861	44.81180306	0.940618
CHI2	9.367222222	11.59578268	1.23791
CHI3	6.196944444	6.201195822	1.000686
CHI4	4.214583333	3.876184548	0.919708
CHI5	2.975115741	2.866613902	0.96353
CHI6	30.56563657	34.71932081	1.135894
CHI7	32.7287037	30.92471059	0.94488
ENT1	1.055034722	0.896805092	0.850024
ENT2	10.88070602	11.72263934	1.077379
ENT3	3.635601852	3.462950314	0.952511
ENT4	2.65650463	2.510011296	0.944855
ENT5	4.731979167	4.682539647	0.989552
ENT6	7.084189815	7.103151826	1.002677
EYE1	1.24306713	1.165597242	0.937678
EYE2	3.776886574	2.84941379	0.754435
EYE3	11.82201389	11.32584947	0.95803
EYE4	1.690185185	1.556996496	0.921199
EYE5	2.781550926	2.44743137	0.87988
GYN1	3.800381944	4.228068671	1.112538
GYN2	12.91415509	13.08480431	1.013214
GYN3	9.680081019	9.476722521	0.978992
GYN4	2.231527778	2.202742326	0.987101
GYN5	6.427847222	6.349583029	0.987824
GYN6	3.184108796	3.07139391	0.964601
GYN7	4.255925926	4.310943446	1.012927
GYN8	17.24841435	17.06070519	0.989117
NEU1	9.937106481	9.80575954	0.986782

NEU2	5.155011574	5.118845157	0.992984
NEU3	7.696076389	7.5767824	0.984499
NEU4	3.417349537	3.300021605	0.965667
NEU5	25.16731481	25.81764887	1.02584
ORT1	26.23199074	24.95793797	0.951431
ORT10	15.37916667	15.08484113	0.980862
ORT11	15.08333333	14.74066891	0.977282
ORT12	4.545381944	4.417659906	0.971901
ORT13	5.949305556	5.986511484	1.006254
ORT14	13.44319444	13.6417024	1.014766
ORT15	12.46956019	12.25529696	0.982817
ORT16	17.7819213	17.67068421	0.993744
ORT17	22.49476852	22.18950114	0.986429
ORT2	6.322916667	6.257430795	0.989643
ORT3	3.801469907	3.320466003	0.873469
ORT4	8.366967593	7.95907303	0.951249
ORT5	3.368055556	3.244690063	0.963372
ORT6	2.720833333	2.724694893	1.001419
ORT7	3.916666667	3.778934158	0.964834
ORT8	14.7153125	12.36717637	0.840429
ORT9	66.62376157	60.06320848	0.901528
PLA1	3.504791667	2.720733418	0.77629
PLA2	8.974583333	6.120539711	0.681986
PLA3	5.420891204	5.039190734	0.929587
PLA4	6.897638889	6.71540372	0.97358
PLA5	10.94146991	14.26494207	1.30375
Total	575.1160069	561.6443058	0.976576

Table 37 – Total surgery duration per cluster from data and constructed sample

Appendix E – Experiment settings and results

First stage of the experiments

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	64800	1800	900	12	TRUE	Random
2	66600	1800	900	12	TRUE	Random
3	68400	1800	900	12	TRUE	Random
4	70200	1800	900	12	TRUE	Random
5	72000	1800	900	12	TRUE	Random
6	73800	1800	900	12	TRUE	Random
7	75600	1800	900	12	TRUE	Random
8	64800	3600	900	12	TRUE	Random
9	64800	5400	900	12	TRUE	Random
10	64800	7200	900	12	TRUE	Random
11	64800	1800	1800	12	TRUE	Random
12	64800	1800	2700	12	TRUE	Random
13	64800	1800	3600	12	TRUE	Random
14	64800	1800	900	14	TRUE	Random
15	64800	1800	900	16	TRUE	Random
16	64800	1800	900	18	TRUE	Random
17	64800	1800	900	12	FALSE	Random
18	64800	1800	900	12	TRUE	OFLRF
19	66600	1800	900	12	TRUE	OFLRF
20	68400	1800	900	12	TRUE	OFLRF
21	70200	1800	900	12	TRUE	OFLRF
22	72000	1800	900	12	TRUE	OFLRF
23	73800	1800	900	12	TRUE	OFLRF
24	75600	1800	900	12	TRUE	OFLRF
25	64800	3600	900	12	TRUE	OFLRF
26	64800	5400	900	12	TRUE	OFLRF
27	64800	7200	900	12	TRUE	OFLRF
28	64800	1800	1800	12	TRUE	OFLRF
29	64800	1800	2700	12	TRUE	OFLRF
30	64800	1800	3600	12	TRUE	OFLRF
31	64800	1800	900	14	TRUE	OFLRF
32	64800	1800	900	16	TRUE	OFLRF
33	64800	1800	900	18	TRUE	OFLRF
34	64800	1800	900	12	FALSE	OFLRF
35	64800	1800	900	12	TRUE	OF
36	66600	1800	900	12	TRUE	OF
37	68400	1800	900	12	TRUE	OF
38	70200	1800	900	12	TRUE	OF
39	72000	1800	900	12	TRUE	OF
40	73800	1800	900	12	TRUE	OF
41	75600	1800	900	12	TRUE	OF

42	64800	3600	900	12	TRUE	OF
43	64800	5400	900	12	TRUE	OF
44	64800	7200	900	12	TRUE	OF
45	64800	1800	1800	12	TRUE	OF
46	64800	1800	2700	12	TRUE	OF
47	64800	1800	3600	12	TRUE	OF
48	64800	1800	900	14	TRUE	OF
49	64800	1800	900	16	TRUE	OF
50	64800	1800	900	18	TRUE	OF
51	64800	1800	900	12	FALSE	OF

Table 38 – Experimental settings first stage experiments

Results

Random schedule

Performance Indicator	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
Average Length of Stay	5:4 2:3 3	5:4 7:0 7	5:5 0:4 9	5:5 3:4 0	5:5 5:3 7	5:5 6:5 9	5:5 7:5 0	5:4 3:3 4	5:4 4:0 0	5:4 4:1 1	5:4 9:5 5	5:5 8:4 2	5:3 9:3 7	5:3 8:1 4	5:3 7:3 3	5:3 9:1 2
Bed Occupancy Ratio	52 %	50 %	48 %	47 %	45 %	44 %	42 %	52 %	52 %	52 %	53 %	54 %	51 %	51 %	51 %	51 %
Operation Room Utilization Ratio	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %
Cancellation Ratio	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %
Overtime Ratio	7.4 %	7.4 %	7.4 %	7.4 %	7.4 %	7.4 %	7.4 %	7.0 %	6.9 %	6.8 %	6.8 %	6.4 %	7.4 %	7.4 %	7.4 %	7.4 %
Average Waiting Time Before Surgery	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5	0:5 4:3 1	1:0 8:4 3	1:2 3:3 1	0:3 8:0 4	0:3 4:3 3	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5	0:4 1:3 5
Patients Moved to Ward	93 8	77 9	63 2	49 9	37 9	29 0	22 5	91 0	90 0	89 6	89 6	87 4	89 0	86 2	84 0	90 4
Lounge Patients Treated at Holding/Recovery	12 61	12 59	12 58	12 58	12 61	12 58	12 58	12 84	12 92	12 95	13 26	13 79	79 2	45 2	23 0	10 58
Lounge Patients Treated	46 49	46 49	46 49	46 49	46 49	46 49	46 49	46 50	46 50	46 50	46 48	46 45	46 49	46 49	46 49	46 49
Inpatients Treated	44 61	44 61	44 61	44 61	44 61	44 62	44 63	44 68	44 69	44 69	44 66	44 68	44 62	44 62	44 63	44 61

Table 39 – Results Random schedule first stage of the experiments

OFLRF schedule

Performance Indicator	18	19	20	21	22	23	24	25	26	27	28	29	31	32	33	34
Average Length of Stay	6:0 5:5 1	6:0 6:3 9	6:0 7:0 8	6:0 7:2 6	6:0 7:2 8	6:0 7:3 2	6:0 7:3 7	6:0 6:5 2	6:0 7:2 4	6:0 7:3 5	6:1 2:3 0	6:2 0:2 7	5:5 6:3 9	5:5 0:4 2	5:4 7:2 6	6:0 1:5 6
Bed Occupancy Ratio	55 %	53 %	51 %	49 %	47 %	45 %	44 %	55 %	55 %	55 %	56 %	57 %	54 %	53 %	52 %	55 %
Operation Room Utilization Ratio	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %
Cancellation Ratio	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %	1.8 %
Overtime Ratio	7.1 %	7.1 %	7.1 %	7.1 %	7.1 %	7.1 %	7.1 %	6.7 %	6.5 %	6.5 %	6.4 %	6.0 %	7.1 %	7.2 %	7.2 %	7.1 %
Average Waiting Time Before Surgery	0:4 0:1 1	0:4 0:1 1	0:4 0:1 1	0:4 0:1 1	0:4 0:1 1	0:4 0:1 0	0:4 0:1 1	0:5 2:5 5	1:0 6:5 5	1:2 1:4 0	0:3 6:4 0	0:3 3:0 9	0:4 0:1 0	0:4 0:1 0	0:4 0:1 0	0:4 0:1 1
Patients Moved to Ward	30 9	24 4	20 4	17 9	16 5	15 4	15 1	29 3	29 2	29 5	30 1	31 4	26 1	24 9	24 2	32 2

Lounge Patients Treated at Holding/Recovery	15 57	15 57	15 56	15 56	15 54	15 55	15 55	15 62	15 64	15 64	15 65	15 69	10 78	68 5	38 6	14 88
Lounge Patients Treated	46 56	46 56	46 56	46 56	46 54	46 54	46 55	46 59	46 61	46 61	46 52	46 46	46 60	46 59	46 59	46 57
Inpatients Treated	44 29	44 28	44 28	44 28	44 28	44 31	44 33	44 49	44 51	44 51	44 23	44 07	44 49	44 53	44 55	44 30

