Process optimization of the Preoperative Anesthesia Clinics at ZGT Almelo and Hengelo

R.C.A. Odijk

2012

UNIVERSITEIT TWENTE.

OPTIMIZATION OF THE PRE ANESTHESIA CLINICS

AT ZGT ALMELO AND HENGELO

R.C.A. Odijk

April 2012

Master's thesis
Industrial Engineering and Management
School of Management and Governance
University of Twente

Supervisors University of Twente:
dr. ir. I.M.H. Vliegen
University of Twente, School of Management and Governance
Industrial Engineering and Business Information Systems

dr. ir. M.R.K. Mes
University of Twente, School of Management and Governance
Industrial Engineering and Business Information Systems

Supervisor Ziekenhuisgroep Twente:
M. Kats, M.Sc.
Ziekenhuisgroep Twente

MANAGEMENT SUMMARY

In the last couple of years, Ziekenhuisgroep Twente (ZGT) successfully reduced the access times for surgical operations. This reduction in access time led to a bottleneck shift within the patient process from surgical operation to preoperative screening (POS). According to regulations [1], only people who are screened and have consent of an anesthesiologist can be operated. In some cases, patients were not screened before the surgical operation, which led to delay and occasionally to cancellation of the surgery.

Currently, the access time and waiting time at the preoperative anesthesia clinic (PAC) are not in line with the objectives of the hospital. To comfort the patients, ZGT aims at screening all patients with a 'one stop shop' approach where possible, but still having a reasonable waiting time for their patients. However, in the current situation patients sometimes have to wait for over an hour or come back another day.

The goal of this research is to come up with suggestions to increase patient satisfaction at the preoperative anesthesia clinic while not delaying the planning of surgical operations. We researched six organizational interventions to increase the one stop shop percentage, reduce the access times (at Almelo) and shorten waiting times (especially at Hengelo) by changing the number of nurses, balancing the mixture between walk-in and appointment, changing timing policies, and changing the timeslot intervals. Therefore, we start with interviewing several involved employees in order to understand the preoperative screening process. Next, we analyze data obtained through the registration software and use a random sample of the current service at the PAC to get more insight in the characteristics of the patients, patient inflow, and preoperative screening performances. With this data, several points of improvement to increase the patient satisfaction are found. These points of improvement are that in the current situation the access time at Almelo is too long, and the waiting times at both locations exceed the acceptable waiting time.

We inquire literature to find whether similar problems are studied in the past and how they were handled. We found that the access and waiting times can be reduced if a right mixture between appointments and one stop shop, another timing policy, or other timeslots intervals are implemented. Several articles give suggestions how to do this.

We develop a conceptual model to determine the effect of the organizational interventions. We start with describing the process steps that a patient needs to take before having consent and the different paths to take these steps. Next, we describe that these process steps are dependent on several factors, what resources are needed, how the processing times per processing step are determined, and last the decision making policies.

We discuss the interventions and output parameters. We distinguished between two different levels for interventions. On the strategic level we studied the effect of changing capacity to two nurses on every day (Section 5.1). On tactical level, we studied the effect of different planning rules and different appointment intervals (Section 5.2). Intervention 2 is based on scheduling appointments on the least busy moments. Intervention 3 studies the effect of a maximum percentage of walk-in and appointments per day. Intervention 4 is a combination of intervention 2 and 3. Intervention 5 focuses on different timing policy for scheduling appointments. Intervention 6 focuses on changing the current timeslots to better match the expected consultation times.

With this information we start to develop a simulation model of the current situation at the PAC. We use several techniques to verify that the simulation model is a good resemblance of the conceptual model and can be used to compare the effect of different interventions. We also determine whether the simulation model was a sufficient representation of the real world. We introduced several correcting factors to better match the outputs of the simulation model with the real world data. The model is a sufficient representation of the real world to determine the effect of the interventions. However, it cannot be used to provide accurate expected waiting times of the real world system. With this in mind, we used the simulation model to test and analyze the six interventions.

We find that changing the number of nurses from one to two on Friday at Hengelo has a positive influence on the overall patient satisfaction. The waiting time and access time both decrease. Changing the number of nurses from three to two for every weekday at Almelo increases the waiting time for a nurse, but decreases the waiting time for an anesthesiologist. The increase for a nurse is higher than the decrease for an anesthesiologist. This intervention does not influence the total waiting time in a positive manner at Almelo, but may not have a significant influence on the patient satisfaction as long as the waiting time per care provider does not exceed the maximum acceptable waiting time. Moreover, the personnel costs will decrease significantly when staffing one nurse less. Therefore, for the interventions on a tactical level at Almelo, we simulate with two nurses Hereby, we keep in mind that the effect of having three nurses would lead to less waiting time for a nurse and more waiting time for an anesthesiologist. Additionally, when the number of nurses does influence the effect of the tactical level interventions differently, we discuss this. At Hengelo, we also continued with two nurses every day for the interventions on a tactical level.

When analyzing the interventions on a tactical level, we keep in mind that to improve patient satisfaction, the one stop shop percentage at Almelo should increase, whereas the desired effect on the waiting times at both locations depends on the planning method. We come to the following conclusions with respect to the tactical interventions:

- **Intervention 2:** The effect of first scheduling appointments on the least busy days and hours depends on the planning methods and timeslot interval. We find that the waiting times at Almelo increases, whereas this intervention leads to a higher one stop shop percentage and lower waiting time at Hengelo. For both locations, the access time increase, because patients are not planned on the first possible day but are planned later in the week.
  We conclude that the effect of this intervention is positive on the waiting times, when not too many appointments are scheduled per week and a correct timeslot interval is used. However, if the planning method is appointment based, the waiting times will increase. In both cases, the average access time will increase.
- **Intervention 3:** The planning policy to schedule a maximum number of appointments per day affects the one stop shop percentage and waiting time at both locations. At Almelo, this leads to extra waiting time for the nurse and anesthesiologist but to a shorter average access time as well. At Hengelo, a lower one stop shop percentage leads to shorter waiting times for a nurse and anesthesia assistant, and increases the average access time. A reason for the increase in access time is that not enough timeslots are available per week.
  We conclude that intervention 3 has a positive influence on patient satisfaction. However other timeslot intervals and more flexibility of the system are needed to deal with the percentage of consent on time.

- **Intervention 4:** We analyzed the effect of combining intervention 2 and 3 and compare the results with intervention 3. We find that intervention 4 has a negative effect on the waiting times and access time at Almelo, and a positive effect at Hengelo.
  When we compare this intervention with intervention 3, we find that the waiting time increases in Almelo and decreases in Hengelo. A significant influence on these changes is the timeslot interval and the one stop shop percentage per day. Additionally, we find that the access times increase at both locations. A cause for this increase is that the access time is influenced by the division of the percentages per day. If there are more (sequential) days with a percentage below the average percentage, the access time will increase. We conclude that when intervention 4 is implemented and timeslots are used that fit the average consultation time, the average waiting time will decrease and the access time will increase.
- **Intervention 5:** This intervention focuses on the timing policy. We found that a late timing policy has a negative influence on the percentage of patients with consent on time when the timing policy is later than 0.80. For timing policies between 0.35 and 0.80 there is only a slight difference in consent on time and waiting times. For earlier timing policies, the effect depends on the planning system.
  We conclude that changing the timing of the appointments has significant influence on the percentage of patients with consent on time, the access times, and the waiting times. Hereby, the effect depends on the planning policy. However, in general, an early timing policy leads to higher waiting times, but to lower access times as well.
- **Intervention 6:** The final intervention on a tactical level is changing the timeslot intervals to better fit the current consultation times. At Almelo, planning more time for an ASA score 3 patient in combination with planning less time for ASA score 1 patients decreases the average waiting time. Changing the intervals at Hengelo has a negative effect on the waiting times for the nurse and anesthesiologist, which may be cause by using an appointment time which is slightly smaller than consultation times
  We conclude that changing the appointment interval to better fit the consultation times can improve the waiting times. However, an appointment interval that is slightly smaller than the consultation time is not improving the outcomes. An appointment interval that is equal to or slightly larger than the average consultation time is advised.

When comparing the interventions, we find that in most cases is a negative correlation between the waiting and access time. Furthermore, there are several tactical interventions that improve the waiting time without influencing the access time and vice versa. Overall, the effect of the intervention differs and deciding which of these interventions is more desirable is up to the management. When implementing the interventions only some minor changes may be necessary.

We recommend further research on the current discrepancies in process and policies. For example, research on the different processes depending on the ASA scores, the ECG machine at Hengelo, hiring a nurse practitioner instead of an anesthesia assistant, policy when a patient is sent for extra examination. Other recommendations are investigating the patient preferences, changing the opening hours to let more patients walk-in, and integrating an integral planning method with the policlinics. With the latter is meant that if a patient has an appointment to visit a policlinic, an appointment is immediately planned for the PAC as well.

MANAGEMENT SAMENVATTING

De afgelopen jaren is het Ziekenhuisgroep Twente (ZGT) gelukt om de wachttijd tot een operatie te reduceren. Deze wachttijdreducties hebben er toe geleid dat het knelpunt van het proces tijdelijk verschoof naar de preoperatieve screening (POS). Volgens de reglementen mogen alleen patiënten met een akkoord van de anesthesioloog geopereerd worden. In sommige gevallen hadden patiënten nog geen akkoord voor de operatiedatum. Dit leidde tot uitstel en soms zelfs afstel van de operatie.

Op dit moment zijn de toegangstijden en wachttijden van de POS afdeling niet in overeenstemming met het doel van het ziekenhuis. Waar mogelijk probeert ZGT patiënten via het 'one stop shop' principe te helpen zonder hierbij een onacceptabele wachttijd te creëren. Echter, in de huidige situatie komt het voor dat patiënten meer dan een uur moeten wachten of op een andere dag terug dienen te komen.

Het doel van ons onderzoek is het aandragen van suggesties om de patiënttevredenheid bij de POS te verhogen zonder de planning van operaties te vertragen. We onderzoeken zes organisatorische interventies om de mogelijkheid voor 'one stop shop' te vergroten, de toegangstijd te verlagen (in Almelo) en de wachttijden (vooral in Hengelo) te verkorten. Dit doen we door een het aantal aanwezige verpleegkundigen te veranderen, een balans te vinden tussen inloop- en afspraakmogelijkheden, de timing van afspraken te veranderen, en de duur van een afspraak te veranderen. We starten met het interviewen van verscheidene betrokkenen om een idee te krijgen van het huidige POS proces. Vervolgens analyseren we data, welke verkregen is via het registratiesysteem en een steekproef, om meer inzicht te krijgen in de karakteristieken van de patiënten, patiëntstroom, en de huidige prestaties. Uit deze data komen verschillende knelpunten voort.

We onderzoeken of de gevonden knelpunten eerder zijn onderzocht en hoe deze zijn verholpen. Hierbij komen we er achter dat de toegangstijden en wachttijden verminderd kunnen worden door een goede mix tussen afspraak- en inloopmogelijkheden te implementeren. Verschillende artikelen geven suggesties hoe dit kan.

We ontwikkelen een conceptueel model om het effect van verschillende interventies te bepalen. We beginnen met het opstellen van de processtappen en de verschillende routes die een patiënt in het proces kan doorlopen. We beschrijven verschillende factoren die de route van een patiënt bepalen. Tevens gaan we in op de benodigdheden, de screeningstijden, en de keuzemogelijkheden binnen het proces.

Vervolgens onderscheiden we twee verschillende levels voor de interventies. Op strategisch niveau bestuderen we het effect van een capaciteitsverandering naar twee verpleegkundigen per dag (interventie 1). Op tactisch niveau bestuderen we het effect van verschillende planningsprocedures, timingsprocedures voor afspraken, en afspraakintervallen. Interventie 2 richt zich op het maken van afspraken tijdens de minst drukke perioden. Interventie 3 richt zich op het maken van maximaal een aantal afspraken per dag en de rest te reserveren voor inloop. Interventie 4 combineert de methoden van interventie 2 en 3. Interventie 5 focust op verschillende timingsprocedures voor afspraken. De laatste interventie richt zich op het veranderen van de afspraakintervallen om dit beter aan te laten sluiten bij de consulttijden.

Met deze informatie ontwikkelen we een simulatie model van de huidige situatie. We gebruiken verschillende technieken om te verifiëren dat het conceptuele model en het simulatie model met

elkaar overeen komen. Vervolgens bepalen we of het simulatie model ook goed genoeg is om de realiteit weer te geven. We komen tot de conclusie dat het simulatie model goed genoeg is om de effecten van de interventies te testen, maar dat de waarden van de wachttijden geen accurate weerspiegeling zijn van de werkelijkheid. Met dit in het achterhoofd gebruiken we het simulatie model om de zes interventies te analyseren.

We vinden dat het veranderen van de capaciteit van 1 naar 2 verpleegkundigen op vrijdag in Hengelo leidt tot een wachttijdvermindering voor de verpleegkundige en een significant lagere toegangstijd. Het veranderen van de capaciteit van 1 naar 2 verpleegkundigen heeft een positieve invloed. Voor de interventies op een tactisch niveau gaan we daarom verder met 2 verpleegkundigen in Hengelo. Deze verandering is toepasbaar omdat het management al bezig is met het testen van deze verandering. In Almelo vinden we dat het veranderen van het aantal verpleegkundigen van 3 naar 2 significant meer wachttijd voor de verpleegkundige en minder wachttijd voor de anesthesioloog oplevert. Hierbij lijkt het erop dat de wachttijd voor de verpleegkundige meer toeneemt dan dat de wachttijd voor de anesthesioloog afneemt. Hoewel de wachttijd toeneemt, heeft deze verhoging geen significante invloed op de patiënttevredenheid zolang de wachttijd beneden het maximum acceptabele aantal minuten blijft. Bovendien leidt het verlagen van het aantal verpleegkundige tot significant lagere personeelskosten. Voor de interventies op tactisch niveau zullen we daarom ook bij Almelo simuleren met 2 verpleegkundigen. Hierbij houden we er rekeing mee dat het effect van 3 verpleegkundigen zou zijn dat de wachttijd voor de verpleegkundigen afneemt en voor de anesthesioloog toeneemt. Als er bij de interventies sprake is van een verschil in effect bij 2 en 3 verpleegkundigen zullen we dit aangeven.

Bij het analyseren van de interventies op tactisch niveau met betrekking tot patiënttevredenheid houden we in het achterhoofd dat het percentage 'one stop shop' in Almelo verhoogd moet worden en dat het effect van de wachttijden afhangt van de planningsmethode. We komen tot de volgende conclusies voor de interventies:

- **Interventie 2:** Het effect van afspraken plannen op de minst drukke tijden hangt af van de planningsmethode en de afspraakduur. We vinden dat de wachttijd in Almelo toeneemt, terwijl in Hengelo de wachttijd afneemt en het inlooppercentage stijgt. Op beide locaties gaat de toegangstijd omhoog, omdat patiënten niet op de eerst mogelijke dag maar later in de week worden gepland.
  We concluderen dat het effect van deze interventie positief is op de wachttijd als er niet te veel afspraken worden gepland en de afspraakduur voldoende is. Hierbij zal de gemiddelde toegangstijd wel toenemen.
- **Interventie 3:** De planningsprocedure waarbij er een maximum aantal afspraken per dag gemaakt mag worden heeft invloed op het inlooppercentage en de wachttijd op beide locaties. In Almelo leidt dit to extra wachttijd voor de verpleegkundigen en de anesthesioloog. Hierbij neemt de toegangstijd wel af. In Hengelo leidt een lager inlooppercentage tot kortere wachttijden voor een verpleegkundige en POS arts, en tot een verhoging van de toegangstijd. Een reden voor deze verhoging is dat er niet genoeg afspraakmogelijkheden beschikbaar zijn per week.
  We concluderen dat interventie 3 een positieve invloed heeft op de patiënttevredenheid. Hoewel betere afspraaktijden en meer flexibiliteit nodig zijn om het percentage dat op tijd akkoord heeft te verhogen.

- **<u>Interventie 4:</u>** Voor interventie 4 analyseren we het effect van de combinatie van interventie 2 en 3. Interventie 4 leidt tot dezelfde conclusies als interventie 3, als we deze vergelijken met de huidige situatie.
  Als we de uitkomst vergelijken met interventie 3, concluderen we dat interventie 4 leidt tot hogere wachttijden in Almelo en lagere wachttijden in Hengelo. De tijdsduur van een afspraak en het inlooppercentage hebben hier een significante invloed op. Bovendien neemt de toegangstijd in beide locaties toe. Een oorzaak hiervoor is de verdeling van de percentages per dag. Als er een aantal achtereenvolgende dagen een lager percentage afspraken is dan het gemiddelde, neemt de toegangstijd toe. We concluderen dat interventie 4, mits de afspraakduur beter aansluit, de wachttijden verder zal verlagen, en de toegangstijden zal verhogen in vergelijken met interventie 3.
- **<u>Interventie 5:</u>** Deze interventie focust op de timingprocedure voor afspraken. We vinden dat een late timingprocedure een negatief effect heeft op het percentage patiënten dat op tijd akkoord heeft. Voor timingprocedures tussen de 35% en 80% is er enkel een klein verschil in percentage met op tijd akkoord en de wachttijden. Voor vroege timingprocedures hangt het effect van het planningssysteem af.
  We concluderen dat de verandering van de timing van afspraken een significant effect heeft op het percentage patiënten dat op tijd akkoord heeft, de toegangstijd, en de wachttijd. Hierbij hangt het effect af van het planningssysteem. Hoewel over het algemeen een vroege timingprocedure leidt to hoger wachttijden en lager toegangstijden.
- **<u>Interventie 6:</u>** De laatste interventie is het veranderen van de afspraakduur om beter aan te sluiten bij de huidige consultduur. We komen tot de conclusie dat deze interventie een positieve invloed heeft op de patiënttevredenheid in Almelo. Het veranderen van de intervallen in Hengelo met deze interventie leidt tot een negatieve invloed, omdat de afspraakduur kleiner is dan de consultduur.
  We concluderen dat het veranderen van de afspraakduur, zodat deze beter aansluit bij de consultduur, leidt tot een verlaging van de wachttijd. Hierbij blijkt een afspraakduur die iets kleiner is dan de consultuur niet te werken, maar een afspraakduur die gelijk is aan of iets groter dan de consultduur wel.

Als we de interventies vergelijken, vinden we dat er in de meeste gevallen een negatieve correlatie is tussen de wachttijd en de toegangstijd. Verder zijn er verschillende tactische interventies die de wachtijd verbeteren zonder de toegangstijd te beinvloeden en vice versa. Over het algemeen verschilt het effect van de interventies en is het aan het management om een beslissing te nemen over de gewenste interventies. Bij het implementeren van de interventies zijn enkel kleine aanpassingen nodig.

We raden aan om verder onderzoek te doen naar de huidige discrepanties in het proces en de procedures. Bijvoorbeeld, er kan onderzoek gedaan worden naar de verschillende processen afhankelijk van de ASA scores, het ECG apparaat in Hengelo, het inhuren van een nurse practioner in plaats van een POS arts, en de procedure wanneer iemand voor extra onderzoek moet. Andere aanbevelingen zijn het onderzoeken van de patiëntvoorkeuren, veranderen van de openingstijden om meer mensen de kans te geven om in te lopen, en het integreren van een integrale planningsmethode met de poliklinieken. Met het laatste wordt bedoeld dat als een patiënt een afspraak maakt met een specialist in de polikliniek dat de patiënt direct ook een afspraak bij de POS afdeling heeft.

GLOSSARY

In the report several abbreviations and terms are used. Below, we describe the most common ones and the translation in Dutch.

Anesthesia assistant: a specialty physician assistant under the direction of a licensed and qualified anesthesiologist (Dutch: POS arts).

Anesthesiologist: a physician trained in anesthesia and perioperative medicine. (Dutch: anesthesioloog)

Appointment: an option where patients choose a day and time to come back for examination. An appointment is always schedule on another day, so no appointments are planned on the same day as the scheduling date. (Dutch: afspraak)

ASA score: A physical status classification system for assessing the fitness of patients before surgery.

Access time (AT): the difference between the day of scheduling an appointment for preoperative screening and the day of the preoperative screening consult. (Dutch: toegangstijd)

Chipsoft-EZIS: Electronic patient registration system. We used this system to find data on patients, patient inflow, and performances of the preoperative anesthesia clinic.

ECG: Electrocardiography, a transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time.

Nurse: medical professional that performs the basic examination for all patients (Dutch: verpleegkundige)

One stop shop: approach where the consultation at the policlinic and the consultation at the preoperative anesthesia clinic are one the same day.

