MASTERTHESIS:

Capacity use of the departments of the specialty surgery in the VieCuri Medisch Centrum

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Management summary

The VieCuri Medical Centrum wants to gain more insight in the use of capacities of the specialty surgery. One reason for this is that some OR sessions are given back because there are not enough patients while other specialists have long waiting list. Another reason is that the hospital is unable to plan far in advance. The departments (clinic, OR, ward) are too busy with solving operational problems. For this reason, they do not have time to match the resources of the different departments. At the moment the improvement of processes and resources is done locally at the department level. This lack of focus of the management on the whole care chain (from entry to discharge) often results in reduced patient access without a decline in costs (de Bruin et al., 2005). The clinic had a increasing access time in 2011, while the occupancy rate remained constant. 18% of the patients had a waiting time that was higher than the Treeknorm of 7 weeks. The average occupancy rate of the OR was good, but this was caused by a lot of overtime of a few sessions. This amount of overtime costs the hospital unnecessary amounts of money. The number of used beds by patients of the specialty surgery is very variable. A reduction in variability should lead to lower costs, because less beds will be needed. In 2011 there were 25% of the patients that had a higher throughput time than the Treeknorm of 8 weeks. The goal of this study consists of two parts:

Give insight into the effect of planning of capacities on the performance of the departments and the performance of the chain for the specialty surgery.
***Investigate interventions that will lead to a better performance for the specialty surgery*.**

The research question of this research is:
How can the different resources be aligned in a way that performance of the patient flow in the surgery chain is improved?

Better coordination could lead to more insight in the total process. If the departments should share more information about the patients that are at the clinic then this information could be used to estimate how much capacity they will need at the OR and the ward. Although it is not possible to have a high utilization of capacities and a short throughput time at the same time. A full utilization of capacities will lead to high throughput time. On the other hand, a short throughput time will lead to low utilization of capacities. A trade off should be made between these. Which combination of throughput time and utilization of capacities is desirable for the hospital is a strategic and/or tactical choice. The model that will be build in this study supports the users/management team in these choices.

Queuing theory is used to developed a model in order to analyze the relationship between the clinic, OR and ward. The most important conclusions of these research are:

- The clinic has a low utilization with 0,71. Less capacity for the clinic can be used, 31 sessions should be enough.

- The capacity of the OR in Venray, 14 sessions, are not used well enough. The number of patients that are operated in Venray could be done with 10 sessions instead of 14 sessions

on aggregate level. The OR in Venlo has too little capacity for the current amount of patients. More patients should be send to Venray. Venray has 4 sessions too much, and could have extra patients. A changing time of 9 minutes instead of 12 minutes will lead to no overtime at the aggregate level.

- A lot of beds are needed to deal with the variability of the number of patients from the OR.

The most important recommendations of this research are:

- There is no overview of all performance indicators of the specialty. Each department may have a few performance indicators. These few performance indicators are in most cases calculated manually. Not everyone is informed about these indicators and clear and general definitions about these indicators are missing. Measurement of performance indicators could lead to more insight in the performance indicators of the network.

- As it is discussed before, the capacity in Venray should be better used. More patients should be send to Venray. This will lead to less overtime in Venlo. In the current situation it is the choice of the patient where the surgery takes places (if it is possible in Venray and Venlo). More patients choose to go to Venlo. Therefore planners and specialist should motivate patients to have a surgery in Venray. Before they can do this properly a choice should be made which sub specialties should send what kind of patients to Venray.

- The model could be extended for other specialties. If the hospital wants to use the model for more years it should check whether the input parameters still hold for the current situation.

Management Samenvatting

Het VieCuri Medisch Centrum wil meer inzicht krijgen in het gebruik van capaciteiten van het specialisme chirurgie. Zij willen meer inzicht omdat sommige OK sessies worden teruggeven omdat er niet voldoende patiënten voor zijn, terwijl andere specialisten lange wachtlijsten hebben. Een andere reden is dat het ziekenhuis niet in staat is om ver vooruit te plannen. De afdelingen (poli, OK en afdelingen) zijn te druk met het oplossen van operationele problemen. Hierdoor is er geen tijd voor het matchen van capaciteiten tussen de verschillende afdelingen. Op dit moment worden de procesverbeteringen op afdelingsniveau uitgevoerd. De ontbrekende focus op de hele keten (van binnenkomst via de poli of SEH tot ontslag) resulteert vaak in een verminderde patiëntenopname zonder een afname in de kosten (de Bruin et al., 2005). De poli had een toenemende toegangstijd in 2011, terwijl de bezettingsgraad constant bleef. 18% van de patiënten hadden een wachttijd van meer dan 7 weken (Treeknorm). De gemiddelde bezettingsgraad van de OK is goed, maar dit wordt veroorzaakt door veel uitloop van enkele sessies. Deze uitlooptijd kost het ziekenhuis onnodig veel geld. Het aantal gebruikte bedden door patiënten van het specialisme chirurgie is heel variabel. Een vermindering van variabiliteit zal leiden tot verminderde kosten omdat minder bedden nodig zullen zijn. Daarnaast had 25% van de patiënten had een doorlooptijd die groter was dan de Treeknorm van 8 weken Het doel van dit onderzoek bestaat uit twee delen:

Inzicht geven in de effecten van planningen van capaciteiten op de performance van de afdelingen en de performance van de keten voor het specialisme chirurgie.
Onderzoeken interventies leiden tot een betere performance voor het specialisme chirurgie.

De onderzoeksvraag van dit onderzoek is:
Hoe kunnen de verschillende capaciteiten op elkaar worden afgestemd zodat de performance van de patiëntenstroom van het specialisme chirurgie in de keten wordt verbeterd?

Betere coördinatie kan leiden tot meer inzicht in het totale proces. Als er meer informatie gedeeld wordt over de patiënten die op de poli zijn, kan deze informatie gebruikt worden om te schatten hoeveel capaciteit er op de OK en op de afdeling nodig is. Het is echter niet mogelijk om hoge bezettingsgraden en korte doorlooptijden en wachttijden te hebben. Hoge bezettingsgraden zullen leiden tot hogere wachttijden. Aan de andere kant zullen lage doorlooptijden leiden tot lage bezettingsgraden. Er moet dus een afweging worden gemaakt tussen deze twee performance indicatoren. Welke combinatie aan doorlooptijden en bezettingsgraden het ziekenhuis wil hanteren is een strategische en/of tactische keuze. Het model dat in dit onderzoek is ontworpen helpt gebruikers/het management team bij het maken van deze keuzes.

Met behulp van wachtrijtheorie is er een model ontwikkeld en gevalideerd waarin de relatie tussen de poli, OK en afdeling is geanalyseerd. De belangrijkste conclusies van dit onderzoek zijn:

- De poli heeft een lagen bezettingsgraad met 0,71. Er kan minder capaciteit voor poli worden gebruikt, 31 sessies zou voldoende moeten zijn.

- De OK capaciteit in Venray, 14 sessies, wordt niet goed benut. Voor het aantal patiënten dat geopereerd wordt in Venray zijn maar 10 sessies nodig in plaats van 14 sessies. De OK in Venlo heeft daarentegen te weinig capaciteit voor het huidige aantal patiënten. Meer patiënten zouden daarom in Venray geopereerd moeten worden. Venray heeft 4 sessies te veel, en kan deze extra patiënten goed gebruiken. Als de sessies in Venray goed worden benut en de wisseltijd van de OK wordt verkleind van 9 naar 12 minuten zal er gemiddeld genomen geen uitlooptijd zijn.

- Veel bedden zijn nodig om de variabiliteit van het aantal patiënten vanuit the OK te kunnen opvangen.

De meest belangrijke aanbevelingen van dit onderzoek zijn:

- Er is geen overzicht van alle performance indicatoren van het specialisme. Elke afdeling heeft enkele performance indicatoren. Deze performance indicatoren worden in de meeste gevallen handmatig berekend. Niet iedereen is op de hoogte van deze indicatoren en er zijn geen duidelijk eenduidige definities. Het meten van performance indicatoren met eenduidige definities zal leiden tot meer inzicht in de performance van de keten.

- Zoals eerder aan bod is gekomen wordt de capaciteit van de OK in Venray niet goed benut. Meer patiënten zouden naar Venray moeten worden gestuurd voor een operatie. Dit zal leiden tot minder uitlooptijd in Venlo. In de huidige situatie maakt de patiënt de keuze over de plaats van de operatie (mits die in Venray en Venlo kan worden uigevoerd). Meer patiënten kiezen ervoor om in Venlo geopereerd te worden. Planners en specialisten zouden daarom meer patiënten moeten stimuleren om in Venray geopereerd te worden. Voordat ze dit goed kunnen doen moet er eerst een keuze worden gemaakt welke subspecialisme(n) welk type patiënten meer in de OK in Venray willen hebben.

- Het model kan worden uitgebreid voor andere specialismen. Als het ziekenhuis het model wil gebruiken voor meerdere jaren, zal er gecontroleerd moeten worden of de input parameters nog steeds gelden voor de huidige situatie.

Preface

Finally the time has come, I have completed my master. Five years ago I started with the bachelor "Technische bedrijfskunde voor de gezondheidszorg" at the Technical University of Eindhoven. During this period I discovered that my interest was in health care. After I completed my bachelor in Eindhoven, I switched to the University of Twente for my master Industrial engineering and management with the track Health care Technology management. Here I have extended my health care knowledge. For my master thesis it was therefore obvious that it would be a subject in health care. This research studies the capacities in the process of patients of the specialty surgery through the hospital. I have had a nice time in the VieCuri Medical Centre and I enjoyed working on the assignment.

I would like to thank everyone that have spent time in this research and have supported me with this research, particularly Chantalle Coenders and Carel Bergmans. I have learned a lot of your knowledge and experience about the things that are going on in a hospital. Your enthusiastic attitude made it nice to work with you. I have had a very nice time in the VieCuri. This research was not possible without your support. I would also like to thank Ahmad Al Hanbali and Ingrid Vliegen for their guidance in this research. The critical attitude of both of you provided a higher quality of my work. Last but not least I want to thank my family and friends for the support during my master thesis.

Sanne Tacken, 12 October 2012, Horst

Inhoud

1 Introduction

Hospitals must increasingly compete with each other through market forces (AZW, 2010). On the one hand, hospitals want to reduce costs and improve their financials positions. On the other hand hospitals want to maximize patient satisfaction (Cardoen et al., 2010). A tradeoff has to be made between the service level that is delivered to the patient and the costs of the hospital. Decreasing the costs of the organization may reduce the level of service, while improving the service level can lead to higher costs.

One of the most expensive resources of the hospital is the operation room. Therefore the hospital wants to make the best possible use of this resource, but also of other resources like the wards and time of specialists. Best possible use of resources includes high utilization, little overtime and minimum cancellations of operating rooms (Vanberkel et al., 2010b).

In this research the use of capacities will be investigated for the planning department of the VieCuri Medical Center. The VieCuri Medical Centre and the planning department are introduced in Section 1.1. The problem description and goal of this research are described in Section 1.2. Section 1.3 discusses a theoretical framework. Finally Section 1.4 formulates the research questions.

1.1 Context description

VieCuri Medical Centre

VieCuri Medical Centre is a top clinical education hospital (STZ). In addition to basic care, the hospital provides top clinical care in two areas; neurosurgery and angioplasty (STZ hospitals, 2012).

The hospital has two locations, one in Venlo and one in Venray. Patients of the VieCuri Medical centre come from North and Middle Limburg and South-East Brabant. This area consists of approximately 285.000 residents. The hospital has 444 beds; 364 of which are in Venlo and 80 are located in Venray. In 2010 it had almost 23.000 hospitals admissions, 400.000 outpatient visits and 27.000 patients for outpatient treatment. The VieCuri Medical Centre has approximately 2.700 employees and 170 specialists across 27 specialties (VieCuri Medical Centre, 2010). These medical specialist are not employed by the hospital. In total the hospital has 11 operating rooms (OR), 7 in Venlo and 4 in Venray. In Venray there are only operations of elective patients with low risks. This is because there is no intensive care unit in Venray.

The VieCuri Medical centre has four sectors: A, B, C, and D. The board of directors are above all sectors in the chart of the structure of the organization. Each sector has its own manager and may consist of different specialties and departments as is shown in Table 1. This research is carried out for the planning department, which will now be further explained. As can be seen in Table 1 the planning department is a part of sector A.

Sector A	***Sector B***	***Sector C***	***Sector D***
Surgery	Oncology	Cardiology	Geyneacology
Orthepedics	Nephrology	Pulmonary medicine	Urology
OR	Endocrinology	Medical psychology	Ophthalmology
Short stay	Reumatology	Paramedical professions	Oral surgery
Vascular center	Geriatrics		Ear nose and throat
Intensive Care	Dermatology		Plastic surgery
Emergency department	Outside clinics		Birth center
Acute Admission department	Neurology		
Planning department			

Table 1 Sector overview

Planning Department

The purpose of the planning department is to optimize the scheduling of patients such that the logistics of the care processes are efficient, well coordinated and patient friendly. In this way the hospital tries to ensure that it can fulfill the appointments that are made with patients The planning department is divided into capacity planning (inflow and flow) and the department care mediation (outflow). Furthermore, there is a policy adviser for health care logistics, who is primarily involved with developing a vision of planning within the hospital. This vision connects the strategic level with the operational level.

The core tasks of the planning department are:

1. To monitor and analyze the produced and expected logistic performance of the care related resources.
2. To advise about care related capacity requirements and planning.
3. To coordinate the operational planning.
4. To create flexibility of staffing through a flex pool.

1.2 Problem description

The patients that have to be admitted in the hospital, enter through the clinic or through the emergency department. Surgical patients that are admitted need a surgery. It is desirable for the patient and the hospital that if necessary emergency patients can be admitted for a surgery immediately. On the other hand, the elective patients don’t want to wait very long either.

If the hospital has not enough beds available, an admission stop for emergency patients will be proclaimed. In 2011 there was one admission stop. In 2012 so far there has been one admission stop. During an admission stop the admissions through the emergency departments are minimized. Ambulances can only come to the hospital to stabilize the patient. For patients that need an admission they have to go to another hospital. The hospital has the rule that emergency patients have priority over elective patients. To prevent an admission stop, some planned operations need to be cancelled. The cancellation of elective surgeries causes a lot of patient dissatisfaction and costs a lot of money.

Another problem that the hospital perceives is that the utilization of the OR is too low. Some specialists give their sessions back because there are no patients. There are other specialties however that have full sessions and waiting lists.

This has the consequence that a lot of people are busy with last minute modifications of the schedules. These modifications for the beds and the OR are carried out by the planning officers. The recovery measures and the inefficient use of resources cost unnecessary extra money.

Insight in the flows of patients can help to allocate capacity properly. After these flows have been mapped, they can be better coordinated. In Section 1.2.1 the health care chain will be described. The processes at the different departments will be discussed. After the chain description the main planning problem will be described in Section 1.2.2.

1.2.1 Chain description

A patient who needs a surgery is going through a process in which multiple departments are involved. These departments are the clinic, the preoperative department, the OR (for elective patients), the emergency OR, and the Ward. This process can be considered as a queuing network/chain. This is shown schematically in Figure 1.

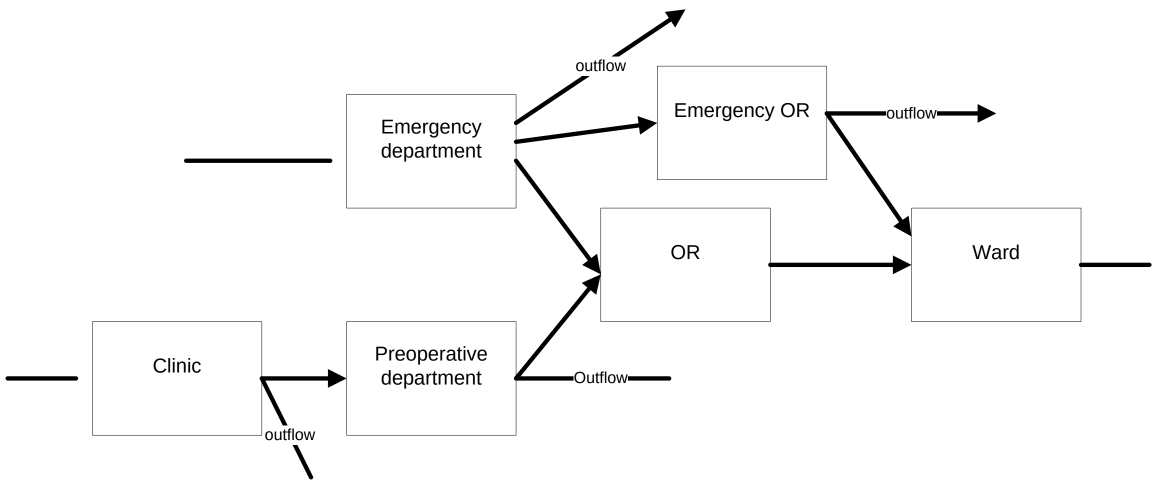

Figure 1 Chain of surgical patient

Clinic

The patient has received a referral from the GP for a consultation with a specialist. After having made an appointment at the clinic, the patient can go to the specialist. The specialist looks at the problem of the patient and decides if a surgery will be needed. Of course not every patient needs a surgery, so there will be some outflow.

Preoperative department

When it is decided by the specialist that a patient needs a surgery the patient has to go to the preoperative department. The patient has to make an appointment for this department and can visit it after approximately one week. At the preoperative department the patient has to consult three different persons: a pharmacy assistant, an intake nurse, and the anesthetist.

With the pharmacy assistant the current list of medications taken by the patient is discussed. Together with the patient an actual list of medications is prepared. The patient takes this list to the anesthetist. After the appointment with the pharmacy assistant, the patient goes to the intake nurse. At the time the patient made the appointment with the preoperative bureau he received an anamneses list. The patient should complete this list at home. This list is discussed with the intake nurse. Then an anesthesia questionnaire is completed by the nurse. Finally the heart and lungs are examined by the nurse.

After this the anesthetist has enough information to assess whether an approval for anesthesia can be given. In most cases an approval is given. In some cases, however, no approval can be given. For example, the patient has to go to a cardiologist first because the nurse and the anesthetist hear something wrong at the heart of the patient. Or the patient cannot have a certain form of anesthetics. If the surgery is not possible with another type of anesthetics the surgery type has to be changed or there can be no surgery at all. When the patient has an approval of the anesthetist the patient can be scheduled for a surgery.

Not every patient that enters the preoperative department will go to the OR. In some cases no approval can be given by the anesthetist and therefore no surgery is possible. Another possibility is that the patient thinks he can be operated faster in another hospital or in an independent treatment center. Due to these reasons some outflow of patients is possible.

OR

If the patient enters the OR department, the patient first receives a (local) anesthesia. If the anesthetics are incorporated the patient is transferred to the operating room and the surgery is executed. After the surgery the patient is brought to the recovery room. If the patient is awake, he goes to the ward. Unfortunately not every patient survives the surgery. This will cause an outflow of patients.

Ward

The patient is transferred to the ward. The patients recovers here from surgery. Every day a specialist comes to the ward to monitor the patients. If the patient has recovered sufficiently, he may go home. After several weeks the patient is expected at the clinic for a control consultation.

Emergency department and Emergency OR

The patient can also enter the hospital through the emergency department. If at the emergency department, the specialist decides that a surgery is needed, the preoperative screening is done by the anesthetist at the emergency department. After the approval of the anesthetist the patient is transferred to the OR.

The emergency patients have their own OR in the afternoon. So if emergency patients arrive in the morning they have to be scheduled in a 'normal' OR or they can wait until the emergency OR is open in the afternoon. If patients arrive in the afternoon they can be scheduled in the emergency OR. Emergency patients have priority over elective patients. This may cause cancellations of elective patients or overtime of the OR.

1.2.2 Planning problem

Every day a variable and uncertain number of beds is released from the ward. These empty beds can be used for new patients. These patients are the emergency patients and elective patients. The elective patients are planned on the basis of OR capacity. The number of beds that remain, are available for emergency patients. As previously mentioned, this number is not always enough.

A tradeoff has to be made between the cost efficiency and the service levels. A high level of service means there should be no admission stops and the throughput time is minimized. This can only be realized if there is high overcapacity.

One cause of these problems is that the hospital is unable to plan far in advance due to lacking knowledge and process controllers. The departments (clinic, OR, ward) are too busy with solving operational problems. For this reason, they don't have time for matching the resources of the different departments. At the moment the improvement of processes and resources is done locally at the department level. The lack of focus of the management of the whole care chain (from entry to discharge) often results in reduced patient access without a decline in costs (de Bruin et al., 2005).The goal of this study consists of two parts:

Give insight into the effect of planning of capacities on the performance of the departments and the performance of the chain for the specialty surgery.
Investigate interventions that will lead to a better performance for the specialty surgery.

Scope of the research

The VieCuri Medical Centre wants to gain more insight into the flows of patients between the departments. There should be more insight in how planning and capacity decisions at one department affect the other departments. The processes of the different departments will not be taken into account in detail, only the flows of patients.

Planning of capacities means the clinic sessions, the OR session and the number of beds and the specialists. The specialist are considered as a capacity because they have to divide their time between the clinic and the OR. Another reason that they are explicitly considered as an capacity is because of the power they have. In the hospital the specialties have their own partnerships. Thus they are not employed by the hospital and have a certain degree of power. They have for example their own preferences of days that they want to operate some patients. In this research the nurses are not considered explicitly as a capacity. Beds are considered as capacity and if there is a bed available in the model then we assume there are nurses available for that bed.

This research will focus on the patient flows of the specialty surgery. These flows will not include all patients that need a surgery. For example a patient of orthopedics can have a surgery but isn't a patient of the specialty surgery. A surgery of the gall bladder is for example a surgery of the specialty surgery. More surgeries of the specialty surgery are listed in Appendix 1.

The patients of the specialty surgery have their own wards and clinic sessions and OR sessions. However other specialties have an influence on the availability of these resources. This is because sometimes patients of other specialties are on the ward of the specialty surgery. On the other hand patients of the specialty surgery are sometimes at other wards too. These 'wrong bed' patients have to be considered this research.

These relationships between the departments can be made clear in a model. When this model is developed some interventions can be implemented in the model and the results/performance indicators can be calculated. This will be small interventions with the aim to improve the performance. For this research it is not possible (due to time constraints) to 'optimize' the whole performance of the chain.