Table 40 – Results OFLRF schedule first stage of the experiments

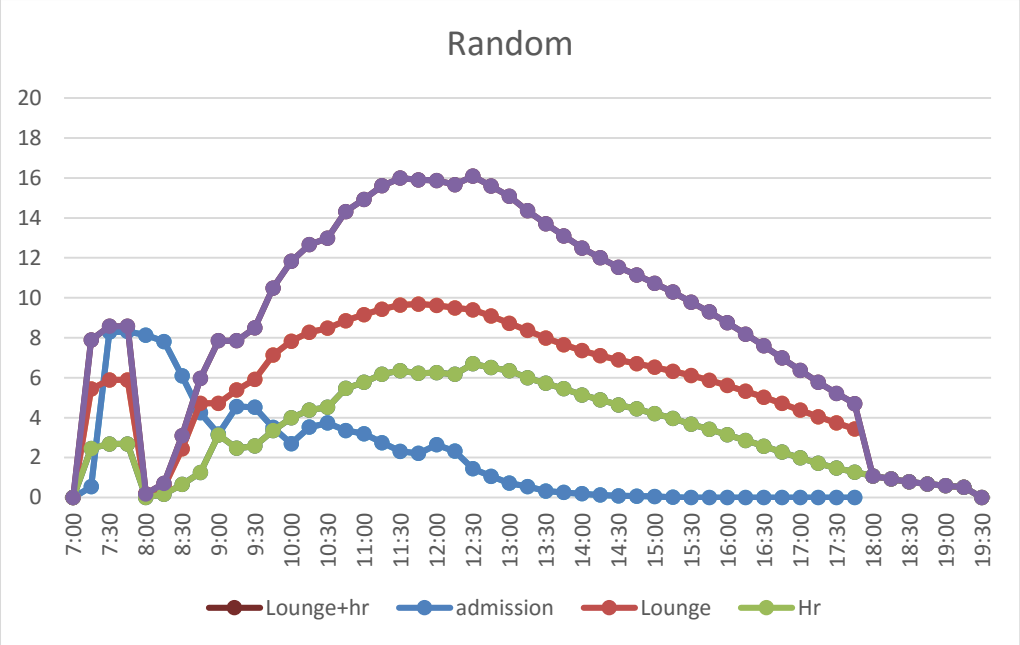
OF Schedule

Performance Indicator	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**48**	**49**	**50**	**51**
Average Length of Stay	5:5 7:4 0	5:5 9:0 0	5:5 9:5 2	6:0 0:2 5	6:0 0:4 2	6:0 0:5 7	6:0 1:0 3	5:5 8:3 6	5:5 9:1 3	5:5 9:2 6	6:0 4:3 0	6:1 2:1 8	5:5 0:5 1	5:4 7:1 6	5:4 5:2 9	5:5 3:0 8
Bed Occupancy Ratio	54 %	52 %	50 %	48 %	46 %	44 %	43 %	54 %	54 %	54 %	55 %	56 %	53 %	52 %	52 %	53 %
Operation Room Utilization Ratio	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %
Cancellation Ratio	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %	1.8 %	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %	1.9 %
Overtime Ratio	7.2 %	7.2 %	7.2 %	7.2 %	7.1 %	7.1 %	7.2 %	6.7 %	6.5 %	6.4 %	6.5 %	6.2 %	7.2 %	7.2 %	7.2 %	7.2 %
Average Waiting Time Before Surgery	0:3 9:2 0	0:3 9:2 0	0:3 9:2 0	0:3 9:2 0	0:3 9:1 9	0:3 9:2 0	0:3 9:1 9	0:5 2:0 3	1:0 6:0 1	1:2 0:4 3	0:3 5:4 8	0:3 2:1 8	0:3 9:1 9	0:3 9:1 9	0:3 9:1 9	0:3 9:1 9
Patients Moved to Ward	38 9	30 0	23 7	19 5	16 8	14 9	14 2	37 1	36 7	37 0	36 8	36 4	34 9	32 9	31 7	38 1
Lounge Patients Treated at Holding/Recovery	14 80	14 80	14 80	14 80	14 79	14 79	14 79	14 90	14 94	14 96	14 97	15 08	98 1	58 6	29 4	13 34
Lounge Patients Treated	46 66	46 66	46 66	46 66	46 67	46 67	46 67	46 66	46 67	46 67	46 65	46 62	46 67	46 67	46 67	46 66
Inpatients Treated	44 55	44 55	44 55	44 55	44 54	44 55	44 58	44 64	44 65	44 61	44 60	44 58	44 57	44 57	44 57	44 55

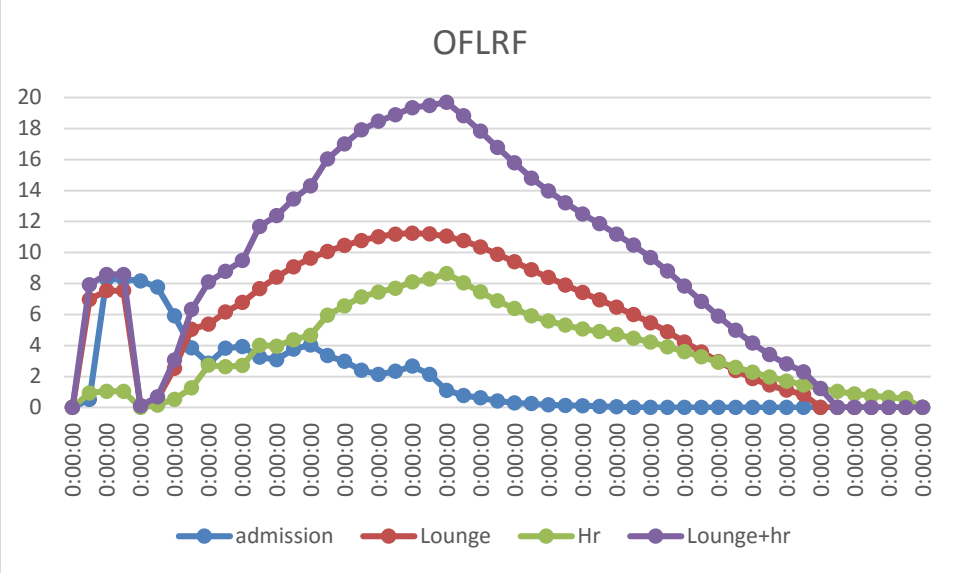
Table 41 – Results OF schedule first stage of the experiments

Graph 26 – Slack on registration and waiting time for admission

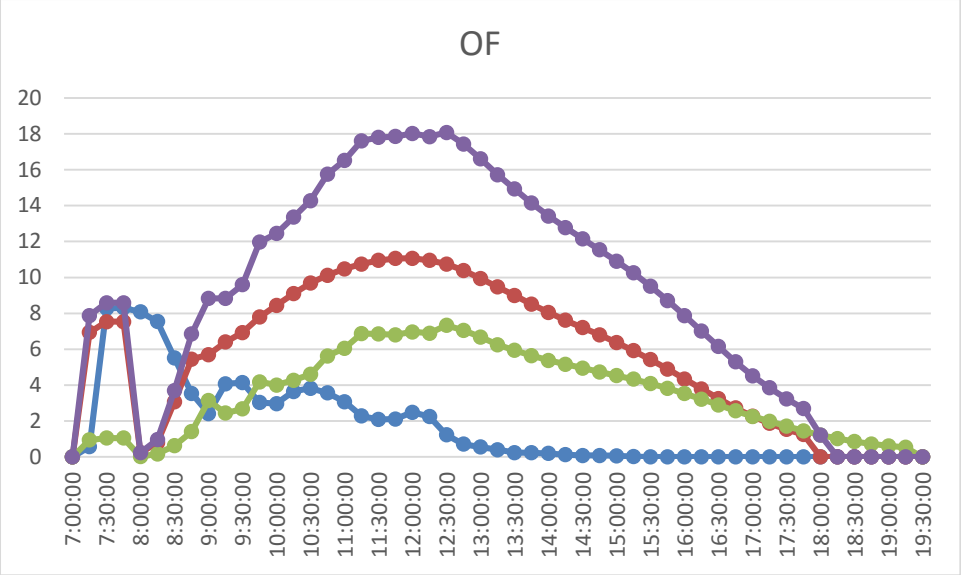
Graph 26 show the relation between the registered time patients sits in the admission center and the *slack on registration*. Even though the slack factor was increased with 400% the actual registered time only doubled.



Graph 27 – Relation between time and present patient for random schedule



Graph 28 – Relation between time and present patient for OFLRF schedule



Graph 29 – Relation between time and present patient for OF schedule

Second stage experiments

Experiment #	Closing time Lounge	Slack on registration	Slack on preparation	Lounge spots	dedicated chairs	Schedule
1	70200	3600	300	18	Flexible	OF
2	70200	3600	600	18	Flexible	OF
3	70200	3600	900	18	Flexible	OF
4	70200	4500	300	18	Flexible	OF
5	70200	4500	600	18	Flexible	OF
6	70200	4500	900	18	Flexible	OF
7	70200	5400	300	18	Flexible	OF
8	70200	5400	600	18	Flexible	OF
9	70200	5400	900	18	Flexible	OF
10	70200	3600	300	18	Flexible	OFLRF
11	70200	3600	600	18	Flexible	OFLRF
12	70200	3600	900	18	Flexible	OFLRF
13	70200	4500	300	18	Flexible	OFLRF
14	70200	4500	600	18	Flexible	OFLRF
15	70200	4500	900	18	Flexible	OFLRF
16	70200	5400	300	18	Flexible	OFLRF
17	70200	5400	600	18	Flexible	OFLRF
18	70200	5400	900	18	Flexible	OFLRF
19	72000	3600	300	18	Flexible	OF
20	72000	3600	600	18	Flexible	OF
21	72000	3600	900	18	Flexible	OF
22	72000	4500	300	18	Flexible	OF
23	72000	4500	600	18	Flexible	OF
24	72000	4500	900	18	Flexible	OF
25	72000	5400	300	18	Flexible	OF
26	72000	5400	600	18	Flexible	OF

27	72000	5400	900	18	Flexible	OF
28	72000	3600	300	18	Flexible	OFLRF
29	72000	3600	600	18	Flexible	OFLRF
30	72000	3600	900	18	Flexible	OFLRF
31	72000	4500	300	18	Flexible	OFLRF
32	72000	4500	600	18	Flexible	OFLRF
33	72000	4500	900	18	Flexible	OFLRF
34	72000	5400	300	18	Flexible	OFLRF
35	72000	5400	600	18	Flexible	OFLRF
36	72000	5400	900	18	Flexible	OFLRF
37	73800	3600	300	18	Flexible	OF
38	73800	3600	600	18	Flexible	OF
39	73800	3600	900	18	Flexible	OF
40	73800	4500	300	18	Flexible	OF
41	73800	4500	600	18	Flexible	OF
42	73800	4500	900	18	Flexible	OF
43	73800	5400	300	18	Flexible	OF
44	73800	5400	600	18	Flexible	OF
45	73800	5400	900	18	Flexible	OF
46	73800	3600	300	18	Flexible	OFLRF
47	73800	3600	600	18	Flexible	OFLRF
48	73800	3600	900	18	Flexible	OFLRF
49	73800	4500	300	18	Flexible	OFLRF
50	73800	4500	600	18	Flexible	OFLRF
51	73800	4500	900	18	Flexible	OFLRF
52	73800	5400	300	18	Flexible	OFLRF
53	73800	5400	600	18	Flexible	OFLRF
54	73800	5400	900	18	Flexible	OFLRF