Preoperative Anesthesia Clinic (PAC): the department where the preoperative screening takes place.

Preoperative screening (POS): This is the examination/consultation of the patient at the preoperative anesthesia clinic.

Waiting time (WT): the time a patient has to wait in the waiting room of the preoperative anesthesia clinic. (Dutch: wachttijd)

Walk-in: an option where patients do not have to schedule an appointment for examination (Dutch: inloop)

Ziekenhuisgroep Twente (ZGT): a hospital located in Almelo and Hengelo, the Netherlands.

PREFACE

After completing my bachelor’s thesis at ZGT Almelo in 2009 under supervision of Michel Kats, I left the hospital with great satisfaction. Therefore, I was very pleased when Michel offered me a possibility for a master’s thesis assignment two years later. In the summer of 2011, I enthusiastically started my research which led to this advisory report today. In the mean time, I finished my courses for the master Psychology and the last course for the Master Industrial Engineering and Management. By finishing this master’s thesis for IEM, a great part of my life with a lot of memorable experiences is almost coming to an end. Luckily, during my almost six years of studying I found that my interests are not limited to IEM, so with one other master´s thesis and a student exchange program in Australia to go this great experience is not completely ended yet.

With my previous experiences with the environment, mentality, and professionalism of ZGT and Michel, I was sure that this research was initiated to learn from the outcomes and maybe even to apply the suggestions provided. Moreover, during my research I really felt like being part of the organization and that my insights and knowledge were appreciated. Therefore, I express my gratitude to the management of the PAC, Nel Nienhuis, Annemarie Visschedijk, Elly Knoop, and Marco Mahangoe, and to my supervisor Michel Kats in particular for their feedback and help during the research. This final master’s thesis report could not have existed without Ingrid Vliegen and Martijn Mes from the University of Twente. Therefore, I thank them as well for their willingness to become my supervisors and for the constructive feedback.

Last but not least, I thank my family and friends for their support. Special thanks go to my parents for supporting me throughout the whole period and to Rebecca for motivating and helping me when necessary!

I hope you will enjoy reading the report and that the suggestions are worthwhile.

Rob Odijk

Enschede, May 2012

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

FIGURES

TABLES

1 INTRODUCTION

In the last couple of years, Ziekenhuisgroep Twente (ZGT) in Almelo (Figure 1.1) and Hengelo (Figure 1.2) successfully reduced the access times for surgical operations. These access time reductions led to a temporary bottleneck shift within the patient process from surgical operation to the preoperative screening (POS). According to regulations [1], only people who are screened and have consent of an anesthesiologist can be operated. In some cases, patients were not screened before the surgical operation, which led to delay and occasionally to cancellation of the surgery. Our research focuses on how to prevent this from happening.

Figure 1.1 ZGT Almelo

Figure 1.2 ZGT Hengelo

1.1 BACKGROUND INFORMATION

Ziekenhuisgroep Twente consists of two hospitals; ZGT Almelo and ZGT Hengelo. Both hospitals are general hospitals with a combined total of more than 3.500 employees, over 200 specialists, and more than 1000 hospital beds. ZGT provides high-quality care for a health care region of 300.000 citizens. This led to almost 600.000 policlinic visits and 255 million euro revenue in 2010 [2].

1.2 PROBLEM DEFINITION

Currently, the access time and waiting time at the preoperative anesthesia clinic (PAC) are not in line with the objectives of the hospital. To comfort the patients, ZGT aims at screening all patients with a 'one stop shop' approach where possible, but still having a reasonable waiting time for their patients. However, in the current situation patients sometimes still have to wait for over an hour or come back another day. It also occurs that a surgical operation is cancelled or postponed because the patient did not have consent on the day of surgery.

There are different variables that influence the preoperative screening process. For example, the reduction of access times for surgical operations has reduced the time span to perform preoperative screening. This leads to less flexibility in planning patients for screening and surgical operations to be postponed or cancelled. Additionally, the number of patients visiting the PAC fluctuates per day and week, and there are different kinds of patients that need different kinds of services. ZGT divides these patients according to the American Society of Anesthesiologists (ASA) physical status classification system. Hereby, the higher the ASA score, the more risk of complications during a surgical operation [3].

The preoperative screening services at Almelo and Hengelo differ in several ways in dealing with these variables. One important difference is related to the planning method. The method of Almelo is mainly based on appointments, whereas Hengelo uses a 'walk-in' method. Another important difference is related to the screening process. At Almelo, patients with ASA score 2 are screened by an anesthesiologist, whereas at Hengelo this is done by an anesthesia assistant. These planning methods and screening processes influence the access time and waiting time of patients. ZGT aims at a similar process at Almelo and Hengelo in the future.

1.3 RESEARCH GOAL

The goal of this research is to come up with suggestions to increase patient satisfaction at the preoperative anesthesia clinic while not delaying the planning of surgical operations. More specifically, the objective is to increase one stop shop percentages, reduce the access times (at Almelo) and shorten waiting times (especially at Hengelo) by changing the number of nurses, balancing the mixture between walk-in and appointment, changing timing policies, and changing the timeslot intervals.

1.4 RESEARCH QUESTIONS

To obtain the research goal we answer six research questions:

1. *What is the current situation at ZGT within the preoperative screening process?* (Chapter 2)

    - *What are the process steps within the preoperative screening process at Almelo and Hengelo?* (Section 2.1)
      An important aspect in understanding the current situation is having an overview of the relevant steps within the preoperative screening process. We determine the relevant steps of the processes at both locations by interviewing several involved employees.

    - *What are the characteristics of the patients and patient inflow?* (Section 2.2)
      Another important aspect of the current situation is understanding the demand side of the process. Patients demand health care service from the hospital. Therefore, the characteristics of patients and patient inflow are taken into account. Some important factors we analyze are number of patients per patient type, division of specialism, and patient arrival times. We analyze several characteristics by using data from the project "Zorg beter georganiseerd", the registration software Chipsoft-EZIS, and a random sample.

    - *What are the characteristics of the preoperative screening service?* (Section 2.3)
      We also include the characteristics of the supply side and performance in the current situation. Important factors we analyze are throughput time, waiting time, consultation time, and patient satisfaction. We analyze the characteristics by using data from the project "Zorg beter georganiseerd", Chipsoft-EZIS, and a random sample.

    - *What are the most important points of improvement?* (Section 2.4)
      During the analysis of the current situation we find several points of improvement. We analyze the different points of improvement and their effect on the service level.

2. *What relevant literature is available?* (Chapter 3)
   We search literature to inquire whether similar problems are studied in the past, and how they were handled.

3. *How can the current situation be modeled?* (Chapter 4)
   We describe a conceptual model with information on the processing steps, process dependencies, resources, processing times, and decision making which is needed to model the current situation.

4. *What organizational interventions are available to improve the service level?* (Chapter 5)
   We analyze different organizational interventions to handle the points of improvement. Performance requirements as one stop shop percentage, access times, and short waiting time are taken as parameters. We come up with interventions by literature search and brainstorming.

5. *How usable is the final simulation model to test the organizational interventions?* (Chapter 6)
   To research the effect of the interventions, we use modeling in simulation software. We verify whether the simulation model is a correct representation of the conceptual model and validate the resemblance with reality as well. This means that we research whether the simulation model is realistic and whether the stakeholders (management and other employees of the PAC) agree with the model.

6. *What are the results of the organizational interventions?* (Chapter 7)
   To determine the effect of the organizational interventions, we analyze the results that we obtain through the model and compare these results with the current situation and each other.

In this chapter we described that the goal of this research is to come up with suggestions to increase patient satisfaction at the preoperative anesthesia clinic while not delaying the planning of surgical operations. Within the preoperative screening process, there are several aspects that can lead to less patient satisfaction or throughput. Therefore, in Chapter 2, we inquire the current situation of the preoperative screening process and determine what the points of improvement are. This is followed by a literature review in Chapter 3. Chapter 4 describes the conceptual model of the preoperative screening process. In Chapter 5, we analyze and provide different organizational interventions for the most important points of improvement. The focus of Chapter 6 is the implementation and evaluation (verification and validation) of the conceptual model in a simulation model. In Chapter 7, we discuss the results of the interventions. Finally, in Chapter 8, we provide conclusions and suggestions for further research.

2 CURRENT SITUATION

In this chapter we describe the current situation within ZGT. We start with an overview of the processes of Almelo and Hengelo in Section 2.1. Section 2.2 follows with the characteristics of the patients and the patient inflow. In Section 2.3 we describe the characteristics of the preoperative screening and planning departments. Finally, in Section 2.4, we discuss the most important points of improvement.

Part of the data in this chapter is obtained from the project "Zorg beter georganiseerd". This project was executed by ZGT, and contained a 2 week sample length (week 5 and 6 of 2009) with a total of 961 patients. We executed another sample period of six days in week 48 and 49 in 2011 with a total of 444 patients. Additionally, data from August 2010 till September 2011 is obtained from the registration system Chipsoft-EZIS.

2.1 PREOPERATIVE SCREENING PROCESSES

In this section we start by giving an overview of the preoperative screening process at Almelo (Section 2.1.1), followed by the process at Hengelo (Section 2.1.2). We discuss the process for patients with different ASA scores. Hereby, the higher the ASA score, the more risk of complications during surgical operation [3]. The information on the process steps are obtained by interviewing several employees at both locations.

2.1.1 ALMELO

In Figure 2.1 we find the simplified preoperative screening process at Almelo. The figure indicates that after visiting a policlinic, patients arrive at the information desk to schedule an appointment. Depending on the patient type (ASA score 1, 2 or 3) different steps are taken. If the policlinic physician did not determine the ASA status, it is determined by the information desk employee immediately. If a patient is indicated with ASA score 1, the information desk employee considers whether it is possible to let the patient walk-in or whether an appointment has to be made to come back another day. Patients can walk-in if they are willing to wait, and if there is enough capacity. For ASA score 2 and 3 patients, an appointment is scheduled. For this there are reserved timeslots of 30 minutes for a nurse from Monday to Friday during opening hours for ASA score 1 patients, and 15 minute timeslots for a nurse and an anesthesiologist for ASA score 2 and 3 patients. The information desk employee checks the time till the operation date of the patient and schedules an appointment at half length of this time till operation.

At the day of the appointment, or the same day for walk-in patients, the receptionist at the secretary of the anesthesia checks the patient type and sends the patient to a nurse, sometimes followed by an examination by the anesthesiologist (if the patient type is ASA score 2 or 3). If a patient has consent for surgery, the POS process ends here. If no consent is given, the patient first has to get an ECG or visit the laboratory, cardiologist or lung specialist for extra examination before obtaining consent.

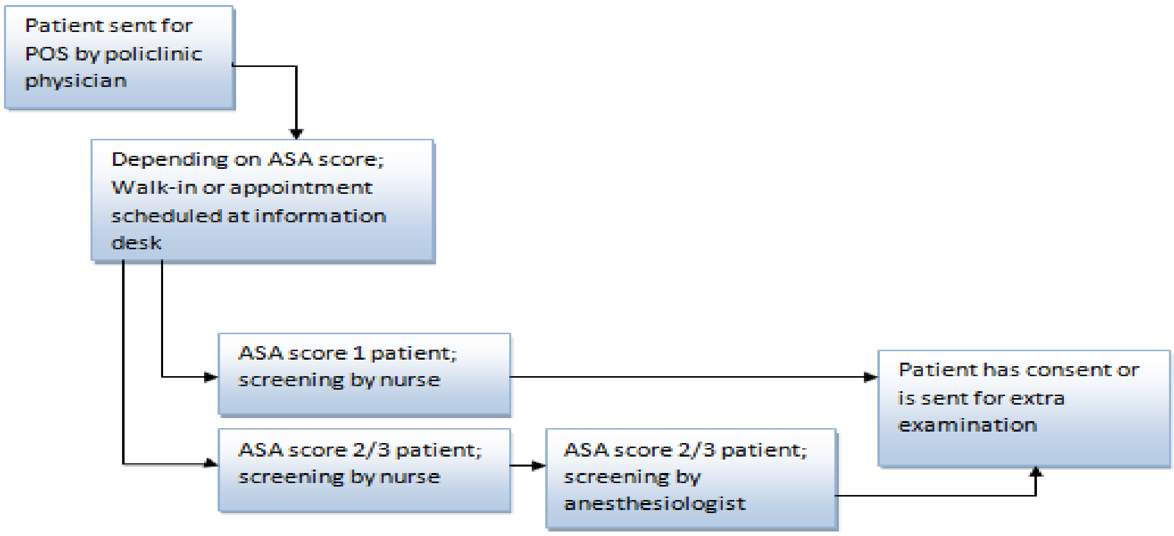


Figure 2.1: Preoperative screening process at Almelo

2.1.2 HENGELO

The process at Hengelo (Figure 2.2) does not differ much from the process at Almelo. After visiting a policlinic, the patient visits the front office. In consultation with the front office employee, the patient decides if he/she wants to make an appointment or wants to wait in the waiting room. If the patient decides to schedule an appointment, the patient will come back another day, when it is less crowded. For an ASA 3 patient, an appointment is made. If the patient decides to wait in the waiting room, depending on the ASA score, the patient will be examined only by a nurse (for ASA score 1 patients) or first by a nurse followed by anesthesia assistant (for ASA score 2 patients). ASA score 3 patients are first examined by a nurse followed by an anesthesiologist. The last step for all patients is getting consent for surgery (with a signature of an anesthesiologist). If a patient has consent for surgery, the POS process ends here and the patient is planned for surgery. If no consent is given, the patient first has to get an ECG or visit the laboratory, cardiologist, or lung specialist for extra examination before obtaining consent.

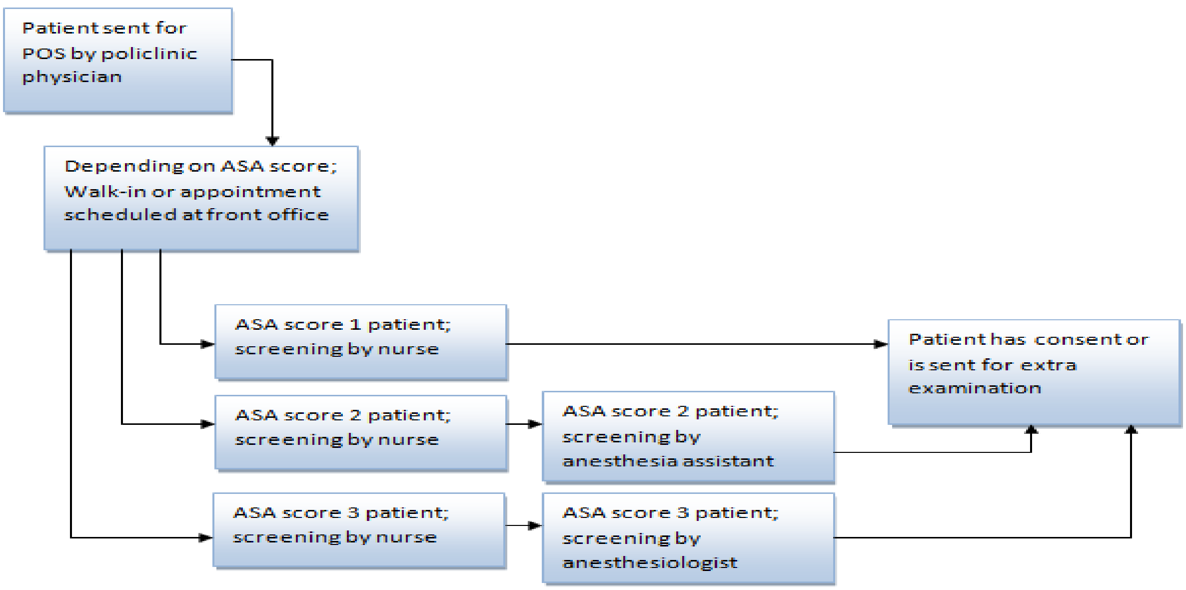


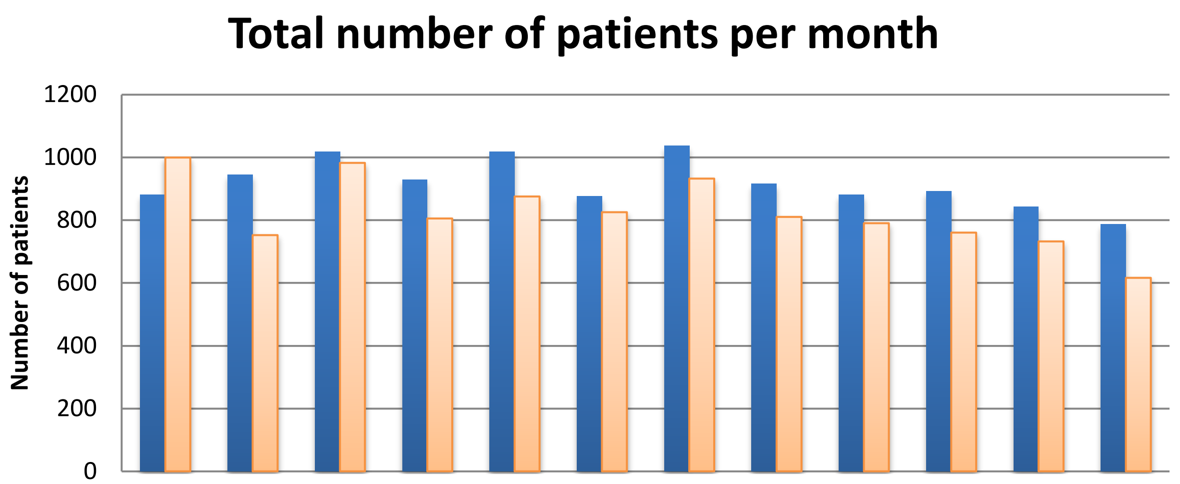
Figure 2.2: Preoperative screening process at Hengelo

2.2 CHARACTERISTICS OF PATIENTS AND PATIENT INFLOW

In this section we focus on the demand side of the preoperative screening process. Therefore, we analyze multiple characteristics of the patients and the patient inflow. We start with the total number of patients (Section 2.2.1), followed by a more detailed overview related to the age range of the patient (Section 2.2.2), division of specialism (Section 2.2.3) and ASA scores (Section 2.2.4). We continue with the arrival time of the patient (Section 2.2.5) and the urgency status (Section 2.2.6). We compare the characteristics of Almelo and Hengelo. We also distinguish between data originated by earlier research within ZGT and data obtained from our own measurements.

2.2.1 NUMBER OF PATIENTS

To determine the number of patients visiting the PAC per month and per year, we count the number of (walk-in) appointments that were made in the registration system between September 2010 and Augustus 2011. The total number of patients per month can be seen in Figure 2.3.



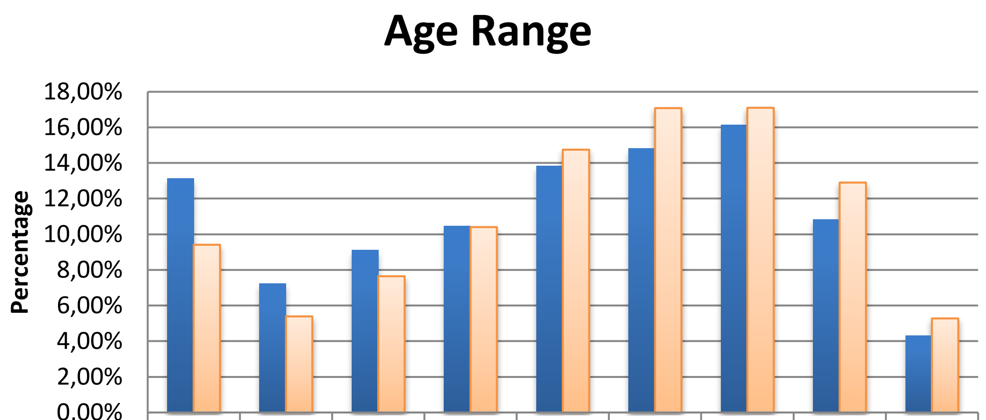
	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11
Almelo	881	945	1017	929	1018	875	1036	915	880	891	843	786
Hengelo	999	752	982	805	875	825	932	810	790	760	732	616

Figure 2.3: Total number of patients per month at Almelo and Hengelo

The total number of patients per year and per month between Almelo and Hengelo differs significantly ($p = 0.001$). In total, the number of patients examined at the PAC per year was 11016 at Almelo and 9878 at Hengelo. The mean number of patients at Almelo was 918 (standard deviation 75.7) and at Hengelo 823 (standard deviation 109.8) per month. The average number of patients per week between August 2010 and September 2011 was 210.9 (st. dev. 28.9) at Almelo and 188.3 (st. dev. 38.3) at Hengelo. These fluctuations in number of arrivals can lead to longer access and waiting times.