1.3 Theoretical Framework

The theoretical framework of Hans et al. (2011) (Figure 1) gives an overview of health care planning and control. This framework can be used for different purposes:

- To structure the different planning and control functions and how they interact.
- To identify and position the different type of management problems. The four common management problems in hospitals are:
    - Lacking planning functions
    - Inadequate planning policies
    - Lack of coherence between planning functions
    - Planning functions with contradictory goals
- Defining the scope of interventions in organizations.
- To support the dialogue between clinical employees and managers.

The horizontal axis in the framework presents the different management areas. The management areas are medical planning, resource capacity planning, materials planning and financial planning. The four management areas consist each of four hierarchical levels. These levels are the strategic, tactical, operational offline and operational online level.

This research will mainly focus on the management area resource capacity planning. In this context resource capacity planning is defined as 'the dimensioning, planning, scheduling, monitoring, and control of renewable resources. These include equipment and facilities (e.g. MRI s, physical therapy equipment, bed linen, sterile instruments, operating theatres, rehabilitation rooms) , as well as staff' (Hans et al., 2011).

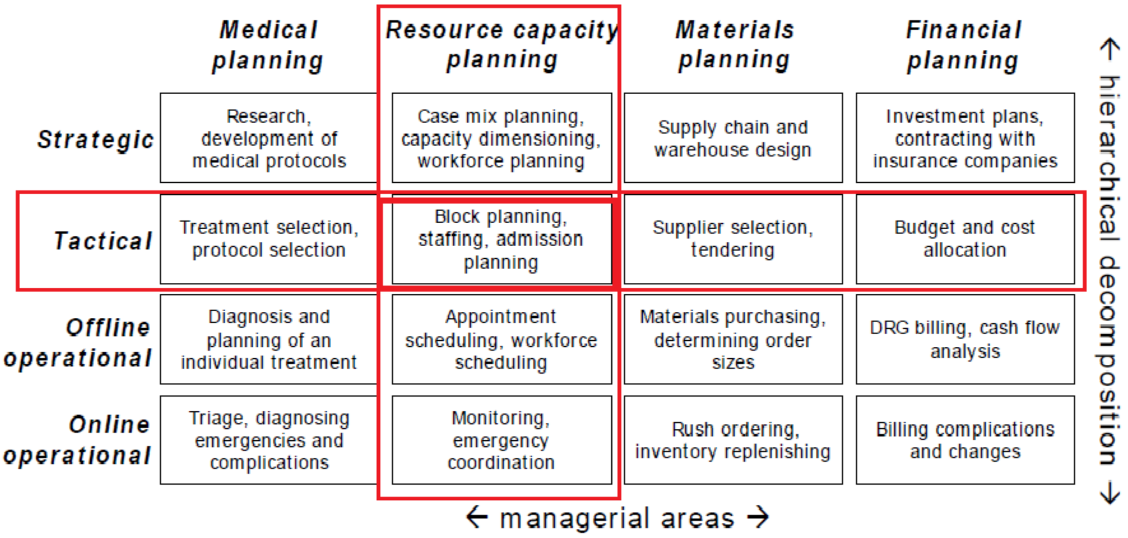

Figure 2 Theoretical framework of Planning and Control (Hans et al., 2011)

The first level of the resource capacity planning is the strategic level. At this level there are structural decisions made by the board of directors of the hospital. This means that the mission of the organizations is defined. The board of directors determines together with the Medical Staff the case mix planning, the dimensioning of the capacity and personnel.

The second level of the resource capacity planning area is the tactical level. At this level the mission and goals of the hospital will be translated in capacities. The planning at this level is for long term, approximately 3 months. Subjects of tactical planning are among other things admission planning and block scheduling. Block scheduling is the allocation of operation blocks or sessions to specialties. These are the amount of sessions and when (which part of the day) these sessions are available to the specialty. Admission planning is the planning of the amount of each type of patient that have to be admitted. Per session it is determined how many patients of which type should be scheduled. Admission planning and Block scheduling are done to make good use of the OR time.

Operational offline is the third level of the resource capacity planning area. This level focuses on short-term planning and decision making (two or three weeks). The patients are assigned to the different capacities. At this level little flexibility is possible because many decisions have been taken at a higher level.

The fourth and final level of the resource capacity planning area is operational online. At this level decisions are made on how to deal with unforeseen or unexpected events in the daily schedule.

This research is a 'resource capacity planning' problem at the tactical level, as shown in Figure 1. This research focuses on the tactical planning and interaction between various departments within the specialty surgery.

1.4 Research questions

The goal of this research has to be translated in a research question and sub questions in order to get more structured and detailed information. The focus of this research is on the capacities in the chain of surgery. There is a limited amount of capacities and they have to be used in a efficient way. So the research question that will be answered in this research:

How can the different resources be aligned in a way that performance of the patient flow in the surgery chain is improved?

In this question performance means throughput of the patient and the utilization of the individual resources. This is under the constraint that the agreed production is achieved. Resources mean the number of OR sessions, clinic sessions, beds in the ward and specialists. The throughput is the time between the moment that the patient made a appointment for the clinic and the moment of discharge at the ward. The aim is to minimize the throughput and to maximize the utilization of the individual resources.

1. **What is the current situation**?
   In Chapter 2 the current situation will be described. In this first section of this chapter the planning policies will be described. The second section of this chapter will describe the used performance indicators in practice and the current performance of the hospital.

2. In Chapter 3 the literature will be reviewed to answer three questions. The data of the patients cannot be aggregated completely, because you lose a lot of details then. Although you cannot take all diseases separately because then it becomes too complex. Therefore the literature is reviewed to answer the following question:
   a. **What is known in literature about the classification of groups?**
      What methods are known in literature for the classification of groups. What method can be used for this model? The flows of surgical patients will be divided in homogeneous groups/categories of patients.

   To measure the performance of a chain there are some performance indicators needed. The literature will be reviewed to see what performance indicators are used in literature. The following question will be answered:

   b. **What performance indicators are used in literature?**
      The literature will be reviewed to see if there are other performance indicators than those used currently for evaluating the performance of a chain.

   The relationships between the different departments can be explained by the use of a model. The literature will be used to find the most appropriate model for this research. The following research question will be answered:

   c. **Which models are known in literature about the relationships between departments?**
      Which models are in literature that explain the relation between departments. Which of these models can be used or adapted for this research.

3. **How can a new model of the current situation be made?**
   In this chapter, Chapter 4, will be determined which techniques will be used to model the current situation. The assumptions of the model will be discussed and explained. Finally the model will be developed. In order to develop the model some input parameters are needed. In Chapter 5 the values of these input parameters will be determined. In this chapter the patients will be categorized in groups and of each group the logistic characteristics will be determined.

4. **Is the model valid?**
   In Chapter 6 the model will be checked for validity. This will be done by structured walk through with some stakeholders of the hospital.

5. **What are the results of the model and which interventions could improve the performance of the chain?**
   Chapter 7 discusses the results that are gained with the model. Then some interventions will be performed using the model to see how the performance of the chain can be improved.

The conclusions of the study and recommendations for further research will be addressed in Chapter 8.

2 Current situation

In this chapter the current situation of the hospital will be described. In Section 2.1 the current situation will be described on the basis of the Framework of Planning and Control (Hans et al., 2011). The performance indicators that are used by the hospital are described in Section 2.2. Then in Section 2.3 the current performance of the hospital will be described on the basis of performance indicators.

2.1 VieCuri Medical Centre

The framework of planning and control (Hans et al., 2011) can also be applied to the VieCuri Medical Centre. In the next subsection the different levels of the resource capacity planning will be explained.

2.1.1 Strategic level

The general mission of the hospital for 2012-2017 is formulated in three areas:

- The hospital is an open organization with specialist medical care for the patients of North and Central Limburg
- The VieCuri Medical Centre wants to be a human and educational top clinical hospital
- The care is given from the core values: 'Sense of business, feeling for people', or 'simply better'. During the patient's stay or visit in the hospital the patient should have the feeling to be at central position in the care process. This central position has to be achieved by care that is easily accessible, safe, high quality and well organized (Sense of business). Also by the treatment of medical specialist, nurses and other employees the patient should get the feeling that he has a central position (Feeling for people). The core values of the hospital are:
    - **Responsible**: All employees should feel responsible for the proper functioning of the hospital.
    - **Together:** In a hospital you work together with other people. This attitude needs to ensure that everyone who comes into contact with the hospital has the feeling that he is important.
    - **Demand-oriented:** Demand-oriented means that the expectations of the patients and the outside world are met.
    - **Sense:** This means motivated employees, employees that are doing useful work. In short, employees who like their work.

These core values have separate meanings, but together they are the basis of what the hospital wants to be.

This general mission will be translated to four management areas. In Figure 1 in Chapter 1 an overview of these activities is given. At the area of resource and capacity planning the following decisions are made:

- A production plan for the OR. This means the number of operations that should be done this year. There are agreements made with the insurance on this number.
- Based on the production agreements a planning is made for the clinic. In the planning for the clinic is indicated how many first clinic consultations they should have each week.
- For the production plan there are number of ORs needed. In Venray there are 4 ORs available and in Venlo 6 ORs. This number of ORs is fixed and cannot be increased.

- To fulfill the production plan there should be enough personnel available. The amount of personnel is fixed for a year. The number of personnel needed is reconsidered every year.
- There are also decisions made about the number of available beds. This amount is a maximum and cannot be increased easily. The hospital has in total 444 beds, 80 beds in Venray and 364 beds in Venlo.

2.1.2 Tactical level

The decisions made at the strategic level are considered as hard constraints at the tactical level. With the number of available capacities, the goals of the hospital have to be achieved. At this level, choices are made about when and how much capacity should be available for any specialty. In this section the decision for the specialty surgery are discussed for each department separately.

2.1.2.1 Clinic

Every week there are on average seventeen to eighteen sessions done by specialists. One session is one morning or afternoon. All specialists have one clinic session in Venray and one clinic session in Venlo. The rest of the planning is variable. A morning session starts at half past eight and last until half past eleven. An afternoon session starts at one o'clock and lasts until a quarter past four. Due to the available space at the clinic there are constraints about the number of specialist that can have a clinic session at the same time. In Venray only one specialist can have a session. In Venlo in the morning four specialists can have clinic consults and in the afternoon three specialists. This is because another specialty uses the room in the afternoon. A clinic session of a specialist is divided in blocks. Each block has their own type of patient, for example first clinic consultations or control consultations. Each type of consultation has their own duration. This varies from five to twenty minutes. There are also blocks reserved for emergency consults. These blocks are scheduled one week in advance.

2.1.2.2 Preoperative Department

The preoperative department has consults four days a week in Venlo and one and a half day per week in Venray. Each day one anesthetist is available at the preoperative department.

2.1.2.3 OR

Two subjects that are important at the tactical level with regard to the OR are admission planning and block scheduling. First we will explain the block scheduling then later the admission planning.

Block scheduling means the assignment of OR blocks/session to specialties, taken the bed capacity into account. In the VieCuri a session is a part of the day, a morning or an afternoon. With block scheduling it is determined how many sessions each specialty receives and on what part of the day. In the hospital these amounts are assigned on the basis of the previous year plus one extra session. This will lead in the future to a shortage in OR blocks. This is not the best way of assigning OR blocks to specialties. They should consider the number of patients they expect and the performance of the specialties in the past (which includes more than one year). The bed capacity is not included when OR time is allocated. The block schedule of the VieCuri of 2012 is shown in Table 1. In the appendix a list with meanings of the abbreviations of the specialties is given. A disadvantage of this planning is that the bed capacity is not considered explicitly.

As shown in Table 1 surgery (HLK) has in Venray and Venlo in together 29 sessions. In Venlo surgery has on Monday surgery has four sessions, on Tuesday three, on Wednesday three, on Thursday four and on Friday three. Thus, the sessions in Venlo are quite well distributed over the five days of the week. The distribution of the number of session over the five days of the week in Venray is not that well. This might lead to a peak in bed usage at certain days. On Monday surgery has three sessions, on Tuesday two, on Wednesday four, on Thursday two and on Friday two. Of these 29 sessions, 12 sessions are part of continuous sessions. A continuous session means that a specialty has the same OR in the morning and the afternoon. Continuous sessions must ensure that OR sessions are better used/filled with patients, and overtime is minimized. Continuous sessions should contribute to this because the two sessions are performed by the same surgeon. This reduces the startup time of that day for that OR and reduces the risk of overtime.

VENLO	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
OR 1	HLK HLK/TR	HLK HLK/TR	ORT ORT	ORT ORT/TR	ORT URO
OR 2	GYN GYN	HLK Emergency	ORT ORT	GYN GYN	HLK HLK/TR
OR 3	HLK HLK		HLK HLK/TR	HLK HLK	HLK NEU
OR 4	URO URO		URO URO	HLK HLK	URO URO
OR 5	KNO PCH	PCH PCH	HLK GYN	URO NEU	OOG/KCH KNO
OR 6	ORT Emergency	KNO KNO	KCH Emergency	ORT Emergency	ORT Emergency
VENRAY	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
OR 1	URO HLK	ORT ORT	HLK HLK	ORT HLK	HLK HLK
OR2	ORT GYN	HLK HLK	PCH	KNO KNO	PCH ORT
OR3	HLK HLK	ORT ORT	KNO KNO	ORT PCH	
OR4	ORT ORT	GYN URO	HLK ORT/HLK	HLK ORT	

Table 2 Block Schedule

Admission planning is the planning of the number of patients that need to be admitted. A specific type of admission planning is determining how many patients of each type has to be admitted at each day or OR block. Determining when and which patients should be admitted influence the throughput time of the patient and the utilization of the capacities. Another advantage of admission planning is that it is also useful for the planners. They know when to schedule which patient. A disadvantage of admission planning is that it could reduce the flexibility of the hospital. If there are no patients of a certain type, they should abandon the admission planning at that moment. In the VieCuri Medical Centre this type of admission planning is not executed.

2.1.2.4 Ward

There need to be decisions made about the number of beds that are available for each specialty. The hospital has the rule 'a bed is a bed'. This means that in principle a patient should be admitted to any ward (except IC). However, the hospital tries to group patients of the same specialty at a department/ward. Table 3 shows an overview of these wards. If there are no available beds at these wards, the patients can be admitted to wards of other specialties too.

Name	Location	Number of beds	Opening restrictions	Patients of other specialties at the ward?
Ward 3	Venray	25-33	Always	Yes
Ward 5	Venray	30	Monday-Thursday 7-21 hr open Friday 7-18 hr open Saturday + Sunday closed	Yes
Ward K3	Venlo	40	Always open	Yes
Ward K5	Venlo	28	Always open	No
Short stay	Venlo	20	Monday 7 hr – Friday 19 hr open	Yes
AOA	Venlo	12	Always open The patient can stay here for maximal 24 hours, and he is discharged or transferred to another department	Yes
IC	Venlo	16	Always open	Yes

Table 3 Overview Wards Surgery

2.1.3 Operational offline level

At operational offline level there are four planning moments. These are the planning of the clinic, the planning of the preoperative department, the planning of the OR and the planning of beds. These schedules are made by different departments/people.

At the clinic the patients are scheduled in the 'right' blocks. The emergency patients have priority. For this type of patients there are blocks reserved too.

At the preoperative department the patients are scheduled according to their order of entrance. It is however also possible that patients get priority because the surgeon wants to operate earlier. For this type of patients there is no capacity reserved and they are placed as extra in the schedule.

When a patient has an approval for anesthesia the patient can be scheduled for an OR. OR planning takes place at the clinic (except for the specialty surgery). This planning is made based on the availability of the specialist (the day that the specialist has a session). The allocation of the patient to the session is in most cases based on the order of the waiting list (First Come First Serve). There are some patients that have to be treated within a certain time. These patients have precedence over patients that can wait longer (from a medical point of view). Within these blocks the big surgeries are planned at the beginning of the session and the smaller surgeries at the end of the session. At this level there is no account of the impact that the OR schedule has on the beds.

2.1.4 Operational online level

At the clinic, preoperative department, OR and ward there are some mutations in the schedule possible. At the clinic and the preoperative department patients don't show up or consults take longer than scheduled. Also, emergency patients have to be scheduled.

At 13 hours the schedule for the next day is ready. There may still be some changes after this time possible because patients cancel their surgery or don't show up. For emergency patient there is a separate session that starts at 12.30 hours. If there is an emergency patient in the morning this patient will be operated in the first available OR. In life-threatening patients, there is the 7th OR on hand (there are 6 ORs planned). This OR is not reserved for emergency patients, but could be used in case there are no other options. Big surgeries are not always scheduled at the beginning of the day because sometimes they need an IC or Medium Care (MC) bed and these patients need some longer preparation time. The availability of IC and MC beds is higher during the day than in the morning.

At the ward there are elective and emergency patients. There is uncertainty about the duration of stay at the ward. If there is no available bed at the ward of the specialty, there will be looked for an available bed at another ward. It is also possible that patients of other specialties are at the ward of the specialty surgery. The rule in the hospital is that patient are at their own wards if this is possible. If this is not possible than is the rule that patients of a cutting specialties are at wards of cutting specialties and patients of contemplative specialties are as much as possible at wards of contemplative specialties.

2.2 Performance Indicators at VieCuri

The VieCuri medical center uses as performance indicators the 'treeknormen', 'Zichtbare Zorg' indicators, and the indicators of the inspection for healthcare.

Since 2000, the 'treeknormen' are used in Dutch hospitals (Treeknorm, 2012). This standard specifies how long people can wait for treatment for non-acute care. For hospitals these standards are as following:

- Access time hospital care: the time between the patient has made an appointment for the clinic and the time the patient has an appointment : 80% within 3 weeks, maximal 4 weeks
- Waiting time treatment day care: time between the diagnosis and the day of treatment in case of day treatment: maximal 6 weeks
- Waiting time treatment admission >1 day: The time between the diagnosis and the treatment that takes more than one day: maximal 7 weeks
- Throughput time: the time between the patient has made an appointment for the clinic and the moment the patient is discharged: maximal 8 weeks

The 'Zichtbare Zorg' indicators are composed by the program 'Zichtbare Zorg', which is established in 2007 by the Ministry Health, Welfare and Sport. Zichtbare Zorg provides care sectors support in making a comparison in their quality of care. The program Zichtbare Zorg makes a distinction between two types of indicators for hospitals: care-related indicators (focused on effectiveness and safety) and customer preference indicators (selection information for customers). The indicators are drawn separately for each disease. For 2012 indicators for 43 diseases are sent to the hospitals (Zichtbare Zorg, 2012).

Each year, the inspection for healthcare composes a basis set of quality indicators for hospitals. These indicators are composed to determine which processes in hospital need extra attention. These indicators are divided in 11 groups on the basis of the disease of the patient (IGZ, 2012).

The treeknormen have a more general character than the Zichtbare Zorg indicators and the indicators of the inspection. The Zichtbare Zorg indicators and the indicators of the inspection are more disease specific. The next section described the general indicators. After the patient groups are made in Chapter 5, for every group will be searched for specific standards that are relevant for this research.

2.3 Performance VieCuri

In this section the performance of the VieCuri Medical Center will be described. The performance indicators will be discussed for each department (Table 4). These indicators are used in the hospital.
The preoperative department is not taken into account in this section. This is because there are patients of all specialties present and there are no delineations possible. Another reason is that there is another project at this department which will make walk in consultations possible. The patients can go to the preoperative department within one week.

Performance Indicators	
Clinic: - Access time Clinic -Occupancy rate Clinic	**OR:** -Waiting time OR - Overtime OR - Occupancy rate OR
Ward: -Number of used beds	**Chain:** - Throughput time

Table 4 Performance indicators

In the following subsections the definitions and values of the performance indicators will be explained. The values are obtained by analyzing all data of all the elective patients in 2011. Finally a conclusion about the performance will be given.

2.3.1 Performance Clinic

The performance of the clinic will be described with the access time to the clinic and the occupancy rate of the clinic. The access time of the clinic is the time between the moment that the patient calls for a consultation and the moment the patient has a consult at the clinic. In 2011 there was an increasing access time for the clinic (Table 5). In Table 5 the average access time for Venray and

Venlo is shown in days. The access times of Venray and Venlo are aggregated because they are quite similar. The peak is in July with more than sixteen days on average.

	Average Access Time (Days)		Average Access Time (Days)
January	7,0	July	16,3
February	9,8	August	13,5
March	9,5	September	14,0
April	10,8	October	13,8
May	12,8	November	14,8
June	12,8	December	15,7

Table 5 Average Access Time (Ezis, 2011, n=3508)

In Figure 3 the access time to the clinic is expressed in the percentage of the patient that can have an appointment at the clinic within one, two, or three weeks as function of time expressed in month. It can be seen that the percentage of patients that can have a consultation within one, two and three weeks is in general decreasing over the year. This means that the access time to the clinic is statistically increasing, and the waiting list also increases. An increasing waiting list can be caused by an increasing demand of the patients, or by a decreasing amount of clinic sessions (decreasing supply).

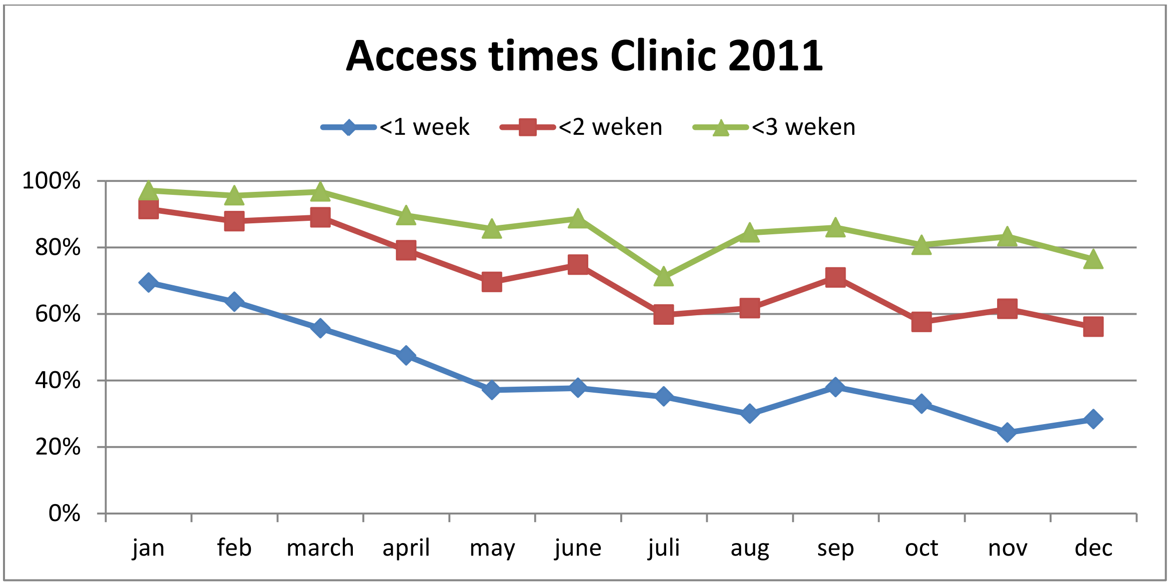

Figure 3 Access times Clinic 2011 (Bussiness objects, 2100)

The amount of available hours at the clinic in 2011 is rather evenly distributed over the weeks. Approximately the same pattern can be seen in the number of used clinic hours. The gap between the used and the available time stays quite constant (See Appendix 3 Figure 16 for more details). This is quite remarkable because there was an increasing access time and waiting list for the clinic. With an increasing waiting list it should be possible to have higher occupancy rates.