Table 42 – Experimental settings second stage experiments

Results

OF schedule

Performance Indicator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Average Length of Stay	5:43:59	5:45:06	5:46:36	5:44:06	5:45:16	5:46:41	5:44:04	5:45:18	5:46:50
Bed Occupancy Ratio	52%	52%	52%	52%	52%	52%	52%	52%	52%
Operation Room Utilization Ratio	70%	70%	70%	70%	70%	70%	70%	70%	70%
Cancellation Ratio	1.9%	1.9%	1.8%	1.9%	1.9%	1.8%	1.9%	1.8%	1.8%
Overtime Ratio	7.3%	7.0%	6.8%	7.1%	6.9%	6.6%	7.0%	6.8%	6.5%
Average Waiting Time Before Surgery	0:54:23	0:53:13	0:52:03	1:01:13	1:00:04	0:58:55	1:08:20	1:07:10	1:06:01
Patients Moved to Ward	169	167	164	166	165	167	167	167	166
Lounge Patients Treated at Holding/Recovery	45	48	55	44	49	54	44	51	55
Lounge Patients Treated	4667	4667	4666	4668	4667	4666	4668	4668	4667
Inpatients Treated	4454	4461	4466	4457	4463	4466	4457	4462	4465

Table 43 – Results OF schedule and closing time of 19:30 second stage of the experiments

OFLRF schedule

Performance Indicator	10	11	12	13	14	15	16	17	18
Average Length of Stay	5:45:00	5:46:17	5:47:46	5:45:04	5:46:21	5:47:55	5:45:07	5:46:24	5:47:59
Bed Occupancy Ratio	52%	52%	52%	52%	52%	53%	52%	52%	53%
Operation Room Utilization Ratio	70%	70%	70%	70%	70%	70%	70%	70%	70%
Cancellation Ratio	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
Overtime Ratio	7.3%	7.0%	6.7%	7.2%	6.9%	6.6%	7.0%	6.8%	6.5%
Average Waiting Time Before Surgery	0:55:16	0:54:06	0:52:56	1:02:08	1:00:59	0:59:49	1:09:15	1:08:06	1:06:57
Patients Moved to Ward	157	155	154	156	155	157	157	156	157
Lounge Patients Treated at Holding/Recovery	223	234	242	228	235	242	229	238	247
Lounge Patients Treated	4663	4663	4662	4664	4664	4663	4665	4665	4664
Inpatients Treated	4454	4461	4466	4456	4462	4464	4454	4460	4462

Table 44 – Results OFLRF schedule and closing time of 19:30 second stage of the experiments

OF schedule

Performance Indicator	19	20	21	22	23	24	25	26	27
Average Length of Stay	5:44:08	5:45:22	5:46:49	5:44:16	5:45:25	5:46:54	5:44:20	5:45:24	5:46:59
Bed Occupancy Ratio	52%	52%	52%	52%	52%	52%	52%	52%	52%
Operation Room Utilization Ratio	70%	70%	70%	70%	70%	70%	70%	70%	70%
Cancellation Ratio	1.9%	1.9%	1.8%	1.9%	1.8%	1.8%	1.9%	1.9%	1.8%
Overtime Ratio	7.3%	7.0%	6.8%	7.1%	6.9%	6.6%	7.0%	6.8%	6.5%
Average Waiting Time Before Surgery	0:54:23	0:53:13	0:52:03	1:01:14	1:00:04	0:58:55	1:08:20	1:07:10	1:06:01
Patients Moved to Ward	150	149	149	147	149	152	152	151	151
Lounge Patients Treated at Holding/Recovery	44	49	54	45	50	56	45	50	56
Lounge Patients Treated	4667	4667	4666	4668	4667	4666	4668	4668	4667
Inpatients Treated	4456	4462	4466	4457	4464	4466	4455	4462	4465

Table 45 – Results OF schedule and closing time of 20:00 second stage of the experiments

OFLRF schedule

Performance Indicator	28	29	30	31	32	33	34	35	36
Average Length of Stay	5:45:05	5:46:24	5:47:55	5:45:10	5:46:28	5:47:59	5:45:10	5:46:32	5:48:05
Bed Occupancy Ratio	52%	52%	53%	52%	52%	53%	52%	52%	53%
Operation Room Utilization Ratio	70%	70%	70%	70%	70%	70%	70%	70%	70%
Cancellation Ratio	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
Overtime Ratio	7.3%	7.0%	6.8%	7.2%	6.9%	6.6%	7.0%	6.8%	6.5%
Average Waiting Time Before Surgery	0:55:16	0:54:06	0:52:56	1:02:08	1:00:59	0:59:49	1:09:15	1:08:06	1:06:57
Patients Moved to Ward	147	147	147	147	145	148	147	150	150
Lounge Patients Treated at Holding/Recovery	225	234	243	228	236	243	229	237	246
Lounge Patients Treated	4663	4663	4662	4664	4664	4663	4665	4665	4664
Inpatients Treated	4454	4461	4466	4456	4462	4464	4456	4459	4463

Table 46– Results OFLRF schedule and closing time of 20:00 second stage of the experiments

OF schedule

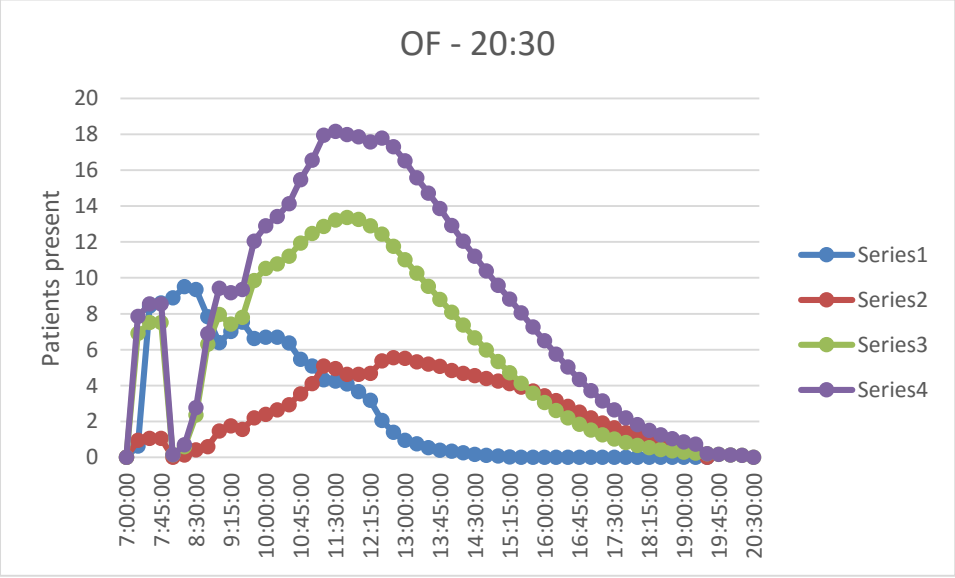
Performance Indicator	37	38	39	40	41	42	43	44	45
Average Length of Stay	5:44:17	5:45:27	5:46:55	5:44:23	5:45:31	5:47:01	5:44:25	5:45:35	5:47:06
Bed Occupancy Ratio	52%	52%	52%	52%	52%	52%	52%	52%	52%
Operation Room Utilization Ratio	70%	70%	70%	70%	70%	70%	70%	70%	70%
Cancellation Ratio	1.9%	1.9%	1.8%	1.9%	1.8%	1.8%	1.9%	1.8%	1.8%
Overtime Ratio	7.3%	7.0%	6.8%	7.1%	6.9%	6.6%	7.0%	6.8%	6.5%
Average Waiting Time Before Surgery	0:54:23	0:53:13	0:52:04	1:01:14	1:00:04	0:58:55	1:08:20	1:07:11	1:06:02
Patients Moved to Ward	144	140	141	141	140	142	142	143	145
Lounge Patients Treated at Holding/Recovery	44	49	54	45	49	55	44	50	56
Lounge Patients Treated	4667	4667	4666	4668	4667	4666	4669	4668	4667
Inpatients Treated	4456	4463	4468	4459	4465	4468	4458	4465	4467

Table 47 – Results OF schedule and closing time of 20:30 second stage of the experiments

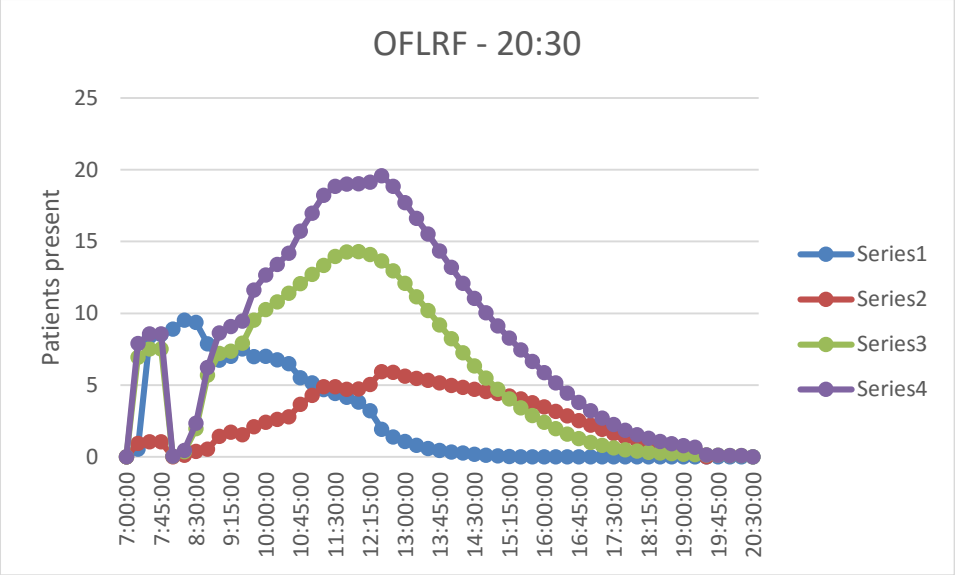
OFLRF schedule

Performance Indicator	46	47	48	49	50	51	52	53	54
Average Length of Stay	5:45:10	5:46:27	5:47:58	5:45:14	5:46:29	5:45:31	5:47:01	5:44:25	5:45:35
Bed Occupancy Ratio	52%	52%	53%	52%	52%	52%	52%	52%	52%
Operation Room Utilization Ratio	70%	70%	71%	70%	70%	70%	70%	70%	70%
Cancellation Ratio	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.9%	1.8%
Overtime Ratio	7.3%	7.0%	6.8%	7.2%	6.9%	6.9%	6.6%	7.0%	6.8%
Average Waiting Time Before Surgery	0:55:16	0:54:06	0:52:56	1:02:08	1:00:59	1:00:04	0:58:55	1:08:20	1:07:11
Patients Moved to Ward	145	144	144	142	144	140	142	142	143
Lounge Patients Treated at Holding/Recovery	223	234	242	229	235	49	55	44	50
Lounge Patients Treated	4663	4662	4662	4664	4664	4667	4666	4669	4668
Inpatients Treated	4456	4465	4468	4458	4465	4465	4468	4458	4465