2.2.2 AGE RANGE

According to the employees of the PAC, children are impatient and take less time to screen, whereas for older people more time for screening is needed. To determine the percentage of children and percentages of other age levels, we analyze what the main differences are for every interval of 10 years. In Figure 2.4 the age range of the patients at Almelo and Hengelo is shown.



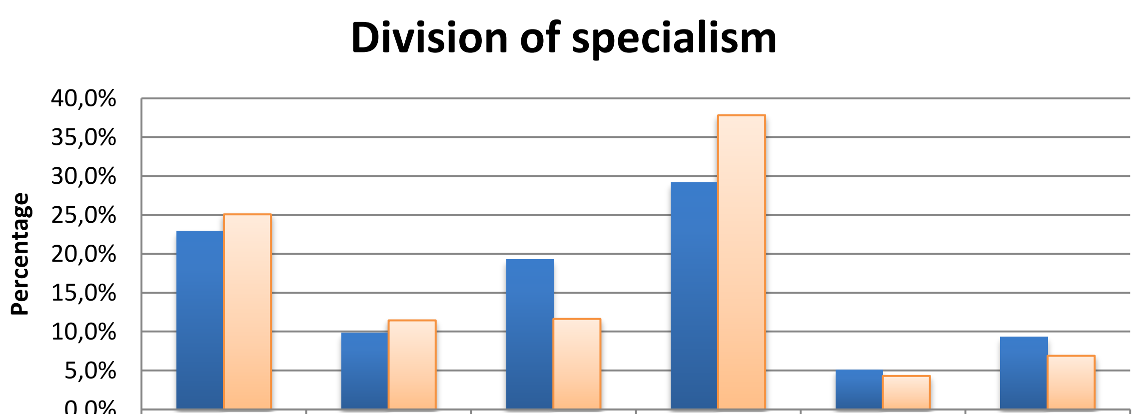
	0 - 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80+
Almelo	13,15%	7,25%	9,12%	10,48%	13,85%	14,83%	16,16%	10,85%	4,32%
Hengelo	9,42%	5,40%	7,65%	10,41%	14,75%	17,08%	17,10%	12,91%	5,28%

Figure 2.4: Percentage of patients per age interval of 10 years of total number of patients per year

As can be seen in the figure, patients visiting the PAC at Almelo are generally younger than the patients at Hengelo. The average age of patients at Almelo is 43.7 (st. dev. 23.8). For patients at Hengelo this is 47.7 (st. dev. 22.7) at Hengelo. As we will discuss in Section 2.2.4, the process steps that a patient needs to take is influenced by the age of the patient.

2.2.3 SPECIALISM OF PATIENTS

The allowed access time for POS depends on the surgical operation date. As we discuss in Section 2.3.6, the operation date differs per specialism. The preferred access time for a specialism with a short waiting list for surgery is shorter than for a specialism with a long waiting list. To obtain more insight in the division of specialism, we analyze the specialism which sends the patients for POS. Figure 2.5 shows the most common specialisms out of thirty. Although ophthalmology was indicated as specialism by 10.8% of the patients on the waiting list for surgical operation at Hengelo, we do not take them into account because these patients are not examined at the PAC.



	SUR	GYN	ENT	ORT	PLA	URO
Almelo	22,9%	9,8%	19,3%	29,2%	5,1%	9,4%
Hengelo	25,1%	11,5%	11,6%	37,8%	4,3%	6,9%

Figure 2.5: Percentage of patients per specialism

Figure 2.5 shows that the most common specialisms are orthopedics (Almelo 29.2%, Hengelo 37.8%) and surgery (Almelo 22.9%, Hengelo 25.1%) at Almelo as well as Hengelo. This is followed by ENT (ear, nose, and throat) (19.3%) at Almelo, and ENT (11.6%) and gynecology (11.5%) at Hengelo.

When we compare these percentages with the data from 2009, we see that at Almelo most patients came from the specialism orthopedics (27%), followed by ENT (26%), and surgery (18%). At Hengelo most patients also came from orthopedics (30%), followed by surgery (22%). This shows that the most common specialisms did not change over the last couple of years at Almelo and Hengelo.

2.2.4 ASA SCORE

To obtain more insight in the service the patients need, we analyze the different ASA scores. The ASA score is determined by the ASA score on the waiting list for the operation, whereby emergency patients and blanks (patients without an ASA score) are excluded from the analysis. Furthermore, according to procedures, all patients with ASA score 1 that are older than forty years old are classified as ASA score 2 patients. Additionally, all patients at Hengelo with an age lower than sixteen years old are classified as ASA score 2 as well. The percentages are shown in Figure 2.6.

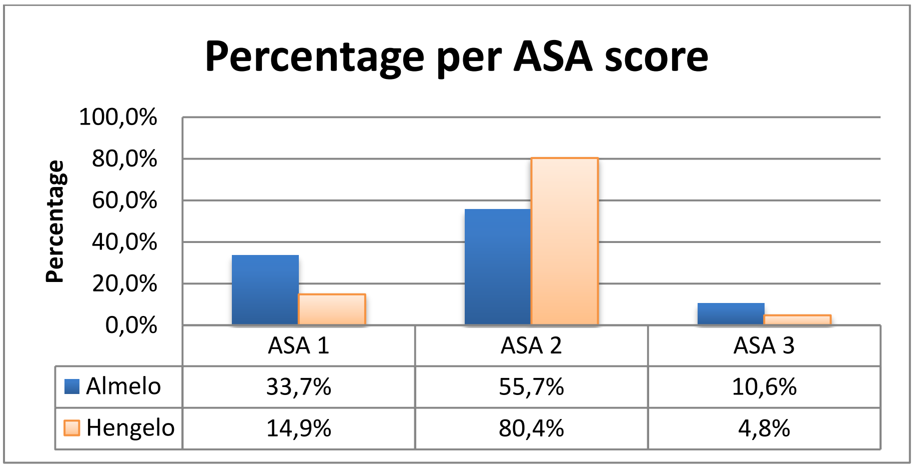


Figure 2.6: Percentage of patients per ASA score at Almelo and Hengelo

This figure shows that at Almelo 34% of the patients were given ASA score 1 and 66% was given ASA score 2 or 3. At Hengelo, 15% was given ASA score 1, 80% was given ASA score 2, and 5% was given ASA score 3.

In 2009, at Almelo 38% of the patients were given ASA score 1 and 62% were given ASA score 2 or 3. Hengelo had 62% ASA score 1, 36% ASA score 2, and 2% ASA score 3 patients. This shows that the average ASA scores at Almelo did not change significantly, whereas at Hengelo the ASA scores are increasing. These differences in ASA scores can partly be explained by the policy at Hengelo that all patients with an age lower than sixteen years old are classified as ASA 2. Furthermore, analysis of the ASA score per age range (Appendix A) shows that the percentage of high ASA score is correlated to the age range of the patients. The higher the age, the more patients are ASA score 2 and 3. With younger patients at Almelo and older patients at Hengelo, this explains the difference in ASA scores at Almelo and Hengelo.

These data on ASA scores indicate that more patients need screening by an anesthesia assistant or anesthesiologist at Hengelo than at Almelo. This may have influence on the waiting times at these care providers.

2.2.5 ARRIVAL OF PATIENTS

As part of the analysis of the patient inflow, we inquire the day and hour of arrival of the patients. We determine this by counting the times an appointment was made in the system per day and per hour.

Day of arrival

As can be seen in Figure 2.7, at Almelo most patients arrive on Monday (22%) and Tuesday (24%) and at Hengelo on Tuesday (24%) and Wednesday (22%). Remarkably, the number of patients arriving at Almelo is very low on Thursdays (16.6%) and at Hengelo on Fridays (15.4%).

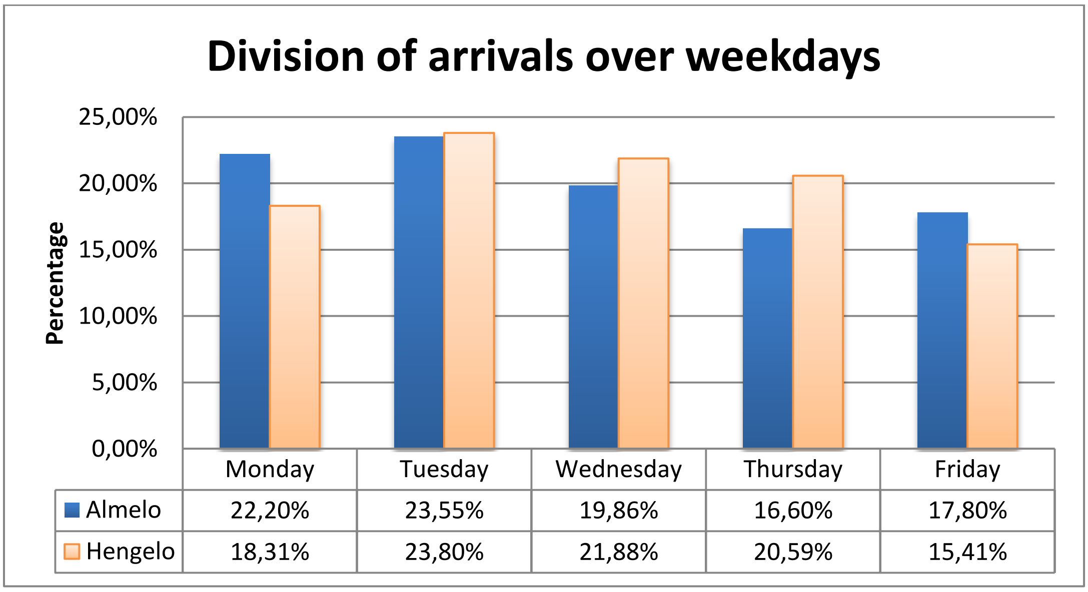
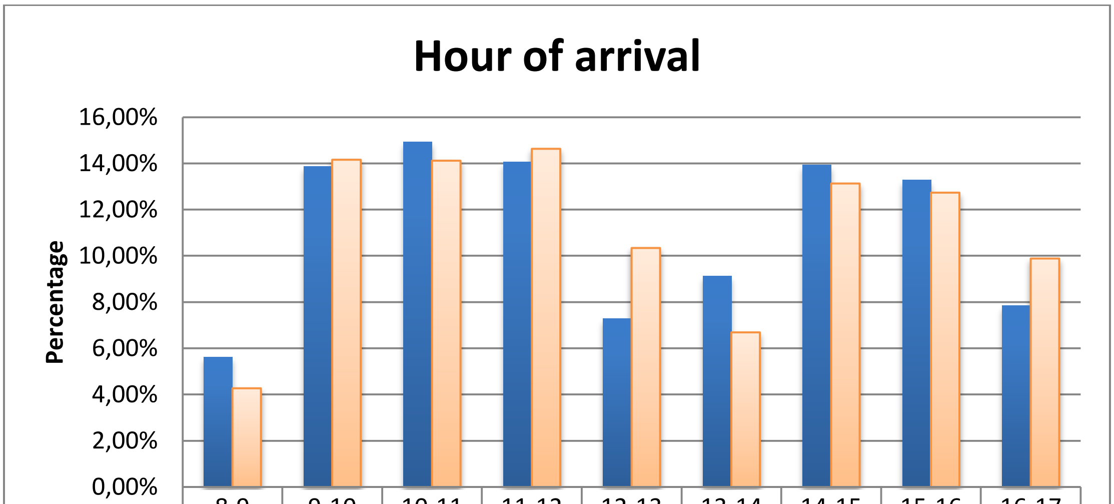


Figure 2.7: Division of arrivals over weekdays at Almelo and Hengelo

We use a two sample t-test to determine if there is a significant difference between weekdays. The test shows that there is a significant difference for almost each combination of weekdays. These different number of arrivals per weekday influences the waiting time per day. On the busiest days the waiting times will be longer than during less busy days.

Time of arrival

Not only is there a difference in number of arrivals per day, there is also a difference in time of arrival. We perform a correlation analysis to determine whether there is any difference between the time of arrival per weekday. The lowest correlation is between Wednesday and Friday at Hengelo, with a value of 0.854. This indicates a significant correlation between the time of arrival per weekday. Figure 2.8 shows the time of arrival of patients in percentage of the total number of arrivals per day. Hereby, on the x-axis, 8 - 9 means arrival time between 8:00 and 9:00 AM, 14 - 15 means between 2:00 PM and 3:00 PM, etc.



	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Almelo	5,63%	13,87%	14,94%	14,06%	7,29%	9,13%	13,93%	13,29%	7,85%
Hengelo	4,27%	14,16%	14,12%	14,64%	10,34%	6,69%	13,14%	12,74%	9,89%

Figure 2.8: Fraction of arrivals per hour of total number of patients at Almelo and Hengelo

Figure 2.8 shows that at Almelo as well as at Hengelo the busiest time of the day is between 9:00 AM and 12:00 PM. More than 46% of all patients per day (Appendix B) arrive within these three hours. Between 12:00 PM and 2:00 PM, the number of arrivals is significantly less. This is probably due to the lunch break at the policlinics. From 2:00 PM till 4:00 PM, the number of arrivals increases, whereas after 4:00 PM the number of arrivals decreases. These data do not differ from 2009. The busiest times of day at Almelo in 2009 were between 9 AM and 11 AM, followed by between 2 PM and 4 PM. At Hengelo, most patients arrived between 9 AM and 11 AM as well.

We come to the same conclusion as for the difference between the number of arrivals per day. Different number of arrivals per hour influences the waiting time. During the busiest hours the waiting times will be longer than during less busy hours. Hereby, we have to keep in mind that the busiest hours in this paragraph indicate the busiest hours for patients to arrive. Patients that arrive during the busiest hours may still have to wait during less busy hours. For example, Figure 2.8 shows that more patients arrive until 12 PM, which leads to more patients in the system at 12 PM as well. It takes time to screen these patients and therefore the number of patients waiting (and the level of busyness) may still be high at 12:15 PM.

2.2.6 URGENCY OF PATIENTS

Another characteristic of the patient inflow is that some patients have to be seen urgently. In general, these patients are already scheduled for an operation and have to be screened as soon as possible. However, the urgency or time before surgery differs per patients. We take into account all urgency levels up to four weeks/one month. Figure 2.9 shows the level of urgency, and the number of patients per year that were marked with this urgency level.

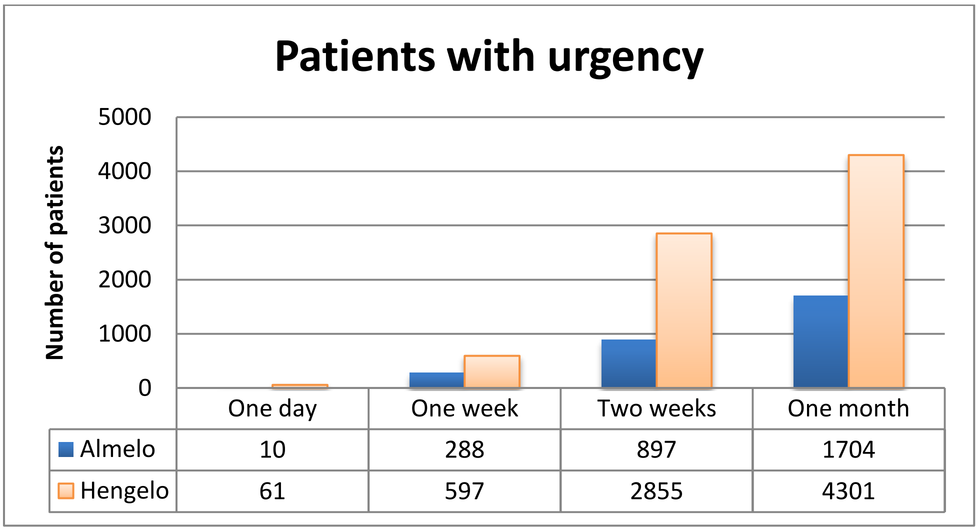


Figure 2.9: Patients with urgency from one day to one month at Almelo and Hengelo between September 2010 and August 2011

As can be seen in Figure 2.9, the number of patients with an urgency level is significantly higher at Hengelo compared to Almelo. Between September 2010 and August 2011, at Almelo, 2755 out of 15054 patients on the surgery waiting list were given an urgency level. 1704 of these patients had an urgency level of at most one month. At Hengelo, 7339 out of 14271 patients were given an urgency level. 4301 of these patients had an urgency level of at most one month. This indicates that more timeslots should be reserved for patients with high urgency at Hengelo than at Almelo.

In this section we focused on the demand side of the preoperative screening process. We found that there are several factors that influence the process of the PAC. In the next section, we continue with an analysis of the supply side and the performances.

2.3 CHARACTERISTICS OF PREOPERATIVE SCREENING SERVICE

In this section, we focus on the supply side of the preoperative screening process. We analyze the characteristics of the preoperative screening service and the performance. We start with the capacity details (Section 2.3.1), followed by the different planning methods (Section 2.3.2). Additionally, we discuss the differences in access (Section 2.3.3) and throughput time (Section 2.3.4) between Almelo and Hengelo, followed by the factors that influences the throughput time (Section 2.3.5). Last, we elaborate on the surgical operation waiting list (Section 2.3.6).

2.3.1 CAPACITY

Almelo has four rooms dedicated for examination. In general, three of these rooms are used by nurses, and one room by an anesthesiologist. Hengelo dedicates three rooms for examination. One or two are used by nurses, depending on the presence of an anesthesiologist, and one by an anesthesia assistant.

ZGT plans with an average examination time of 30 minutes per patient. With this examination time it is possible to examine a maximum of 8 patients per hour at Almelo, and 6 patients at Hengelo.

2.3.2 WALK-IN VERSUS APPOINTMENT

ZGT wants to have a one stop shop approach when possible and desired by the patient. A possible method to achieve this approach is providing the possibility to walk-in (or combining appointments with policlinics). The percentage of patients that walk-in depends on the location and ASA score. We define that a patient walks in if the appointment is scheduled and authorized on the same day. Therefore, an appointment is an option where patients choose a day and time to come back for examination. An appointment is always schedule on another day, so no appointments are planned on the same day as the scheduling date.

In 2009, at Almelo all patients made an appointment. At Hengelo, only all ASA 3 patients had to make an appointment with the anesthesiologist. For ASA 1 and 2 it was possible to walk-in or to make an appointment. Between 49% and 60% of the patients used the walk-in service depending on the day.

We compare this data from 2009 with 2010-2011 by determining the percentage of appointments scheduled and authorized on the same day. According to this analysis, the percentage of walk-in patients has increased in 2010-2011. On average, 31.6% of ASA score 1 patients and 11.8% of ASA score 2 or 3 walk-in at Almelo. At Hengelo this percentage is about 80% for ASA score 1 and 2 patients and 6.4% for ASA score 3. Overall, as shown in Figure 2.10, the average percentage of walk-in patients at Almelo is 20.5% and 78.4% at Hengelo.

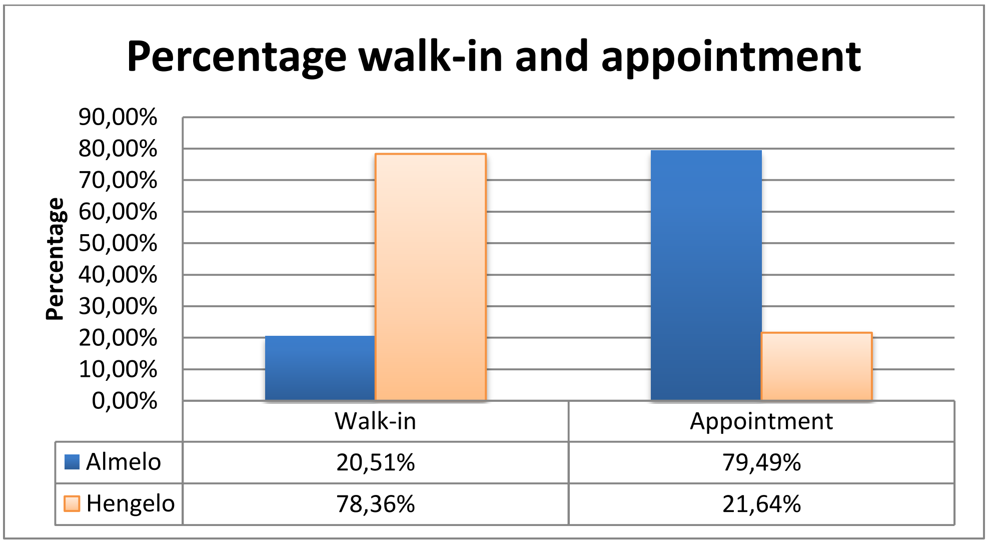


Figure 2.10: Percentage walk-in and appointment at Almelo and Hengelo

These planning methods influence the access time and waiting time. If all patients are offered an appointment instead of a walk-in possibility, the access times will be higher because patients have to come back at a later moment. On the other hand, an appointment planning method can regulate the number of patients waiting in the waiting room and the waiting time will therefore be lower than with a walk-in system.