With available time and used time at the clinic is the occupancy rate calculated (Appendix 3 Figure 17 for more details). The occupancy rate of the clinic is the percentage of the available time that is used for consults with patients. The average occupancy rate is 67,4 and the standard deviation is 8,7. The occupancy rates are very fluctuating, the maximal occupancy rate is 81,7% in week 24 and the minimal occupancy rate is 44,2% in week 34. The high occupancy rate has to be compared with the number of available hours in order to determine the performance of the clinic. The number of available hours is below average in week 24. So if there are less clinic hours available, they are able to plan their time more efficiently.

The realization of higher and stable occupancy rates at the clinic could lead to shorter access times. A part of the outflow of the clinic is inflow for the OR. For having a good performance of the chain, these two departments should be aligned properly. In the next subsection the performance of the OR will be described.

2.3.2 Performance OR

The performance of the OR will be described by the waiting time OR, occupancy rate OR and the overtime OR. In the calculations of these performance indicators, the emergency patients and the emergency ORs are disregarded. The emergency patients have a small waiting time for the OR and are usually operated in the emergency OR. In this emergency OR there are also patients of other specialties operated. So, the data of elective patients of the specialty surgery will be analyzed in this section. The waiting time for the OR is the time between the moment that the patient is placed at the waiting list for the OR and the moment of the operation.

The average waiting time for the OR is 38,7 days, with a standard deviation of 7,7 days. The average waiting time for the OR per week is ranging from 25 days up to 60 days (See Appendix 3, Figure 18 for more details). The Treeknorm for an admission for more than one day is maximal 7 weeks, this is 49 days. In 2011 82 % of the patient had a waiting time for the OR that was maximal 7 weeks (See Appendix 3, Table 25 for more details). This waiting time does not always say something about the performance of the hospital. It could be the case that the patient doesn't want to be operated in some weeks. This increases the average waiting time.

If the waiting time for the OR increases, the waiting list for the OR will increase too. A large waiting list for the OR should mean an increasing/high occupancy rate. The occupancy rate is the percentage of the time the OR is used for an operation of a patient. If there is more than one patient operated in the OR, 12 minutes changing time is counted. These time is included in the occupancy rate (See equation 1).

$$Occupancy\ rate = \frac{Total\ operations\ time + (number\ of\ patients\ in\ OR - 1) * 12}{Session\ duration} \qquad (1)$$

In Figure 4 a distinction is made between three types of occupancy rates, the planned occupancy rate, the net occupancy rate and the gross occupancy rate. The planned occupancy rate is the 'expected' percentage of the time the OR is used for surgery. The gross occupancy rate is the 'actual' percentage of the time the patient is in the OR, plus 12 minutes change time. The net occupancy time is the percentage of the time the surgeon is operating the patient excluding changes time and setup time. The gross occupancy rate is always higher than the planned occupancy rate. If the aim of the hospital was to have 100% planned occupancy rate, than there would be more overtime than at the moment. The difference between gross and net occupancy rate is quite constant. This means that the positioning and opening of the patient takes on average the same amount of time. The average occupancy rates is quite similar over the five workdays. The average occupancy rate on a Monday and Thursday is 95%, on Tuesday 96%, on Wednesday 92% and on Friday 94%.

The average occupancy rates are high. This can be caused by some sessions with overtime. Overtime of the OR means the time a session lasts longer than the end time of the session. Overtime costs the hospital extra money because the staff has to work longer. In Figure 5 the total overtime of the OR per week in 2011 is shown and the planned occupancy rate. The planned occupancy rate can influence the chance of overtime. When there is a planned occupancy rate of 95% than the chance of overtime might be bigger that if the planned occupancy rate was 50%. The planned occupancy rate is most of the times around or above 80%. Only is week 52 the planned occupancy rate is lower, 70%. That’s probably why in week 52 there was less overtime. There can be seen four peaks in overtime OR. Some peaks of overtime can be explained most likely by the high occupancy rate. In these weeks the planned occupancy rate was above 95%. Although there seems not always to be connection between planned occupancy and overtime. The correlation coefficient of these two variables is 0,13 which implies low correlation.

In 2011 the waiting time for the OR was very fluctuating from 25 up to 60 days on average. In most of the weeks the waiting time remained below the Treeknorm of 49 days. The average occupancy rate of the OR is very high. This causes a big overtime in some sessions. These sessions with overtime have a high occupancy rate. The performance of the OR affects the performance of the ward. The patients that need surgeries need to be admitted in a bed in the ward for at least one day. In the next subsection the performance of the ward will be discussed.

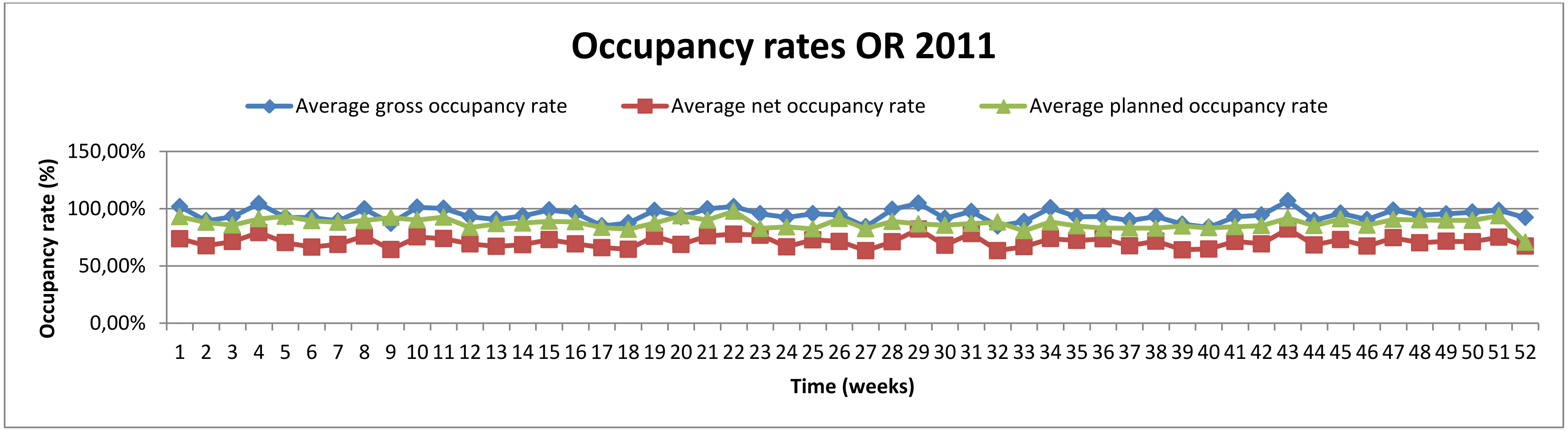

Figure 4 Occupancy rates OR 2011 (Ezis, 2011, n=3508)

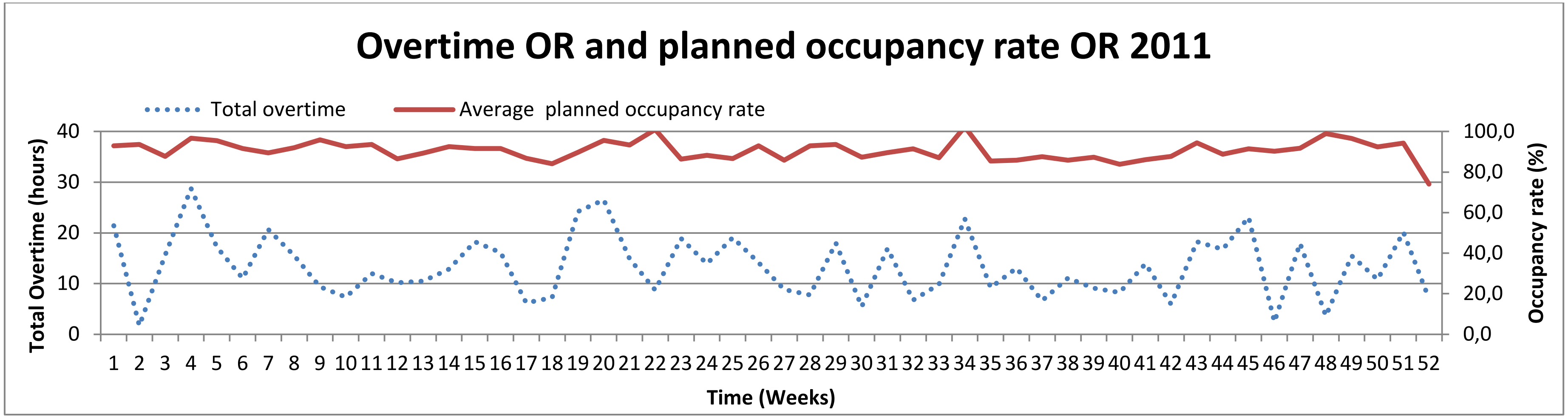

Figure 5 Overtime and planned occupancy rate (Ezis, 2011, n=3508)

2.3.3 Performance ward

The performance of the ward is measured by the performance indicator number of used beds by specialty surgery. The number of beds in which an patient of the specialty surgery was, is counted. These are all patients that were in a bed that day. If one should calculate the occupancy rate in this way it is possible to have a occupancy rate that is higher than 100%.

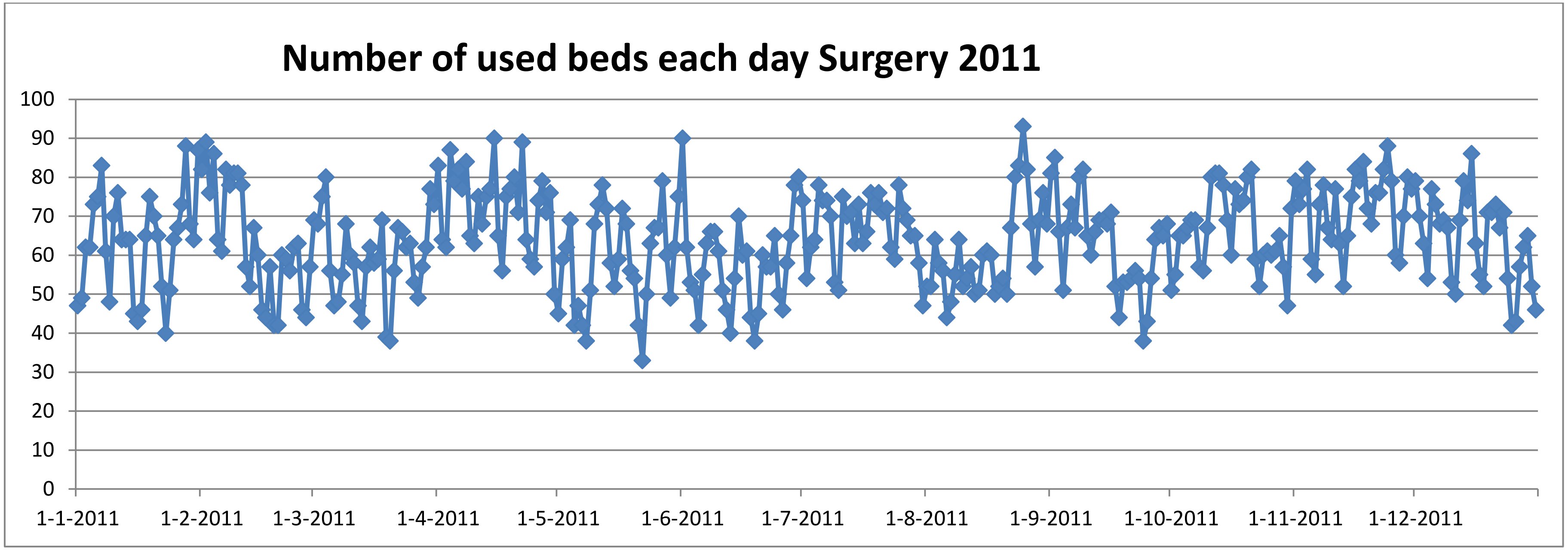

Figure 6 Number of used beds Surgery 2011 (Ezis, 2011, n=3508)

In Figure 6 the distributions of occupied beds by patients of the specialty surgery in 2011 is shown. Surgical patients occupied on a day minimal 33 beds and maximal 93 beds. The standard deviations of the number of occupied beds is 12,1. A certain amount of dispersion is normal because there are no elective surgeries during the weekend. For this reason it is good to see how the distribution is over the different days of the week.

In Figure 7 the average number of used beds for each day by the specialty surgery of the week in 2011 is shown.

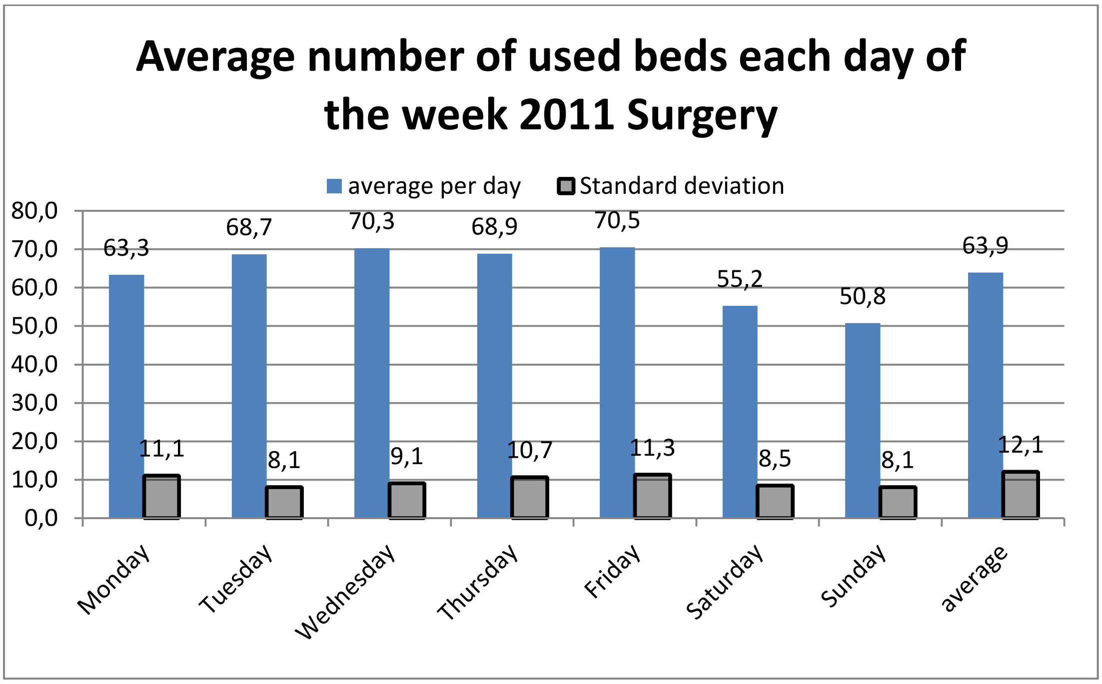

Figure 7 Average number of beds used each day of the week 2011 (Ezis, 2011, n=3508)

As can be seen in Figure 7 the most beds are occupied from Tuesday to Friday, with a peak on Friday. At Friday many patients are discharged and few patients are admitted. The number of used beds declines with 16 beds. The number of occupied beds is very variable. During the weekend there are less beds used than during the week. This is because there are no elective surgeries during the weekend. The variations within a day of the week is very variable too. This can be seen in the high standard deviations. The standard deviations varies from 8,1 until 11,3 (and 12,1 for all days together). If the variability of the used beds could decrease, less beds should be needed to treat the same amount of patients. This would result in lower costs.

2.3.4 Performance chain

The performance of the chain is described by the throughput time of the patient through the chain. The throughput time means the time between the registration of the patient at the clinic and the time of discharge at the ward. In Figure 8 the throughput time is shown for the week the patient makes an appointment for the clinic.

As can be seen in Figure 8 the average throughput time is very fluctuating, from 25 days to 75 days. According to the Treeknormen a patient may have a maximal throughput time of 8 weeks, this is 56 days. In 2011 approximately 25% of the patients had a throughput time that is higher than 8 weeks (Appendix 3, Table 26 for more information). In the throughput time the waiting time for the OR is included. As mentioned earlier, not every patient wants to be operated as soon as possible. This results in a longer OR waiting time and a longer throughput time.

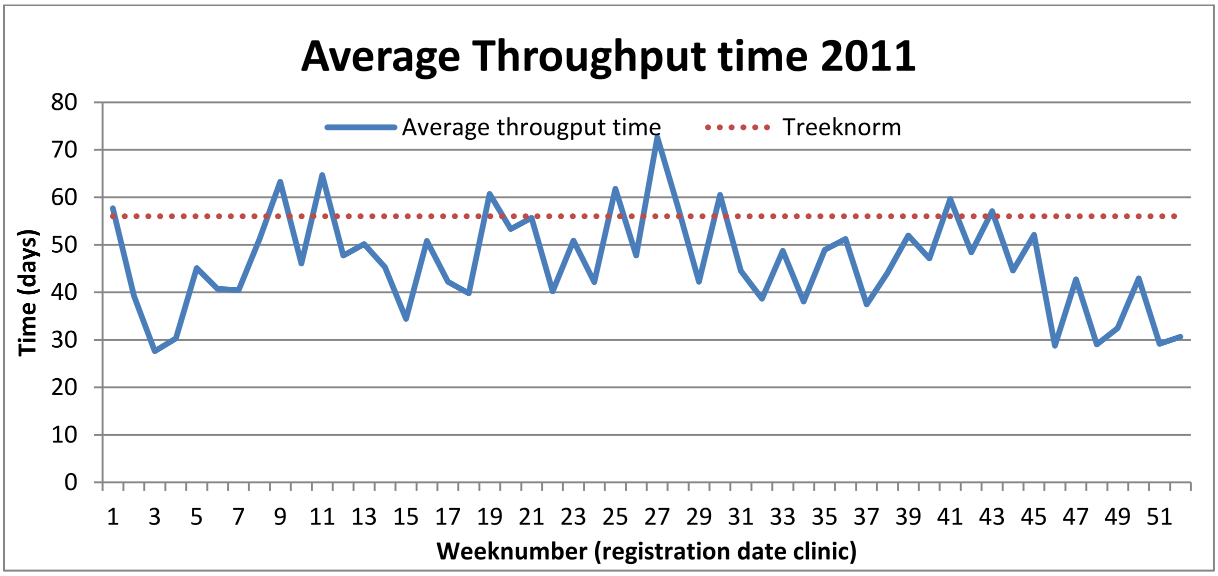

Figure 8 Average througput time 2011 (Ezis, 2011, n=3508)

2.3.5 Conclusion

In this section the performance of the different departments is described by performance indicators. The most important conclusions are:

The clinic had a increasing access time for the Clinic in 2011, while the occupancy rate remained constant. 18% of the patients had a waiting time that was higher than the Treeknorm of 7 weeks. The average occupancy rate of the OR was good, but this was caused by a lot of overtime of a few other sessions. The difference between the minimum and maximum occupancy rate in a week is very large. This amount of overtime costs the hospital amounts of money which might be saved.
The number of used beds by patients of the specialty surgery is very variable. A reduction in variability should lead to lower costs, because less beds will be needed.

The influence of all department together result in a varying throughput time. 25% of the patients had a higher throughput time than the Treeknorm of 8 weeks.
Better coordination could lead to more insight in the total process. If they should share more information about the patients that are at the clinic they could use this information to estimate how much capacity they will need at the OR and the ward. Better coordination between the OR and the ward may result in less variability in bed occupancy. Thus, better coordination of the departments could lead to a shorter throughput time and/or better use of capacities.

Although it is not possible to have a high utilization of capacities and a short throughput time. A full utilization of capacities will lead to high throughput time. On the other hand, a short throughput time will lead to low utilization of capacities. A trade off should be made between these. Which combination of throughput time and utilization of capacities is desirable for the hospital is a strategic and/or tactical choice. The model that will be build in this study supports the users/management team in these choices.

3 Literature

In literature is a tendency to focus mainly on the individual level of departments and patients. The complex relationships between departments are often overlooked. This is at the expense of the insight in the whole (Vanberkel et al., 2010b). The goal of our study is to give insight into the effect of planning of capacities on the performance of the departments and the performance of the chain for the specialty surgery and to investigate which interventions will lead to a better performance for the specialty surgery. Thus, our study includes multiple departments. There are few models in literature that describe multiple departments. In these models, diagnostic departments are often not taken into account. However, for a good overview of the whole process, these departments should be included (Vanberkel et al., 2010b).

The lacking attention to the whole process has often the result that less patients can be admitted, without perceiving a decline in costs (de Bruin et al., 2005). The lacking attention for the whole process is caused by the complexity and variability of the processes and the lacking standard care pathways (Vanberkel et al., 2010b). According to Carter (2002) the focus on the individual departments is the main cause of the inefficiency in health care. This local expertise is partly caused by the professional obligations and ethics. Physicians and nurses are obligated to focus at the individual patient (Vanberkel et al., 2010b).

To gain more insight in the complex processes in a hospital, the processes should be described on the basis of the flows of patients (Visser & Beech, 2005). Knowing where a patient is going to, and when, is essential when designing models with multiple departments (De Bleser et al., 2006). Section 3.1 discusses several techniques for modeling systems. The classification of groups will be discussed in Section 3.2. Then, Section 3.3 describes some extra performance indicators that describe the performance of a network/chain. In Section 3.4 the main conclusion of this chapter is given.

3.1 Multiple department models

In literature multiple methods can be found to model processes (Cardoen et al., 2010; Vanberkel et al., 2010b). These methods can be sorted in simulation techniques, queuing theory and mathematical programming. Clinical pathways are an alternative method to describe patient care trajectories and to gain insight in the relationships between departments in hospitals (Vanberkel et al., 2010b). These methods are explained in the following sections.