Table 48– Results OFLRF schedule and closing time of 20:30 second stage of the experiments c



Graph 30 – Relation between time and present patient for OF schedule



Graph 31 – Relation between time and present patient for OFLRF schedule

Increased number of ORs

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	72000	5400	900	18	Flexible	OF

Table 49 – Experimental setting increased number of ORs

Cluster	# patients
CHI1	1856
CHI2	286
CHI3	238
CHI4	194
CHI5	114
CHI6	615
CHI7	820
ENT1	182
ENT2	474
ENT3	167
ENT4	95
ENT5	269
ENT6	206
EYE1	64
EYE2	131
EYE3	726
EYE4	82
EYE5	137
GYN1	212
GYN2	438
GYN3	211
GYN4	162
GYN5	265

GYN6	132
GYN7	83
GYN8	360
NEU1	290
NEU2	174
NEU3	144
NEU4	97
NEU5	468
ORT1	843
ORT10	255
ORT11	277
ORT12	107
ORT13	73
ORT14	294
ORT15	207
ORT16	179
ORT17	367
ORT2	249
ORT3	179
ORT4	172
ORT5	137
ORT6	115
ORT7	117
ORT8	373
ORT9	1085
PLA1	244
PLA2	299
PLA3	236
PLA4	211
PLA5	252
Total	**15963**

Table 50 – Sample patient group increased number of ORs experiment

	Monday	Tuesday	Wednesday	Thursday	Friday	
CHI	3	3	3	3	2	14
GYN	2	2	1	1	1	7
ENT			1	1	1	3
NEU	1	1	1	1	1	5
EYE	1				1	2
ORT	4	5	5	5	5	24
PLA	1	1	1	1	1	5
Total	**12**	**12**	**12**	**12**	**12**	**60**

Table 51 – Increased number of ORs experiment OR division

Results

Performance Indicator	COS	Stage 3
Average Length of Stay	5:46:59	5:57:54
Bed Occupancy Ratio	44%	75%
Operation Room Utilization Ratio	70%	83%
Cancellation Ratio	1.8%	1.8%
Overtime Ratio	6.5%	11.1%
Average Waiting Time Before Surgery	1:06:01	1:08:45
Patients Moved to Ward	151	425
Lounge Patients Treated at Holding/Recovery	56	2532
Lounge Patients Treated	4667	7601
Inpatients Treated	4465	6858

Table 52 – Results increased number of OR experiment

Without Lounge

Results

Performance Indicator	COS	No Lounge
Average Length of Stay	5:46:59	
Bed Occupancy Ratio	44.4%	0.0%
Operation Room Utilization Ratio	70.3%	70.3%
Cancellation Ratio	1.8%	1.8%
Overtime Ratio	6.5%	6.5%
Average Waiting Time Before Surgery	1:06:01	1:05:58
Patients Moved to Ward	151	211
Lounge Patients Treated at Holding/Recovery	56	4682
Lounge Patients Treated	4667	4659
Inpatients Treated	4465	4453

Table 53 – Results without Lounge experiment

Number of Lounge spots

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	72000	5400	900	26	Flexible	OF
2	72000	5400	900	25	Flexible	OF
3	72000	5400	900	24	Flexible	OF
4	72000	5400	900	23	Flexible	OF
5	72000	5400	900	22	Flexible	OF
6	72000	5400	900	21	Flexible	OF
7	72000	5400	900	20	Flexible	OF
8	72000	5400	900	19	Flexible	OF
9	72000	5400	900	18	Flexible	OF
10	72000	5400	900	17	Flexible	OF
11	72000	5400	900	16	Flexible	OF
12	72000	5400	900	15	Flexible	OF
13	72000	5400	900	14	Flexible	OF
14	72000	5400	900	13	Flexible	OF

15	72000	5400	900	12	Flexible	OF

Table 54 – Experiment setting number of Lounge spots

Results

Experiment #	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12
ALoS	5:46:56	5:46:56	5:46:56	5:46:56	5:46:55	5:46:55	5:46:56	5:46:57	5:46:59	5:47:10	5:47:43	5:48:52	5:50:46	5:53:42	5:58:08
BOR	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	53%	53%	53%	53%	54%
ORUR	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
CR	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
OvR	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%
AWTA	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01	1:06:01
PMtW	199	199	199	199	199	199	199	199	199	200	200	202	202	204	207
LPTaH/R	0	0	0	0	0	2	6	19	56	136	270	457	696	998	1347
LPT	4667	4667	4667	4667	4667	4667	4667	4667	4667	4667	4667	4667	4667	4667	4667
IT	4465	4465	4465	4465	4465	4465	4465	4465	4465	4465	4465	4465	4465	4465	4464

Table 55 – Results number of Lounge spots

Inpatients admitted at Lounge

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	68400	5400	900	18	Flexible	If
2	70200	5400	900	18	Flexible	If
3	72000	5400	900	18	Flexible	If
4	73800	5400	900	18	Flexible	If
5	75600	5400	900	18	Flexible	If
6	77400	5400	900	18	Flexible	If
7	79200	5400	900	18	Flexible	If
8	81000	5400	900	18	Flexible	If
9	82800	5400	900	18	Flexible	If

Table 56 – Experimental setting inpatient admitted at Lounge

Results

Closing time	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30
Experiment #	1	2	3	4	5	6	7	8
ALoS	5:53:36	5:58:58	6:02:32	6:04:46	6:06:06	6:06:52	6:07:20	6:07:35
BOR	50%	51%	51%	52%	52%	52%	52%	52%
ORUR	70%	70%	70%	70%	70%	70%	70%	70%
CR	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
OvR	6.6%	6.6%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%
AWTA	1:15:19	1:15:19	1:15:19	1:15:19	1:15:19	1:15:19	1:15:19	1:15:19
PMtW	1085	786	555	394	286	221	186	165
LPTaH/R	127	124	125	125	125	125	125	125
LPT	4381	4381	4382	4384	4385	4385	4384	4384
IT	4632	4632	4633	4633	4633	4633	4633	4633

Table 57 – Results inpatient admitted at Lounge

COS with altering closing times

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	72000	5400	900	18	Flexible	OF
2	68400	5400	900	18	Flexible	OF
3	64800	5400	900	18	Flexible	OF

Table 58 – Experiment setting altering closing time with COS

Results

Performance Indicator	18:00	19:00	20:00
Average Length of Stay	5:45:17	5:46:33	5:46:59
Bed Occupancy Ratio	52%	52%	52%
Operation Room Utilization Ratio	70%	70%	70%
Cancellation Ratio	1.8%	1.8%	1.8%
Overtime Ratio	6.5%	6.5%	6.5%
Average Waiting Time Before Surgery	1:06:01	1:06:01	1:06:01
Patients Moved to Ward	279	186	149
Lounge Patients Treated at Holding/Recovery	56	55	56
Lounge Patients Treated	4667	4667	4667
Inpatients Treated	4465	4465	4465

Table 59 – Results altering closing time with COS

COS with slack on registration of 1:00

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	72000	3600	900	18	Flexible	OF

Table 60 – Experiment setting COS with slack on registration at 1:00 hour

Results

Performance Indicator	COS	4
Average Length of Stay	5:46:59	5:46:49
Bed Occupancy Ratio	52%	52%
Operation Room Utilization Ratio	70%	70%
Cancellation Ratio	1.8%	1.8%
Overtime Ratio	6.5%	6.8%
Average Waiting Time Before Surgery	1:06:01	0:52:03
Patients Moved to Ward	149	147
Lounge Patients Treated at Holding/Recovery	56	54
Lounge Patients Treated	4667	4666
Inpatients Treated	4465	4466

Table 61 – Results COS with slack on registration at 1:00 hour

COS with slacks of 0:05

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	72000	300	300	18	Flexible	OF

Table 62 – Experiment setting COS with slack of 0:05 hour

Results

Performance Indicator	COS	Slacks of 0:05
Average Length of Stay	5:46:59	5:43:42
Bed Occupancy Ratio	52%	52%
Operation Room Utilization Ratio	70%	70%
Cancellation Ratio	1.8%	1.9%
Overtime Ratio	6.5%	8.3%
Average Waiting Time Before Surgery	1:06:01	0:32:06
Patients Moved to Ward	149	187
Lounge Patients Treated at Holding/Recovery	56	47
Lounge Patients Treated	4667	4662
Inpatients Treated	4465	4417

Table 63 – Results COS with slack of 0:05 hour

COS with random schedule

Experiment #	Closing time Lounge	slack on registration	slack on preparation	Lounge spots	dedicated chairs	Schedule
1	72000	5400	900	18	Flexible	Random

Table 64 – Experiment setting COS with random schedule

Results

Performance Indicator	1	6
Average Length of Stay	5:46:59	5:47:53
Bed Occupancy Ratio	52%	52%
Operation Room Utilization Ratio	70%	70%
Cancellation Ratio	1.8%	1.8%
Overtime Ratio	6.5%	6.9%
Average Waiting Time Before Surgery	1:06:01	1:08:44
Patients Moved to Ward	149	281
Lounge Patients Treated at Holding/Recovery	56	53
Lounge Patients Treated	4667	4650
Inpatients Treated	4465	4469

Table 65 – Results COS with random schedule

Appendix F – Methods

Pearson's Chi Square Test

To determine Fitting the distribution where performed described by (Law & Kelton, 2000). A confidence interval of 95% was using for the Goodness-Of-Fit-Test.