2.3.3 ACCESS TIME

To decrease the possibility that preoperative screening delays surgical operations, access time which is shorter than the time till surgical operation is necessary. We define access time as the difference between the day of scheduling an appointment for preoperative screening and the day of the preoperative screening consult. To comfort the patient and improve patient satisfaction, a one stop shop approach (or otherwise a short access time) is desired.

However, 5.0% of surgical operations at Almelo and 7.2% at Hengelo is planned more than three months ahead. With an official expiration period of three months for consent, one stop shop or short access time has no use for these patients. Therefore, we analyze the current access times for 95% of the patients at Almelo and 92.8% at Hengelo with the shortest access times. Hereby, we assume that patients with the longest access time have a surgical operation date which exceeds three months.

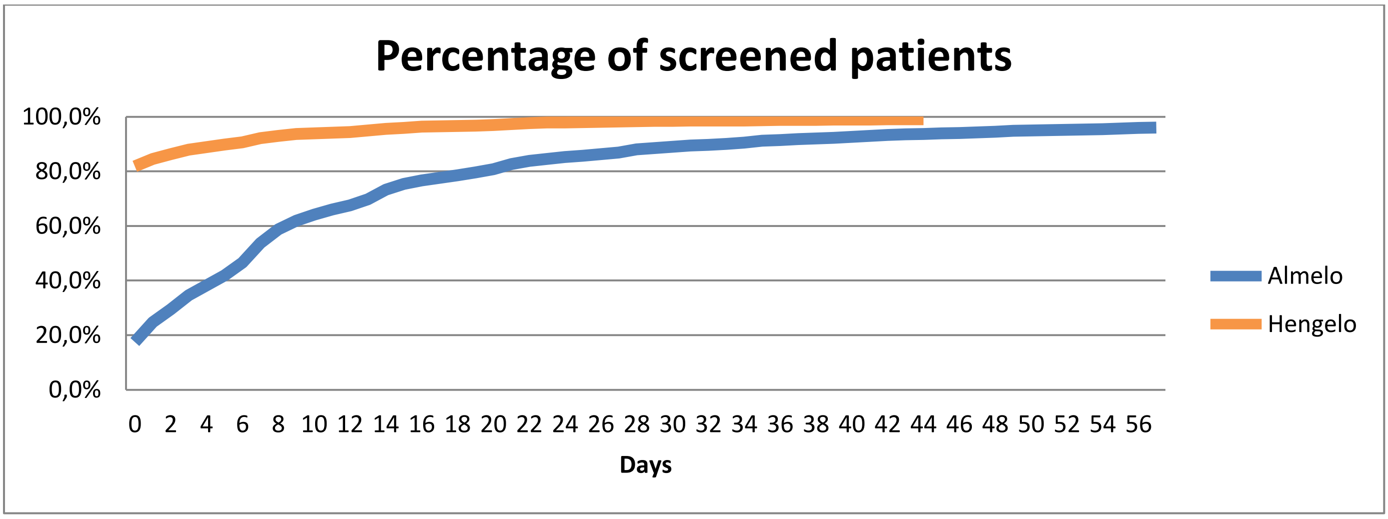


Figure 2.11: Percentage of patients screened in number of days at Almelo and Hengelo

The results in Figure 2.11 show that the access time for 95% of the patients at Almelo is within 50 days. For Hengelo, 92.8% of the patients is screened within 8 days. ASA score 1 patients were examined within 39 days and ASA score 2 or 3 patients within 57 days at Almelo. For Hengelo, 92.8% of ASA score 1 or 2 patients were examined within 8 days, and ASA score 3 patients within 13 days. There are several explanations for these results. First, the significant difference in access times can be explained by the different planning methods. 80% of the patients at Hengelo are seen on the same day as their policlinic appointment. This leads to an access time of 0 days for those patients. Second, the patients at Almelo are scheduled for POS at approximately half of the expected access time for their surgery, whereas at Hengelo patients are scheduled earlier. This leads to an increased access time at Almelo. Third, the percentage of patients at Almelo with a surgery within three months is higher (95% versus 92.8%), which leads to a higher access time. However, if we analyze the access time at Hengelo with a percentage of 95%, this still leads to significantly shorter access time (14 days).

Access time distribution

We analyze the most recent data to determine how the current distribution of the access time is. In September 2011, 1133 patients arrived at Almelo for preoperative screening. 301 of the patients could be examined using walk-in (27%). The remaining 832 patients schedule an appointment. 402 were examined within one week (48%), and 228 within two weeks (27%).

At Hengelo, 919 patients arrived at Hengelo for preoperative screening. 772 of the patients could be examined using walk-in (84%). The remaining 147 patients made an appointment. 78 were examined within one week (53%), and 42 within two weeks (29%). The distributions for the access times for Almelo (Figure 2.12) and Hengelo (Figure 2.13) are shown below.

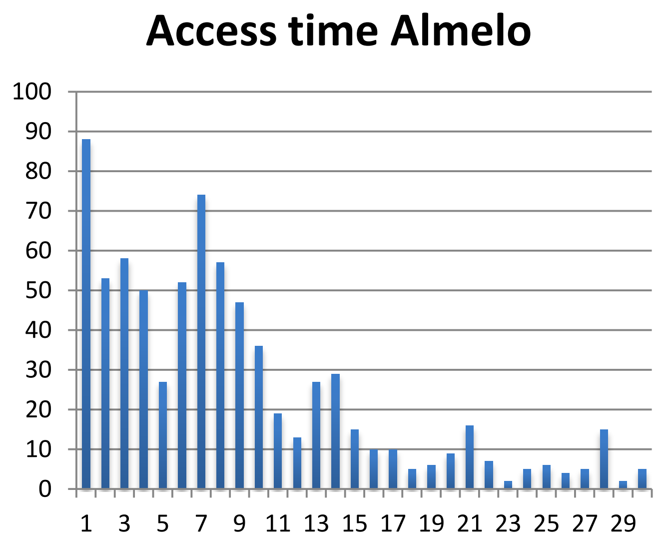


Figure 2.12: Access time distribution at Almelo (Sept 2011)

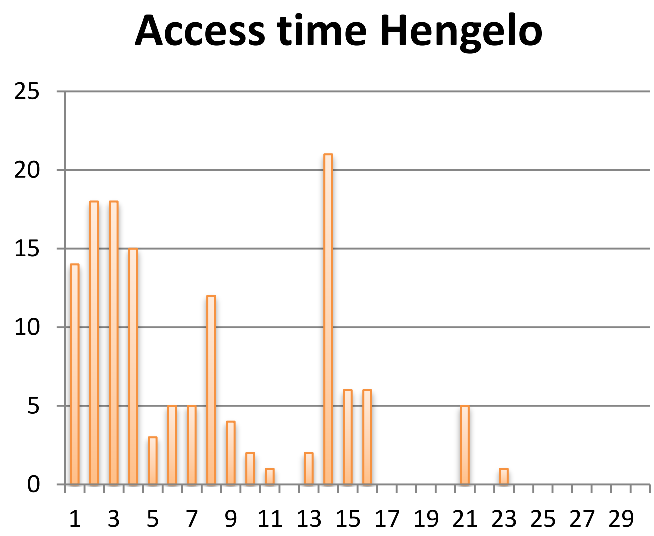


Figure 2.13: Access time distribution at Hengelo (Sept 2011)

These figures show that patients at Hengelo are scheduled for POS as soon as possible, whereas the timing for an appointment at Almelo is further in the future. The most important aspect of the access time is that it is shorter than the time till operation date. However, having short access times is desired by the patients and by the ZGT as well. If patients are already screened, there are fewer backlogs and more flexibility to (re-)schedule patients for an operation.

2.3.4 THROUGHPUT TIME

An important characteristic of the POS service is throughput time. We define throughput time as the difference between the time that the patient arrives at the front office to walk-in or the appointment time and the time the patient leaves after examination at the PAC. We distinguish the throughput time in four stages.

1. The first stage is the time between entering the waiting room and entering the examination room of the nurse. This is the first waiting time for the patient and is categorized as the waiting time for a nurse.
2. The second stage is the screening time of the patient by the nurse. This is the time between entering and leaving the examination room. If the patient is of type ASA 1 the throughput time ends here. In case of ASA score 2 or 3 patients, a visit to the anesthesia assistant or anesthesiologist is required.
3. For ASA score 2 and 3 patients, in the third stage, patients again wait in the waiting room until they are seen by the anesthesia assistant or anesthesiologist. This second waiting period is categorized as the waiting time for an anesthesiologist or anesthesia assistant.
4. The fourth and final stage is the screening time of the anesthesia assistant or anesthesiologist. Hereby, the screening time is the time between entering and leaving the examination room of the anesthesia assistant or anesthesiologist.

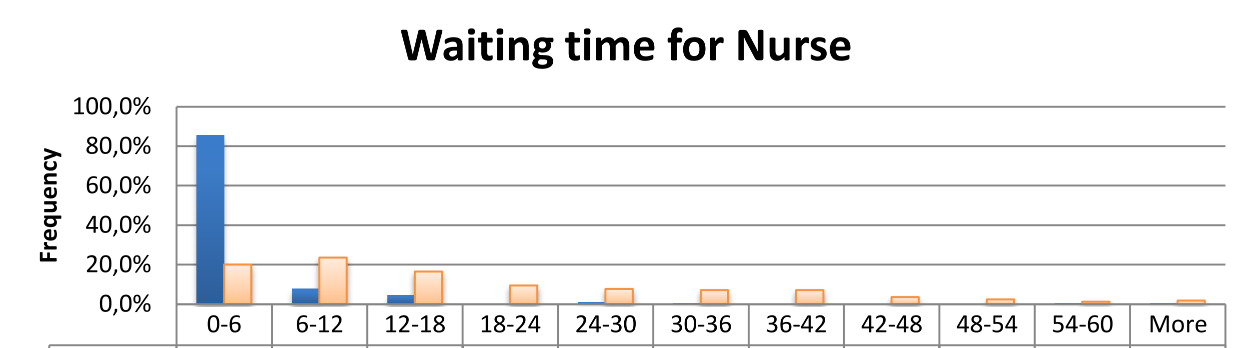
Random sample

To determine the current waiting and screening times, we take a random sample at both locations. A random sample to measure all stages was taken from Monday till Friday in week 48 of 2011, and on Monday in week 49 of 2011. Surprisingly the exact same number of patients participated in the sample at both locations. In total, 222 patients participated in Almelo and 222 patients at Hengelo.

With an estimated population of 10000, 222 patients in the random sample, and a confidence interval of 95%, a marginal error of 6.5% was calculated. The calculations can be found in Appendix C.

Waiting time nurse

In the first stage the waiting time for the nurse is determined. The waiting times are shown in Figure 2.14.



	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	More
Almelo	85,5%	7,7%	4,5%	0,0%	0,9%	0,5%	0,0%	0,0%	0,0%	0,5%	0,5%
Hengelo	20,0%	23,5%	16,5%	9,4%	7,6%	7,1%	7,1%	3,5%	2,4%	1,2%	1,8%

Figure 2.14: Waiting time for nurse at Almelo and Hengelo

During the sample period the average waiting time was 3.1 minutes (st. dev. 7.9 minutes) at Almelo and 19.7 minutes (st. dev. 15.3 minutes) at Hengelo. Additionally, the examination starts within 15 minutes for 95% of the patients at Almelo, whereas this was 48 minutes at Hengelo. The maximum waiting time for a nurse in Almelo was 75 minutes and 87 minutes in Hengelo.

There was a difference between the average waiting time for walk-in patients and patients with an appointment at Almelo. The average waiting time for walk-in patients at Almelo was 3.9 minutes, whereas this was 2.7 minutes for patients with an appointment.

Notable, for patients with an appointment, we distinguish between voluntary waiting time (arriving early for an appointment) and involuntary waiting time. For these patients we only take into account the difference between the appointment time and the actual start of the screening. We do not take the (voluntary) waiting time for patients that arrive earlier than the appointment time into account. We discuss the effect of this factor in detail in Section 2.3.5.

Screening time by nurse

The second stage is the screening time by a nurse. The duration of the screening is shown in Figure 2.15.

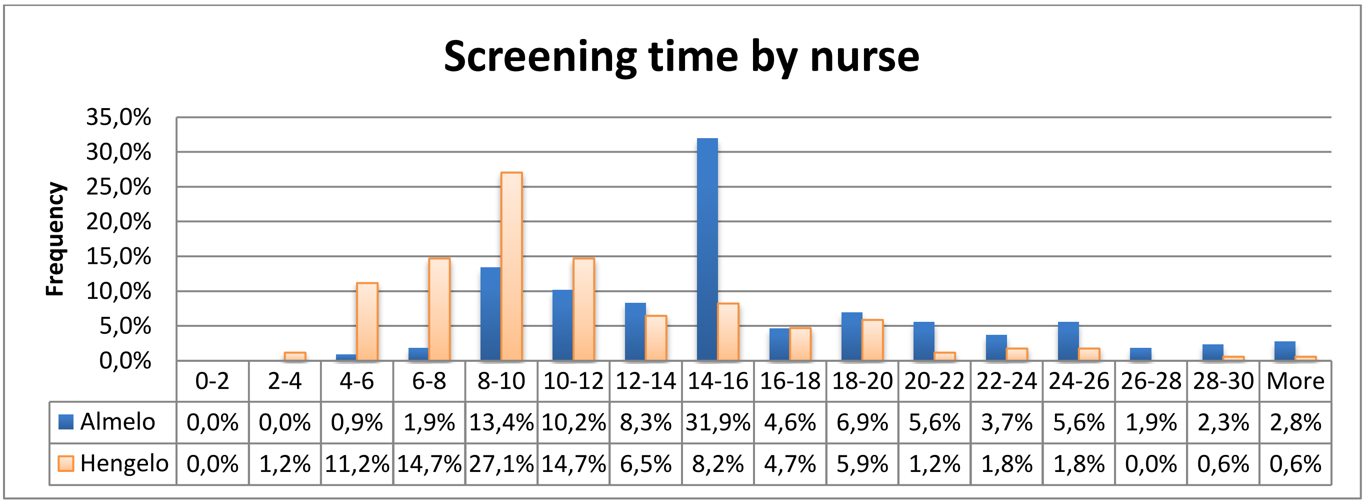


Figure 2.15: Screening time by nurse for Almelo and Hengelo

During the sample period the average screening time was 16.5 minutes (st. dev. 6.2 minutes) at Almelo and 11.6 minutes (st. dev. 5.2 minutes) at Hengelo. Additionally, the screening was done within 26 minutes for 95% of the patients at Almelo, whereas this was 22 minutes at Hengelo. The maximum screening time by a nurse was 40 minutes at Almelo and 33 minutes at Hengelo. Remarkable, as can be seen in Figure 2.15, the screening time was often determined exactly on 10 minutes at Hengelo and exactly 15 minutes at Almelo.

After analyzing the difference in screening time per ASA score at Almelo, we find that the average screening time by the nurse for ASA score 1 and 2 patients does not differ significantly. On average, an ASA score 1 patient is screened in 15.4 minutes (st. dev. 5.3 minutes) whereas an ASA score 2 patient is screened in 15.7 minutes (st. dev. 5.3 minutes). The average screening time for ASA score 3 patients was 24.5 minutes (st. dev. 7.3 minutes). Additionally, because of not having enough information on the different ASA scores at Hengelo (e.g. the number of ASA score 3 patients was only four), we assume the same consultation time by a nurse of 11.6 minutes (st. dev. 5.2 minutes) for all patients at Hengelo.

Waiting time for anesthesiologist/anesthesia assistant

The third stage is the waiting time for an anesthesiologist or anesthesia assistant. The duration of the screening is shown in Figure 2.16

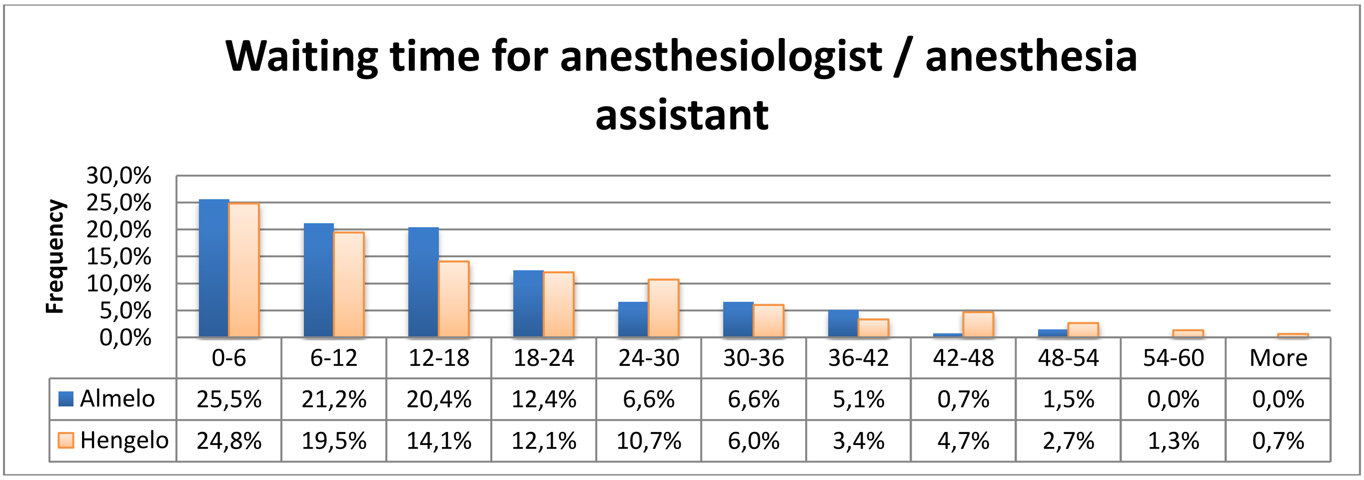
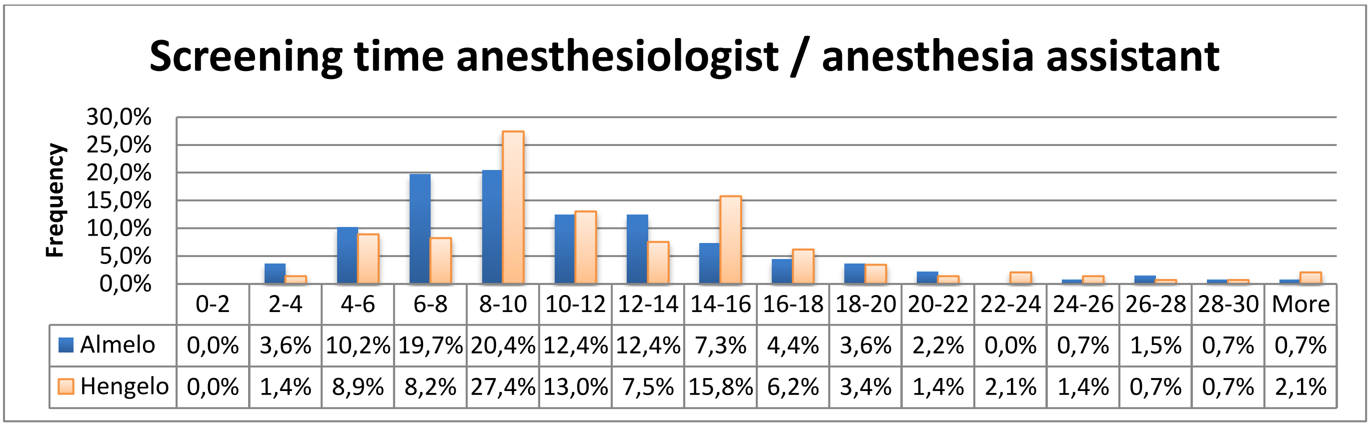


Figure 2.16: Waiting time for anesthesiologist or anesthesia assistant at Almelo and Hengelo

During the sample period the average waiting time was 15.5 minutes (st. dev. 11.8 minutes) at Almelo and 18.4 minutes (st .dev. 14.7 minutes) at Hengelo. Additionally, the examination by the anesthesiologist starts within 21 minutes for 95% of the patients at Almelo, whereas this was 48 minutes for consultation by an anesthesiologist or anesthesia assistant at Hengelo. The maximum waiting time for an anesthesiologist or anesthesia assistant was 51 minutes at Almelo and 65 minutes at Hengelo.