3.1.1 Simulation

Simulation is often used to model the behavior of processes in health care (Angelis, Felici & Impellusso, 2003). The simulation method most often used is discrete event simulation. 'Discrete event simulation concerns the modeling of a system as it evolves over time by a representation in which state variables change instantaneously at separate points in time' (Law, 2007). Discrete event simulation is known as a powerful way to evaluate logistic systems (Van Dijk & Van der Sluis, 2008).
A simulation model can among other things be used as a decision support tool (Long & Mirabelli, 2008), or to test the effect of planning approaches on the performance (Ma & Demeulenmeester, 2012; Dexter et al., 1999).

In literature simulation is often used to model the relationship between departments. For example Bagust et al. (1999) uses simulation to study the relationship between the emergency department and the ward. Simulation is not only used to study the relationship between departments. Sobolev et al. (2008) uses simulation to study the relationship between the waiting lists and the OR.

Simulation models are preferred over other models because it is possible to model the dynamics, complexity and uncertainty in the model and because it is relatively easy to include a lot of details in the model(Person & Araldi, 2009; Van Dijk, 2000). Simulation models are often used to executed what-if analyses (Angelis, Felici & Impelluso, 2003).

Simulation has some limitations too. Simulation will not gain optimal results, it is an evaluation method. Another disadvantage is that there is a lot of detailed information needed to design the model. Some values of the parameters should be known in advance. Simulation cannot be used as a search method for the 'right' parameters (Van Dijk 2000; Van Dijk & Van der Sluis, 2008). So if mathematical solutions are possible they are preferred to simulation (Law, 2007).

3.1.2 Queuing theory

A queuing network analysis is very effective to balance a system fast and easily (Vanberkel et al., 2010b). A department in a hospital can be modeled with a queuing model. A queuing model consists of a flow of customers that arrive at a department in which they are served after which they leave the department. The queue is described by the arrival process of the customers, the services times, the number of servers and the capacity (See for example, Kulkarni, 1999). Koa & Tung (1981) minimize overflows of patients for the inpatient bed units with a queuing model. In this model the patients have a poison arrival process, general distributed service times and there is an infinite buffer. Van Dijk & Kortbeek (2009) modeled the OR and the IC with queuing theory. A patient can be rejected at the OR because there is not enough IC capacity. There is no formulation in queuing theory that can take the rejection probability of the IC into account. With a special tandem formulation they prove a lower and upper bound for the rejection probability for the IC. A chain in a hospital (multiple departments together) can be modeled as a queuing network. Cochran & Roche (2008) use a open multi class queuing network to model the emergency department. They use non-homogenous arrival patterns and non-exponential service time distributions.

Vanberkel (2010a) developed a method to model the relationship between the MSS and the workload of the ward. This method is based on parts of queuing theory. The output of the method is a steady state probability distribution for the amount of recovering patients at the ward as result of the MSS. Vanberkel (2010a) uses the method to evaluate the MSS. The steady state distribution of recovering patients at the ward as result of the original MSS is calculated. The output is discussed with a team of involved people. If necessary, the MSS is changed. Then this changed MSS will be checked for feasibility with the OR restrictions. This new MSS is evaluated again and the results are discussed by the team. This process is repeated until the results are 'good enough'. This MSS is implemented.

There are several people that extended the model of Vanberkel (2010a). Vlijm (2011) extended the model of Vanberkel et al. (2010a) with ward specific distributions, number of discharges and admission each day, and morning and afternoon shifts or OR blocks. Vanberkel et al. (2010a) used the model to analyze the MSS, while Vlijm (2011) extended the model further and made an optimization possible. Smeenk (2011) extended the model in a way that makes it possible to predict the bed census of the ward from hour to hour. Recently Fügener (2012) involved the IC in the model.

The advantages of a queuing model are based on exact calculations, fewer data is needed, implementation in spreadsheets is possible, and it provides good insight (Cochran & Roche, 2008; Van Dijk, 2000). However queuing theory has some limitations too. Queuing models are based on steady state assumptions and therefore they are not suitable for analyzing dynamic plans with a finite horizon (Hulshof et al., 2011). A queuing model makes strong simplification with regard to the uncertainties (Van Dijk, 200). In some queuing models there are assumptions about the arrival process and service process that may not always be true for every situation. Queuing models often use averages values of some variables (Vanberkel et al., 2010b). Therefore queuing models have limited possibilities to model real life situations properly.

3.1.3 Mathematical programming

Several types of mathematical programming can be distinguished, such as linear, inter, mixed integer programming (Van Dijk & Van der Sluis, 2008). Hulshof et al. (2011) has developed an mixed integer linear programming model for admission planning. This model takes the fluctuation of patient arrivals and availability of capacities into account.

The advantage of mathematical programming is that it searches for an optimal solution, based on exact calculations.. This computation can be done by the computer. A disadvantage of mathematical programming is that most real life problems are too complex to be solved in reasonable time. For these problems it is not possible to find a optimal solution. If mathematical programming is not possible than a heuristic is often used. Heuristics are not as time consuming as the other operations research methods. Although heuristics cannot be proven to give the best solution, it may be a good alternative when other methods are not possible or too time consuming (Van Dijk & Van der Sluis, 2008).

3.1.3.1 Combination of methods

In the previous section queuing theory, mathematical programming and simulation are described separately. It is also possible to use the methods in addition to each other. Queuing theory and/or mathematical programming can be used to propose scenarios for simulation or as additional information. Queuing and mathematical programming are used to optimize and the simulation models in order to evaluate the OR results (Van Dijk & Van der Sluis, 2008).

3.1.4 Clinical pathways

In the mid 1980-s the first clinical pathways were introduces by Zander. Zander adopted a evaluation and review technique for the management of clinical processes in order to improve the quality of care (Hoffmann, 1993). Clinical pathways give insight in the trajectory of the patients through the hospital. Clinical pathways define a time span for a homogeneous group of patients. If there is no insight in the trajectory of the patient, it is not possible to gain insight in the interaction between departments (Vanberkel et al., 2010b).

The definition of a clinical pathway is 'a clinical pathway is a patient care management method for a specific group of patients during a specific time period. A clinical pathway defines the goals and main elements of care based on Evidence Based Medicine (EBM) guidelines, best practices and expectations of patients. The goal of clinical pathway is improving the quality of care, reducing risks, increasing the patient satisfaction, decreasing documentation burdens, decrease variation, selecting best practices and improving the efficient use of capacities '(De Bleser et al., 2006; Every et al. 2000).

In 2003 clinical pathways were implemented in more than 80% of the hospitals in the USA (Kingsman et al., 2010). A clinical pathway is mostly implemented in paper based systems (Wakamiya & Yamauchi, 2009. However there are developed electronic clinical pathways in the early 1990s (DiJerome, 1992). An electronic clinical pathway is linked with the medical record and/or the nursing process. A electronic clinical pathway has six function categories (Wakamiya & Yamauchi, 2009);

- It displays the checklist that are involved in the clinical pathway.
- It records medical treatment and care.
- It orders data about among other things medication, examinations and injections.
- It edits checklists.
- It records variance that may occur in the clinical pathway.
- It gives statistics about the variance of types of clinical pathways.

There are some issues with clinical pathways. Clinical pathways display the process of the 'ideal' patient. The majority of the patients are not the ideal patient. Identification of the 'right' patients is therefore an important implementation issue. A second issue is that is unknown yet how to evaluate critical pathways as effective tool in improving patient care. Little research is done about the effectiveness of clinical pathways. Another issue of a clinical pathway is that the cost of pathway development and implementation has not been evaluated. The savings of pathway may be approximately 0,5 days in length of stay resources, but the development costs and the need for a case manager should be included in the cost-effectiveness analysis (Every et al, 2000).

The scope of a clinical pathway is very wide. It contains multiple disciplines and departments. However, a clinical pathway is focused on one patient type. The effects for other patients that use the same capacities are overlooked.

3.1.5 Conclusion

Several methods for modeling multiple departments are discussed in the previous sections. Simulation is a powerful tool, but a lot of detailed information is needed. Simulation is a good option if no other technique is possible. With queuing theory it is possible to model multiple departments. The effects for the capacity of resources and the waiting times of patients can become clear with queuing. A disadvantage of queuing is that it makes use of some assumptions that may not represent reality very well. Mathematical programming, is not possible for this problem because it is too big to solve in reasonable time. Clinical pathways include multiple departments but include only one type of patients. The model of Vanberkel et al. (2010a) only focuses on the relationships between the wards and the OR. Other departments, such as clinic and emergency department, are not involved. So queuing theory is an appropriate way to model the multiple departments in this research. To represent the reality better, a distinction should be made between the different patients. The next section describes several ways to cluster patients.

3.2 Clustering of patients

This study describes the complex processes in a hospital for the specialty surgery. To gain more insight in the complex processes in a hospital, the processes should be described on the basis of the flow of patients (Visser & Beech, 2005). Knowing where a patient is going to and when, is essential when designing models with multiple departments (De Bleser et al., 2006)

As discussed before, the patients have to be clustered to gain a better insight in the relationships between departments. The clusters should be made on the basis of equal care demand and equal characteristics. These type of grouping of patients increases the efficiency of management. However, some information will be lost by looking at groups of patients instead of individuals (Ward, 1963). The groups that need to be made must meet the following requirements (Ward, 1963):

- The groups can be distinguished by the planners
- The groups should be big enough otherwise it is difficult to describe the cycles of the group
- The variance in the group has to be small
- The variance between the groups has to be big
- The groups has to be mutually exclusive

There are several clustering methods in literature. Maruster et al. (2002) clusters patients with the aid of the software package SPSS. Patients are divided in groups on the basis of logistic variables with the aid of the 'two-step' grouping method. The goal of this method is to minimize the variability in groups/clusters and maximize the variability between groups. These method has two advantages: there don't have to be determined in advance how many clusters/groups that are necessary, compared to other methods it is much faster for large amounts of data and logistic variables. A disadvantage of this method is that the choice between size of the group versus variability is not clear.

Van Oostrum et al. (2008) used a clustering method for designing a master surgical schedule. This method consists of four steps and is based on the hierarchical clustering method of Ward (1963). In the first step in the method of Van Oostrum (2008) every type of surgery is a group. Then a combination of surgeries is made. The surgeries that have together the largest savings are combined. This will be done until there is no surgery left. The savings are calculated by the reduction of the Error Sum of Squares (ESS) of the length of stay and the surgery duration. A disadvantage of this method is that the surgery types that are chosen as starting point are often difficult to distinguish for the planners.

Ma & Demeulenmeester (2012) use a method for the classification of groups of patients according to a iso-process groupings method (Vissers et al., 2001). Every patient group has similar variables. The chosen parameters in the research of Ma & Demeulenmeester (2012) are average returns for each treatment, the surgical group, the expected surgery duration and the expected length of stay.

In a clinical pathway the trajectory of a patient group will be taken into account. Patients that belong to the same patient group have a similar routing through the hospital with similar logistic variables. A clinical pathway can be seen as a method for classifying patients.

There are several ways to classify patients. For this research the classification on the basis of similar logistic variables and sub specialty is for this research most suitable. The logistic variables that will be used in this research are expected duration of a consultation at the clinic, expected surgery duration and expected length of stay at the ward.

3.3 Performance indicators

A system is evaluated on the basis of performance indicators. Performance indicators can often be divided over four groups: quality, time, costs and flexibility (Cai et al., 2009). As was mentioned in Chapter 2, the hospital uses the Treeknormen, IGZ indicators and the Zichtbare Zorg indicators. The IGZ and Zichtbare Zorg Indicators are especially quality indicators. The treeknormen are especially time indicators. Although these indicators are related to the costs, for example, occupancy rates and overtime OR.

Cardoen et al. (2010) distinguishes eight indicators, namely waiting time, throughput time, occupancy rate, leveling, make span, patient refusal/deferral, financial indicators and preferences of patients and surgeons. Most of these indicators are already used in the hospital. Only leveling and make span are not used. Make span is the time between entry of the first patient and the discharge of the last patient (Cardoen et al., 2010). For this research it is not directly interesting to study the make span, because some patient may wait longer than others. This is included in the throughput time of each patient type.

Leveling is the variability in occupancy rates of capacities and/or patients volumes (Cardoen et al., 2010). Reducing the variability may ensure that there are less resources needed to treat the same number of patients. Less required resources means less costs. For this reason this indicator will be added for this research for the occupancy rate clinic, occupancy rate OR, and the number of used beds.

3.4 Conclusion

Queuing theory will be used to model the multiple departments for the specialty surgery. Van Dijk & Kortbeek (2009) modeled the OR and the IC with queuing theory. In this research a queuing network will be developed for the specialty surgery. To represent the reality better, a distinction should be made between the different patients. Ma & Meulenmeester (2012) use a iso-process method for the classification of groups. The classification is based on similar variables of each group. The classification on the basis of similar logistic variables and sub specialism is for this research most suitable. The logistic variables that will be used in this research are expected duration of a consultation at the clinic, expected surgery duration and expected length of stay at the ward. Leveling of occupancy rate clinic, occupancy rate OR and the number of used beds is added to the performance indicators of this research.

4 Model

The aim of this research is to give insight into the effect of planning of capacities on the performance of the departments and the performance of the chain for the specialty surgery and to investigate interventions that will lead to a better performance for the specialty surgery. As discussed before, a model could give more insight in the use of capacities. This chapter discusses the model that will be used in this research. Section 4.1 describes the structure and assumptions of the model. Then Section 4.2 describes the formulas with which some performance indicators can be calculated. Section 4.3 describes the capacity constraints of the system. Then Section 4.4 explains some model features. Finally Section 4.5 gives the conclusion of this chapter.

4.1 Model description

The model that will be developed in this research should give insight into the effect of planning of capacities on the performance of the departments and the performance of the chain for the specialty surgery. The scope of this model is at the tactical level of the framework of Hans et al. (2011) (as is explained in Chapter 1). At this level, choices are made about when and how much capacity should be available for any specialty.

Figure 9 presents the network of departments for the specialty surgery. The system has six departments which are: 1 (Clinic), 2 (OR Venray), 3 (OR Venlo), 4 (Ward Venray), 5 (IC), and6 (Ward Venlo). The number in the blocks of each department represent i, the number of the department. Patients can enter the network in two ways, through the clinic or through the emergency department. The emergency department is not taken into account in this research. This is because the capacity of the emergency department is shared with patients of other specialties. For the Clinic and the OR it is possible to divide the capacity among the different specialties in clinic session, OR blocks and beds. For the emergency department this is not possible. The emergency patients have an own emergency OR. For this reason only the flow of patients that come from the emergency department to the Ward in Venlo and the IC are taken into account. In the network there is no distinction between the clinic in Venray and Venlo. This is because all patients can come to both clinics, regardless of where the surgery will be. Patients that had an surgery have to go to the IC or to the ward.

At each department there are capacities. At the clinic, one clinic session is considered as a capacity. At the OR is one OR block considered as a capacity and at the ward and IC is one bed considered as an capacity. An clinic session lasts four hours and an OR block lasts 225 minutes, 3,75 hours. Nurses and other staff are not considered as a capacity. At the end it will be checked if the number of clinic and OR sessions are possible with the number of specialists. If there is a bed available it is assumed that there is enough staff for the bed. The model that will be developed should give for each department the utilization, the waiting time and the throughput time of the patients.

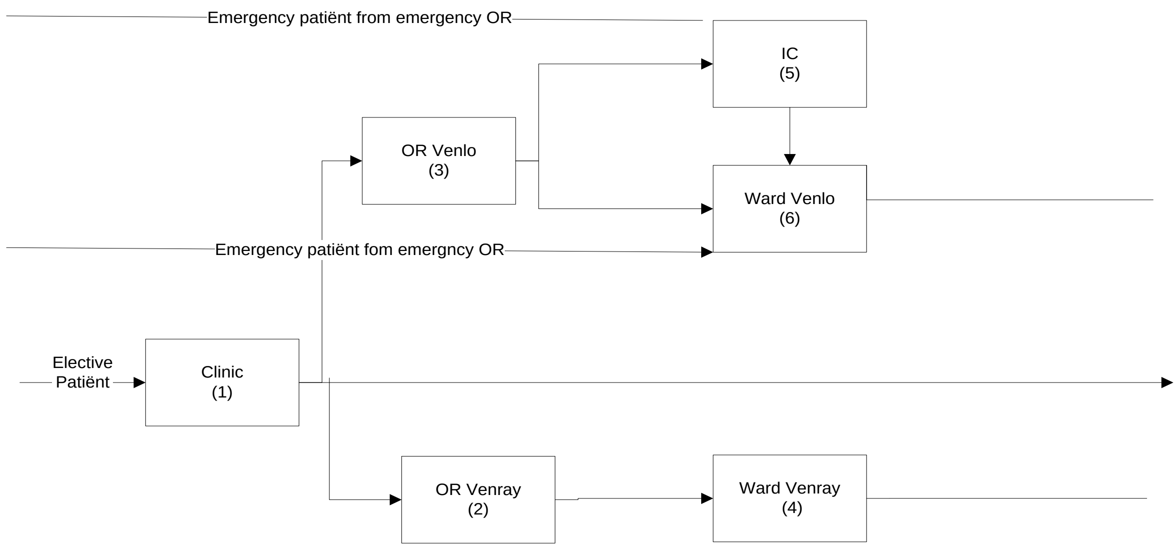

Figure 9 Overview Model

Queuing theory will be used to develop as a modeling framework of the different departments. Each department is considered as a queuing system, in which patients arrive at the department, wait until they are served and then leave.

The whole network can be seen as a queuing network. There are several types of queues possible, which are described by three characteristics; the arrival process, the service times and the number of servers. For this research an open multi class G/G/c network will be used. In an open queue it is possible that patients can enter and exit the system at each department. In a closed network patients remain circulating in the system. A multi class network means that there are different types of patients with different inter arrival times and service times. The patients are treated first come first serve (FCFS). G/G/c means that the arrival process and the service times have a general distribution and each station has c servers and an infinite buffer. The infinite buffer holds for the clinic, and for the elective patients of the OR, but not for the other departments. Emergency patients cannot wait too long before they are operated. Emergency patients have their own OR block, so they won't interfere with the elective schedule. This emergency OR block is shared with other emergency patients, for this reason this is not included in this research. The emergency OR is open from 12.30 hours. In practice there are very few emergency patients that cannot be operated in this emergency OR. So we assume that this number is negligible. The patients that come from the emergency OR block will be modeled as separate streams from outside the system to the IC or the Ward. Consultations at the clinic after surgery will be modeled as new arrivals.

In the network there is waiting time possible for each department. In reality there is no waiting time possible for the IC and the Ward. Patients that had a surgery should be transferred to the IC or ward when the patient is ready (after the patient is awake). In the model the waiting time for the IC and the wards will be calculated and should be very small. A high waiting time for the IC and the wards will mean that there are surgeries cancelled because of a shortage of beds. When the waiting time for the IC and the Wards is too high, more capacity at the wards should lead to a lower waiting time.

4.2 Performance indicators

In order to measure the performance of a system some performance indicators should be calculated. These performance indicators are the expected utilization of each department, expected throughput time of each group of patients, and the expected waiting time at each department. These performance indicators are calculated with the formulas in the following.

Utilization rate

The utilization of the department is the percentage of the time that the department is busy with a patient. At the clinic for example this is the percentage of the clinic time that is used for consultations. The utilization of each department, $\rho_{i,}$, is calculated with Equation 2. The utilization rate will be calculated by dividing the arrival rate with the service rate. For the calculation of the utilization of the OR the changing time is included in the utilization rate. This is 12 minute for each change. The arrival rate and service rate have to be in the same time scale. For the calculation the chosen time scale is per week. In the model we have R classes of patients. This patient grouping is done in Chapter 5. The arrival rate of patients to department i is calculated with Equation 3 and 4. Equation 3 calculates the arrival rate of patients to department i of class r. The arrival rate of patients of class r to a department consists of two parts; the arrival rate of patients from outside the network to the department and the arrival rate of patients from other departments to department i. The arrival rate of patients from other departments to department i has to be calculated with the routing matrix for each class of patients, $P_{i,j}^{(r)}$. In the routing matrix for each class of patients r is determined which percentage of the patients that are at station i, will go to station j, i,j =1,2,3,4,5,6. The percentage of patients that need an IC bed is based on the number of patients, who actually need an IC bed and not on the number of patients for who an IC bed was reserved. Sometimes the reservation of an IC bed for a patient, and after the surgery it turns out that there is no need for an IC bed. This reservations are not registered in the data. For this reason it is not possible to include these reservations in the arrival process. Few assumptions are made:

- All patients that have an OR go the Ward or the IC. This is not true for all patients. Some patients will die during or after the surgery and do not need a bed. You cannot plan for the death of people so this will not be included in the model. Other patients have a day care treatment, these patients will need a bed for one day. This is included in the average length of stay.
- All patients that are at the IC will go to the ward before they go home. Some patients will die at the IC and don't go to the ward, but you cannot plan for dead people.
- Consultations at the clinic after surgery are modeled as new arrivals, which will leave the system after the consultation.

This leads to R routing matrices of the following form:

$$P_{i,j}^{(r)} = \begin{bmatrix} 0 & x1 & x2 & 0 & 0 & 0 \\ 0 & 0 & 0 & x3 & 0 & 0 \\ 0 & 0 & 0 & 0 & x4 & x5 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & x6 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

x1: percentage of the patients that are at the clinic that have a surgery in Venray
x2: percentage of the patients that are at the clinic that have a surgery in Venlo
x3: percentage of the patients that have a surgery in Venray and go to the ward in Venray
x4: percentage of the patients that have a surgery in Venlo and go to the IC
x5: percentage of the patients that have a surgery in Venlo and go to the ward in Venlo
x6: percentage of the patients that are at the IC and will go to the Ward in Venlo

By adding the arrival rate from outside the system and from other departments the arrival rate of patients of class r to department i is calculated. Then in Equation 4 the arrival rates of all classes are added in order to get the total arrival rate of patients to department i. Equation 5 calculates the service rate of each department per week. This service rate depends on the number of sessions each week, the duration of these sessions (hours) and the expected service time at the department. Equation 7 calculates the expected service time at department i with the expected service times of the classes at department i, the arrival rate of patients of class r to department i and the arrival rate of patients to department i

Equations utilization and definitions

$$\rho_i = \frac{\mathbb{E}S_i}{\mathbb{E}A_i} = \frac{\lambda_i}{\mu_i} \qquad i = 1, \ldots M \qquad (2)^1$$

$$\lambda_i^{(r)} = \lambda_{0,i}^{(r)} + \sum_{j=1}^{M} \lambda_j^{(r)} P_{ji}^{(r)} \qquad r = 1, \ldots R \qquad (3)^1$$

$$\lambda_i = \sum_{r=1}^{R} \lambda_i^{(r)} \qquad i = 1, \ldots M \qquad (4)^1$$

$$\mu_i = c_i * d_i * \mathbb{E}S_i \qquad (5)$$

$$\mathbb{E}S_i = \frac{1}{\lambda_i} \sum_{r=1}^{R} \lambda_i^{(r)} \, \mathbb{E}S_i^{(r)} \qquad (6)^1$$

c_i: Number of servers at department i; Clinic sesions, OR blocks, beds
d_i: Duration of session at department i
λ_i: Arrival rate at department i
i, j 1 … M Number of a deparment
$\lambda_i^{(r)}$: Arrival rate of patient group r at department i
$\lambda_{0,i}^{(r)}$: Arrival rate of patient group r at department i from outside the system
M : Number of departments in the network
μ_i : Service rate at department i
ρ_i: Utilization at department i
R: Number of groups of patients
$P_{i,j}^{(r)}$: Routing matrix which gives the percentage of the patients that are at station i, will go to station j

Figure 10 utilization closed form expressions (1= Zijm, 2012)

Mean Waiting Times

For the clinic and the OR the patients have to wait before they are treated. For these departments the waiting times have to be calculated. The IC and the ward should not have any waiting time, because patients cannot wait too long for a bed after they have had surgery. Although there is no waiting time possible the waiting time for these department will be calculated anyway. This is in order to check how many beds there should be needed to be able to operate all patients. The number of beds that are available for the specialty surgery is not very strict. Wards are shared with other specialties and the planners will do their best to find a bed for a patient. The mean waiting times for the departments will be calculated with Equations 7-17. Equation 7 is an approximation for the mean waiting times because an exact calculation is not known so far in literature. The mean waiting times are calculated with the squared variation coefficient of the inter arrival times, the squared variation coefficient of the service times, the expected service times, the number of servers and the utilization.