First the lognormal mu is estimated using Equation 5.

$$\mu = \frac{\sum_{i=1}^{n} \ln(X_i)}{n}$$

Equation 5 – lognormal mu

Then the lognormal standard deviation is estimated using Equation 6

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (\ln(Xi) - \mu)^2}{n}}$$

Equation 6 – Lognormal sigma

An expected value is calculated for each observed value using the inverse lognormal function in Excel and mu and sigma as estimated above. The observed value are sorted from low to high from which the percentage is calculated. The percentage of the expected value depends on the sequence number of the observed value as can be seen in Equation 7.

$$p_i = \frac{(n - 0.5)}{N}$$

Equation 7 – Chance distribution

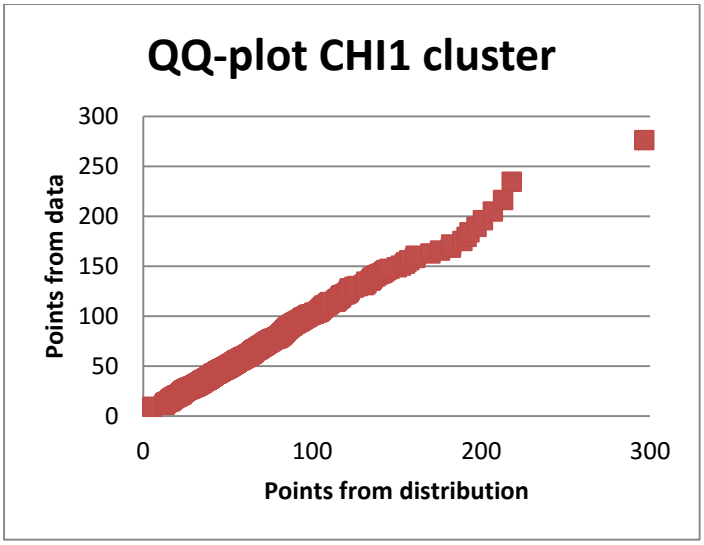
A goodness of fit test is performed using Pearson's chi-squared test. Bins are made using the square-n rule and the number of observed samples are counted in each bin.

$$\chi^2 = \sum_{k=1}^{k} \frac{(n_i - N * p)^2}{N * p}$$

Equation 8 – Pearson's chi -squared test

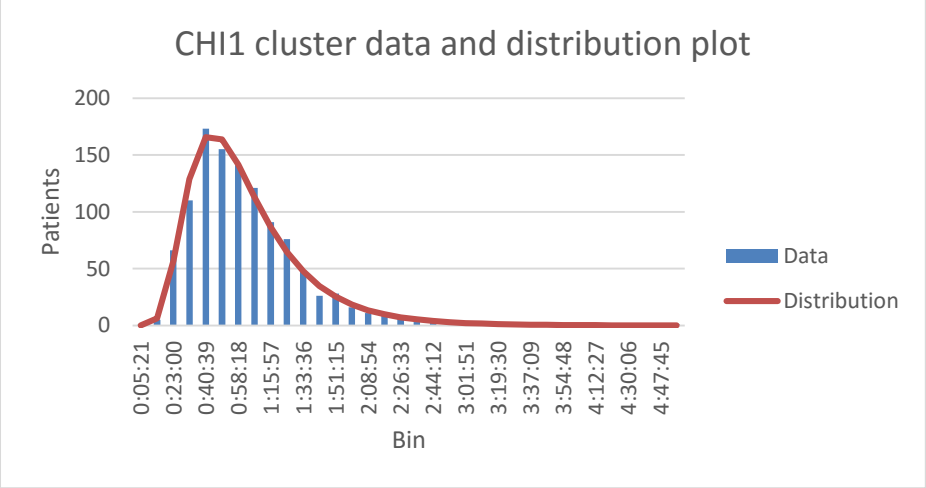
If $\chi^2 < \chi^2_{0.95,df-1}$ the lognormal function is an appropriate fit for $a = 0.05$.

To visually check the fit of the distribution of the sample two type of graphs can be made. A QQ-plot can be made to check the fit between each point of data with the point from the distribution. An example of CHI1 cluster with sample size 1104 is shown in Graph 32.



Graph 32 – QQ-plot CHI1 cluster n=1104

In addition to the QQ-plot the distribution is checked using the frequency of the bins. An histogram is made using the data and the probability distribution function is used to determine frequency with the distribution. Graph 33 shows the plot of the data and distribution of CHI1 cluster.



Graph 33 – CHI1 cluster data and distribution plot

These graphs are made for each distribution but as can be seen in Table 66 a total of 86 distribution are determined. To prevent this thesis to become too long these graphs are not included.

Duration	Number of distributions
Surgery	53
Inter-OR	14
Transport	10
Recovery	9
Total	86

Table 66 – Number of distribution per stage of the process

Method to determine significance differences between outcomes

A Pairwise T-test was done to check for significance differences between different outcomes. W was determined by subtracting outcome X from Y, or W = Y – X. Further, W was averaged over the number of runs up to 20 runs. If by then then the difference was not significant, this was taken over in the report as insignificant. This does not mean that the difference will remain insignificant when increasing the number of runs. Further, mathematical determination of the interval is shown in equation Equation 9.

$$\overline{W} \pm t_{n-1,1-\alpha/2}\sqrt{Var\left[\overline{W}\right]}$$

$$\overline{W} = \frac{1}{n}\sum_{j=1}^{n} W_j$$

Equation 9 – Pairwise T-test interval

In which a = 0,05.

In which Var[W} is determined by Equation 10.

$$Var\left[\overline{W}\right] = \frac{1}{n(n-1)}\sum_{j=1}^{n}\left[W_j - \overline{W}\right]^2$$

Equation 10 – Pairwise T-test variation

Method to determine number runs and run length

We need to determine the number of replications or years. To determine this we use the relative error γ=0,10 . This yields a corrected target value for the relative error of $\gamma' = \frac{\gamma}{1-\gamma}$`.

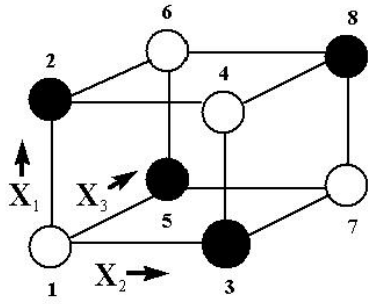
$$n^* = Min\left\{i \geq n : \frac{t_{i-1,1-a/2}\sqrt{S_n^2/i}}{|\bar{X}_n|} \leq \frac{\gamma}{1-\gamma}\right\}$$

Equation 11 – Run length

With this formula the minimum number of replications is determined with n^*. Within the excel files the total calculations are displayed.

Factor analysis

In the first stage all factors were changed one by one. Now in the second stage the combination of factors are altered, which causes multiple factors to be changed. Instead of comparing the results with the 'starting point' a factor analysis is performed.



Experiment	Factor 1	Factor 2	Factor 3	Response
1	-	-	-	R1
2	+	-	-	R2
3	-	+	-	R3
4	+	+	-	R4
5	-	-	+	R5
6	+	-	+	R6
7	-	+	+	R7
8	+	+	+	R8

Table 67 – Factorial design example with illustration (2016)

Example computational effect of experiment 1: E1=((R2+R4+R6+R8)-(R1+R3+R5+R7))/4

In the example a 2^3 full factorial design is shown in Table 67. In our factor analysis we have a 3*3*3*2 factorial design. This way in case of the two scheduling methods, the 27 experiments with OF schedule have been subtracted from 27 experiment with OFLRF schedule. As c*losing time*, *slack on registration* and *slack on preparation* have three different factor settings 18 experiments will be subtracted.