Screening time by anesthesiologist/anesthesia assistant

The last stage is the screening time by an anesthesiologist or anesthesia assistant. The duration of the screening is shown in Figure 2.17.



	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	More
Almelo	0,0%	3,6%	10,2%	19,7%	20,4%	12,4%	12,4%	7,3%	4,4%	3,6%	2,2%	0,0%	0,7%	1,5%	0,7%	0,7%
Hengelo	0,0%	1,4%	8,9%	8,2%	27,4%	13,0%	7,5%	15,8%	6,2%	3,4%	1,4%	2,1%	1,4%	0,7%	0,7%	2,1%

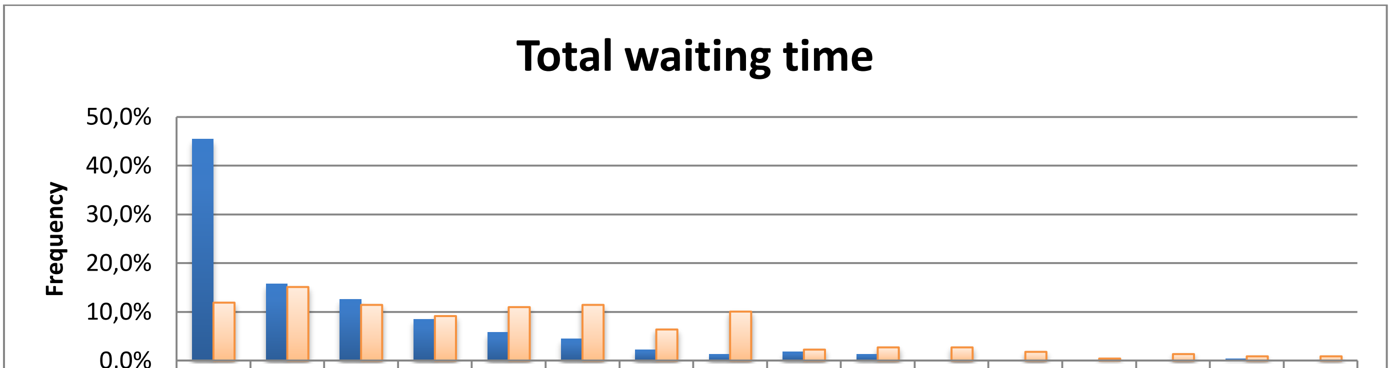
Figure 2.17: Screening time by anesthesiologist or anesthesia assistant at Almelo and Hengelo

During the sample period the average screening time was 11.2 minutes (st. dev. 5.3 minutes) at Almelo and 12.7 minutes (st. dev. 6.0 minutes) at Hengelo. Additionally, the screening was done within 18 minutes for 95% of the patients at Almelo, whereas this was 24 minutes at Hengelo. The maximum screening time by an anesthesiologist was 31 minutes at Almelo and 41 minutes at Hengelo. Remarkable, the screening time at Hengelo was often set exactly at 10 or 15 minutes.

After analyzing the difference in screening time per ASA score at Almelo, we find that the average screening time by an anesthesiologist is the shortest for ASA score 1 with an average of 8.9 minutes (st. dev. 3.5 minutes). ASA score 2 patients are screened in 10.9 minutes (st. dev. 4.6 minutes) whereas an ASA score 3 patient is screened in 17.3 minutes (st. dev. 5.6 minutes). The consultation by an anesthesia assistant or anesthesiologist of 12.7 minutes (st. dev. 6.0 minutes) at Hengelo is the same for all patient types. There are two reasons: (1) not enough information was obtained on anesthesiologists to treat them separately, (2) pre-classified ASA score 1 patients who were examined by an anesthesia assistant actually were ASA score 2 patients.

Average total waiting time

During the sample period the average total waiting time was 12.6 minutes (st. dev. 14.6 minutes) at Almelo and 28.4 minutes (st. dev. 20.8 minutes) at Hengelo. The distribution of total waiting time is shown in Figure 2.18.



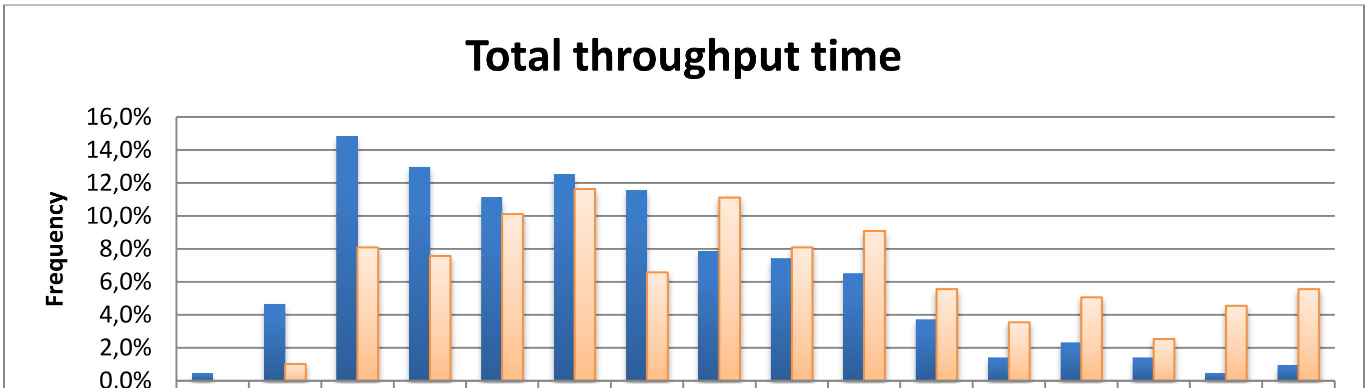
	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72	72-78	78-84	84-90	More
Almelo	45,5%	15,8%	12,6%	8,6%	5,9%	4,5%	2,3%	1,4%	1,8%	1,4%	0,0%	0,0%	0,0%	0,0%	0,5%	0,0%
Hengelo	11,9%	15,1%	11,5%	9,2%	11,0%	11,5%	6,4%	10,1%	2,3%	2,8%	2,8%	1,8%	0,5%	1,4%	0,9%	0,9%

Figure 2.18: Total waiting time at Almelo and Hengelo

The total waiting time for 95% of the patients at Almelo was within 41 minutes, whereas this was within 68 minutes at Hengelo. The maximum total waiting time was 88 minutes at Almelo and 87 minutes at Hengelo.

Average throughput time

During the sample period the average total throughput time was 36.3 minutes (st. dev. 19.5 minutes) at Almelo and 48.4 minutes (st. dev. 24.3 minutes) at Hengelo. The distribution of total waiting time is shown in Figure 2.19.



	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72	72-78	78-84	84-90	More
Almelo	0,5%	4,6%	14,8%	13,0%	11,1%	12,5%	11,6%	7,9%	7,4%	6,5%	3,7%	1,4%	2,3%	1,4%	0,5%	0,9%
Hengelo	0,0%	1,0%	8,1%	7,6%	10,1%	11,6%	6,6%	11,1%	8,1%	9,1%	5,6%	3,5%	5,1%	2,5%	4,5%	5,6%

Figure 2.19: Total throughput time at Almelo and Hengelo

The total throughput time for 95% of the patients at Almelo was within 74 minutes, whereas this was within 91 minutes at Hengelo. The maximum total throughput time was 124 minutes at Almelo and 149 minutes at Hengelo. Hereby, the biggest influence on throughput time was the waiting time.

This section shows that the total average waiting time is longer than accepted, especially at Hengelo. Moreover, the waiting time has a big influence on the throughput time. In the next section we analyze several factors that influence the throughput time as well.

2.3.5 FACTORS INFLUENCING THROUGHPUT TIME

There are different factors that influence the waiting time and thereby the throughput time. We first discuss the influence of patients arriving early or late for their appointment, followed by the influence of patients who do not show up, and the assignment of wrong ASA scores. Last, we discuss the influence of extra examination before consent and the effect on the percentage of consent on time.

Earliness

Patients arriving earlier than the appointment time leads to extra waiting time for these patients. However, this waiting time is defined as 'voluntary' for a patient. As mention in the previous section on the waiting time for a nurse (Section 2.3.4), the low average waiting time at Almelo is partly caused by the method we use to calculate the waiting times. For patients with an appointment, we only take into account the difference between the appointment time and the actual start of the screening and do not include the extra waiting time for patients that arrive earlier than the appointment time. When we take the extra (voluntary) waiting time into account, the waiting time for a patients with an appointment at Almelo increases to 9.8 minutes (st. dev. 11.2 minutes) with a division as shown in Figure 2.20.

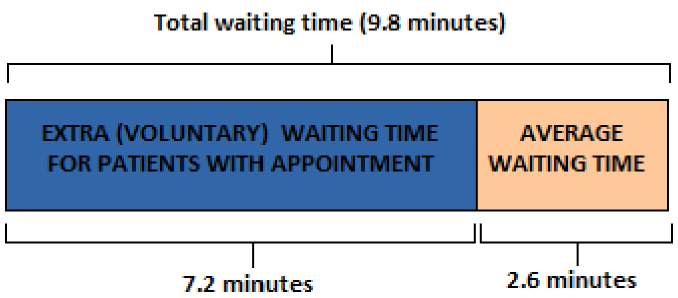


Figure 2.20: Division of average waiting time at a nurse for patients with an appointment at Almelo

To determine the extra voluntary waiting time we first analyze the number of patients that arrive early by a random sample. 167 patients at Almelo enter the PAC with an appointment. We find that in total 141 of these patients arrived before or on time of appointment. The maximum amount of time a patient was early was 55 minutes. On average, patients that arrived before appointment time were 12.7 minutes early, with a standard deviation of 9.9 minutes. 95% of these patients (131 patients) arrived within 31 minutes before their scheduled appointment time.

An advantage of arriving earlier than the appointment time is the possibility for a patient to be screened earlier than appointment time, if a nurse is unoccupied. Therefore, for the second step, we analyze the patients that arrived early and find that the screening is started before the appointment time for 74 out of 141 patients (52.5%). The maximum amount of time a patient was screened early was 40 minutes before appointment time. On average, patients that arrived before appointment time were screened 10.4 minutes earlier, with a standard deviation of 8.6 minutes. A drawback of screening patients before their appointment time is that patients that arrive later, but still on time for their appointment, may have to wait longer.

With the previous figures we calculate the average voluntary waiting time. We find that 53% of the patients that arrive early are on average screened 10.4 minutes before appointment time. The other 47% do not have any advantage of arriving early. This leads to an average start of the screening of 5.5 minutes before appointment time if patients arrive early. When including the average arrival time before appointment of 12.7 minutes, we determine that the voluntary waiting time for patients is (12.7-5.5=) 7.2 minutes. This leads to the conclusion that patients with an appointment have an extra (voluntary) waiting time of 7.2 minutes. Furthermore, because 75% of the patients at Almelo had an appointment, 5.4 minutes (0.75 * 7.2) can be added to the average waiting time for a nurse and the total waiting time at Almelo as voluntary waiting time.

Lateness

Patients arriving late for their appointment influence not only the waiting time for the patients, but the utilization of the nurse and anesthesiologist as well. We analyze the number of patients that were late by a random sample. 167 patients at Almelo enter the PAC with an appointment. We find that in total 13.8% of these patients arrived late. The maximum amount of time a patient was late was 50 minutes. This amount of time is considered as an outlier for the analysis. On average, late patients arrived 7.0 minutes after their scheduled appointment time, with a standard deviation of 6.6 minutes. 95% of the late patients arrived within 20 minutes of their scheduled appointment time.

No shows

Patients not showing for their appointment influence the utilization of care providers. We analyze the number of patients that did not show by counting the number of appointments that were cancelled on day of screening. At Almelo, we find that in total 2.9% of the patients did not show, whereas this percentage is 3.6% at Hengelo. Hereby, the estimation of the percentage at Hengelo may be too high, because when walk-in patients decided to make an appointment instead, the walk-in appointment is cancelled and is included as no show.

Assignment of wrong ASA type

It occasionally happens that a patient is planned for the wrong POS process because of the assignment of the wrong ASA score. There are two possibilities for this to happen.

The first possibility is that the policlinic physician assigns an ASA score that is too low. In this case a patient with an actual ASA score 2 is indicated to be screened only by a nurse, because of the ASA score 1. The random sample shows that this happens to 5.4% of the patients at Almelo and 9.7% at Hengelo. Part of these percentages may be caused by procedures at the PAC of both locations that patients older than forty years old assigned as ASA score 1 are reassigned as ASA score 2 patients. Moreover, at Hengelo, an ASA score 1 patient younger than sixteen years is reassigned as ASA score 2 patient as well.

The second possibility is an ASA score that is too high. In this case a patient with an actual ASA score of 1 is screened by an anesthesiologist and a nurse, whereas screening by a nurse was sufficient. There are two ways for this to happen. The first one is by the policlinic physician, the second by the nurse of a PAC. The random sample shows that in 4.1% the policlinic physician indicates an ASA score which is too high, whereas this is the case for 5.9% for the nurse of the PAC.

Extra examination before consent

Another influential factor for throughput time is extra examination. In some cases preoperative screening is not enough to determine whether the patient is ready for surgery. In that case, the patient is addressed for further research. There is one difference between Almelo and Hengelo related to this research. In Hengelo, nurses at the PAC perform an ECG themselves, whereas at

Almelo the patient is directed to another department. Therefore, the throughput time at Hengelo may be higher for patients with an ECG.

Analysis of the random sample shows that 86% of the patients at Almelo and 77% at Hengelo leave the PAC with consent for surgery. Hereby, 38 patients (17%) at Hengelo got consent after an ECG. The division of the most ordered examinations does not differ that much. Figure 2.21 shows that ECG is ordered/performed most of all extra examinations (57% - 62%), followed by lab (27% - 30%) and cardio (5% – 7%).

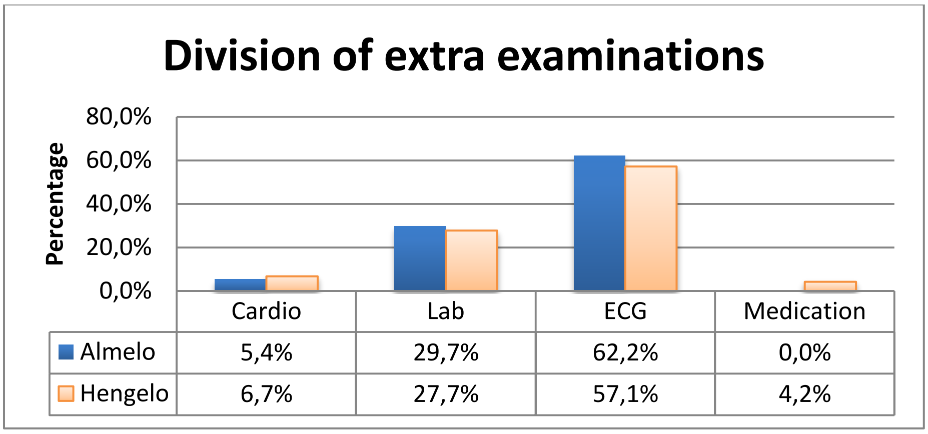


Figure 2.21: Division of extra examinations at Almelo and Hengelo

Although the division of extra examinations does not differ, the number of extra examinations ordered does differ significantly between Almelo and Hengelo. In total, 37 extra examinations were ordered at Almelo and 119 were performed at Hengelo. Figure 2.22 shows that extra examinations are ordered/performed approximately three times as often at Hengelo as at Almelo. For example, an ECG is performed at almost 31% of the patients at Hengelo, whereas this is only ordered for 10% at Almelo. Same rule applies for examination at the laboratory. Almost 15% of the patients at Hengelo have to visit the lab before consent, in comparison to 5% at Almelo.

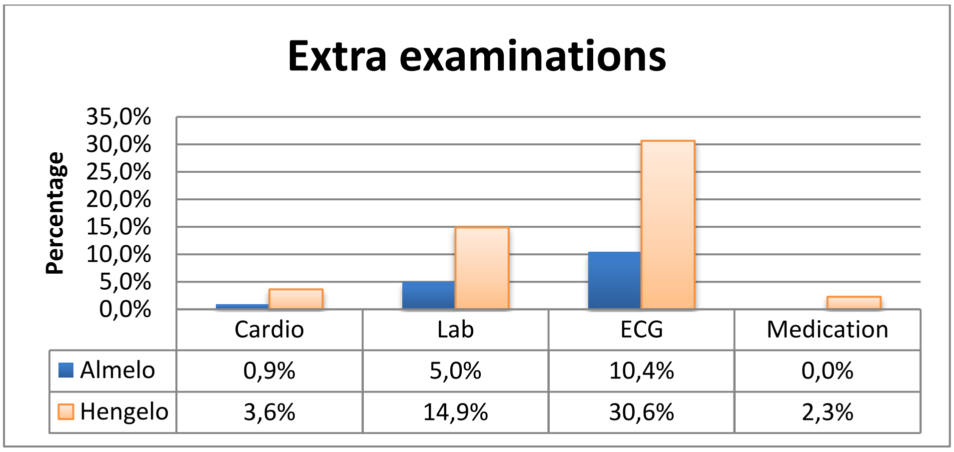


Figure 2.22: Percentage of patients with extra examination at Almelo and Hengelo

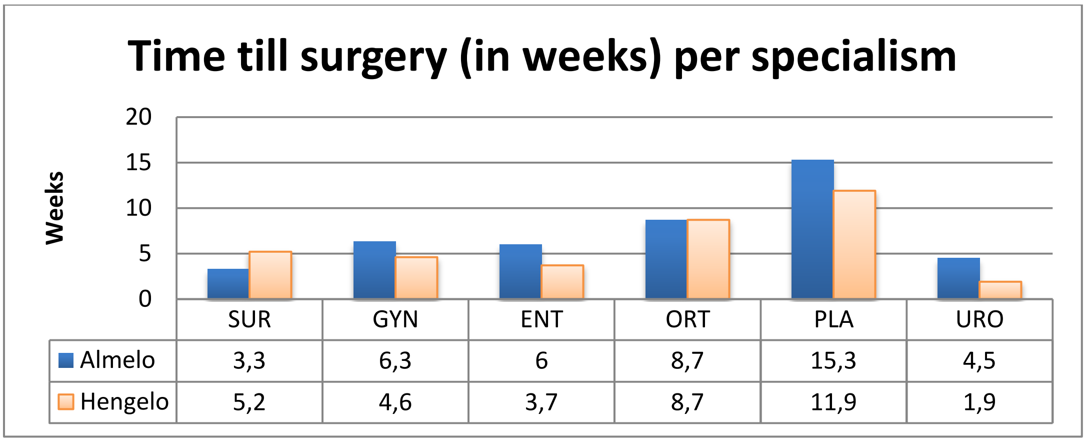
According to the employees at Almelo and Hengelo the time before results of extra examination are known depends on the kind of examination. Results of an ECG or Lab are known within one or two days, whereas consult and results from the cardiologist take up 20 to 30 days. This indicates that patients that are sent for a consultation to a cardiologist or lung specialist have a higher probability of not having consent before operation date.

Percentage consent on time

A consequence of these extra examinations (and the timing of planning an appointment) is that some operations have to be postponed or even cancelled. We determine the cancellation rate by first calculation the number of operations where the patient did not have consent at the time the operation was cancelled. We compare this number with the total number of operations. At Almelo, 98.4% has consent on time. At Hengelo, this is 99.8%. Notably, the number of cancellations may not always be due to not having consent on time, therefore the percentage may be too low.

2.3.6 WAITING LIST FOR SURGERY

The waiting list for surgery influences the number of patients at the PAC within a certain time frame. If there is a short waiting list and therefore a short access time, there is not much room for scheduling the POS. The waiting list for surgery depends on the location. The average time till surgery per specialism for December 2011 is shown in Figure 2.23.