The squared coefficient of variation of the service times is calculated with formulas 8 and 9. Equation 8 calculates the squared variation coefficient of the service times of each patient category at each department. This is combined to the squared variation coefficient of service times at each department in Equation 9. This will be calculated with the arrival intensities at each department and the service times at each departments. The arrival intensities are needed in this equation to get the right proportions of arrivals of patients.

Equations 10-17 calculates the squared variation coefficient of the inter arrival times at each department. The squared variation coefficient of the inter arrival times of patients from outside the system are calculated with Equation 10. This is the arrival flow to the clinic and the emergency patients. The ORs have arrivals of patients, that are departures of the clinic. For this reason the squared variation coefficient of departures of the clinic has to be calculated. This squared variation coefficient of departures of the clinic is determined by the utilization rate, the squared variation coefficient of the arrivals of the clinic and the squared variation coefficient of the service times in Equation 11. When the department has a high utilization the arrivals at the next department are determined by the squared variation coefficient of the service times, with a low utilization the arrivals at the next department are determined by the arrivals at the clinic. Equation 12 determines which part of the departure process of the previous department will go to the next department. Equation 13 combines the squared variation coefficient of all incoming flows with the use of Equations 14-17.

Equations mean waiting times and definitions

$$\mathbb{E}W_{Qi} = \frac{C_{ai}^2 + C_{si}^2}{2} \frac{\rho_i^{(\sqrt{2(c_i+1)}-1)}}{c_i(1-\rho_i)} \mathbb{E}S_i \qquad \rho_i < 1 \qquad (7)^1$$

$${C_{si}^{(r)}}^2 = \frac{\sigma_{si}^2}{(\mathbb{E}S_i)^2} \qquad i = 1, \dots M \qquad (8)^1$$

$$C_{si}^2 = \frac{1}{\lambda_i (\mathbb{E}S_i)^2} \sum_{r=1}^{R} \lambda_i^{(r)} (\mathbb{E}S_i^{(r)})^2 \left((C_{si}^{(r)})^2 + 1 \right) - 1 \qquad i = 1, \dots M \qquad (9)^1$$

$$C_{ai}^2 = \sigma_i^2 \lambda_i^2 \qquad i = 1, \dots M \qquad (10)^1$$

$$C_{di}^2 = 1 + (1 - \rho_i^2)(C_{ai}^2 - 1) + \frac{\rho_i^2}{\sqrt{c_i}} (C_{si}^2 - 1) \qquad i = 1, \dots M \qquad (11)^1$$

$$C_{ij}^2 = P_{ij} C_{di}^2 + 1 - P_{ij} \qquad i, j = 1, \dots M \qquad (12)^1$$

$$C_{aj}^2 = w_j \sum_i^M Q_{ij} C_{ij}^2 + 1 - w_j \qquad j = 1, \dots M \qquad (13)^1$$

$$w_j = [1 + 4(1 - \rho_j)^2 (v_j - 1)]^{-1} \qquad j = 1, \dots M \qquad (14)^1$$

$$v_j = [\sum_i^M Q_{ij}^2]^{-1} \qquad j = 1, \dots M \qquad (15)^1$$

$$Q_{ij} = \frac{\lambda_{ij}}{\lambda_j} \qquad i = 1, \dots M \quad j = 2, \dots M \qquad (16)^1$$

$$\lambda_{ij} = \lambda_i * P_{ij} \qquad i = 1, \dots M \qquad (17)^1$$

c_i: Number of servers at department i
C_{ai}^2: Squared variation coefficient of the aggregate arrival process at department i
C_{di}^2: Squared variation coefficient of the aggregate departure process at department i
C_{ij}^2: Squared variation coefficient of the flow from department i to j
C_{si}^2: Squared variation coefficient of the aggregate service times at department i
${C_{si}^{(r)}}^2$: Squared variation coefficient of a job r at station i
$\mathbb{E}S_i$: Expected service time of job at department i
$\mathbb{E}S_i^{(r)}$: Expected service time of job at department i
$\mathbb{E}W_{Qi}$: Expected time in the queue of department i
λ_i: Arrival rate at department i
$\lambda_i^{(r)}$: Arrival rate of patient group r at department i
λ_{ij}: Arrival rate at department j from department i
ρ_i: Utilization at department i
P_{ij}: Routing matrix which gives the percentage of the patients that are at station i, will go to station j
Q_{ij}: The proportion of the arrival flow of station j orginating from station i

Figure 11 mean waiting times approximates (1=Zijm, 2012)

Mean Throughput times

The mean throughput time is the time that the patient is in the system. The throughput time is the sum of all waiting times and services times of a patient. These throughput times are calculated with Equations 18-22. The throughput times are calculated for each patient group separately. This is because the patients groups have different length of stay at the ward. For this reason it could be that patients that have a longer LOS at the ward have a longer throughput time too.

The throughput time of patients can be calculated by applying Little's Law (See Kulkarni, 1999); $\mathbb{E}L = \lambda * \mathbb{E}W$. This law states that the mean number of patients in the systems equals the arrival rate multiplied by the expected time that the patient is in the system, the throughput time. Equation 18 calculates the throughput time of patient group r with the fraction of patients that go to department i, the expected number of patients of group r that are at department i, and the arrival rate of patient group r at department i. Equation 19 calculates the visit ratio of patients of class r that go to department i, by dividing the arrival rate of patients of class r to department j by the total arrival rate of patient class r to the system. With Equation 20 the total arrival rate of patient class r to the system is calculated by adding all arrival rates from outside the system to a department of patient class r. Equation 21 calculates the number of patients of class r that are at department j. This is done by adding the patients that are in the queue and the patients that are served/treated. Equation 22 calculates the number of patients that are in the queue for department j by multiplying the arrival rate of patients to department i with the expected time in the queue at department i.

Equations mean throughput times and definitions

$$\mathbb{E}W^{(r)} = \sum_{i=1}^{M} V_i^{(r)} \frac{\mathbb{E}L_i^{(r)}}{\lambda_i^{(r)}} \quad (18)^{1}$$

$$V_i^{(r)} = \frac{\lambda_i^{(r)}}{\gamma^{(r)}} \quad (19)^{1}$$

$$\gamma^{(r)} = \sum_{i=1}^{M} \lambda_{o,i}^{(r)} \quad (20)^{1}$$

$$\mathbb{E}L_i^{(r)} = \frac{\lambda_i^{(r)}}{\lambda_i} \mathbb{E}L_{Q,i} + \lambda_i^{(r)} \mathbb{E}S_i^{(r)} \quad (21)^{1}$$

$$\mathbb{E}L_{Q,i} = \lambda_i * \mathbb{E}W_{Q,i} \quad (22)^{1}$$

$\mathbb{E}L_i$: Expected number of patients at department i
$\mathbb{E}L_{Q,i}$: Expected number of patients waiting in the queue at department i
$\mathbb{E}S_j^{(r)}$: Expected service time of job at department i
$\mathbb{E}W^{(r)}$: Expected throughput time of patient group r
$\mathbb{E}W_{Qi}$: Expected time in the queue of department i
$\gamma^{(r)}$: Arrival rate of patients of class r to the whole network of departments
λ_i: Arrival rate at department i
$\lambda_{0,i}^{(r)}$: Arrival rate of patient group r at department i from outside the system
i: 1,…M Number of a department
$\lambda_i^{(r)}$: Arrival rate of patient group r at department i
M Number of departments in the network
ρ_i: Utilization at department i
$V_i^{(r)}$: Visit ratio of patients of class r to department i

Figure 12 Equations throughput times and definitions 1= (Zijm, 2012)

4.3 Available capacity

Of each department the current capacity should be determined. This is an input for the model and could be constraint for the solutions of the model. The number of specialists and assistants are a shared capacity for the clinic and the OR. The number of OR session is another constraint for the OR. Although these two constraints may not be hard constraints. If it is financial feasible/attractive more specialists could be hired or more OR sessions could be gained by redistributing the OR sessions. With the amount capacities can be varied in order to get a 'better' solution. If the solution of the model exceeds the available capacity a warning should be given. This means that more capacity should be added in order to get the desirable solutions. The model may also suggest that there is an excess of capacity.

4.4 Model features

The method that is discussed in this chapter uses averages and standard deviations to model the system. It assumes that the network is continuously working, 24 hours per day for seven days per week. In reality there are no clinic sessions and elective surgeries during the night and weekends. For the wards is the continuous working assumption more realistic. The wards are working 24 hours per day for seven days a week. Emergency patients may come to the ward during the night or weekends. However the discharges of patients are not continuously, only during the day. This continuity assumption will affect the answers of the model in a way. The model will be validated in Chapter 6 to see if the answers of the model will be represent reality well.

The model gives answers for the system in a steady state. However the arrival rate of patients can be different during time. During the holidays there are less patients. Or in the winter there could be more patients than the rest of the year. The standard deviations of the arrival process deal with some of this variation. For a better representation of this seasonality each period should get a different arrival intensity. It is assumed that in this period the system has reached another steady state. For each month it could be reasonable that the system has reached a steady state again. For this reason different arrival rates for each month will be implemented in the model.

4.5 Conclusion

A multiple class G/G/c queuing network will be used to model the chain for the specialty surgery. The network consists of six departments, the clinic, OR Venray, OR Venlo, Ward Venray, IC and Ward Venlo. The patients will be divided into groups. Figures 10-12 present the formulas for the performance indicators that will be calculated. For the calculation of the performance indicators some input parameters should be calculated. As mentioned before the patients will be divided into groups to get more detailed information about the situation. So the next steps are to classify the patients in groups and determine the input parameters of each group. These input parameters are the inter arrival times of each class of patients for each station, the expected service times for each class of patients for each station, the routing matrix and the squared variation coefficient of the inter arrival times and the services times. The classification of groups and the determination of the input parameters will be done in the next chapter. With these patients groups and input parameters some performance indicators can be calculated.

5 Input parameters

Previous chapter explains the theory of the model that will be used in this research. This theory will be applied to the specialty surgery for the VieCuri. In Section 5.1 the patients will be divided into groups. Then Section 5.2 determines the input parameters for the model. Section 5.3 explains the capacity constraints and seasonality of the model. Finally Section 5.4 gives the conclusion of this chapter.

5.1 Classification of groups

Chapter 3 describes among others things different ways to divide patients into groups. In this chapter, the categories of patients are made. Ma & Demeulenmeester (2012) used the parameters average income for each treatment, the surgical group, the average surgery duration and the average length of stay for the classification of patients. In this research the classification of patients will be based on the parameters; sub specialty, the average surgery duration and the average length of stay. Average income for each treatment is not taken into account in this research, because the focus of the research is to gain insight in the logistics of the flows of patients. The economical part is not taken into account in this research. The other parameters are the same as in the research of Ma & Demeulenmeester (2012). In this research the surgical group is the sub specialty where the patient belongs to. Another aspect that plays a role in the classification of the groups, is the size of the groups. The groups should not be too small, because otherwise the occurrence of that group is too low. This results in a high number of groups which makes the model too complex. Ma & Demeulenmeester (2012) used 9 groups to model the patients of 4 surgeon groups and Cochrane & Roche (2008) used 5 groups to model the patients at the emergency department. So for this research around 10 groups should be made. The classification steps will now be further explained.

The patients can be distinguished in 162 diagnosis codes. Of these diagnosis codes the number of patients during a year at the clinic, the number of patients during a year in the OR, the average OR duration and the average length of stay at the ward are determined (See Appendix 4 for more information).
The first step of the classification is based on the sub specialty that the diagnosis codes belong to. This initial classification is made because not every surgeon is suitable for every sub specialty. There are four sub specialties: general surgery, traumatology, oncology and vascular surgery. The diagnosis codes that start with a one belong to general surgery, the diagnosis codes that start with two to traumatology, with a three to oncology and with a four to vascular surgery. This leads the four groups (Table 6). As can be seen in Table 6 traumatology is the sub specialty with the most diagnosis codes.

Sub Specialty	Diagnosis codes
General surgery	101, 111, 113, 115, 116, 117, 120, 121, 123, 124, 126, 127, 129, 131, 132, 133, 134, 135, 140, 141, 150, 151, 159, 160, 161, 163, 170, 171, 172, 175, 176, 177, 179
Traumatology	203, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 224, 236, 237, 238, 241, 249, 250, 253, 254, 255, 256, 257, 258, 261, 262,

	269, 270, 273, 274, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299
Oncology	301, 302, 303, 304, 305, 306, 310, 311, 312, 313, 315, 316, 317, 318, 320, 321, 322, 323, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 348, 349, 350, 351, 352, 353, 359,
Vascular surgery	401, 402, 403, 404, 405, 406, 408, 409, 410, 413, 416, 417, 418, 419, 420, 421, 422, 423, 425, 426, 427, 432, 434, 435, 439, 441, 442, 449

Table 6 Subspecialtys & Diagnosis codes

Then the patients are further grouped on the basis of the expected operation duration and the expected length of stay. In the last step it is checked if the groups are big enough. If they are small groups then they are combined. The classification in each group is done with the following rules 1-5. These rules are based on a combination of the variable surgery duration and length of stay at the ward. Clinic duration is not chosen as variable to group the patients because there is less variation in this variable than the other two. The criteria 60 minutes and 5 days are chosen because when you look to the data you see separation point for all sub specialties. Unfortunately it doesn't lead to groups of equal size. The range of the variables of each group is quite wide, but a smaller range would lead to more groups. The last criteria is chosen because the groups may not be too small. If there are less than 52 patients a year in a group, this means that there on average less than one patient per week of that group. This number is too few to calculate the performance indicators. The effort that it takes to calculate the performance indicators does outweigh the value of the additional information.

1. Group diagnosis codes that have all patient that go only to the clinic.
2. Group diagnosis codes that have an average length of stay of 0-5 days and an average surgery duration that is 60 minutes or smaller.
3. Group diagnosis codes that have an average length of stay of 0-5 days and an average surgery duration that is higher than 60 minutes.
4. Group patients that have an average of length of stay that is more than 5 days.
5. All groups should have at least 52 patients a year.

The next step is to apply the rules that were listed above to each sub specialty. The first group is general surgery. In this group a distinction can be made between diagnosis codes that have patients that need an surgery and diagnosis codes that have all patients that need only a consultation at the clinic. The next step is to search for similar parameters; the average surgery duration and the average length of stay at the ward. With rules 1-4 we get three groups because rule 3 has no patients.

Group 1: Diagnosis codes with only clinic consultations
Group 2: Diagnosis codes with average length of stay 0-5 days and
average surgery duration: 0-60 minutes
Group 3: Length of stay is more than 5 days

Then for these three groups the number of patients at the clinic is calculated. This is because (as mentioned before) the groups should be large enough (minimal 52 patients a year). For General surgery, group 1 has with 27 patients per year, which is too few patients. Groups 2 and 3 have respectively 4122 and 1238 patients per year at the clinic. Because group 1 has too few patients they have to be combined with group 2 or 3. Group 1 can be combined only with group 2 or 3 because this are the only groups of the subspecialty general surgery. The patients will be grouped on the basis of subspecialty because they have separate specialists/capacities. Group 2 is in this case the most suitable, because it has the lowest average surgery duration and average length of stay. So group 1 and 2 are together the new group 1 and group 3 becomes group 2. The two groups are shown in Table 7.

Group one is the biggest group of surgery for general surgery. The average surgery duration is 44,65 minutes and the average length of stay 1,62 days. The average surgery duration of group 2 is 64,81 minutes and the average length of stay is 7,25 days. At the end of this section in Table 8 an overview of all groups and diagnosis codes is given.

The groups for the other sub specialties are made with the same rules as for general surgery. For traumatology this results in 4 groups, groups 3 up to and including 6. For oncology there are three groups. This is because the group clinic only has only 11 patients. This is smaller than 52 and therefore the oncological patients that go only to the clinic are attached to group 7. For vascular surgery there are 3 groups. There is only one diagnosis code that has an average surgery duration that is smaller than 60 minutes. This diagnosis code contains one patient for the OR. For this reason this diagnosis code is attached to group 11.

The grouping rules result in 12 groups. In Appendix 5 an overview of the group numbers and diagnosis codes is given.

Group	**Sub Speci alty**	**Number Clinic (per year)**	**Average surgery duration (minutes)**	**Average Length of Stay (days)**	**Criteria**
1	**G**	7375	44,65	1,62	Length of stay: 0-5 days Average sugery duration: 0-60 min
2	**G**	1046	64,81	7,25	Length of stay: >5 days
3	T	303	0,00	0	Only Clinic
4	T	4275	46,83	0,53	Length of stay: 0-5 days Average sugery duration: 0-60 min
5	T	4640	79,22	2,57	Length of stay: 0-5 days Average sugery duration: >60 min
6	T	1389	78,20	9,56	Average Length of stay: > 5 days

7	O	1398	59,27	1,28	Length of stay: 0-5 days Average sugery duration: 0-60 min
8	O	2112	83,75	2,24	Average sugery duration: >60 min
9	O	2810	76,59	11,32	Average Length of stay: > 5 days
10	V	113	0,00	0	Only Clinic
11	V	1935	79,19	2,27	Length of stay: 0-5 days Average sugery duration: >60 min
12	V	4616	86,74	8,13	Average Length of stay: > 5 days

Table 7 Overview groups (G= General surgery, T= Traumatology, O= Oncology, V= Vasuclar surgery)

5.2 Parameters Groups

In order to compute performance indicators of the network some parameters should be determined. These are parameters about the arrival process, the service times and the routing matrix. These parameters will be determined in the next sections with the data of 2011 from Ezis (n=3508).

5.2.1 Arrival process

The arrival process of patients from outside the hospital will be determined out of the data. The arrival intensity and the variation of the inter arrival times needs to be determined. The variable $\lambda_{0,i}^{(r)}$ is the arrival intensity from outside the system to department i of patient group r, which is the average number of arrivals in a time span (See Figure 9 Chapter 4 for index representatives). Patients arrive to the hospital for treatment through the clinic or the emergency department. As it is explained before the emergency department is not taken into account. Only the flow of patients that come from the emergency department to the IC or the ward in Venlo are taken into account. Now $\lambda_{0,i}^{(r)}$ is usually calculated with $\lambda_{o,i}^{(r)} = 1/\mathbb{E}A_i^{(r)}$ (2). $\mathbb{E}A_i^{(r)}$ is the average inter arrival time of the patient group r to department i. With an arrival at the clinic is meant the time that the patients calls for a consultation at the clinic. This is registered in the data with the date and not with the time. Therefore it is not possible to calculate the arrival intensity with the expected inter arrival time. The arrival intensity is calculated with the average number of arrivals. The arrival at the OR from the emergency department is the moment that the patient is ready to go to the OR. This moment is not registered in the data either. For this reason this arrival intensity is calculated with the average number of arrivals too. Table 8 gives the arrival intensities for both departments.

Group (r)	$\lambda_{0,1}^{(r)}$ (per week)	$\lambda_{0,5}^{(r)}$ (per week)	$\lambda_{0,6}^{(r)}$ (per week)
1	141,826923	0,12	2,28
2	20,12	0,00	0,32
3	5,83	0,00	0,00
4	82,21	0,00	0,23
5	89,23	0,04	0,84
6	26,71	0,02	0,41
7	26,88	0,03	0,35
8	40,62	0,17	1,27
9	54,04	0,02	0,80
10	2,17	0,00	0,00
11	37,21	0,06	1,10
12	88,77	0,01	0,51

Table 8 Arrival process patients (Ezis, 2011, n=3508)

The second parameter of the arrival process is the variation of the inter arrival times. It is not possible to calculate the variation of the inter arrival times, because the inter arrival times cannot be extracted of the data. For this reason, assuming that the arrival process of patients to the clinic is renewal, the squared coefficient of variation of the inter arrival times can be approximated by dividing the variation of the number of arrivals of each week in 2011 by the mean of the number of arrivals of each week in 2011 (Ross, 1997). Table 9 shows the results for the arrival process at the clinic. The mean number of arrival per week and the standard deviation of the number of arrivals per week is calculated with the number of arrivals of each week in 2011. This means that no trends within a week are considered. At the clinic 615,56 per week arrive at the clinic on average, with a standard deviation of 95,33.This leads to a squared coefficient of variation of 14,76. With the squared coefficient of variation of the clinic the squared coefficient of variation of the other departments can be calculated (Equation 11-12, Chapter 4).

	Aggregate	General Surgery	Traumatology	Oncology	Vascular surgery
Mean (number of arrivals per week)	615,56	161,94	203,98	121,54	128,10
Standard deviation (number of arrivals per week)	95,33	30,87	27,23	29,66	32,34
Squared coefficient of variation	14,76	5,88	3,64	7,24	8,16

Table 9 Calculation squared coefficient of variation

5.2.2 Expected service times

The expected service times of each department and the variance of the service time of each department have to be calculated. Table 10 shows the expected surgery duration of each department. It is not possible to determine the actual consultation time at the clinic of each patient. Although it is registered how many patients have had a consultation at the clinic by each specialist.