Appendix G – Simulation model flowcharts

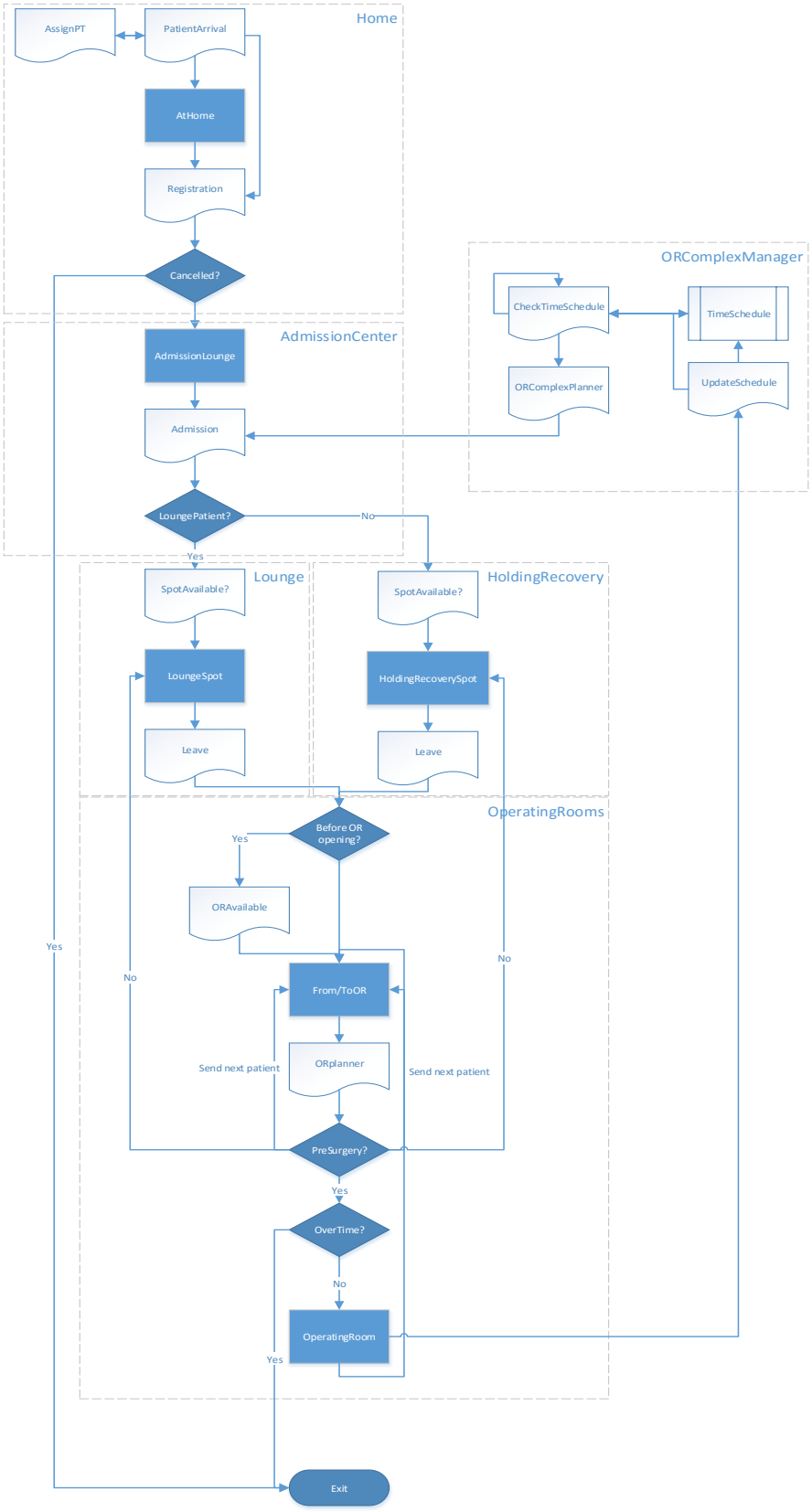


Figure 21 – Overview Simulation model flowchart

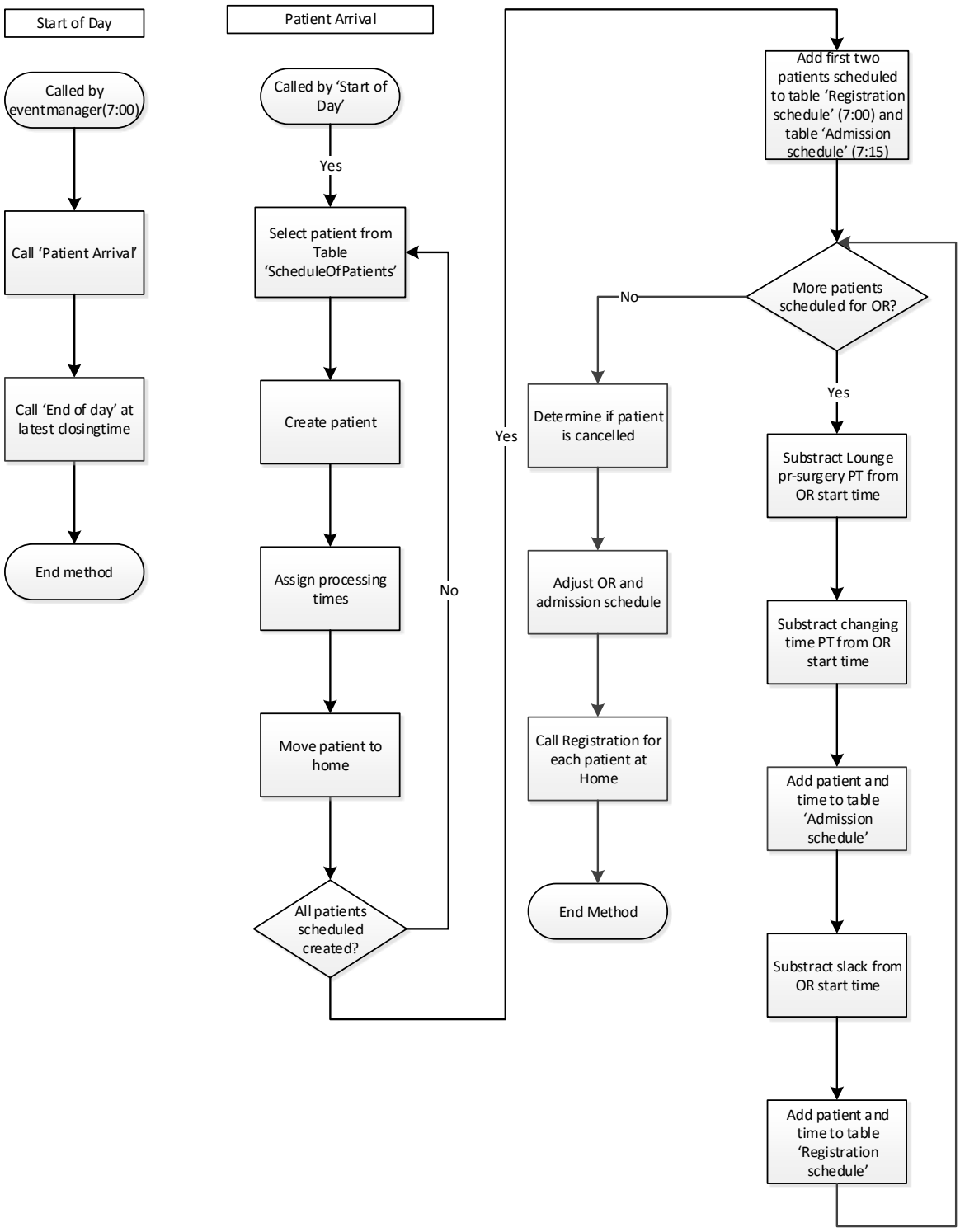


Figure 22 – Start of day and Patient arrival flowchart

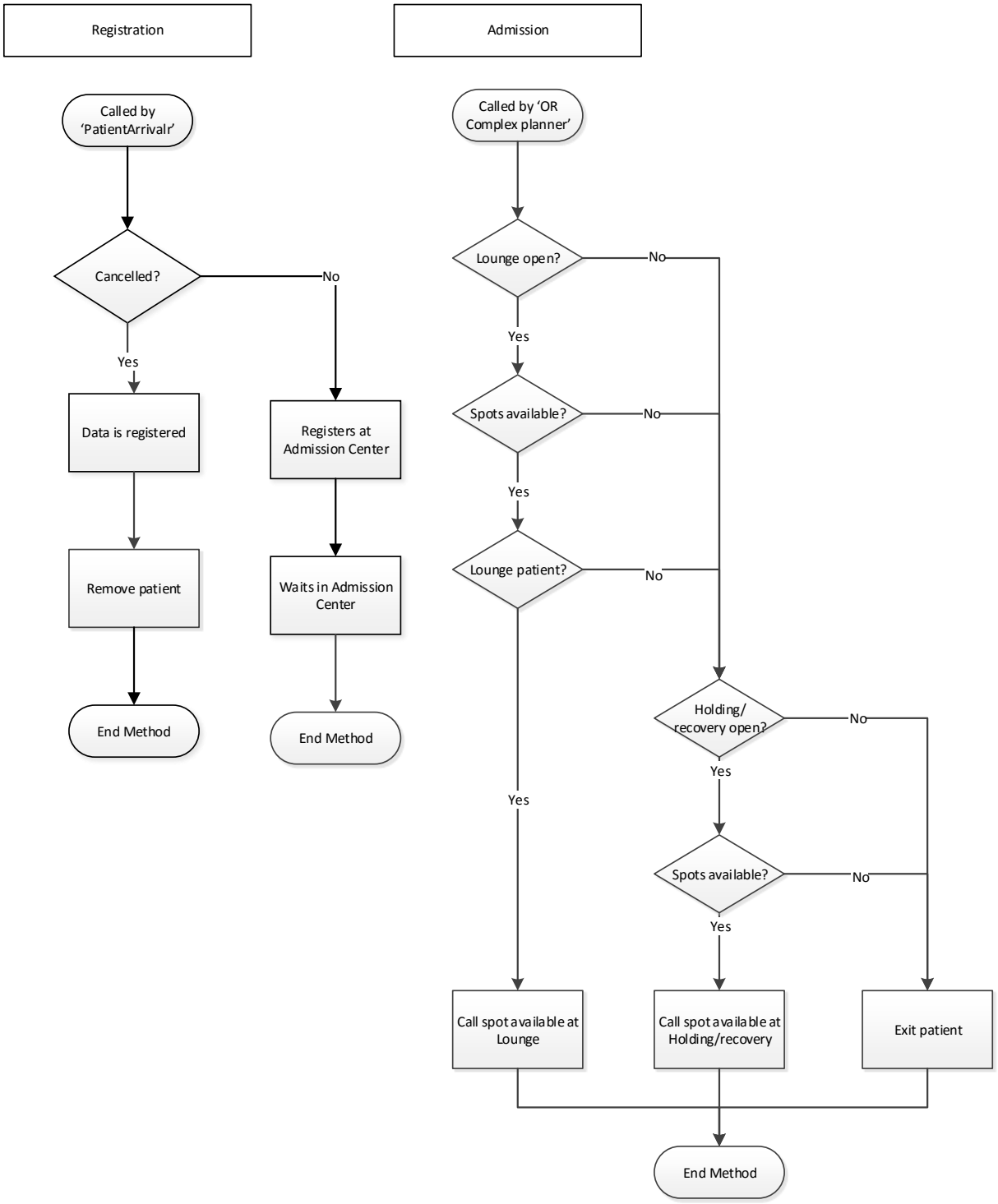