	SUR	GYN	ENT	ORT	PLA	URO
Almelo	3,3	6,3	6	8,7	15,3	4,5
Hengelo	5,2	4,6	3,7	8,7	11,9	1,9

Figure 2.23: Time till surgery in weeks per specialism at Almelo and Hengelo (December 2011)

The figure shows that the average time till surgery is highest for a plastic surgery patient at Almelo with 15.3 weeks and lowest at Hengelo with 1.9 weeks for a urology patient. For orthopedic patients we were only able to obtain the average time till surgery of Almelo and Hengelo combined. Therefore, we assume that time till surgery for an orthopedic patient is 8.7 weeks for both locations. These figures indicate that in general patients arriving from the urology policlinic should have a shorter access time for POS than patients from orthopedics.

2.4 POINTS OF IMPROVEMENT

In this section we discuss the most important points of improvement found by analyzing the demand side, supply side and performances. An important aspect in our research is the satisfaction of the patients. Long access times and long waiting times have a negative influence on this patient satisfaction. Therefore, we explain how current patient satisfaction, and thereby the current quality of care, is influenced by the long access (Section 2.4.1) and waiting time (Section 2.4.2). We define access time as the difference between the day of scheduling an appointment for preoperative screening and the day of the preoperative screening consult. We define waiting time as the time a patient has to wait in the waiting room of the preoperative anesthesia clinic (without the voluntary waiting time).

2.4.1 LONG ACCESS TIME

As we found in Section 2.3.3, the access time is longer at Almelo than at Hengelo. At Almelo 95% of the patients is examined within 50 days, whereas this is 14 days at Hengelo. The most important aspect of the access time is that it is shorter than the time till operation date. However, having short access times is desired by ZGT. If patients are already screened, there are fewer backlogs and there is more flexibility to (re-)schedule patients for an operation. Moreover, the hospital states that they want to provide a one stop shop service when possible and desired by the patient. This is in line with the patients preferences. Scholtens [4] shows that the most preferred service aspect by patients (for a CT scan) is a one stop shop service (43.2% of respondents), followed by short access time (22.4%), short waiting time (18.8%) and finally the autonomy in choice of moment (15.7%). We assume that these percentages are roughly the same for preoperative screening. There are several aspects that may influence the length of access times:

- The number of patients that needs an examination differs per month (Section 2.2.1). If fewer patients need to be screened the access time can decrease. On the other hand, if more patients need screening the access time increases.
- The demand for a preoperative screening differs per specialism. Most common specialisms are orthopedics (Almelo 29.2%, Hengelo 37.8%) and surgery (Almelo 22.6%, Hengelo 25.1%). This is followed by ENT (19.3%) for Almelo, and ENT (11.6%) and gynecology (11.5%) for Hengelo (Section 2.2.3). Collaboration between the departments, by for example combining appointments, can decrease access time. Additionally, the waiting list for surgical operation differs per specialism. The preferred access time for a specialism with a short waiting list is shorter than for a specialism with a long waiting list.
- The preferred planning method differs per location. At Almelo, most patients (79%) have to schedule an appointment to come back another day, whereas most patients at Hengelo are examined on a walk-in basis (78%) (Section 2.3.2). The appointment planning method at Almelo leads to less one stop shop possibilities and therefore to longer access time as well. Hereby, a factor that influences the possibility to walk-in is the ASA score. Patients with a low ASA score have a higher possibility to walk-in because they only have to be screened by a nurse. This influences the access time for the patients as well. In both hospitals the access time for lower ASA scores is shorter than high ASA scores (Section 2.3.3).
- Last, the timing of scheduling an appointment influences the access time. At Almelo, policy is to schedule an appointment at half length of the time till surgery, whereas at Hengelo patient are asked to come back the next day (Section 2.1 and 2.3.3). This leads to more backlogs and less flexibility to (re-)schedule patients.

This section showed that there are several aspects that influence the patient satisfaction. Patients prefer the possibility of one stop shop and a short access time. This is currently not the case at Almelo. The most influential factors on the one stop shop possibility and the access time are the planning method and the timing of scheduling an appointment. Currently, most patients that arrive at the PAC have to schedule an appointment at approximately half length of the operation date. This decreases the possibility of one stop shop and increases the access time. In the next section we focus on another aspect that influences patient satisfaction, long waiting time.

2.4.2 LONG WAITING TIME

As found in Section 2.3.4, the average total throughput time was 36.3 minutes (st. dev. 19.5 minutes) at Almelo and 48.4 minutes (st. dev. 24.3 minutes) at Hengelo. A large influence on the difference in throughput time was waiting time. The total average waiting time is longer at Hengelo than at Almelo. On average, patients have to wait for 12.6 minutes (st. dev. 14.6 minutes) at Almelo, whereas this is 28.4 minutes (st. dev. 20.8 minutes) at Hengelo. Total waiting time for 95% of the patients at Almelo was within 41 minutes, whereas this was within 68 minutes at Hengelo.

In 2009, ZGT stated that an average waiting time of 15 minutes, with a maximum of 30 minutes, is acceptable. Although this is a reasonable objective, research by Scholtens [4] reveals that the accepted waiting time for patients depends on the planning method. The mean maximum acceptable waiting time when having an appointment is 12.38 minutes, whereas with a walk-in system patients are willing to wait longer. In this case the accepted waiting times is almost doubled with a maximum acceptable waiting time of 23.19 minutes. This suggests that the total average waiting times are exceeding these acceptable waiting times by patients, especially at Hengelo. There are several aspects that may influence the length of waiting times:

- The arrival rate of patients differs per day and per hour. At Almelo most patients arrive on Monday (22%) and Tuesday (24%) and at Hengelo on Tuesday (23%) and Wednesday (22%). The busiest time of the day is between 9 and 12 in the morning. Over 46% of all patients per day arrive within these three hours. Between 12 and 14 in the afternoon, the number of arrivals is significantly less. This is probably due to the lunch break at the policlinics. From 2PM till 4PM, the number of arrivals increases, whereas after 4PM the number of arrivals starts to decrease (Section 2.2.5). This leads to longer waiting times during the busiest days and hours of the week.
- Patients with a high urgency level influence the waiting times. They have to be scheduled for POS within a short time period to not delay the surgical operation (Section 2.2.6). This may lead to disturbance in the process for other patients and increases waiting times.
- The different planning methods influence the waiting time as well. If patients are planned according to an appointment scheduling system the waiting time should be less than when a walk-in based system is used. Patients with a specific time of appointment expect to be examined within an acceptable waiting time. The average waiting time for a nurse for walk-in patients at Almelo was 3.9 minutes, whereas this was 2.7 minutes for patients with an appointment. This indicates that patients in both situations have to wait an acceptable waiting time for a nurse at Almelo (Section 2.3.4).
- The screening time by the nurse differs per hospital. The screening time by a nurse was 16.5 minutes (st. dev. 6.2 minutes) at Almelo and 11.6 minutes (st. dev. 5.2 minutes) at Hengelo. Additionally, the screening was done within 26 minutes for 95% of the patients at Almelo, whereas this is 22 minutes at Hengelo (Section 2.3.4).
- The screening time by the nurse differs between ASA score 1/2 and 3. For ASA score 1 and 2 patients does not differ that much. On average, an ASA score 1 patient is screened in 15.4 minutes (st. dev. 5.3 minutes) whereas an ASA score 2 patient is screened in 15.7 minutes (st. dev. 5.3 minutes). The average screening time for ASA score 3 patients was 24.5 minutes (st. dev. 7.3 minutes). Almelo has a timeslot of 30 minutes of screening by a nurse for ASA score 1 patients and 15 minutes for ASA 2/3 patient. On average, 14 minutes of a timeslot for ASA

score 1 patients at Almelo is not used, whereas ASA score 3 patients need more time than the planned 15 minutes at the nurse (Section 2.3.4).

- The average screening time by an anesthesiologist is the shortest for ASA score 1 with an average of 8.9 minutes (st. dev. 3.5 minutes). ASA score 2 patients are screened in 10.9 minutes (st. dev. 4.6 minutes) whereas an ASA score 3 patient is screened in 17.3 minutes (st. dev. 5.6 minutes). Almelo has a timeslot of 15 minutes of screening by an anesthesiologist for ASA score 2 and 3 patients. Shorter timeslot than average screening time lead to increased waiting times, whereas longer timeslots lead to lower utilization (Section 2.3.4).
- On average, patients that arrived on time for an appointment are 12.7 minutes (st. dev. 9.9 minutes) early. An advantage of arriving earlier than the appointment time is the possibility for a patient to be screened earlier than appointment time, if a nurse is unoccupied. However, this also creates extra 'voluntary' waiting time for a patient. Approximately, 53% of the patients are screened earlier than the appointment time. This leads to an average extra (voluntary) waiting time of 7.2 minutes for patients with an appointment (Section 2.3.5). We do not take this waiting time into account when determining the waiting time of a nurse in Section 2.3.4. However, this influences the absolute total waiting time of a patient.
- On the other hand, patients that arrive late for their appointment does not only influences the waiting time for the patients, but the utilization of the nurse and anesthesiologist as well. In total 13.8% of patients with an appointment arrived late (Section 2.3.5).
- The waiting time for patients differs per ASA score. Patients with ASA score 1 only have to wait for a nurse, whereas patients with ASA score 2 and 3 have to wait for an anesthesiologist or anesthesia assistant as well. Assignment of wrong ASA scores can lead to extra unplanned patients or to unnecessary screening of patients. In both case the waiting time can be influenced (Section 2.3.5). Moreover, the assignment of ASA scores differs per location. At Hengelo, patients younger than sixteen years old are assigned for the ASA score 2 process, whereas at Almelo they are ASA score 1. This leads to extra patients for the anesthesia assistant at Hengelo and therefore to longer waiting times (Section 2.2.4).
- Last, extra examinations influences the waiting time as well. At Hengelo, ECG is done by nurses themselves. If a nurse decides to perform an ECG, other patients have to wait to be screened (Section 2.3.5).

This section showed that there are several aspects that influence the waiting time. An influential factor on the waiting time is the planning method. With an appointment planning method at Almelo, a lower waiting time is expected and accepted than with walk-in at Hengelo. Currently, the waiting time is still too high, especially at Hengelo. Another influential factor is the ASA score of a patient. A patient with a higher ASA score needs screening by an anesthesiologist or anesthesia assistant and needs more time to be screened than a low ASA score. Moreover, the timeslot intervals per ASA score do not match the expected screening time for a patient. These aspects lead to more waiting time for at the PAC.

In this chapter we first described the POS process at Almelo and Hengelo, followed by the characteristics of the patient, patient inflow, and POS service in the current situation. We found that in the current situation the access times (at Almelo) and the waiting times (especially at Hengelo) are too long, and need to improve to increase patient satisfaction. In Chapter 3 we search literature to find out whether these points of improvement are studied in history, and how organizations handled them.

3 LITERATURE REVIEW

This chapter describes theories and practices on how to deal with the most important points of improvement found in Chapter 2. Hans, Van Houdenhoven and Hulshof [5] developed a framework (Figure 3.1) that distinguishes and combines different hierarchical levels and managerial areas. This research focuses on the managerial area related to resource capacity planning on all hierarchical levels. Hereby, our main focus is on tactical and operational level. Section 3.1 contains a short introduction on preoperative anesthesia clinics, their benefits, and the different regulations stated by national health care organizations. These subjects are mostly related to the strategic level. Section 3.2 focuses on the tactical level and the literature related to different screening methods, timing of preoperative screening, and planning methods. Section 3.3 focuses on the relationship between patient satisfaction and access times, waiting times, and cancellation. These are categorized as aspects of the operational level. In Section 3.4, we briefly explain our decision to implement simulation modeling in our research.

	Medical planning	***Resource capacity planning***	***Materials planning***	***Financial planning***
Strategic	Research, development of medical protocols	Case mix planning, capacity dimensioning, workforce planning	Supply chain and warehouse design	Investment plans, contracting with insurance companies
Tactical	Treatment selection, protocol selection	Block planning, staffing, admission planning	Supplier selection, tendering	Budget and cost allocation
Offline operational	Diagnosis and planning of an individual treatment	Appointment scheduling, workforce scheduling	Materials purchasing, determining order sizes	DRG billing, cash flow analysis
Online operational	Triage, diagnosing emergencies and complications	Monitoring, emergency coordination	Rush ordering, inventory replenishing	Billing complications and changes

← managerial areas →

↑ hierarchical decomposition ↓

Figure 3.1: Framework for healthcare planning and control (Hans et al., 2011)

3.1 STRATEGIC LEVEL

On a strategic level, we search literature to find out what the benefits of preoperative anesthesia clinics are. More than fifty years ago, preoperative anesthesia clinics were introduced to decrease the pressure of work in surgical outpatient clinics. Nowadays, a PAC is defined as “the process of clinical assessment that precedes the delivery of anesthesia care for surgery and for nonsurgical procedures” [6] [p.485]. A PAC is used to optimize the condition of patients who are not in the best possible state for surgery [7]. The preoperative screening which takes place in a PAC consists of evaluating the patient’s medical record, a clinical interview, physical examination, and additional tests and evaluations [6][8][9].

There is an extensive amount of literature that supports the development of PACs. According to several authors, preoperative screening creates a bond with the patient and allays their anxiety [10][11][12]. It also reduces the risks of complications, morbidity, mortality [10][13][14][15][16][17] and number of surgery delays and cancellations [7][14][16][18][19] [20][21]. The clinics diminish unnecessary preoperative consultations [15][22], improve the cost-efficiency of hospitals [9][10][16][23][24][25][26][27] and increase patient satisfaction as well [7][28]. Research also shows that there is no significant difference between an anesthesiologist-only and a nurse based PAC [29][30][31].

These benefits led preoperative screening to be a common practice in outpatient clinics [24]. Additionally, the benefits led to the development of PACs in 50% of hospitals in the Netherlands in 2000, which increased to 74% in 2004. The number of PACs available for all elective patients increased from 20% to 52% [9]. Holt et al. [7] also indicate that 69% of the respondents who attended the annual ASA meeting in 2005 worked at an institution that uses an anesthesia-staffed PAC.

In 1994, France regulated the anesthesia process. This process contains three obligatory steps; preoperative consultation, anesthesia delivery, and patient management in post anesthetic care [32]. This process is implemented by several hospitals outside of France as well. In 2010, regulations related to the preoperative process were stated in the Netherlands. This process contains four aspects: (1) consultation with surgeon, (2) preoperative assessment and intake by nurse, (3) surgery planning, and (4) preparation for surgery [1].

In this section several benefits of a PAC are discussed. Moreover, we found that some countries have regulated the preoperative screening process in the obligatory steps for a surgery. In the next section we discuss literature related to the tactical level.

3.2 TACTICAL LEVEL

On tactical level the allocation of time and resources to specialties is the most important aspect. We discuss three different elements of allocation. First, we discuss different methods that can be used to screen patients (Section 3.2.1). Second, we elaborate on different timings for screening (Section 3.2.2). Third, we discuss different planning methods (Section 3.2.3).

3.2.1 SCREENING METHODS

There are several methods to screen a patient. Gupta [15] distinguishes between physician-based, nurse-based, standardized questionnaires, and internet-based health questionnaires. He indicates that no single system is ideal under all circumstances and hospitals need to combine their local policies and the existence of co-morbidities of a patient to find the optimal method for preoperative assessment. For example, Harnett et al [33] indicate that in the Center for Clinical Effectiveness at the Brigham and Women's Hospital in Boston, they made the decision that ASA score 1 and 2 patients are screened by phone and do not visit the clinic at all. For our research we will not change the screening methods.

3.2.2 TIMING

The second element is the timing of the assessment. Lew, Pavlin, and Amundsen [16] indicate that there is no strong evidence in literature on the optimal timing for preoperative screening. Different authors propose different timing policies. Halaszynski, Juda, and Silverman [34] indicate that testing should be performed within 30 days of surgery. According to Lew et al. [16] and Gupta and Gupta [8], in general, all patients are assessed between 2 and 30 days before their scheduled date of surgery. Whereas, articles by the American Society of Anesthesiologist [6] and Fischer [23] indicate that the assessment of a patient depends on the clinical condition and invasiveness of the surgery. They indicate that in order for the assessment to be cost-effective, at least low severity of disease and medium or low surgical invasiveness surgeries should be assessed on the day of surgery, or the day before. Pollard and Olson [35] indicate that there is no significant difference between the number of days and cancellation rate. Therefore, outpatients may be seen at any convenient time.

3.2.3 PLANNING METHODS

The third element relates to the planning methods for scheduling an examination. In literature, two broadly discussed planning methods are based on an appointment system and a walk-in system. Hereby, a walk-in system is also defined as 'same-day scheduling' ,'open access', and 'advanced access'.

Dexter [36] indicates that a well designed appointment system is an important reason to avoid long waiting times. PACs without appointments will have longer average patient waiting times than the same clinic with appropriate appointments. Also, simulation studies indicate that clinic scheduling recommend appointment intervals that are equal, or slightly greater than mean consultation time. This is currently not the case for all patients at the PAC.

Research by Murray and Tantau [37] indicates that walk-in reduced the access time for patients and increased satisfaction. Additionally, Mallard et al. [38] performed a pilot study to research the effects of a same-day scheduling approach within a public health clinic. They found that same-day scheduling results in shorter waiting times, lower no-show rates, more new patients, and increased provider productivity. In 2005, Parente, Pinto, and Barber [39] found that open access indeed reduced the access time for patient. However, no significant difference in patient satisfaction was found.

Kortbeek et al. [40] developed an iterative methodology to design an appointment system for outpatient clinics that offer both walk-in and appointments. The model prescribes the number of appointments to plan per day and the moment on the day to schedule the appointments. The model determines the best appointment schedule to minimize access and waiting times with a first come first served priority rule for patient planning. Basically, the outcome of the methodology is to schedule more patients during the least busy days and hours than at the busiest moments. Although this is a promising methodology, the methodology of Kortbeek et al. is only applicable for a short time period (one week) whereas the situation at the PAC is more complex.

When applying the methods in practice to PACs, depending on the ASA score, different methods may be used. For instance, Leiden University Medical Center (LUMC) evaluates patients with an ASA score 1 and 2 on walk-in basis only, whereas patients with ASA score 3 and higher always have to schedule an appointment. On the other hand, at Academic Medical Center (AMC) in Amsterdam, all patients are given an appointment [40][41]. Another method is scheduling patients based on the specialism of a patient. However, research by Schoenmakers shows that this led to more variability and higher waiting times at the Isala klinieken in Zwolle than scheduling based on ASA scores [43].

In this section we found that there are different methods to screen a patient. Additionally, we found that the best timing of scheduling a POS is not the same in all articles. In the last part of this section we elaborated on several planning methods that can be used to increase the one stop shop percentage or decrease the waiting time. The next section will focus on a factor on the operational level, patient satisfaction.

3.3 OPERATIONAL LEVEL

When a patient is satisfied differs per individual. In this section we search literature that focuses on patient satisfaction on an operational level. We discuss several aspects of patient satisfaction (Section 3.3.1) and three influential factors on patient satisfaction in the following order; access time (Section 3.3.2), waiting time (Section 3.3.3), and delays and cancellations of surgery (Section 3.3.4).

3.3.1 PATIENT SATISFACTION

ZGT strives to provide a high quality of care to their patients. Patient satisfaction is an important aspect to determine this high quality. In the literature there are several articles that focus on the improvement of patient satisfaction. An study by Scholtens [4], focusing on patient preferences, shows that the most preferred service aspect by patients for a CT scan is a one stop shop service (43.2% of respondents), followed by short access time (22.4%), short waiting time (18.8%) and finally the autonomy in choice of moment (15.7%). We assume that these preferences can be used for the preoperative screening service as well. Additionally, Harnett et al. [33] suggest that patients prefer seeing one nurse practitioner rather than sequentially a nurse and surgeon or physician assistant. A tertiary care, teaching hospital, implemented an educational program and shifted to nurse practitioner assessment with anesthesiologist supervision. This approach improved patient satisfaction [33]. Another factor to improve patient satisfaction is the amount of information provided to the patient. Informing patients increases the standard of service as well [42][43]. In addition to short access time and short waiting time, few delays and cancellations of surgery influence patient satisfaction as well. These factors are discussed in the next sections.

3.3.2 ACCESS TIME

We define access time as the difference between the day of scheduling an appointment for preoperative screening and the day of the preoperative screening consult. There are different strategies to reduce access time. A well-know strategy, already described in the tactical section, is using a walk-in system. Research by Murray and Tantau [37] shows that this system can reduce the number of waiting days from 55 to just one day. Mallard et al. [38] and Parente et al. [39] came to the same conclusion. Another strategy to reduce the access time to a maximum of 10 days for 95% of the patients, according to a case study by Edward et al. [44], is to temporarily increase capacity to reduce current backlog. Then determine the required regular capacity to handle the fluctuating demand.