For each sub specialty we determine on average how many patients have a consultation per clinic session. With this average number of patients per session, the average consultation time of the clinic is determined for each sub specialty by dividing it by the total time of a session. This is not very reliable because the overtime of a session is not registered. It could be that more patients can have a consultation in one session because there is a lot of overtime. The expected service durations of the other departments are calculated by the sum of all service times of a department divided by the number of patients that are served at that department. The average surgery duration in Venlo is larger than in Venray, because the most complicated surgery (that takes more time) will be done in Venlo because there is an IC. The length of stay at the IC of a group is in many cases higher than the length of stay at the ward. This is because the patients that do not need a IC bed are not taken into account in the expected length of stay IC.

Group	Consultation time clinic (minutes)	Surgery duration OR Venray (minutes)	Surgery duration OR Venlo (minutes)	Length of stay IC (days)	Length of Stay Ward (days)
1	10,90	57,61	88,18	6,08	1,62
2	10,90	65,54	76,80	6,67	7,25
3 (only clinic)	9,79	0,00	0,00	0	0
4	9,79	58,08	96,27	6,5	0,53
5	9,79	63,44	91,93	6,67	2,57
6	9,79	59,57	89,25	6,9	9,56
7	12,15	60,00	83,27	4,56	1,28
8	12,15	55,56	90,23	4,9	2,24
9	12,15	63,28	84,38	4,9	11,32
10(only clinic)	12,31	0,00	0,00	0	0
11	12,31	62,27	85,88	5,4	2,27
12	12,31	70,54	96,50	8,6	8,13

Table 10 Expected service times at each department (Ezis, 2011, n=3508)

The next step is to calculate the variation of the service times. The service times of the OR and the Wards are registered. Table 10 presents σ_{si}, the standard deviation of the service times of each department for each group of patients. There is no data about the exact data over the service times at the clinic. For this reason it is not possible to calculate the standard deviations.

Group	σ_{s2} OR Venray (minutes	σ_{s3} OR Venlo (minutes	σ_{s5} IC (days)	σ_{s4} = σ_{s6} Ward (days)
1	26,88	64,52	7,45	7,984205
2	40,41	49,81	4,16	8,733726
3 (only clinic)	0,00	0,00	0	0
4	20,06	77,14	6,21	7,814018
5	26,70	58,32	10,1	8,672581
6	27,04	72,51	7,22	8,533395

7	31,04	62,42	4,3	4,16416
8	25,80	58,21	4,5	9,072669
9	32,75	50,66	7,7	7,069404
10 (only clinic)	0,00	0,00	0	0
11	27,53	67,63	8,6	8,425747
12	41,67	90,90	11,3	9,23288

Table 11 Standard deviations of service times at each department (Ezis, 2011, n=3508)

5.2.3 Routing matrix

As it is explained in Chapter 4 the routing matrix of each patient group needs to be calculated. The values of the routing matrix are displayed with x1-x6.

x1: percentage of the patients that are at the clinic that have a surgery in Venray
x2: percentage of the patients that are at the clinic that have a surgery in Venlo
x3: percentage of the patients that have a surgery in Venray and go to the ward in Venray
x4: percentage of the patients that have a surgery in Venlo and go to the IC
x5: percentage of the patients that have a surgery in Venlo and go to the ward in Venlo
x6: percentage of the patients that are at the IC and will go to the Ward in Venlo

Table 11 gives the values of these parameters.

r	x1	X2	x3	x4	x5	x6
1	0,07	0,11	1	0,05	0,95	1
2	0,02	0,04	1	0,01	0,99	1
3 (only clinic)	0,00	0,00	0	0	0	0
4	0,01	0,01	1	0,02	0,98	1
5	0,03	0,05	1	0,05	0,95	1
6	0,06	0,07	1	0,04	0,96	1
7	0,02	0,03	1	0,08	0,92	1
8	0,06	0,14	1	0,12	0,88	1
9	0,08	0,14	1	0,03	0,97	1
10(only clinic)	0,00	0,00	0	0	0	0
11	0,01	0,02	1	0,05	0,95	1
12	0,03	0,05	1	0,02	0,98	1

Table 12 Parameters of routing matrices (Ezis, 2011, n=3508)

In the previous sections the patients are classified into 12 groups, on the basis of sub specialty, average surgery duration and length of stay at the ward. For these groups the parameters of the arrival process, the service times and the routing matrix is determined. These parameters can be used to calculate some performance indicators of the system.

5.3 Constraints & Seasonality

This section explains the capacity constraints of the systems and the seasonality of the arrival process of patients.

5.3.1 Available capacity

The available capacity can be divided in: the available number of clinic sessions, the available number of OR sessions in Venray and Venlo and the number of beds at the IC and the Wards. The maximum number of clinic sessions and OR sessions is determined by the availability of the specialists and the availability of the clinic rooms and the OR rooms.

The available clinic and OR sessions are determined by counting the amount of clinic sessions and OR sessions in a schedule of 2011. In this year there are approximately 40 clinic session a week. This is includes the assistants. The number of OR sessions in Venray and Venlo are now at 14 and respectively 15 per week. If these numbers are not enough there should be considered if the specialty surgery should get more clinic and/or OR sessions. This is not a question that can be answered with this model because it involves a lot of other specialties.

As it is discussed in Chapter 2, the wards are shared with other specialties. Table 3 in Chapter 2 displays the wards at which the patients of the specialty surgery are usually. If there is no available bed at these departments than the patient can go to another department. For this reason it is difficult to give a maximum number of available beds. For this reason is chosen to use the maximal number of used beds in 2011, 93 beds (rounded to 90). This are 35 beds in Venray and 55 beds in Venlo.

There is a limited amount of capacity of specialists. This capacity has to be divided over the clinic and the OR. For this reason the maximum capacity of the specialists and the OR rooms capacity have to be checked. There are in total 10 surgeons divided over the four sub specialties. All surgeons perform a little bit of general surgery. Traumatology has two surgeons, oncology five and vascular surgery has three surgeons. All sub specialties have some assistants that can perform clinic sessions. Some surgeons have some parts of the day reserved for management. Table 13 displays the number of parts of the day (four hours) per week each sub specialty has available for patients or management tasks. General surgery is not included in this table because every surgeon does a bit general surgery (For more details see Appendix 6).

Sub specialty	Available parts of the day per week
Traumatology	19
Oncology	45,8
Vascular surgery	26,5

Table 13 Available capacity per specialty with assistants

5.3.2 Seasonality

To apply seasonality in the model the arrival intensities of each month of each group are calculated. These arrival intensities can be found in Appendix 7. The model will choose for these arrival intensities when a corresponding month is completed in the model. (For more information of the code See Appendix 8).

5.4 Conclusion

The first section of this chapter has divided the patients into 12 groups on the basis of sub specialty, average surgery duration and average length of stay . The second section has determined the input parameters for the model in Excel. The capacity constraints and the seasonality of the arrival process of the patients is explained in the third section. The next step is to validate the results of the model. This will be done in the next chapter.

6 Validation

The model should be checked for validity. In this section a brief check for validity will be done, due to time constraints. 'Validation is the process of determining whether a model is accurate representation of the system, for the particular objectives of the study" (Law, 2007). Simulation is an often used method to validate queuing models (Woensel et al., 2006).

Law (2007) states four ways to validate models: Collect high quality information and data for the model, interact with the manager on regular basis, maintain a written assumptions document and validate the output of the overall model. These four methods are applied in this research.

The first way is to collect high-quality information and data on the system. The information about the network is gained by interviews with subject-matter experts. There were interviews with the head of surgery, the planning officer of the OR, the planning officer of the surgeons, the general logistic manager, the head of the capacity bureau. The meetings about capacities are attended. Here a lot of information about the network is gained and applied in the model. The input data for the model is data out of the systems of the hospital. These data systems are among other things Chipsoft Ezis. Finally a literature review is done and has compared different methods to develop a model for a network. Queuing theory is chosen for this research. Queuing theory has been used before. As mentioned before Van Dijk et al. has used queuing theory for modeling the relationship between the OR and the IC.

The second way is to interact with the manager on a regular basis. Once a week a meeting was planned with the logistic manager and a senior information advisor. In these meetings the progress of this study and eventual assumptions in the models were discussed.

The third way is to maintain a written assumptions document and perform a structured walk-through. In the previous chapters the assumptions of this model are discussed. These assumptions are discussed with the logistic manager, the senior information advisor and the manager of the operational unit surgery. The assumption that are made in this model are:

- Patients are treated First Come First Served
- No distinction is made between the clinic in Venlo and Venray
- All patients that have an OR go the Ward or the IC. This is not true for all patients. Some patients will die during or after the surgery and do not need a bed. You cannot plan for death people so this will not be included in the model. Other patients have a day care treatment, these patients will need a bed for one day. This is included in the average length of stay.
- All patients that are at the IC will go to the ward before they go home. Some patients will die at the IC and don't go to the ward, but you cannot plan for dead people.
- Every patient has a consultation at the clinic after the ward.
- The inter arrival times and service times are general distributed.

A last way to validate the model is to validate the output of the overall model. The output of the model is the occupancy rate of each department, the waiting times and the throughput times. The validation of the output of the overall model can be done by a comparison with data of the existing system. In the next sections the comparison with the real data and the results of the model of the average of the year and for each month are validated.

6.1 Aggregate model results

Table 14 displays the aggregate performance indicators of the first six months of 2012 and of the model. The average number of OR sessions each week in Venray in the first six months in 2012 is 11, this is much lower than the 14 available sessions. In Venlo they used on average 15 OR session per week. The number available beds for the specialty surgery is not fixed because wards are shared with other specialties. For this reason the maximum number chosen that was used in 2011 is chosen for the number of beds. This number is 93 and is rounded to 90, 35 in Venray and 55 in Venlo.

The average utilization of the clinic of the first six months of 2012 is 0,71. The model estimates the utilization rate of the clinic also at 0,71. The mean waiting time for the clinic is in 2012 11 days. The mean waiting time of the clinic according to the model is very small, 0,002 days. In reality this waiting time is higher because of patient preferences. Patients may not be able to have an appointment at the first possible moment. This will increase the waiting time. The lower waiting time can also be explained by the continuity assumption. The model assumes that the clinic is continuously working, 24 hours per day, 7 days a week. In reality the clinic is closed during the evening, nights and weekends. This causes a longer waiting time. A last reason why the waiting time in reality is higher are emergency patients. The clinic has the reserve space for emergency patients. These spaces may not always be used. This causes a longer waiting time for other patients and a lower utilization of the clinic.

The average utilization of the OR in Venray is 0,84. The model estimates the utilization of the OR in Venray a little bit lower, 0,80. The average waiting time for the OR in Venray is 35,8 days. According to the model, the mean waiting time for the OR in Venray is 10 days. The lower mean waiting time can again be explained by the continuity assumption and patient preferences. The model assumes that the OR is continuously working, 24 hours per day, 7 days a week. The OR is only open for elective patients five days per week in the morning and the afternoon. This causes a longer waiting time. The other reason that causes a longer waiting time are patient preferences. The surgeries that are done in Venray are not as complex as in Venlo. For this reason patients have more preferences and sometimes want to delay their surgery. This causes longer waiting time.

The average utilization of the OR in Venlo 1,28. The model estimates the utilization of the OR in Venlo 1,30. The average waiting time for the OR in Venlo is 28,3 days. According to the model, the mean waiting time for the OR in Venray in Venlo is infinite. This because the utilization rate of the OR in Venlo is higher than 1. A utilization rate which is higher than one means that more patients arrive at a department than that will leave in a time period. For this reason the mean waiting time is infinite. Although in reality the mean waiting time for the OR is not infinite but 28,3 days. This could be explained by shorter changing times and/or overtime. If the maximum overtime of 2011 is added to the model then the model estimates the mean waiting time for the OR at 24,8 days.

The last part that should be validated are the performance indicators of the wards. For this departments the utilization rate and the mean waiting time are estimated by the model too. It is very difficult to validate these two performance indicators for the wards. It is difficult to determine the utilization rate of the wards. This is because the wards are shared with other specialties and a bed can be used by more than one patient in one day. For the calculation for the utilization it is therefore not correct to count the amount of patients in one day divided by the number of beds, because this could lead to a utilization that is higher than one. The mean waiting time for the wards is difficult to validate because in reality is no waiting time for the wards possible. Patients that have a surgery should go to the ward after their surgery is finished. If no bed is available for a patient, a surgery will be delayed. According to the model the average utilization is 0,49 in Venray and 0,60 in Venlo. These results are quite reasonable compared with the data in Figure 6, Chapter 2. The utilizations of the wards are low. Reality shows a lot of variance in the number of used beds. Although it is not true that half of the beds are empty. In the weekend a part of the beds are closed and other beds are used by other specialties too. The mean waiting times for the wards are small as should be, 0,3 and 0,5 days. This is not very small but it is acceptable.

2012	**Sessions /Beds**	**Duration (hours)**	**Utilzation**	**Mean waiting time (weeks)**	**Mean waiting time (days)**
Clinic	40	4	0,71	1,57	11
OR Venray	11	3,75	0,84	5,11	35,8
OR Venlo	15	3,75	1,28	4,04	28,3
Model	**Sessions /Beds**	**Duration (hours)**	**Utilzation**	**Mean waiting time (weeks)**	**Mean waiting time (days)**
Clinic	40	4	0,7103	0,0003	0,0020
OR Venray	11	3,75	0,8021	1,4493	10,1451
OR Venlo	15	3,75	1,2982	infinite	infinite
Ward Venray	35	24	0,4945	0,0293	0,2052
IC	8	24	0,2729	0,0659	0,4615
Ward Venlo	55	24	0,6089	0,1758	1,2304

Table 14 Performance indicators current situation

The model gives quite good aggregate results if overtime for the OR in Venlo is included in the model. The following section validates the results for each month.

6.2 Seasonality model results

With the same capacity input parameters the performance indicators for the first six months of 2012 are estimated with the model and will be compared with the real performance indicators of the first six months of 2012 (Table 15). It is assumed that the capacity is the same at each month. For each month different arrival intensities for the clinic are determined. This leads to quite good results for the utilization of the clinic. The model overestimates the utilization of the clinic a little bit, but it gives a good indication. The waiting time for the clinic is again underestimated. As it is discussed before, this can be explained by patient preferences , the continuity assumption of the model and emergency patients. The utilization of the OR in Venray are similar to the estimates of the model. Only in March and May the utilization is a little bit different than the estimates. As we saw with the aggregate results, the mean waiting times for the OR in Venray is underestimated by the model. This can again be explained by patient preferences and the continuity assumption of the model, as it is discussed before.

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2012	Access time Clinic (days)	Utilization rate Clinic	Utilization rate OR Venray	Mean waiting time OR Venray (days)	Utilization OR Venlo	Mean waiting time OR Venlo (days)
Jan	13,31	0,71	0,81	43,17	1,15	28,74
Feb	10,72	0,72	0,87	34,53	1,28	33,13
March	9,91	0,68	0,82	30,25	1,37	25,03
April	11,53	0,71	0,82	34,16	1,28	26,46
May	10,76	0,67	0,89	33,55	1,28	30,72
June	10,53	0,74	0,80	39,73	1,32	25,92
Model	**Access time Clinic (days)**	**Utilization rate Clinic**	**Utilization rate OR Venray**	**Mean waiting time OR Venray (days)**	**Utilization OR Venlo**	**Mean waiting time OR Venlo (days)**
Jan	0	0,79	0,83	11,9	1,38	Infinite
Feb	0	0,76	0,87	21,3	1,33	Infinite
March	0	0,71	0,81	10,9	1,31	Infinite
April	0	0,77	0,82	13,4	1,34	Infinite
May	0	0,72	0,86	21,9	1,27	Infinite
June	0	0,71	0,80	9,9	1,29	Infinite

Table 15 Performance indicators 2012 and model

For the OR in Venlo are the estimates of the utilization quite good. There are some small differences within the months but it provides a good indication. The mean waiting time for the OR in Venlo is infinite. In reality this is not infinite. The previous section showed that this difference could be explained by the use of overtime. For this reason the maximum overtime is added to the OR of Venlo. Table 16 shows the mean waiting times for the OR for Venlo when overtime is allowed. Adding the overtime to the OR in Venlo leads to better results for the mean waiting times. Only the mean waiting time for the month January doesn't make any sense. January 2012 was much more quite than other years and is not representative.

	Mean waiting time OR Venlo (days)
Jan	53,8
Feb	36,7
March	28,1
April	34,8
May	20,2
June	23,3

Table 16 Mean waiting time OR Venlo with overtime

As it is discussed before it is difficult to validate the performance indicators of the wards, because it is difficult to calculate the utilization rate and in reality is no waiting time possible. Therefore the validation of performance indicators of each month for the wards is not done.

6.3 Conclusion

This chapter has validated the model in four ways: Collect high quality information and data for the model, interact with the manager on regular basis, maintain a written assumptions document and validate the output of the overall model. The model gives quite good aggregate and seasonality results if overtime for the OR in Venlo is included in the model.

7 Results and interventions

This chapter discusses the results of this research. The first section discusses the aggregate results of the performance indicators with the current available capacities. Then the second section discusses the performance indicators without any capacity constraints. The third section divides the capacity that is needed on the aggregate level over the four sub specialties. Next in the fourth section the seasonality pattern is discussed in relation with the demand for capacities. Finally the conclusion of this chapter is discussed in Section 7.5.

7.1 Aggregate results with current available capacities

This section displays the results with the current capacities. As is discussed before in Chapter 5 the current available capacity is 40 clinic sessions, 14 OR sessions in Venray, 15 OR sessions in Venlo, 35 beds in Venray, 8 IC beds, and 55 beds in Venlo. The larger number of beds is needed to deal with the variability. The larger number of beds causes a lower waiting time. The number of available beds is not fixed because they are shared with other specialties.

The values of the performance indicators with these capacities are displayed in Table 17. The utilization of the clinic is quite low with 0,71. The mean waiting time for the clinic is very low too. According to the model patients could visit the clinic the same day as they call for an appointment. The utilization of the OR in Venray is 0,65, which is too low. The mean waiting time for the OR in Venray is 1,5 days. This is very low too. While the utilization and mean waiting times for Venray are very low, the OR in Venlo is very busy. The utilization rate of the OR in Venlo is 1,30. More patients arrive at the OR in a week than could be treated. This leads to an infinite mean waiting time. A utilization that is higher than one means that there is too little capacity in Venlo. In the previous chapter is showed that in reality this problem is solved with overtime. The performance indicators of the wards are also shown in Table 17. The utilization for the ward in Venray is 0,49 and the mean waiting time is 0,2 days. This doesn't mean that the beds are empty half of the time. Some beds are closed during the weekends and other beds may be used by other specialties. The utilization of the IC is 0,27 and the mean waiting time is 0,46. This means that the specialty surgery uses 27 percent of the IC capacity. The utilization for the ward in Venlo is 0,60 and the mean waiting time is 1,2 days. This waiting time for the ward in Venlo is a bit high.

	Sessions /Beds	Duration (hours)	Utilzation	Mean Waiting time (weeks)	Mean Waiting time (days)
Clinic	40	4	0,7103	0,0003	0,0020
OR Venray	14	3,75	0,6455	0,2115	1,4805
OR Venlo	15	3,75	1,2982	Infinite	Infinite
Ward Venray	35	24	0,4945	0,0293	0,2052
IC	8	24	0,2729	0,0659	0,4615
Ward Venlo	55	24	0,6089	0,1758	1,2304

Table 17 Aggregate results current capacity

7.2 Aggregate results without capacity constraints

The last Sections explained the results with the current capacities. Now will be determined what theoretically, without capacity constraints, the best solution is. With the best solutions is meant a high utilization rate with waiting times within the Treeknormen. As it is explained in Chapter 2, the Treeknormen are:

- Maximum access time clinic 4 weeks
- Waiting time OR maximum 7 weeks
- Throughput time maximum 8 weeks

This are maximum numbers. The model only calculates averages. For this reason the constraints become: average access time below 2 weeks, average waiting time OR below 3,5 weeks, and average throughput time below 4 weeks. This leads to the following number of session and performance indicators (Table 18).

	Sessions /Beds	Duration (hours)	Utilization rate	Mean Waiting time (weeks)	Mean Waiting time (days)
Clinic	29	4	0,9797	0,0790	0,5528
OR Venray	10	3,75	0,8752	3,6526	25,5680
OR Venlo	23	3,75	0,8688	3,4169	23,9185
Ward Venray	35	24	0,4945	0,0611	0,4279
IC	8	24	0,2729	0,0318	0,2226
Ward Venlo	55	24	0,6089	0,0663	0,4641

Table 18 Results without capacity constraints

In Table 18 can be seen that there are less clinic sessions needed than the current number. 29 clinic sessions will lead to a utilization of 0,98 and a waiting time of 0,6 days. In practice is a utilization of 0,98 probably a bit too high because there should be some space reserved for emergency patients. This space is not always used. So 30 or 31 sessions should probably be better in reality. In Venray 10 sessions should be enough to treat all patients. This will lead to a waiting time of 3,65 weeks, which is a little bit higher than 3,5 weeks.

For the OR in Venlo there should be 23 sessions available to treat all patients with a average waiting time of 23,9 days. In Venray there are 4 sessions ‘too much’, while in Venlo there are 8 session too less. Expanding the capacity costs a lot of money and is therefore not very desirable. Although a high amount of overtime costs a lot of money too, which may be saved. If the 4 ‘empty’ sessions in Venray could be filled with patients from Venlo then the overtime should be reduced and the utilization rate in Venlo increases. In the model this is translated by 19 session in Venlo and 10 in Venray. However not all patients can be send to the OR in Venray, because there is no IC and not all equipment is available in Venray. This results in a utilization of 0,96 in Venray and 1,03 in Venlo. So in Venlo there is still some overtime. To have no overtime at both ORs, the changing time should be 9 minutes instead of 12 minutes. The ward in Venray has a utilization of 0,5 on average. With these extra session this utilization is higher (0,6) but still acceptable.

7.3 Results per Subspecialty

The previous sections discussed the results at aggregate level. At the moment the capacity allocation is done per specialty. In the future they may want to do the capacity allocation per sub specialty because every subspecialty has different surgeons (except general surgery). This section shows how the capacity could be divided over the four sub specialties. The wards are not classified with a sub specialty. Therefore the wards are not included in this section.

The previous section concludes that 31 clinic sessions should be enough to have a low waiting time and a higher utilization. Table 19 shows that these 31 sessions can be divided in 8 sessions for general surgery, 9 sessions for traumatology, 7 sessions for oncology, and 7 sessions for vascular surgery. This leads to utilization rates between 0,88 and 0,94. The waiting time remains low with maximal 0,6 days.