Figure 23 – Registration and admission flowchart

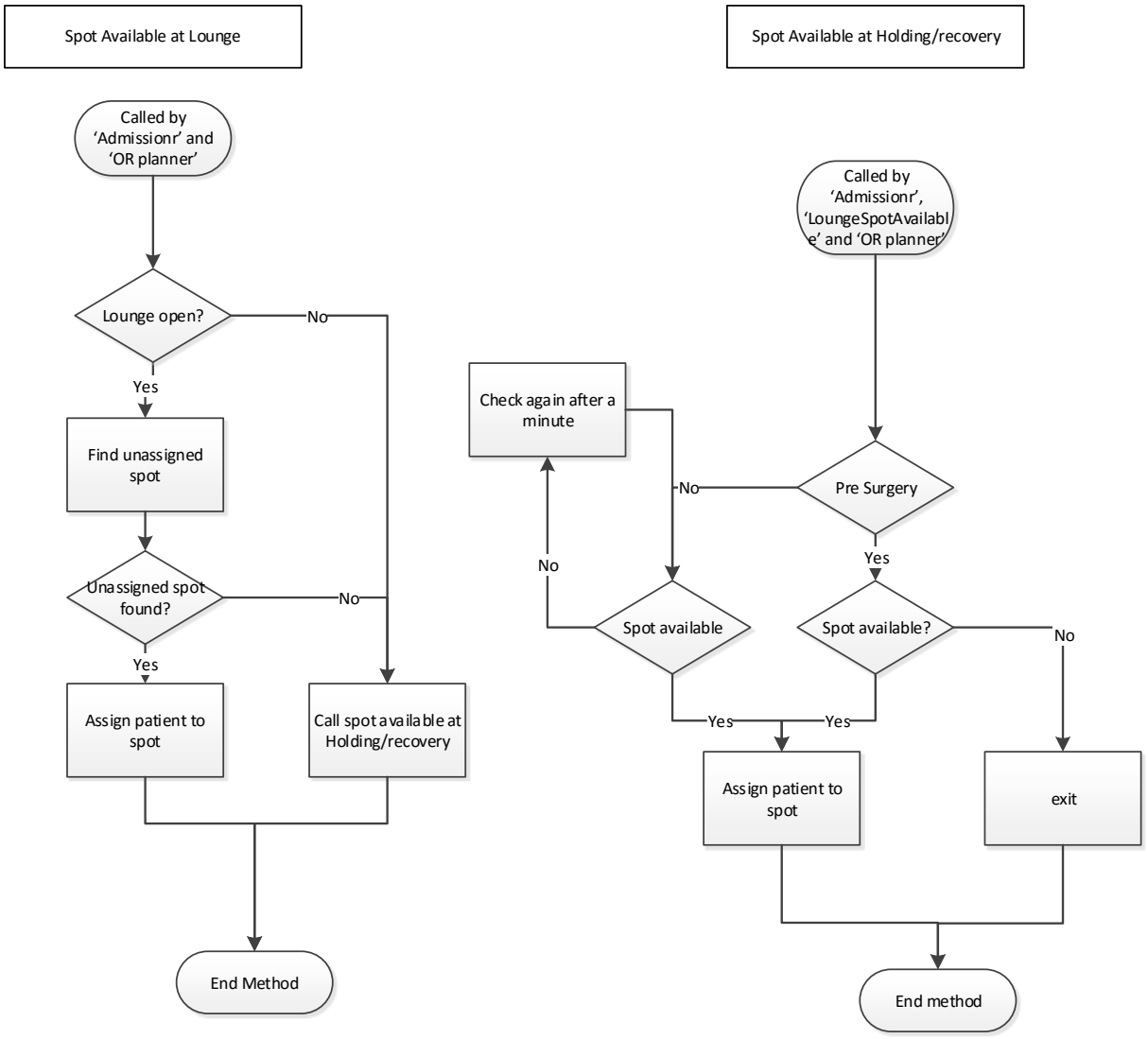


Figure 24 – Spot available at Lounge and Spot available at holding/recovery flowchart

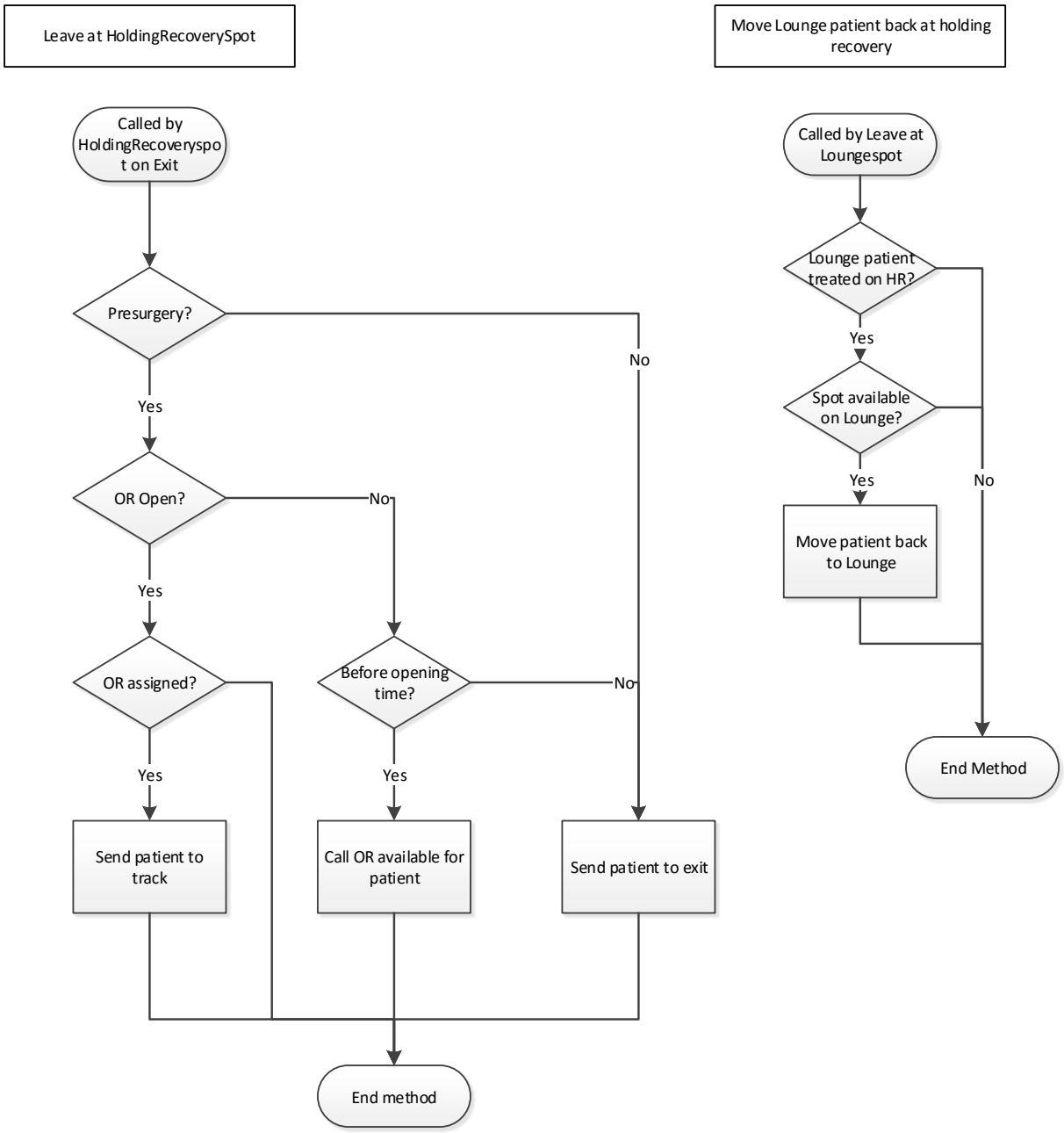


Figure 25 – Leave at holding/recovery spot and move lounge patient back at holding/recovery flowchart