3.3.3 WAITING TIME

The length of the time waiting correlates inversely with patient satisfaction [33]. This indicates that the longer a patient has to wait, the less satisfied a patient is. Moreover, waiting is found to be the least positive experience within a PAC [42]. Research by Heaney, Howie, and Porter [45] shows that patients do not mind waiting reasonable times for their doctor, only 3% complained about waiting up to 15 minutes. Dexter [36] agrees that a waiting time of 15 minutes is still reasonable. However, if the waiting time exceeds 30 minutes, half of the patients feel they waited too long. More recent research by Scholtens [4] reveals that the accepted waiting time for patients depends on the planning method. If a patient has an appointment, 31% of the patients think that the appointment has to be at the scheduled time and do not accept any waiting time. The mean maximum acceptable waiting time when having an appointment is 12.38 minutes, with a standard deviation of 13.18 minutes. With a walk-in system, patients are will to wait longer. In this case, only 18.7% of the patients still thinks they should be helped right away. Additionally, the accepted waiting times is almost doubled with a maximum acceptable waiting time of 23.19 minutes and a standard deviation of 27.24 minutes.

In 1966, Fetter and Thompson [46] identified different variables that influence waiting times. They suggest that the appointment interval, service time, patients' arrival pattern, number of no-shows, number of walk-ins, physicians' arrival pattern, and interruptions in patient services all influence waiting time. More than thirty years later, Dexter [36] came to the same conclusion, when finding that the following factors influence waiting time: (1) Patients not arriving promptly for their appointment, (2) health care providers arriving late at the start of the day, (3) and patients not having an appointment. However, in contrary to the third factor stated by Dexter, Edward et al. [40] found that the waiting times at LUMC are shorter than at AMC, even though only approximately 30% of patients at LUMC have an appointment.

In literature, several strategies to reduce waiting time and increase patient satisfaction at the PAC are researched. Dexter [36] and Edward et al. [40] suggest two strategies: (1) decreasing the variability of the consultation time, and (2) increasing the reserved appointment time and thereby accept idle time for health care providers. A study by Zonderland et al. [41] tested four different strategies for waiting time reduction at LUMC. They found that assigning a clinic assistant at the front desk (strategy 1), reschedule appointments (strategy 3), and regrouping employee tasks and amend patient flows (strategy 4) all had a significant effect on waiting time at LUMC. Treating all patients on appointment basis (strategy 2), did not lead to a significant waiting time reduction. Other strategies are to arrange shorter consultations or to tailor the appointment system to the individual doctor's style [45][47]. Another strategy by Dexter [36], less related to effective waiting time reduction, is creating a more pleasant office environment for waiting.

3.3.4 DELAYS AND CANCELLATIONS OF SURGERY

Cancellations and delays of surgery have an impact on patient satisfaction as well [48]. Patients react negatively to cancellations, especially if it had organizational reasons [49]. The probability of a delayed or cancelled surgery depends on different factors. Hariharan et al. [19] and Dexter [36] found that there was a significant difference between probability of delays and cancellations of patients who did not attend a PAC and those who did. Other factors are the inefficient use of booking tests and obtaining test results before scheduled surgery date [50], and dealing with new medical problems [51]. According to Gupta and Gupta [8] unnecessary last minute delays and cancellations can be avoided if all patients with an ASA score greater than 2 are discussed with the senior anesthesiologist. Latter is already the case at the ZGT.

In this section we discussed several aspects of patient satisfaction. We found that access time, waiting time, and delays and cancellations of surgery all influence the patient satisfaction. Additionally, several approaches for increasing patient satisfaction are discussed.

3.4 SIMULATION MODEL

Simulation modeling is a frequently used methodology to study health care systems and test organizational interventions. We search literature to determine whether simulation is the best methodology to test the organizational intervention for the situation at the PAC as well.

Law [52] defines different possibilities and several steps that have to be taken to determine how to research a system. These steps are shown in Figure 3.2.

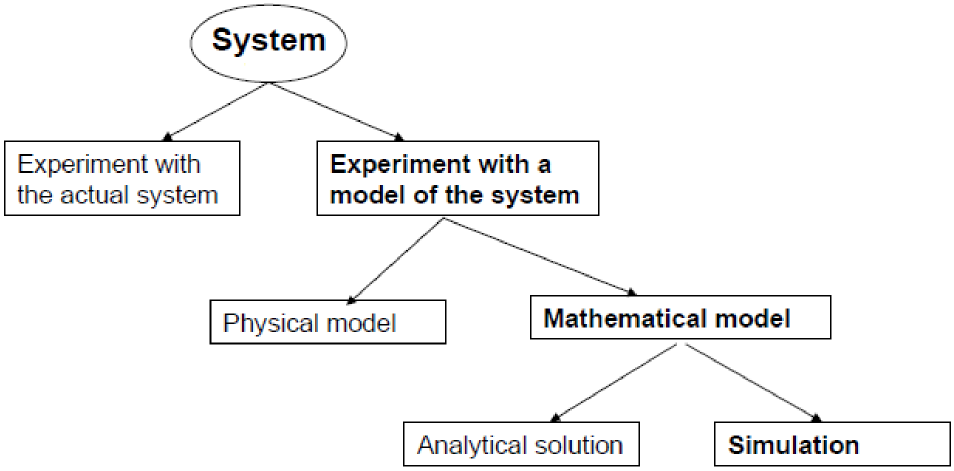


Figure 3.2: Ways to study a system (Law, 2007)

The first step is choosing between starting an experiment with the actual system or experiment with a model of the system. In case of our research experimenting with the actual system is too expensive and would be too disruptive to the system. Therefore, we prefer experimenting with a model of the system.

The second step is choosing between experimenting with a physical (e.g. tabletop scale model) or mathematical model. We choose a mathematical model because it is less expensive and it is a common used approach for operations research and systems analysis. Hereby, we are aware that the mathematical model should be a valid one.

The last step is choosing between an analytical solution and a simulation model. Law argues that "if an analytical solution to a mathematical model is available and is computationally efficient, it is usually desirable to study the model in this way rather than via a simulation" [p. 5]. However, in our research the preoperative screening system is highly complex and therefore a valid mathematical model would be complex as well. Harper and Gamlin [53] agree and suggest that if a system is complex, applying an exact analytic approach is not applicable. Too many assumptions would have to be made and this would remove variability and uncertainty. This would lead to a non accurate representation of the real-life situation. With these suggestions in mind, we choose to use simulation to study the preoperative screening system. Hereby, we use discrete-event simulation to model the system as it evolves over time.

With our choice for modeling with simulation software we proclaim the different advantages and drawbacks of our approach. According to Law, at least five advantages can be stated: (1) simulation is often the only type of possible investigation for complex, real-world systems with stochastic elements, (2) performance of an existing system can be estimated under some projected set of operating conditions (3) alternative proposed system designs can be compared (4) experimental conditions can be controlled much better, and (5) simulation allows studying a system with a long time frame in compressed time.

A drawback of simulation is that the model only produces estimates of a model's true characteristics for a particular set of input parameters, whereas analytical models (if valid) produce the exact true characteristics. Other drawbacks are that simulation models are often expensive, time-consuming, and that the outcomes are only useful if the model is a valid representation of the system.

Law mentions several pitfalls as well. Some important pitfalls are failure to collect good system data, failure to account for randomness, using arbitrary distributions as input, failure to have a warm-up period, and comparing alternative systems designs on only one replication for each design. We keep these advantages and drawbacks in mind throughout our research.

3.5 CONCLUSION ON LITERATURE REVIEW

In this chapter we discussed literature related to PACs on a strategic, tactical, and organizational level. The strategic sections focused on motives to implement preoperative screening. The tactical level focused on different screening methods, timing of POS, and different planning methods. At the organizational level, we reviewed literature related to patient satisfaction.

We found that there are several methods to screen a patient (physician-based, nurse-based, internet based questionnaires, etc.). However, there are regulations on how a patient should be screened at ZGT. We choose not to change the screening methods for the situation at the PAC in our research. We also found that there is no clear indication on the optimal timing of POS. We perform a sensitivity analysis to research the effect of changing the timing at the PACs (Section 6.3.3).

On the subject of planning methods, literature shows that there are several planning methods that can decrease access and waiting times. Hereby, a distinction is made between an appointment system and a walk-in system. Kortbeek et al. [40] developed an iterative methodology to design an appointment system for outpatient clinics that offer both walk-in and appointments. The idea is to schedule more patients during the least busy days and hours than at the busiest moments. We research the effect of this approach with intervention 2 (Section 5.2.1). Murray and Tantau [37] suggest that scheduling a maximum percentage of appointment per day reduces the access time and increases the patient satisfaction. We research the effect of several maximum percentages with intervention 3 (Section 5.2.2). Intervention 4 is a combination of intervention 2 and 3 (Section 5.2.3). When using an appointment system, appointment intervals that are equal or slightly greater than mean consultation time is recommended [36]. This is currently not the case for all patient types at the PAC. We develop and research the effect of changing the appointment intervals in intervention 5 (Section 5.2.5).

Focusing more on patient satisfaction, we found that patients prefer a one stop shop over short access times, short waiting times, and autonomy in choice of moment. Furthermore, patient satisfaction related to waiting time depends on the planning method. Patients accept a longer waiting time if they walk-in than if they arrived with an appointment. Strategies to reduce the waiting times are to arrange shorter consultations or to tailor the appointment system to the individual doctor’s style [45][47]. We perform a sensitivity analysis to find out what the effect is of assigning care provider that needs more consultation time than on average (Section 6.3.3). To test these interventions and to perform the sensitivity analyses we concluded that simulation modeling is the best approach (Section 3.4). In Chapter 4, we describe the conceptual model we use for this simulation model of the situation at the PAC.

4 CONCEPTUAL MODEL

Currently, the PAC at Almelo and Hengelo is open on weekdays from Monday till Friday between 8:30AM and 4:30PM (eight hour working day). Depending on the location and the ASA score, patients have the possibility to walk-in or schedule an appointment within this time period. As discussed in Section 2.4, this policy leads to long access times and long waiting times. ZGT is now studying new configurations to increase one stop shop probabilities, reduce access times, and reduce waiting times. In this chapter we describe a conceptual model of the situation at the PAC which can be used to analyze these new configurations. We start with describing the process steps of our model and the different paths that can be taken (Section 4.1). We describe how these process steps are dependent on several factors (Section 4.2), followed by what resources are needed (Section 4.3). Next, the processing times (Section 4.4) and decision making policies (Section 4.5) are discussed. Within this chapter we discuss several assumptions for the conceptual model. These assumptions are marked italic.

4.1 PROCESS STEPS

This section describes the activities that take place within the model and the different paths a patient can take. We separate the processes at Almelo and Hengelo, because of their differences in arrival rate, consultation times, and processing activities.

As mentioned in Section 2.1, the preoperative screening process at Almelo and Hengelo involves several activities. Figure 4.1 shows a flowchart of the POS process at Hengelo. Appendix D shows the flowchart of Almelo. The activities that we discuss below take place in different stages and departments. The different departments are indicated with different colors in the flowchart: The orange color indicate activities that take place in several policlinics before POS. The yellow color indicates activities that take place in the PAC, and activities that take place after the regular POS are shown in red.

The process starts when a patient leaves a policlinic and is sent to the PAC. Before the patient arrives at the front office of the PAC, the expected screening time per care provider is determined based on the generated ASA score. Additionally, an operation date is given based on the assigned specialism.

When a patient arrives at the front office of the PAC, the patient and an employee of the front office discuss the possibilities and preferences related to walk-in. There are two possibilities:

- The patient and employee come to the conclusion that walk-in is possible and desired. In this case, at Almelo, the patient first checks in at the secretary of the PAC. Next, at both locations, the patient is sent to the waiting room to wait for a nurse.
- The patient and employee come to the conclusion that walk-in is not possible or desired. The employee schedules an appointment for the patient to come back at another day and time.

If an appointment has to be scheduled, an appointment is scheduled for an ASA score 1 patient in the ASA1 agenda at Almelo. Appointments for ASA score 2 and 3 patient are scheduled in the ASA23 agenda. At Hengelo, an appointment for ASA score 1 and 2 patient is scheduled in the ASA12 agenda. Appointments for ASA score 3 patients are schedule in the ASA3 agenda. After an appointment is scheduled, the patient leaves the PAC and waits at home till the appointment date. On the day of the appointment, the patient first checks in at the secretary (Almelo) or front office (Hengelo) of the PAC before being sent to the waiting room.

When the patient arrives in the waiting room, it is checked whether the nurse is occupied. The following situations can occur:

- A nurse is not occupied and the patient can enter the room to be screened.
- All nurses are occupied and the patient needs to wait in the waiting room until a nurse becomes unoccupied and is ready to screen the patient.

After consultation by the nurse, the following decisions can be made:

- The patient is ready for surgery. Consent is given and the patient leaves the system.
- The patient needs extra examination and is sent to the extra examination department.
- The patient has to wait in the waiting room to be screened by the next care provider. At Almelo, this is the anesthesiologist. At Hengelo, this is the anesthesia assistant or anesthesiologist.

When the patient arrives in the waiting room for the second time, it is checked whether the anesthesiologist or anesthesia assistant is available. The following situations can occur:

- The anesthesiologist or anesthesia assistant is not occupied and the patient can enter the room to be screened.
- The anesthesiologist or anesthesia assistant is occupied and the patient needs to wait in the waiting room until the anesthesiologist or anesthesia assistant becomes unoccupied and is ready to screen the patient.

After screening by an anesthesiologist or anesthesia assistant the same decisions can be made as after consultation by a nurse:

- The patient is ready for surgery. Consent is given and the patient leaves the system.
- The patient needs extra examination and is sent to the extra examination department.

When a patient needs extra examination, the patient has to wait for consent until the results of the ECG, laboratory, or cardiologist are in. After the results are in the patient is ready for surgery and leaves the system.

Within our model we assume that *patients always arrive with the correct ASA score*. Assignment of wrong ASA scores can lead to extra unplanned patients or to unnecessary screening of patients by anesthesiologist and anesthesia assistants. This assumption can lead to lower utilization and waiting times in the simulation model than in reality.

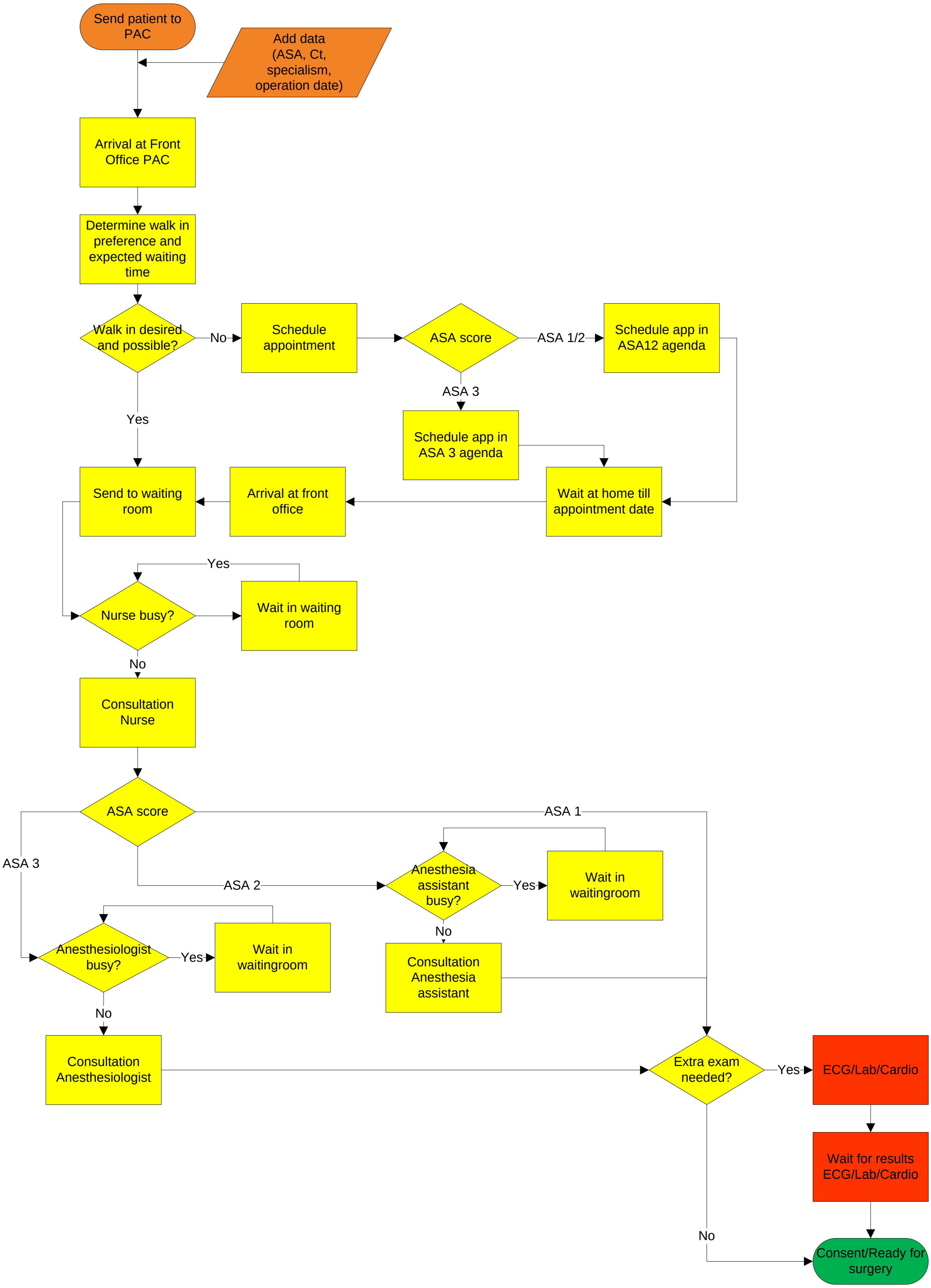


Figure 4.1: Flowchart of the POS processes at Hengelo.

This assumption together with the process as described above leads to twelve possible paths per location that can be taken by a patient, after being sent from the policlinic to the PAC, depending on the location and ASA score. The paths at Almelo are shown in Table 4.1, and the paths at Hengelo in Table 4.2.

ASA score	Path
ASA 1	Front office – Secretary – Nurse – Consent
ASA 1	Front office – Secretary – Nurse – Extra examination – Consent
ASA 1	Front office – Home – Secretary – Nurse – Consent
ASA 1	Front office – Home – Secretary – Nurse – Extra examination – Consent
ASA 2	Front office – Secretary – Nurse – Anesthesiologist – Consent
ASA 2	Front office – Secretary – Nurse – Anesthesiologist – Extra examination – Consent
ASA 2	Front office – Home – Secretary – Nurse – Anesthesiologist – Consent
ASA 2	Front office – Home – Secretary – Nurse – Anesthesiologist – Extra examination – Consent
ASA 3	Front office – Secretary – Nurse – Anesthesiologist – Consent
ASA 3	Front office – Secretary – Nurse – Anesthesiologist – Extra examination – Consent
ASA 3	Front office – Home – Secretary – Nurse – Anesthesiologist – Consent
ASA 3	Front office – Home – Secretary – Nurse – Anesthesiologist – Extra examination – Consent

Table 4.1: Possible paths of a patient at Almelo per ASA score.

ASA score	Path
ASA 1	Front office – Nurse – Consent
ASA 1	Front office – Nurse – Extra examination – Consent
ASA 1	Front office – Home – Nurse – Consent
ASA 1	Front office – Home – Nurse – Extra examination – Consent
ASA 2	Front office – Nurse – Anesthesia assistant– Consent
ASA 2	Front office – Nurse – Anesthesia assistant – Extra examination – Consent
ASA 2	Front office – Home – Nurse – Anesthesia assistant– Consent
ASA 2	Front office – Home – Nurse – Anesthesia assistant – Extra examination – Consent
ASA 3	Front office – Nurse – Anesthesiologist – Consent
ASA 3	Front office – Nurse – Anesthesiologist – Extra examination – Consent
ASA 3	Front office – Home – Nurse – Anesthesiologist – Consent
ASA 3	Front office – Home – Nurse – Anesthesiologist – Extra examination – Consent

Table 4.2: Possible paths of a patient at Hengelo per ASA score.