	Sessions /Beds	Duration (hours)	Utilization rate	Mean Waiting time (weeks)	Mean Waiting time (days)
Clinic General surgery	8	4	0,92	0,0586	0,4099
Clinic Traumatology	9	4	0,93	0,0598	0,4184
Clinic Oncology	7	4	0,88	0,0365	0,2558
Clinic Vascular surgery	7	4	0,94	0,0882	0,6173

Table 19 Clinic capacity per sub specialty

The previous section shows that 10 sessions for the OR in Venray are sufficient. Table 20 displays the division of the capacity of the OR in Venray. The division is based on the mean waiting time within the Treeknorm and a high utilization (See previous section). This leads to 4 sessions for general surgery, 2,5 for Traumatology, 3,5 for Oncology and 2,5 for Vascular surgery. A half session means one session in the two weeks. The sum of these sessions is 12,5 instead of 10. The utilization rate of the ORs are quite low, especially the utilization rate of vascular surgery. If the capacity is restricted to 10 sessions the 'best' division should be general surgery 3 sessions, Traumatology 2 sessions, Oncology 3 sessions and vascular surgery 2 sessions a week. This leads to higher utilization rates (0,56 – 0,95) and higher mean waiting times. (5-8,8 weeks).

	Sessions /Beds	Duration (hours)	Utilization rate	Mean Waiting time (weeks)	Mean Waiting time (days)
OR Venray General surgery	4	3,75	0,73	3,0614	21,4296
OR Venray Traumatology	2,5	3,75	0,63	2,7651	19,3554
OR Venray Oncology	3,5	3,75	0,66	2,7350	19,1452
OR Venray Vascular surgery	2,5	3,75	0,45	2,2656	15,8595

Table 20 OR Venray results per sub specialty

For the OR in Venlo are 19 (15 in Venlo + 4 'empty' sessions in Venray) sessions enough on the aggregate level. The division for the sub specialties that lead to a mean waiting time within the

Treeknorm doesn't exist with 19 sessions (Table 21). A division of the 19 sessions that will lead to a utilization below one (no overtime) is 7 sessions for general surgery, 3,25 sessions for Traumatology, 6 sessions for oncology and 2,75 sessions for Vascular surgery. However 0,25 and 0,75 sessions are not very practical, it means 1 session per four weeks and three sessions per four weeks.

	Sessions /Beds	Duration (hours)	Utilization rate	Mean Waiting time (weeks)	Mean Waiting time (days)
OR Venlo General surgery	7,5	3,75	0,91	2,8199	19,7394
OR Venlo Traumatology	4	3,75	0,81	2,0929	14,6502
OR Venlo Oncology	6,5	3,75	0,90	3,0825	21,5777
OR Venlo Vascular surgery	3,5	3,75	0,73	2,7422	19,1957

Table 21 OR Venlo results per sub specialty

So it is difficult to divide the aggregate capacity over the four sub specialties. Division over the four sub specialties leads to a higher capacity need than on the aggregate level.
Another choice that has to be made is which sub specialty should send what kind of patients to Venray. Venray does not have an IC and all equipment. For this reason it is not possible to send all patients to Venray.

7.4 Seasonality results

The arrival intensities are not the same for every month. During the summer less patients are in the hospital than during the other months. With the current capacities (Table 22) the performance indicators are calculated. These are shown in Table 23.

	Sessions/beds
Clinic	40
OR Venray	14
OR Venlo	15
Ward Venray	35
IC	8
Ward Venlo	55

Table 22 Current capacities

The busiest months for the clinic are January, February and April. The previous section concludes that 31 sessions are enough for a low waiting time and a high utilization. For these busy months this number of sessions is not enough. To have similar utilization and waiting time as at the aggregate level 35 clinic sessions should be needed in these busy months. On the other hand, July, August and December are very quite months for the Clinic. In July and December 30 sessions would be enough and in August 26 clinic sessions is enough to have a low waiting time and a high utilization.

In the OR in Venray the busiest months are January, February and April too. However 10 sessions are enough in February and April. The most quietest periods are August and December. In these months are 8 sessions and 9 sessions sufficient. The seasonality can also be seen in Venlo. But is Venlo is too little capacity. More patients should be send to Venray, as it is discussed before.

Month	Access time Clinic (days)	Utlization rate clinic	Waiting time OR Venray (days)	Utilization rate OR Venray	Waiting time OR Venlo (days)	Utilization rate OR Venlo
Jan	0	0,79	3,13	0,72	Infinite	1,38
Feb	0	0,76	2,5	0,70	Infinite	1,33
March	0	0,71	1,6	0,65	Infinite	1,31
April	0	0,77	1,8	0,67	Infinite	1,34
May	0	0,72	1,4	0,63	Infinite	1,27
June	0	0,71	1,5	0,64	Infinite	1,29
July	0	0,68	1,2	0,63	Infinite	1,25
Aug	0	0,57	0,4	0,50	Infinite	1,00
Sept	0	0,73	1,8	0,66	Infinite	1,35
Oct	0	0,72	1,7	0,66	Infinite	1,33
Nov	0	0,71	1,7	0,66	Infinite	1,34
Dec	0	0,67	1,0	0,61	Infinite	1,22

Table 23 Seasonality results current capacity clinic and OR

Table 24 presents the performance indicators of each month of the wards. The same seasonality pattern as it is mentioned by the OR can be seen by the wards. During the summer, in July and August, is the utilization of the wards lower. In these months a lot of nurses have holidays and probably less beds are available. The utilization of the IC is quite stable.

Month	Waiting time Ward Venray (days)	Utlization rate Ward Venray	Waiting time IC (days)	Utilization rate IC	Waiting time Ward Venlo (days)	Utilization rate Ward Venlo
Jan	0,8	0,53	0,5	0,32	1,8	0,67
Feb	0,6	0,52	0,4	0,32	1,1	0,65
March	0,3	0,49	0,3	0,28	0,4	0,61
April	0,4	0,50	0,3	0,28	0,7	0,63
May	0,4	0,50	0,2	0,24	0,4	0,60
June	0,4	0,50	0,2	0,26	0,7	0,62
July	0,1	0,46	0,3	0,26	0,3	0,55
Aug	0,03	0,42	0,1	0,20	0,1	0,49
Sept	0,3	0,51	0,6	0,28	1,4	0,61
Oct	0,3	0,51	0,5	0,27	1,8	0,63
Nov	0,3	0,52	0,5	0,29	2,1	0,64
Dec	0,2	0,48	0,3	0,26	1,0	0,61

Table 24 Seasonality results current capacities wards

So in January, February and April is more capacity needed than on average. In July, August and December is less capacity needed than in reality.

7.5 Conclusion

The first section shows that the clinic has a low utilization with 0,71. Less capacity for the clinic can be used, 31 sessions would be enough. These 31 sessions can be divided in 8 sessions for general surgery, 9 sessions for traumatology, 7 sessions for oncology, and 7 sessions for vascular surgery. January, February and April are busy months for the Clinic. In these months 35 sessions are needed to have low waiting time and no overtime. July, August and December are not as busy as the other months. In these months are 30, respectively 26, respectively 30 sessions enough.

The capacity in Venray, 14 sessions, are not used well enough. The number of patients that are operated in Venray could be done with 10 sessions instead of 14 sessions on aggregate level. These 10 session can be divided to the four sub specialties. This leads to 3 sessions for general surgery, 2 for Traumatology, 3 for Oncology and 2 for Vascular surgery. In Venray the busiest months are January, February and April too. However 10 sessions are enough in February and April. The most quietest periods are August and December. In these months are 8 sessions and 9 sessions sufficient. The OR in Venlo has too little capacity for the current amount of patients. More patients should be send to Venray. Venray has 4 sessions too much, and could have extra patients. A choice should be made which sub specialties should send what kind of patients to Venray. Venray does not have an IC and all equipment. For this reason it is not possible to send all patients to Venray.

A lot of beds are needed to deal with the variability of the number of patients from the OR. The same seasonality pattern as it is mentioned by the OR can be seen by the wards. During the summer, in July and August, is the utilization of the wards lower. In these months a lot of nurses have holidays and probably less beds are available. In January, February and April is more capacity needed than on average. The utilization of the IC is quite stable.

8 Conclusions and Recommendations

This chapter describes the conclusions and recommendations of this research.

8.1 Conclusions

In this sections the conclusions of this research will be discussed by means of answering the research questions.

8.1.1 What is the current situation?

The average access time for the clinic was 12,8 days in 2011. This access time was increasing, while the average occupancy rate remained constant. The average occupancy rate was 67,4 percent. The average waiting time for the OR was 38,7 days with a standard deviation of 7,7 days. 18% of the patients had a waiting time that was higher than the Treeknorm of 7 weeks. The average occupancy rate of the OR was good (average 94,5), but this was caused by a lot of overtime of a few other sessions. The difference between the minimum and maximum occupancy rate in a week is very large. This amount of overtime costs the hospital amounts of money which might be saved. The number of used beds by patients of the specialty surgery is very variable with minimal 33 and maximal 93 used beds each day. A reduction in variability should lead to lower costs, because less beds will be needed. The influence of all department together result in a varying throughput time. 25% of the patients had a higher throughput time than the Treeknorm of 8 weeks.

Better coordination could lead to more insight in the total process and could lead to a shorter throughput time and/or better use of capacities. Although it is not possible to have a high utilization of capacities and a short throughput time. A trade off should be made between these. Which combination of throughput time and utilization of capacities is desirable for the hospital is a strategic and/or tactical choice.

8.1.2 What is known in literature about the classification of groups?

As discussed before, the patients have to be clustered to gain better insight in the relationships between departments. The clusters should be made on the basis of equal care demand and equal characteristics. (Ward, 1963). There are several clustering methods in literature. Maruster et al. (2002) clusters patients with the aid of the software package SPSS. Patients are divided in groups on the basis of logistic variables with the aid of the 'two-step' grouping method. Van Oostrum et al. (2008) used a clustering method based on the hierarchical clustering method of Ward (1963). Surgeries are combined if they have together the highest reduction of the Error Sums of Squares (ESS). A disadvantage of this method is that the surgery types that are chosen as starting point are often difficult to distinguish for the planners. Ma & Demeulenmeester (2012) use a method for the classification of groups based on similarity of the parameters: average returns for each treatment, the surgical group, the expected surgery duration and the expected length of stay. A clinical pathway can be seen as a method for classifying patients. Patients with similar variables belong to the same clinical pathway. For this research the classification on the basis of similar logistic variables and sub specialty is for this research most suitable. The logistic variables that will be used in this research are expected duration of a consultation at the clinic, expected surgery duration and expected length of stay at the ward.

8.1.3 What performance indicators are used in literature?

The most used performance indicators for health care are waiting time, throughput time, occupancy rate, leveling, make span, patient refusal/deferral, financial indicators and preferences of patients and surgeons (Cardoen et al., (2010).

The hospital uses the Treeknormen, IGZ indicators and the Zichtbare Zorg indicators. The IGZ and Zichtbare Zorg Indicators are especially quality indicators. The treeknormen are especially time indicators. Although these indicators are related to the costs, for example, occupancy rates and overtime OR.

8.1.4 Which models are known in literature about the relationships between departments?

Several methods for modeling multiple departments can be found in literature. Simulation is a powerful tool, but a lot of detailed information is needed. Simulation is a good option if no other technique is possible. With queuing theory it is possible to model multiple departments. The effects for the capacity of resources and the waiting times of patients can become clear with queuing. A disadvantage of queuing is that it makes use of some assumptions that may not represent reality very well. Mathematical programming, is not possible for this problem because it is too big to solve in reasonable time. Clinical pathways include multiple departments but include only for one type of patient. The model of Vanberkel et al. (2010a) only focuses on the relationships between the wards and the OR. Other departments, such as clinic and emergency department, are not involved. So queuing theory is an appropriate way to model the multiple departments in this research.

8.1.5 How can a new model of the current situation be made?

A multiple class G/G/c queuing network will be used to model the chain for the specialty surgery. The network consists of six departments, the clinic, OR Venray, OR Venlo, Ward Venray, IC and Ward Venlo. For this departments the flows of patient will be modeled. To measure the performance of the chain the waiting times and the utilization rates of the departments and the throughput times of the different patient groups will be calculated. Figures 10-12 present the formulas for these performance indicators. The assumptions of the model are:

- Patients are treated First Come First Served
- No distinction is made between the clinic in Venlo and Venray
- All patients that have an OR go the Ward or the IC. This is not true for all patients. Some patients will die during or after the surgery and do not need a bed. You cannot plan for death people so this will not be included in the model. Other patients have a day care treatment, these patients will need a bed for one day. This is included in the average length of stay.
- All patients that are at the IC will go to the ward before they go home. Some patients will die at the IC and don't go to the ward, but you cannot plan for dead people.
- Every patient has a consultation at the clinic after the ward.
- The inter arrival times and service times are general distributed

8.1.6 Is the model valid?

The model that is developed in this research is validated in four ways: Collect high quality information and data for the model, interact with the manager on regular basis, maintain a written assumptions document and validate the output of the overall model (Law, 2007).

The model gives good results for the utilization of the clinic and the OR in Venray. The waiting times for the clinic and the OR in Venray are underestimated. The utilization for the OR in Venlo agrees quite well with reality. The waiting times for the OR in Venlo are infinite , because the utilization of the OR is higher than 1. In reality this is not true because overtime is allowed. If this overtime is included in the model, then the model gives better results for the waiting times. The model gives in general quite good results.

8.1.7 What are the results of the model and which interventions could improve the performance of the chain?

The clinic has a low utilization with 0,71. Less capacity for the clinic can be used, 31 sessions would be enough. These 31 sessions can be divided in 8 sessions for general surgery, 9 sessions for traumatology, 7 sessions for oncology, and 7 sessions for vascular surgery. January, February and April are busy months for the Clinic in these months 35 sessions are needed to have low waiting time and no overtime. July, August and December are not as busy as the other months. In these months are 30, respectively 26, respectively 30 sessions enough.

The capacity in Venray, 14 sessions, are not used well enough. The number of patients that are operated in Venray could be done with 10 sessions instead of 14 sessions on aggregate level. These 10 session can be divided to the four sub specialties. This leads to 3 sessions for general surgery, 2 for Traumatology, 3 for Oncology and 2 for Vascular surgery. In Venray the busiest months are January, February and April too. However 10 sessions are enough in February and April. The most quietest periods are August and December. In these months are 8 sessions and 9 sessions sufficient.
The OR in Venlo has too little capacity for the current amount of patients. More patients should be send to Venray. Venray has 4 sessions too much, and could have extra patients. A choice should be made which sub specialties should send what kind of patients to Venray. Venray does not have an IC and all equipment. For this reason it is not possible to send all patients to Venray. The changing time for the OR should be reduced to 9 minutes instead of 12 to reduce overtime.

A lot of beds are needed to deal with the variability of the number of patients from the OR. The same seasonality pattern as it is mentioned by the OR can be seen by the wards.

8.2 Recommendations

In this section the recommendations for improvement will be discussed.

8.2.1 Central measurement and definitions of KPI's

There is no overview of all performance indicators of the specialty. Each department may have a few performance indicators. These few performance indicators are in most cases calculated manually. Not everyone is informed about these indicators and there are no clear and general definitions about these indicators are missing. Measurement of performance indicators could lead to more insight in the performance indicators of the network.

The hospital should start with a central measurement and display of the key performance indicators. These performance indicators can be measured by each patient group or by department. For each department the following performance indicators should be measured: waiting time / access time, utilization rate, throughput times, leveling of waiting/access time, number of used beds, overtime clinic and OR.

For the wards it should be better to measure the number of used beds instead of the utilization rate, because the number of available beds is not fixed. Another reason that utilization is not very useful for the ward is the confusing definition of utilization rate for the ward. At one day there can be more than one patient in a bed and this can cause a high utilization rate. The definitions that are used in this research can be used as uniform definitions or as a starting point for the conversation about the definitions. The definitions that are used for the performance indicators in this research are:

Access time Clinic: The access time of the clinic is the time between the moment that the patient calls for a consultation and the moment the patient has a consult at the clinic.
Waiting time OR: The waiting time for the OR is the time between the moment that the patient is placed at the waiting list for the OR and the moment of the operation.
Utilization Clinic: The occupancy rate of the clinic is the percentage of the available time that is used for consults with patients.
Utilization rate OR: The occupancy rate is the percentage of the time the OR is used for an operation of a patient. If there is more than one patient operated in the OR, 12 minutes changing time is counted. These time is included in the occupancy rate (See Equation 1).

$$Occupancy\ rate = \frac{Total\ operations\ time + (number\ of\ patients\ in\ OR - 1) * 12}{Session\ duration} \qquad (1)$$

Throughput times: The throughput time means the time between the registration of the patient at the clinic for an appointment and the time of discharge at the ward if an operation is needed.
Overtime OR: the time that the session takes longer than the end time.
Overtime Clinic: the time that the session takes longer than the end time.

Uniform definitions of performance indicators through the hospital makes it possible to compare performances of different specialties. These indicators can help by the allocation of resources of by signalizing if reallocation of resources is needed.

8.2.2 Capacity allocation

As it is discussed before, the capacity in Venray should be better used. More patients should be send to Venray. This will lead to less overtime in Venlo.
In the current situation it is the choice of the patient where the surgery takes places (if it is possible in Venray and Venlo). More patients choose to go to Venlo. Therefore planners and specialist should motivate patients to have a surgery in Venray. Probably the specialist has more influence on the patient than a planner. Although both should say that a surgery in Venray could take place faster than in Venlo. If both the specialist and the planner stimulate the patient to go to Venray, more patients probably will go to Venray.

8.2.3 Model

The previous chapters has developed a model that gives insight in the use of the capacities for the specialty surgery. Now some recommendations about the maintenance and possible extensions or the model are explained.

8.2.3.1 Maintenance

The model in Excel is based on the data of 2011. Perhaps is this data not representative anymore for the far future. The model requires some maintenance. The case mix of patients may change during the years and therefore the arrival intensities should be adapted to the new case mix. Due to new technologies the expected service durations could be changed or the routing patients have through the hospital. Another reason that the model may be change is that there is more or less space available for clinic, OR or ward or there are more or less surgeons.

8.2.3.2 Extensions

The model is developed for the specialty surgery, but could be quite easily be applied to other specialties. Surgery is a specialty of which a lot of patients have a surgery. The model is also applicable for specialties that do not have so many surgeries. The steps that should be done to extend the model are group the patients and determine the input parameters. The input parameters are displayed in Excel in the sheet “Input parameters”. The required input parameters for this model are the arrival intensities the mean service times at the departments, the standard deviation of the service times at the departments and the routing matrix.

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10 Appendix

In this chapter the appendices are presented. In the appendices additional information can be found.

10.1 Appendix 1: List of Surgeries of the specialty surgery

The specialty surgery can be divided in four subspecialties: general surgery, traumatology, oncology and vascular surgery. Every subspecialty consists of a lot of surgeries. Below some surgeries will be mentioned of each subspecialty.

- General surgery:
  - Gall Bladder
  - Umbilical hernia
  - Appendicitis
  - Peritonitis
  - Abdominal surgery
  - Perianal abscess
- Traumatology:
  - Fractures of several bones (hip/leg/arm etc.)
  - Proximal humerus
  - Trauma screening
- Oncology
  - Cancer of differ organs and tissues such as breast cancer.
- Vascular surgery:
  - Varicose veins
  - Aneurysm
  - Closure of the vessels

10.2 Appendix 2: List of abbreviations of specialties

Abbreviation of the specialties

ANA	Anesthesia
GYN	Gynecology
HLK	Surgery
KNO	Ear, nose and ears
NEU	Neurology
ORT	Orthopedics
PCH	Plastic surgery
Emergency	Emergency patients
TR	Trauma
URO	Urology

10.3 Appendix 3: Figures Current situation

This appendix presents additional figures that describe the current situation in the hospital and the used equation for occupancy rate.