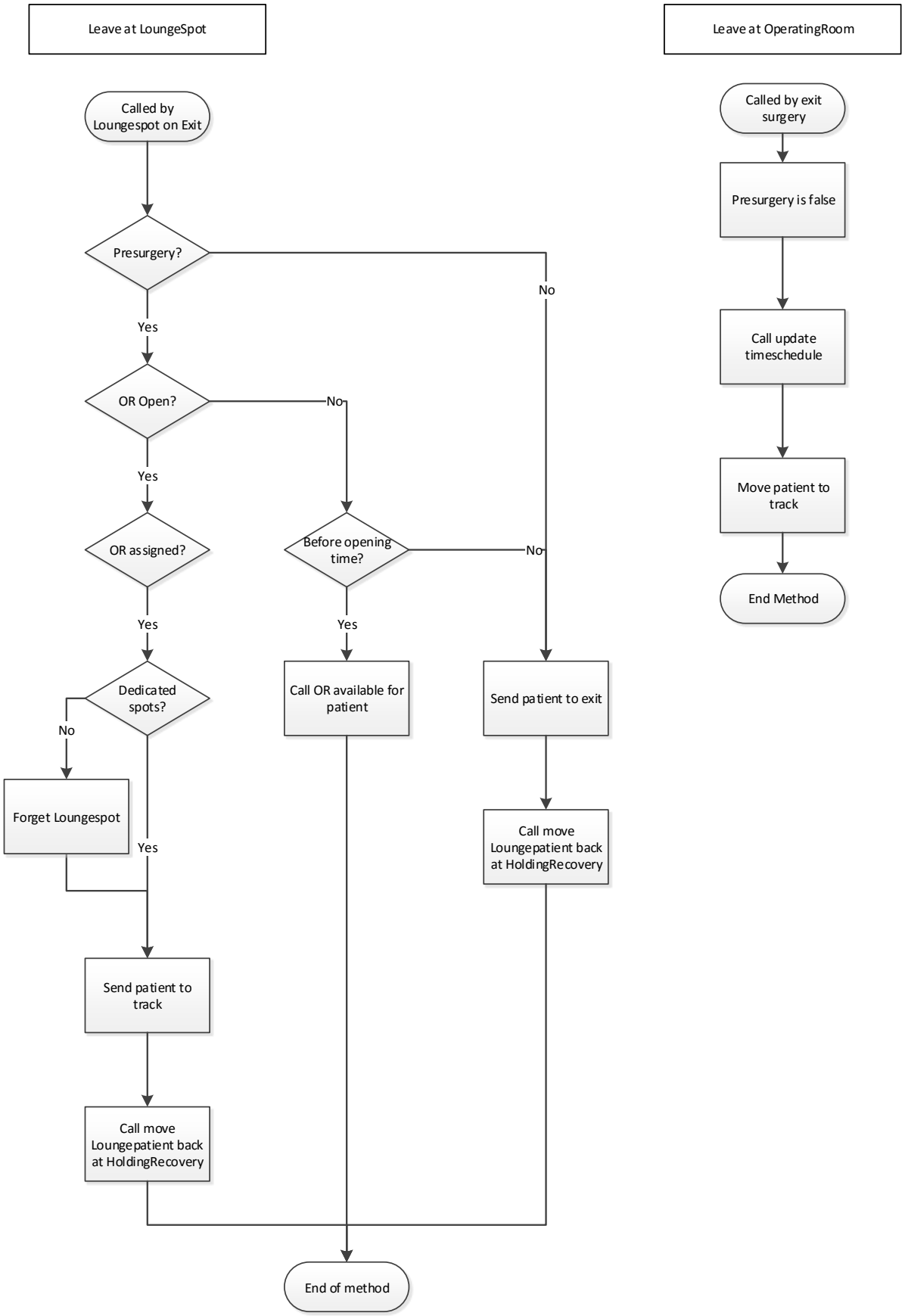


Figure 26 – Leave at Lounge spot and operating room flowchart

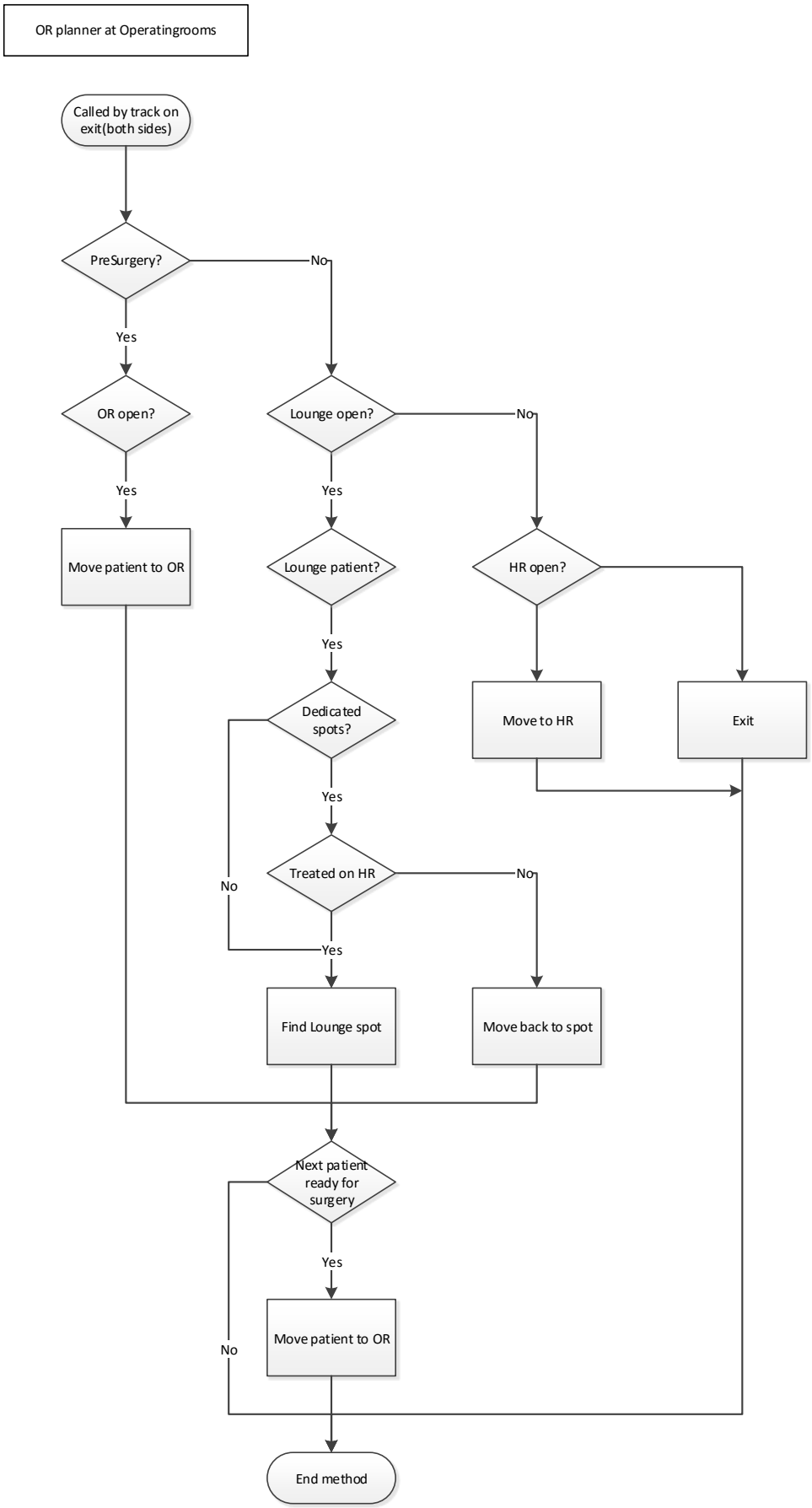


Figure 27 – OR planner at operating room flowchart

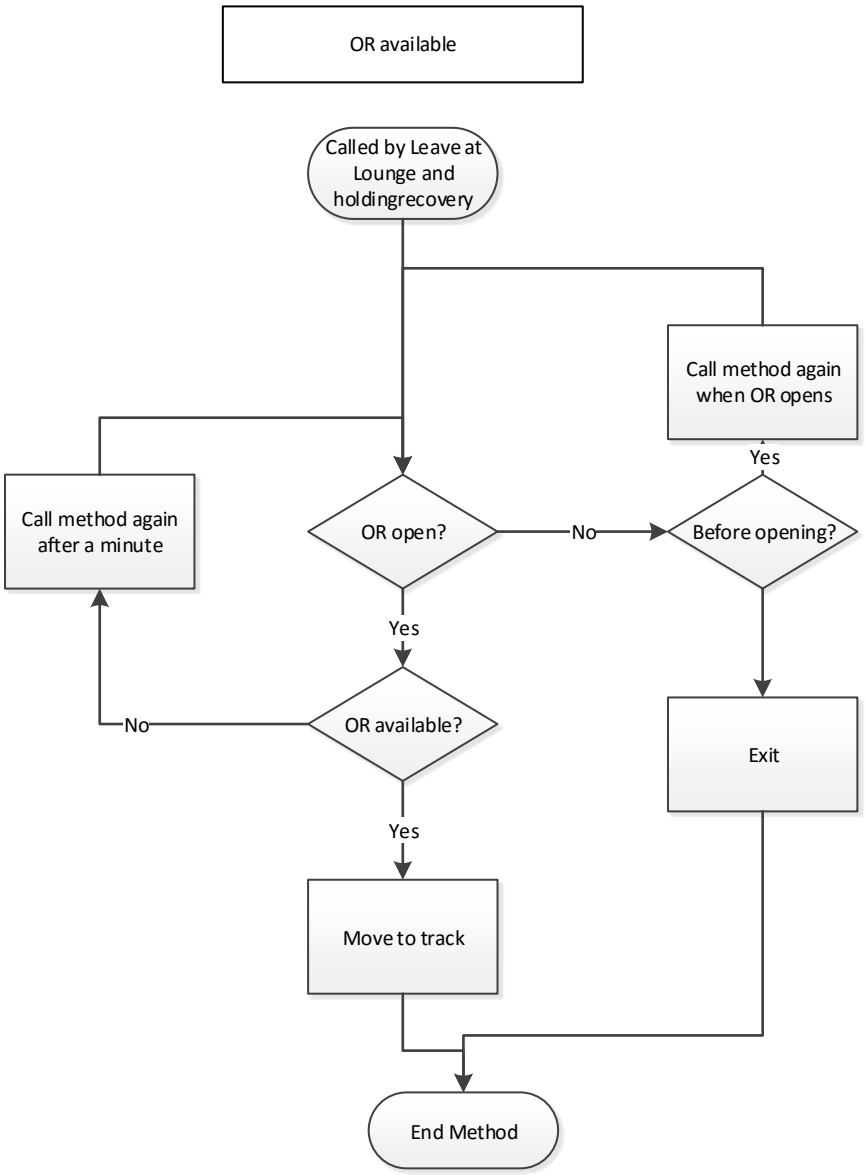


Figure 28 – OR available flowchart

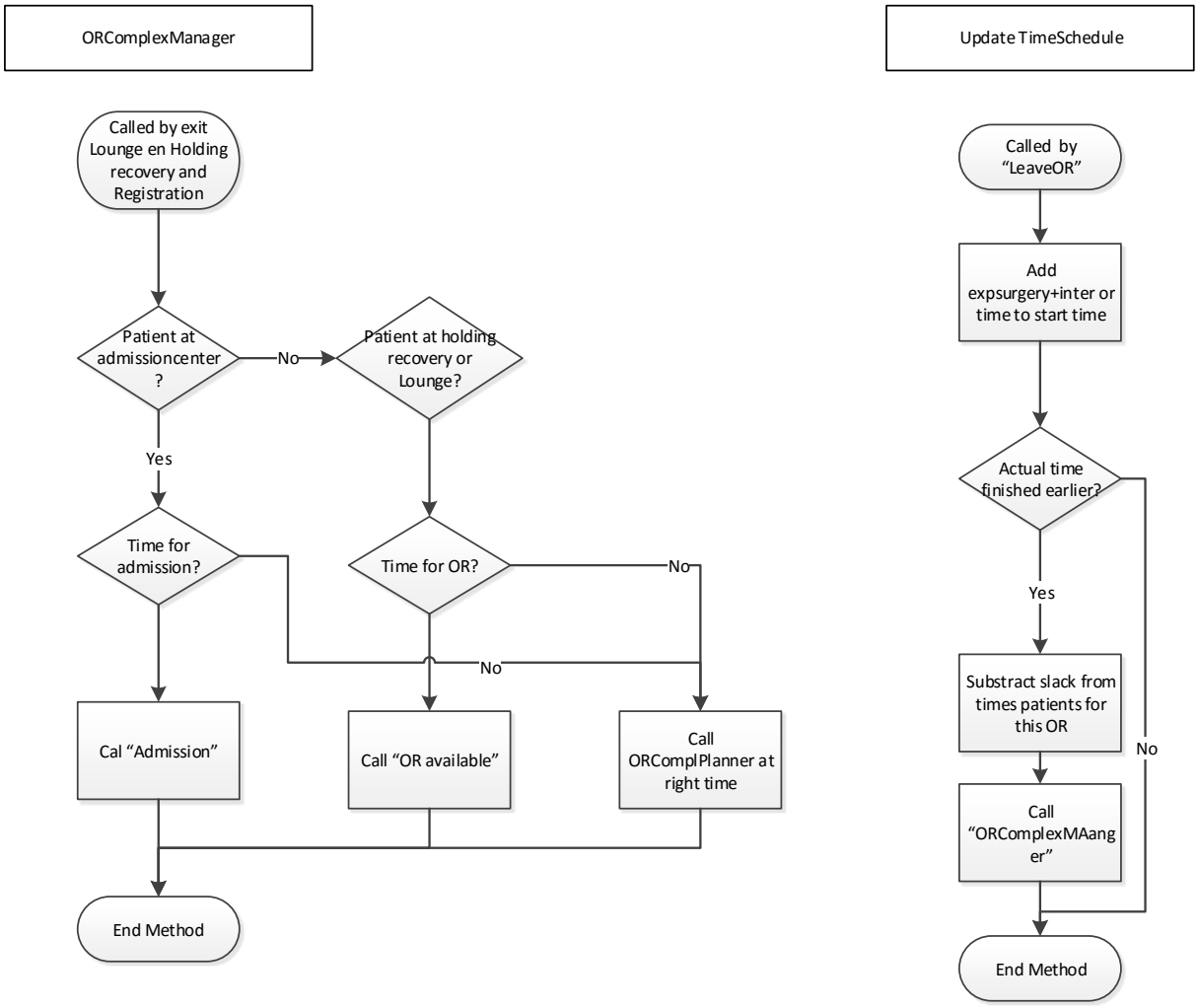


Figure 29 – OR Complex manager and Update time schedule flowchart