10.3.1 Available and Used clinic time 2011

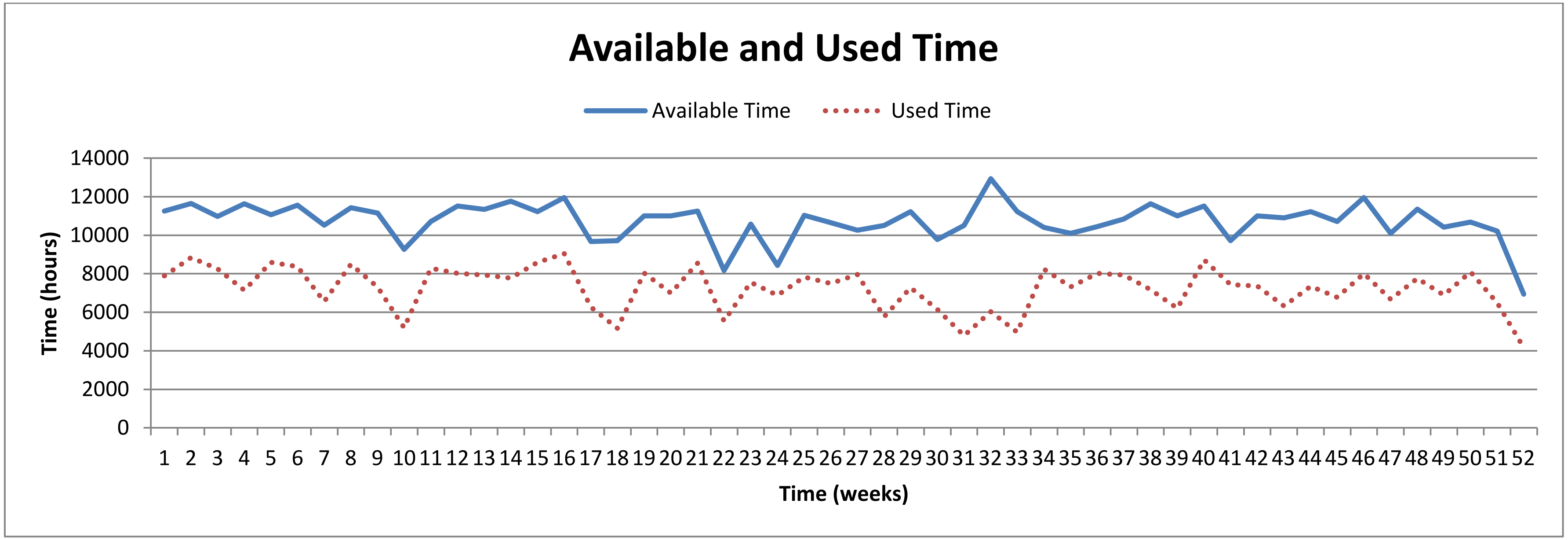

Figure 13 Available and Used Time (Ezis, 2011, n=3508)

10.3.2 Occupancy rate clinic 2011

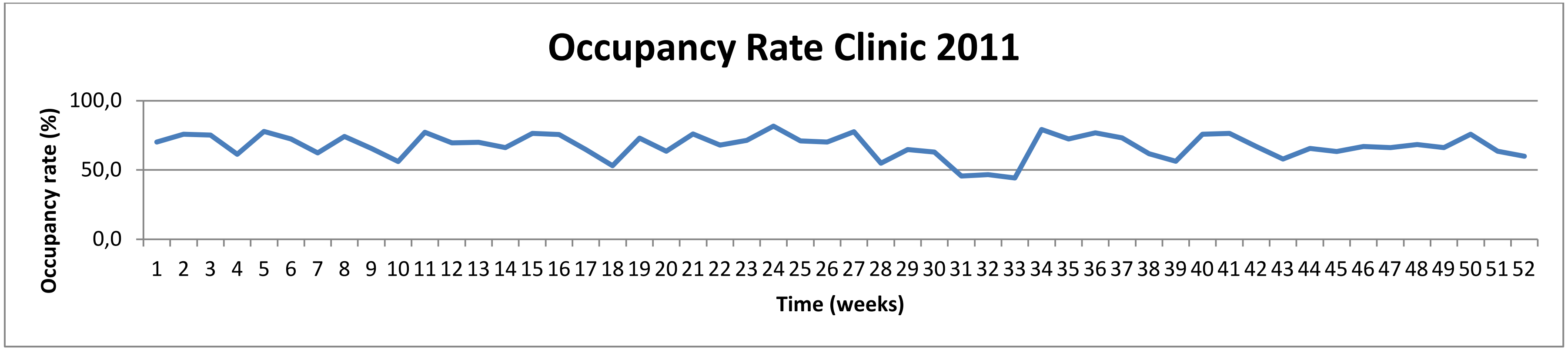

Figure 14 Occupancy Rate Clinic 2011 (Ezis, 2011, n=3508)

10.3.3 Average waiting time OR 2011

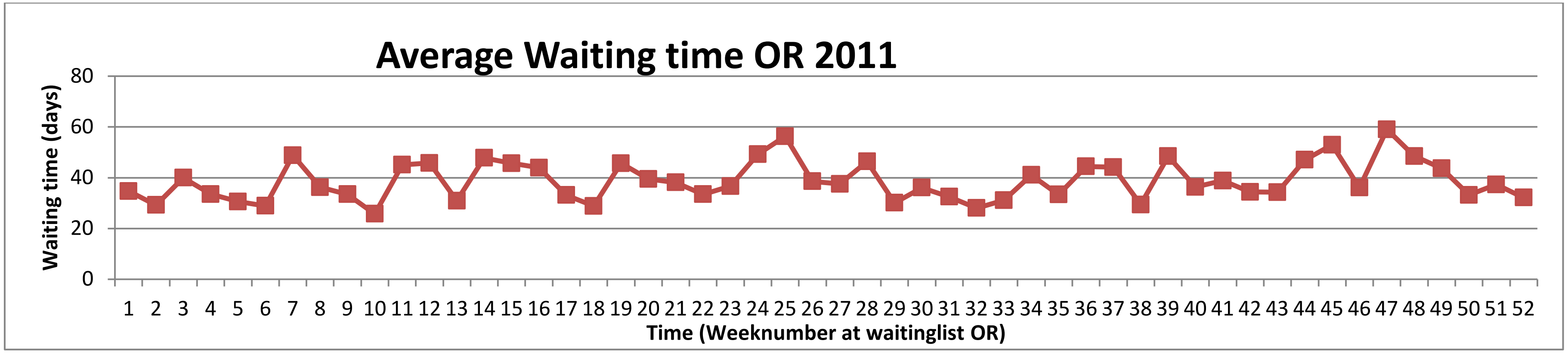

Figure 15 Average waiting time OR 201 (Ezis, 2011, n=3508)

10.3.4 Percentage OK waiting time 2011

Time (weeks)	Percentage within time
1	0,28
2	0,36
3	0,48
4	0,60
5	0,70
6	0,77
7	0,82
8	0,86
9	0,88
10	0,91
> 10	1,00

Table 25 Percentage OK waiting time 2011 (Ezis, 2011, n=3508)

10.3.5 Pecentages of Troughput time 2011

Time (weeks)	Percentage within time
1	0,19
2	0,29
3	0,35
4	0,41
5	0,51
6	0,61
7	0,69
8	0,75
9	0,80
10	0,84
15	0,95
20	0,99
25	1,00

Table 26 Percentages of throughput time 2011 (Ezis, 2011, n=3508)

10.4 Appendix 4: Diagnosis codes with parameters

Diagnosis code	description	Number	Number OR	Surgery duration	Length of stay
101	halscyste lat / med	14	5	41	0,9
111	acute buik (peritonitis)	15	9	79	19
113	appendicitis	232	225	60	3,2
115	abces perianaal	89	52	27	2,5
116	fissuur en fistel ano-rectaal	160	65	22	0,7
117	hemorroïden	394	119	15	0,2
120	hernia diaphragmatica	66	9	183	4,4
121	hernia femoralis/inguinalis	520	399	59	1,3
123	hernia umbilicalis / epigastr	115	67	49	1,4
124	hernia cicatricalis	87	42	66	2,7
126	pylorospasme	2	0	0	0
127	sinus pilonidalis	81	56	31	0,8
129	overige (buik)kl algemeen	1070	325	61	7,6
131	bursitis olecrani	40	1	23	0,2
132	carpaal tunnel syndroom	116	5	23	0
133	epicondylitis med / lateralis	1	0	0	0
134	tendovaginitis stenosans,M.Que	189	4	20	0
135	Dupuytren	15	4	47	0,3
140	kniekuil- Bakerse cyste	7	0	0	0
141	bursitis prepatellaris	9	0	0	0
150	decubitus ulcus	5	0	0	0
151	osteoporose	2	0	0	0
159	kl bew.app nno(surmen,PHS etc)	153	8	34	4
160	lokale inf huid en subcutis	287	76	35	1,5
161	panaritium	37	8	25	2,6
163	abces weke delen	30	13	34	3,5
170	ganglion,gr lipoom,ung incarn	760	51	25	0
171	naevus,klein lipoom,atheroom	430	2	23	0
172	hydrokèle en spermatokèle	3	2	31	1
175	vasectomie	53	3	20	0
176	phimosis, preputium afw.	6	3	20	0,5
177	circumcisie op verz.	1	0	0	0
179	overige algemene diagnoses	398	28	37	5
203	wervelkolom	118	25	60	0
205	clavicula	155	25	75	1,1
206	scapula	24	2	73	1
207	humerus proximaal en schacht	242	42	103	5,7
208	dist humerus / (epi)condyl(en)	47	12	73	1,5
209	olecranon	33	17	73	1,7

210	radiuskop	91	13	57	1
211	onderarm nno	107	44	73	1,1
212	pols	453	47	69	1,1
213	carpus	200	4	40	1
214	metacarpalia	178	13	67	0,9
215	falangen van de hand	415	19	52	0,7
216	ribben, sternum	91	24	19	8,5
217	bekken / sacrum	67	18	55	20,5
218	femur, proximaal (+ collum)	202	148	76	10,7
219	femur overig	36	15	87	7,3
220	patella	16	2	68	1,3
221	tibiaplateau	30	14	83	3,5
222	tibia(± fibula)nno(excl enkel)	101	35	106	4,9
224	enkel	264	84	86	2,4
236	calcaneus	32	9	124	2,3
237	tarsus	85	0	0	0
238	metatarsalia	113	4	60	1
241	talus	2	0	0	0
249	overige fracturen	15	2	87	1
250	hals	12	0	0	0
253	enkel / voet	713	1	46	0,7
254	artrose nno(schoud,knie,enkel)	7	0	0	0
255	schouder (humerus)	86	8	37	8,2
256	elleboog	37	2	81	1,2
257	vinger, incl MCP	81	3	49	1
258	heup / knie	20	4	59	3
261	Mallet pees, biceps	25	3	52	1
262	achillespees	38	27	48	1
269	overige rupturen	63	16	47	1
270	enkelvoudig	1615	25	108	1
273	matig ernstig schedelhers.lets	9	0	0	0
274	pneumo-en/of hemothorax (311)	8	5	91	7,2
279	letsel organen buik en bekken	18	12	95	5,7
280	open wond eenvoudig,bijv snijw	2167	12	34	2,4
281	open wond multipel/uitgebreid	93	16	85	1,7
282	open wond gecompliceerd	80	14	53	2
283	brandwond eenvoudig	48	0	0	0
284	brandwond ernstig	59	11	35	0,3
285	bevriezing	3	0	0	0
286	schaafwond,blaar,insectenbeet	49	0	0	0
287	st-en lengte-afw ond extrem	2	1	145	2
288	st- en lengte-afw bov extrem	10	2	84	1
290	corpus al, natuurlijke opening	12	1	26	60
291	corpus alienum perforerend	59	4	26	0,1

292	verwijderen osteosynthese mat	129	98	43	0,8
293	osteïtis / osteomyelitis	17	10	67	10,3
294	traumascreening nno	317	180	23	0
295	multitrauma nno	82	52	98	7,6
296	posttraumatische dystrofie	20	0	0	0
297	posttraum afw onder extrem	59	10	97	6,4
298	posttraum afw boven extrem	66	8	78	1,8
299	overige trauma / SEH diagnoses	204	18	30	0,3
301	neoplasma bijschildklier	8	6	104	1,5
302	benigne neoplasma schildklier	36	22	114	2,3
303	maligne neoplasma schildklier	15	9	170	2,3
304	benigne neoplasma parotis	26	7	67	1
305	ben neopl overige speekselkl	2	0	0	0
306	maligne neopl speekselklieren	4	0	0	0
310	mediast.scop/-tomie/thor.scop	37	34	98	4,1
311	pneumothorax,niet trauma (274)	7	6	113	4,5
312	thoraxempyeem	1	1	118	13
313	neoplasma bronchus, long	27	25	212	9,2
315	maligne neoplasma oesophagus	2	0	0	0
316	gynaecomastie, hypertrof mamma	24	3	26	1
317	benign neopl mamma/mastopathie	1310	28	30	0,6
318	maligne neoplasma mamma	1458	228	74	1,7
320	abces intra-abdominaal	5	5	55	10,2
321	ulcus duodeni/ventriculi +perf	14	11	91	14,8
322	benigne neoplasma intestinum	16	9	37	2,2
323	cholecystitis / cholelithiasis	501	10	74	2,3
325	colitis ulcerosa	6	3	117	5
326	Crohn (enteritis regionalis)	34	20	76	6,2
327	diverticulosis / -itis	123	101	113	13,6
328	ileus:paralyt,obstr znd hernia	80	68	64	11
329	overige niet maligne GI aand	74	40	69	10,5
330	maligne neoplasma maag	29	11	154	12,8
331	maligne neoplasma galblaas	3	0	0	0
332	maligne neopl pancr/galwegen	4	3	64	3
333	maligne neoplasma colon	313	145	103	9,2
334	maligne neopl recto-sigmoïd	136	74	124	8,8
335	maligne neoplasma rectum	203	105	113	12,3
336	mesenteriaal trombose	4	3	109	50
337	pancreatitis	9	1	83	44,5
338	rectum prolaps	10	4	90	4,7
339	incontinentie voor faeces	31	12	86	5
340	obstipatie	26	19	58	19,5
341	morbide obesitas BMI <45	1	1	124	3
342	morbide obesitas BMI >45	2	2	124	3

348	neoplasma lever (incl meta)	25	12	116	12,4
349	overige maligne neoplasm abd	17	11	69	11,5
350	maligne melanoom van huid	116	20	38	0,9
351	lymphadenopathie eci, nno	58	16	39	1,2
352	maligne neoplasma weke delen	114	26	56	1,8
353	ziekte van Hodgkin,non-Hodgkin	15	9	39	1,4
359	overige oncologische diagnoses	57	9	30	1,9
401	arteritis temporalis	3	1	32	0
402	carotispathologie	77	50	140	3,3
403	aneurysma aorta thor, ruptuur	16	0	0	0
404	thoracic outlet syndroom	5	0	0	0
405	aneurysma aorta iliacaal	280	85	115	6,6
406	aneurysma aorta abd, ruptuur	27	15	176	17
408	nierarteriestenose	1	0	0	0
409	vaat afw abdominaal / bekken	30	14	168	7
410	vaatletsel bovenste extremit	23	8	110	4,4
413	lymphoedema bovenste extremit	1	0	0	0
416	aneurysma onderste extremiteit	30	12	181	7,6
417	arteriële embolie+trombose,336	25	17	83	9,5
418	P.A.O.D. 2, claudicatio interm	757	255	195	6,4
419	P.A.O.D. 3, rustpijn	109	63	190	9
420	P.A.O.D. 4, gangreen	90	63	108	10,9
421	vaatletsel lies / bovenbeen	8	7	84	16
422	vaatletsel knie / onderbeen	6	3	77	0,9
423	varices onderste extremiteiten	582	347	71	1,8
425	diepe ven trombose,evt longemb	4	0	0	0
426	lymphoedema onderste extremit	6	0	0	0
427	ulcus cruris	18	7	62	6
432	diabetische voet(diabetes nno)	53	22	62	7,7
434	Raynaud	16	1	66	1
435	shuntchir+revisie tbv nierlijd	100	86	72	3,5
439	overige perifere vaatziekten	38	24	63	11
441	uitsluiten C.V.I.	22	0	0	0
442	uitsluiten P.A.O.D.	195	4	119	1
449	overige vaat-diagnoses	104	44	47	8,8

Table 27 Diagnosis codes with parameters

10.5 Appendix 5: Groups with diagnosis codes

Group number	Diagnosis codes
1	101, 113, 115, 116, 117, 121, 123, 126, 127, 131, 132, 133, 134, 135, 140, 141, 150, 151, 159, 160, 161, 163, 170, 171, 172, 175, 176, 177, 179
2	111,120, 124, 129
3	237, 241, 250, 254, 273, 283, 285, 286, 296
4	203, 210, 213, 215, 238, 253, 257, 258, 261, 262, 269, 280, 282, 284, 291, 292, 299
5	205, 206,208, 209, 211, 212, 214, 220, 221, 222, 224, 236, 249, 256, 270, 281, 287, 288, 298
6	207, 216, 217, 218, 219, 255, 274, 279, 290, 293, 295, 297
7	305, 306, 315, 316, 317, 322, 331, 350, 351, 352, 353, 359
8	301, 302, 303, 304, 310, 311, 318, 323, 325, 332, 338, 339, 341, 342
9	312, 313, 320, 321, 326, 327, 328, 329, 330, 333, 334, 335, 336, 337, 340, 348, 349
10	403, 404, 408, 413, 425, 426, 441
11	401, 402, 410, 422, 423, 434, 435, 442
12	405, 406, 409, 416, 417, 418, 419, 420, 421, 427, 431, 432, 439,449

Table 28 Patient Groups with diagnosis codes

10.6 Appendix 6: Availability specialists

Traumatology	Available dayparts per week	Management dayparts per week	Available dayparts clinic + OR per week
Janzing	9	3	6
Wieland	9	1	8
Assistants	5	0	5
Total	**23**	**4**	**19**
Oncology	Available dayparts per week	Management dayparts per week	Available dayparts clinic + OR per week
Van Berlo	9	0	9
Froon	8,1	0	8,1
Konsten	8,1	0	8,1
Nijhuis	9	0	9
Vogelaar	8,1	0,5	7,6
Assistants	4	0	4
Total	**46,3**	**0,5**	**45,8**
Vascular surgery	Available dayparts per	Management dayparts per	Available dayparts clinic + OR per week

	week	week	
Janssen	9	0	9
Reuwer	6,75	0,25	6,5
Samyn	9	0	9
Assistants	2	0	2
Total	**26,75**	**0,25**	**26,5**

Table 29 Overvieuw availabillity specialities

10.7 Appendix 7: Arrival intensities per month

Month/ group	1	2	3	4	5	6	7	8	9	10	11	12
1	159	21	5,5	79,5	117,25	31,5	27	51,75	54	2,75	42,5	91,25
2	157,5	24,25	4,5	65,75	99	27,5	35,75	48	53,25	1,5	48,5	93,5
3	146,8	20,8	5	76,8	88,4	26,6	28,2	45,2	53,4	1,25	36,8	82
4	142,25	20,75	6,75	94	102	21,5	33	41,25	52	2	44,75	103
5	131,25	18	5,75	86,75	91,75	28	30,75	34	52,75	2	36,5	103,25
6	145,6	16	6	85,8	81,8	19,2	24,6	33,8	61,8	1,6	40	93,4
7	147,5	20,25	8,25	92,75	90,75	27,5	26	40,5	49	2	25,75	67
8	97	14,75	7,5	69,75	72,75	31,5	15,5	28,5	42,25	1,5	29,5	82,75
9	151	23,6	5,2	90,2	81	28,8	29	44,8	56,2	4,6	31,6	85,6
10	142,75	22	5,25	83,25	98,25	32	25,25	41,75	55	1,5	34,75	85,75
11	146,75	21,5	5,75	83,75	84,25	22,75	28,25	43,25	64,75	2,5	35,25	78,25
12	132,4	18,8	5	77,8	72	25,4	20,6	35,4	52,2	2,2	40,6	98,4

Table 30 Arrival intensities clinic per week in month x

Month/group	1	2	3	4	5	6	7	8	9	10	11	12
1	2,5	0,75	0	0,25	0,5	0,25	0	3	1,25	0	2	0,5
2	2,75	0,5	0	0,25	1,75	0	0,5	2,25	1	0	2,25	0,5
3	1,4	0	0	0,2	1,6	0,6	0,2	1,4	1	0	1,2	0,4
4	3,25	0,25	0	0,25	1	0,25	0,75	1,25	1,25	0	0,75	0,75
5	1,75	0,25	0	0	0,25	0,25	0	0,5	0,5	0	0,5	1
6	2,8	0,4	0	0	0,8	0,6	0,4	1,4	0,8	0	0,2	0,6
7	1,25	0,25	0	0,25	0,75	0,75	0,5	1,75	0,5	0	0,75	0
8	1,5	0	0	0	0,5	1	1	0,75	0,25	0	0,5	0,25
9	2,2	0,4	0	0,4	0,6	0,4	0,8	1,6	0,6	0	0,8	0,2
10	3,25	0	0	0,5	0,75	0	0	0,5	1,25	0	1	1
11	3,5	0,5	0	0,25	0,25	0,25	0,25	2,5	0,5	0	1,25	0,75

12	3,2	0,6	0	0,4	1,6	0,4	0,2	0,8	0,8	0	2,4	0,4

Table 31 Arrival intensities emergency patients per week in month x

10.8 Appendix 8: Code seasonality Excel

In this appendix the code of excel for group 1 is displayed. Due to space limits only the code of group one is represented here.

Group 1

Month clinic

=ALS(Totaal!$B$23=0;'Seizoenseffecten clinic'!B55;ALS(Totaal!$B$23=1;'Seizoenseffecten clinic'!Q2;ALS(Totaal!B$23=2;'Seizoenseffecten clinic'!Q3;ALS(Totaal!$B$23=3; 'Seizoenseffecten clinic'!Q4;ALS(Totaal!$B$23=4;'Seizoenseffecten clinic'!Q5;ALS(Totaal!$B$23=5;'Seizoenseffecten clinic'!Q6;ALS(Totaal!$B$23=6;'Seizoenseffecten clinic'!Q7;ALS(Totaal!$B$23=7;'Seizoenseffecten clinic'!Q8;ALS(Totaal!$B$23=8;'Seizoenseffecten clinic'!Q9;ALS(Totaal!$B$23=9;'Seizoenseffecten clinic'!Q10;ALS(Totaal!$B$23=10;'Seizoenseffecten clinic'!Q11;ALS(Totaal!$B$23=11;'Seizoenseffecten clinic'!Q12;ALS(Totaal!$B$23=12;'Seizoenseffecten clinic'!Q13)))))))))))))

Month IC

=ALS(Totaal!$B$23=0;'Seizoenseffecten ward'!B55 * U2;ALS(Totaal!$B$23=1;'Seizoenseffecten ward'!R2 * U2;ALS(Totaal!B$23=2;'Seizoenseffecten ward'!R3 * U2;ALS(Totaal!$B$23=3; 'Seizoenseffecten ward'!R4 * U2;ALS(Totaal!$B$23=4;'Seizoenseffecten ward'!R5 * U2;ALS(Totaal!$B$23=5;'Seizoenseffecten ward'!R6 * U2;ALS(Totaal!$B$23=6;'Seizoenseffecten ward'!R7 * U2;ALS(Totaal!$B$23=7;'Seizoenseffecten ward'!R8 * U2;ALS(Totaal!$B$23=8;'Seizoenseffecten ward'!R9 * U2;ALS(Totaal!$B$23=9;'Seizoenseffecten ward'!R10 * U2;ALS(Totaal!$B$23=10;'Seizoenseffecten ward'!R11 * U2;ALS(Totaal!$B$23=11;'Seizoenseffecten ward'!R12 * U2;ALS(Totaal!$B$23=12;'Seizoenseffecten ward'!R13 * U2)))))))))))))

Month Ward

=ALS(Totaal!$B$23=0;'Seizoenseffecten ward'!B55 * V2;ALS(Totaal!$B$23=1;'Seizoenseffecten ward'!R2 * V2;ALS(Totaal!B$23=2;'Seizoenseffecten ward'!R3 * V2;ALS(Totaal!$B$23=3; 'Seizoenseffecten ward'!R4 * V2;ALS(Totaal!$B$23=4;'Seizoenseffecten ward'!R5 * V2;ALS(Totaal!$B$23=5;'Seizoenseffecten ward'!R6 * V2;ALS(Totaal!$B$23=6;'Seizoenseffecten ward'!R7 * V2;ALS(Totaal!$B$23=7;'Seizoenseffecten ward'!R8 * V2;ALS(Totaal!$B$23=8;'Seizoenseffecten ward'!R9 * V2;ALS(Totaal!$B$23=9;'Seizoenseffecten ward'!R10 * V2;ALS(Totaal!$B$23=10;'Seizoenseffecten ward'!R11 * V2;ALS(Totaal!$B$23=11;'Seizoenseffecten ward'!R12 * V2;ALS(Totaal!$B$23=12;'Seizoenseffecten ward'!R13 * V2)))))))))))))