These tables show that there are several possible paths a patient can take. In the next section we discuss the factors that influence which path a patient will have, the so-called process dependencies.

4.2 PROCESS DEPENDENCIES

The steps that a patient takes within the POS depend on several factors. In this section we discuss different variables that are taken into account and assumptions that are made. The dependencies we discuss are patient arrivals (Section 4.2.1), ASA score (Section 4.2.2), specialism (Section 4.2.3), and extra examination (Section 4.2.4). The details of the figures are discussed in Chapter 2.

4.2.1 PATIENT ARRIVALS

As discussed in Section 2.2, we found that the number of patients arriving varies between weeks, days, hours, and location. Therefore, we have to generate different expected number of patients. The method we use is based on a method described by Visser [55] and Ozcan [57]. We start with generating an expected number of patients per week. The average number of patients arriving per week is 210.9 (st. dev 28.9) at Almelo and 188.3 (st. dev. 38.3) at Hengelo. Next, we found that there is a significant difference in number of arrivals between weekdays. Some days are busier than others. For example, the busiest days are Monday and Tuesday at Almelo and Tuesday and Wednesday at Hengelo. Therefore, we expect that a fraction of the total number of expected patients per week arrives per day. Not only is there a difference in number of arrivals per day, there is also a difference in time of arrival. The busiest time of the day is between 9AM and 12PM. Between 12PM and 2PM the number of arrivals is significantly less, whereas from 2PM till 4PM, the number of arrivals increases. After 4PM the number of arrivals decreases. Because of these differences, for every hour we use a fraction of the expected total number of patients per day to determine the expected number of patients per hour. We use this expected number as parameter for the Poisson arrivals. As discussed in Section 2.2.5, *the division in time of arrivals does not differ between days*.

We make the following assumptions for modeling the arrivals:

- *Patients arrive according to a Poisson process with $\lambda_{w,d,h}$ being the average number of patients arriving in the time interval.* A property of a Poisson distribution is that the variance of a random variable is equal to the mean. The variance of the number of arrivals per week at the PAC is larger than suggested by the Poisson distribution, which may influence the results. Therefore, we correct this by taking a fraction of the total number of patients, per day and per hour.
- *We know that the average number of patients varies per week, per day and per hour. Therefore, a time interval has the length of one hour. The average number of patients arriving in a time interval is $\lambda_{w,d,h}$.*
- *There is no relation between the day of the week and the week of the year. This means that throughout the entire year, every weekday contains the same fraction of the total number of patients per week.*
- *Public holidays (and their possible deviant arrival patterns) are not included.*
- *A day at the policlinics begins at 8:00 AM and ends at 5:00 PM. Therefore, patients will only be sent to the PAC during this period. No patients will arrive from the policlinic before 8:00 AM or after 5:00 PM.*
- *One week consists of five days: day 1 till day 5, Monday till Friday. Every 6th day is the start of a new week.*

We generate the parameters $\lambda^A_{w,d,h}$ and $\lambda^H_{w,d,h}$ and introduce a similar notation as Visser [55]:

$\lambda^A_{w,d,h}$	The average number of patients arriving in week w, on day d, at hour h, at Almelo.
$\lambda^H_{w,d,h}$	The average number of patients arriving in week w, on day d, at hour h, at Hengelo.
α^A_w	The total number of patients arriving in week w at Almelo, for w = 1,...,52.
α^H_w	The total number of patients arriving in week w at Hengelo, for w = 1,...,52.
β^A_d	The fraction of patients arriving on day d of the total number of patients per week at Almelo, with d = 1,...,5.
β^H_d	The fraction of patients arriving on day d of the total number of patients per week at Hengelo, with d = 1,...,5.

γ_h^A	The fraction of patients arriving at hour h of the total number of patients per day at Almelo, for h = 1,...,24.
γ_h^H	The fraction of patients arriving at hour h of the total number of patients per day at Hengelo, for h = 1,...,24.

The patient arrival rates $\lambda_{w,d,h}^A$ and $\lambda_{w,d,h}^H$ are determined by:

$$\lambda_{w,d,h}^A = \alpha_w^A * \beta_d^A * \gamma_h^A \quad arrivals\ at\ Almelo$$

$$\lambda_{w,d,h}^H = \alpha_w^H * \beta_d^H * \gamma_h^H \quad arrivals\ at\ Hengelo$$

For our model we use *a uniform distribution to generate the total number of patients arriving per week*. We take into account the arrival rates that deviates at most one standard deviation from the mean. We use a uniform distribution with one standard deviation from the mean because almost all number of patients arriving per week stay within these limits. This leads to the following uniform distributions:

$\alpha_w^A = U[210.9 - 28.9, 210.9 + 28.9]$ at Almelo, and

$\alpha_w^H = U[188.3 - 38.3, 188.3 + 38.3]$ at Hengelo.

For the different arrival fractions per day, α_w^A and α_w^H, we use the fractions as shown in Table 4.3:

Day	Monday	Tuesday	Wednesday	Thursday	Friday
Almelo	0.222	0.235	0.199	0.166	0.178
Hengelo	0.183	0.238	0.219	0.206	0.154

Table 4.3: Arrival fraction per weekday at Almelo and Hengelo

For the different arrival fractions per hour, γ_h^A and γ_h^H, we use the fractions as shown in Table 4.4:

Hour	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Almelo	0.056	0.139	0.149	0.141	0.073	0.091	0.139	0.133	0.078
Hengelo	0.043	0.142	0.141	0.146	0.103	0.067	0.131	0.127	0.099

Table 4.4: Arrival fraction per hour at Almelo and Hengelo

With the figures above, we can determine the number of patients arriving per hour at Almelo and Hengelo. For example, if we expect 211 patients to arrive in a week at Almelo, 47 (211*0,222) patients are expected on Monday. 7 of these patients are expected between 10 and 11 AM (47*0,149). Detailed information on the origin of the figures can be found in Section 2.2.5.

Within the arrival rates and our model, *urgency patients are not included.* This may lead to lower average waiting time than when urgency patients are included. However, the number of urgency patients that had to be screened within one day was less than one per week (Section 2.2.6) and may therefore not influence the average waiting time much.

4.2.2 ASA SCORE

Another process dependency is the assigned ASA score. As discussed in Section 4.1, the path a patient takes and the screening time for a patient depends on the ASA score. For example, an ASA score 1 patient only needs screening by a nurse, whereas an ASA score 3 patient needs screening by a nurse and an anesthesiologist. For every patient we generate a random number to determine the

ASA score. We use the figures in Table 4.5 to assign an ASA scores to a patient. Detailed information on the origin of the figures can be found in Section 2.2.4.

Patient type	ASA score 1	ASA score 2	ASA score 3
Almelo	0.337	0.557	0.106
Hengelo	0.149	0.804	0.047

Table 4.5: Division of ASA scores at Almelo and Hengelo.

As mentioned before, we assume that *patients always arrive with the correct ASA score*. Assignment of wrong ASA scores can lead to extra unplanned patients or to unnecessary screening of patients by anesthesiologist and anesthesia assistants. This assumption can lead to lower utilization and waiting times in the simulation model than in reality. However, our model will be used to compare the effect of different interventions instead of giving an accurate representation of the real world system.

A process dependency related to the assigned ASA score is appointment scheduling. The timing of an appointment depends on the ASA score. As mention in Section 4.1, if an appointment has to be scheduled, an appointment is scheduled for an ASA score 1 patient in the ASA 1 agenda at Almelo. Appointments for ASA score 2 and 3 patient are scheduled in the ASA 23 agenda. At Hengelo, an appointment for ASA score 1 and 2 patient is scheduled in the ASA 12 agenda. Appointments for ASA score 3 patients are schedule in the ASA 3 agenda. The access time of a patient depends on the available timeslots which differ per agenda. Detailed information on the decision making related to appointment scheduling can be found in Section 4.5.3.

4.2.3 SPECIALISM

The maximum access time for a patient depends on the assigned specialism. For every patient we generate a random number to determine the specialism. We use the division of specialism as shown in Table 4.6 to assign a specialism. We determine the specialism by adding the probabilities per specialism starting with the specialism on the left of the table until the sum exceeds the random number.

Specialism	SUR	GYN	ENT	ORT	PLA	URO
Almelo	0.229	0.098	0.193	0.292	0.051	0.094
Hengelo	0.251	0.115	0.116	0.378	0.043	0.069

Table 4.6: Division of specialism at Almelo and Hengelo

When the specialism of a patient is known, the surgery date can be determined. *To assign surgery dates to patients we use a normal distribution with the mean and standard deviation as shown in Table 4.7*. Because the planning of surgeries of the next week has to be submitted the week before, we always assign a minimum time till surgery of one week. Detailed information on the origin of the figures can be found in Section 2.2.3 and 2.3.6.

Specialism	SUR	GYN	ENT	ORT	PLA	URO
Almelo	3.3 (1.1)	6.3 (2.1)	6.0 (2.0)	8.7 (2.9)	15.3 (5.1)	4.5 (1.5)
Hengelo	5.2 (1.7)	4.6 (1.5)	3.7 (1.2)	8.7 (2.9)	11.9 (4.0)	1.9 (0.6)

Table 4.7: Average time till surgery (standard deviation) in weeks at Almelo and Hengelo.

Assuming a normal distribution may lead to a lower percentage of consent on time, because more patients will have a higher possibility to get an operation date in the near future than is possible in reality.

4.2.4 EXTRA EXAMINATION

The last process dependency we discuss is related to extra examination. 14% of the patients at Almelo and 23% at Hengelo do not get consent after POS. For every patient we generate a random number to determine if extra examination is needed. These patients are sent for extra examination (Section 2.3.5). Next, another random number is generated to determine what kind of extra examination is needed. The division of the type of extra examination differs per location and is shown in Table 4.8.

Type of extra examination	Ratio of total extra exam (Almelo)	Ratio of total extra exam (Hengelo)	Time till results in days
Cardiologist	0.06	0.07	20
Lab	0.30	0.28	2
ECG	0.62	0.57	1

Table 4.8: Division of extra examination and expected time till results per location

The table above also shows the number of days it takes before the results of extra examination are in. We use these figures to determine the waiting time till results for extra exam.

We assume that *the probability of extra examination does not differ between patients*. This may lead to more assignment of lower ASA score patients and less assignment of higher ASA score patients to extra examination than in reality. However, extra examination influences the percentage of consent on time. In our model this is related to the surgery date of a patient which does not differ between ASA scores.

In this section we determined several dependencies that may influence the process of a patient. In the next section we focus on different resources that are needed and influence the process.

4.3 RESOURCES

There are different resources that influence the POS process. For this section we discuss resources that influence the process within our model. Therefore, we focus on the rooms available and on the employees.

Currently, Almelo has four rooms available for examination and one waiting room. Normally, three rooms are used by nurses, and one room by an anesthesiologist. Hengelo has three examination rooms and one waiting room available. From Monday till Thursday, two of the examination rooms are used by nurses and one by an anesthesia assistant. On Friday morning an anesthesiologist is present to screen ASA score 3 patients. Therefore, during this period there is only room for one nurse instead of two. These figures are also shown in Table 4.9.

Location	Days	Nurses	Anesthesia assistants	Anesthesiologists
Almelo	Monday – Friday	3	0	1
Hengelo	Monday – Thursday	2	1	0
	Friday	1	1	1

Table 4.9: Number of employees per day per

We assume that *the waiting rooms have an unlimited capacity*. This may lead to more patients waiting in the waiting room and higher waiting time in the simulation model than in reality. On the other hand, in reality not all patients decide to wait in the waiting room. Some patients decide to already visit the laboratory or go for lunch. Additionally, we assume *a fixed number of care providers without shifts in personnel during the day*. For example, a nurse leaving in the afternoon, a situation with two anesthesiologists, or a fixed lunch break is not modeled. Management of the PAC at Hengelo is currently considering the effect of dedicating an extra room to a nurse on Friday morning to reduce the waiting time. An extra examination room for a nurse could be created if needed. Therefore, we will take this change into account within our interventions.

4.4 PROCESSING TIMES

The next step for the conceptual model of the situation at the PAC is to determine the length of the process steps. We distinguish between the processing times before the care providers at the PAC (policlinic, front office, secretary), of the care providers (nurse, anesthesia assistant, anesthesiologist), and after the care providers (extra examination, ready for surgery).

4.4.1 POLICLINIC, FRONT OFFICE, AND SECRETARY

Within our model, we assume that *the processing time of leaving a policlinic, arriving at the front office (and maybe schedule an appointment), and checking in at the secretary does not influence the process at the PAC*. Therefore, we set the processing times of these actors at zero minutes. The consequence of not including any processing time for these actors is that the possible waiting time at the front office or secretary is not taken into account. However, our goal is to increase one stop shop percentage and reduce the waiting times of the POS process at the PAC. Hereby, the waiting times we determine for the current situation do not include the front office and secretary as well.

4.4.2 CONSULTATION TIMES PER CARE PROVIDERS

The consultation time of a patient depends on the patient type, care provider, and location (2.3.4). Based on the consultation of 222 patients per location, we determine the probability distribution function per patient type, care provider, and location. More detailed information on the calculations can be found in Appendix E. We conclude that the probability distribution functions, shown in Table 4.10, best fit the consultation times (in minutes). The best fit always was a lognormal (μ, σ) or gamma(α, β) distribution function.

Patient type	ASA score 1	ASA score 2	ASA score 3
Almelo			
Nurse	Lognormal(15.51, 5.295)	Lognormal(15.51, 5.295)	Gamma(12.164, 1.979)
Anesthesiologist		Log normal(10.89, 4.570)	Gamma(10.245, 1.642)
Hengelo			
Nurse	Lognormal(11.62, 5.182)	Lognormal(11.62, 5.182)	Lognormal(11.62, 5.182)
Anesthesia Assistant		Lognormal(15.39, 7.650)	
Anesthesiologist			Lognormal (15.39, 7.650)

Table 4.10: Probability distribution function of the consultation time per patient type per location

As mentioned in Section 2.3.4, the probability distribution functions of ASA score 1 and 2 patients at Almelo are the same, because no significant difference was found. Additionally, because there is not enough information on the different ASA scores at Hengelo, we use the same distribution function for consultation time by a nurse for all patients at Hengelo. Hereby, we assume that the difference in consultation time for ASA score 1 and 2 is not significant at Hengelo. The distribution function for consultation by an anesthesia assistant or anesthesiologist at Hengelo is the same for all patient types as well. There are two reasons: (1) not enough information was obtained on anesthesiologists to treat them separately, (2) pre-classified ASA score 1 patients who were examined by an anesthesia assistant actually were ASA score 2 patients.

At Almelo and Hengelo there are several nurses, anesthesia assistants, and anesthesiologists that screen patients. The consultation times of these care providers may differ per person. However, for our model we assume that *the probability distribution functions of the consultation times do not differ between nurses, between anesthesia assistants, and between anesthesiologists.* This assumption may influence the waiting times at the PAC. The influence of having different consultation times per care provider will therefore be investigated with a sensitivity analysis in Section 6.3.3.

4.4.3 EXTRA EXAMINATION AND READY FOR SURGERY

After consultation by the care providers, a patient gets consent and is ready for surgery, or is sent for extra examination. If a patient is sent for extra examination, the time it takes before results are available depends on the type of extra examination. According to employees of the PAC, an ECG takes one day, laboratory results two days, and consultation with a cardiologist in general takes at least twenty days. We assume that *the processing times of extra examination are fixed and distributed the same for every patient*. As mentioned before, this may lead to more assignment of lower ASA score patients and less assignment of higher ASA score patients to extra examination than in reality. Additionally, this may lead to a higher percentage of consent on time if the processing time of a cardiologist in reality is longer. Therefore, in Section 6.3.3, we use sensitivity analysis to investigate the effect of different processing times for a consultation by a cardiologist. After the results are in a patient is set to be ready for surgery. Being ready for surgery does not take any time anymore and the patient leaves the system.

4.5 DECISION MAKING

Now we have determined the processes that need to take place, we determine the rules for making decisions. We distinguish between the policies for walk-in (4.5.1), the maximum acceptable expected waiting time (4.5.2), the timing of scheduling an appointment (4.5.3), and selection of the next patient (4.5.4).

4.5.1 WALK-IN POLICY

The walk-in policy differs between Almelo and Hengelo (Section 2.3.2). We introduce a variable that regulates the maximum percentage of patients that may walk in. Hereby, the maximum percentage is determined by the walk-in policy of the PAC and the preferences of the patients. For example, if the policy at the PAC is to schedule an appointment for 80% of the patients, a maximum of 20% of the patients will be given an opportunity to walk in. On the other hand, if 80% of the patients are allowed to walk in, but only 40% prefers to walk in, a maximum of 40% of the patients that arrive at the PAC are given an opportunity to walk in.

The preferred policy at Almelo is to schedule an appointment for almost all patients with some exceptions. Hengelo tries to let as many patients walk-in as possible. The current situation (21% of the patients at Almelo and 78% of the patients at Hengelo that walk in) is a good reflection of these policies. We introduce the variables ε_A for the maximum percentage of patients allowed to walk in at Almelo, and ε_H for the maximum percentage of patients allowed to walk in at Hengelo. Hereby, we estimate that, in the current situation, ε_A would be approximately 25%, based on the percentage of ASA score 1 patients and the current walk-in percentage. ε_H would be approximately 92%, based on the percentage of patients with surgery within consent time of three months (Section 2.3.3).

A study by Scholtens [4], focusing on patient preferences, shows that the most preferred service aspect by patients for a CT scan is a one stop shop service (43.2% of respondents), followed by short access time (22.4%), short waiting time (18.8%) and finally the autonomy in choice of moment (15.7%). We assume that *these preferences can be used for the preoperative screening service* as well and that these *patients who want to choose a convenient moment at another day are able to* do so. These figures show that approximately (43.2 + 22.4 + 18.8 =) 84.4% of the patients would prefer a walk-in possibility if the expected waiting times is acceptable (more information on the acceptable waiting time in Section 4.5.2). This leads to a variable ζ for the maximum percentage of patients that prefer walk-in.

Taking above figures into account, the possibility to walk-in depends on the policy of the PAC and the willingness of the patient. Therefore, in the model we introduce the following variables:

δ_A The maximum percentage of patients allowed and preferred to walk-in at Almelo.

δ_H The maximum percentage of patients allowed and preferred to walk-in at Hengelo.

Hereby, the walk-in probability is the minimum percentage of both variables. The values of the variables are determined by:

$\delta_A = \min [\varepsilon_A , \zeta]$ and $\delta_H = \min [\varepsilon_H , \zeta]$

For the situation at the PAC this would lead to δ_A = 0.25 and δ_H = 0.84. Including these variables influences the access time and waiting time at both locations. Because we do not schedule appointments on the same day, the low value of δ_A may lead to a higher access time, and the higher value of δ_H may lead to higher waiting times. These percentages may change when testing the interventions.

4.5.2 EXPECTED WAITING TIME FOR WALK-IN

As mention in the previous section, the choice of letting a patient walk-is not only influenced by the preferred walk-in policy. The desire of a patient to walk-in is also influenced by the expected time a patient has to wait before being screened. When a patient arrives at the front office to see if walk-in is desired, we determine the expected waiting time. Here we distinguish between the expected waiting time for a nurse and an anesthesiologist or anesthesia assistant. The expected waiting time for a nurse and anesthesiologist is determined by first checking the number of patients in the waiting room, waiting for a nurse or anesthesiologist. With this number, estimation can be made on how long it would take before these patients are screened. This leads to an expected starting time of the patient that is currently at the front office. If expected waiting times of both care providers are below a maximum acceptable waiting time, the patient prefers walk-in. We assume that *the maximum acceptable waiting time does not differ between patients or between different care providers*. However, the acceptable waiting time differs between planning methods.

To get an indication on an acceptable waiting time for walk-in patients, we make use of a study by Scholtens [4]. This study suggests that the mean maximum acceptable waiting time depends on the planning method. When having an appointment, the mean maximum acceptable waiting time is 12.38 minutes, with a standard deviation of 13.18 minutes. With a walk-in system, patients are will to wait longer. In this case, the accepted waiting times is almost doubled with a mean maximum acceptable waiting time of 23.19 minutes and a standard deviation of 27.24 minutes. We decide to use a fixed maximum acceptable waiting time of 23 minutes.

4.5.3 APPOINTMENT PLANNING IN AGENDA

In the previous sections we explained that the possibility for a patient to walk in depends on several factors. The patient only walks in if the expected waiting time for a nurse or anesthesiologist does not exceed a preset maximum acceptable waiting time. Furthermore, not all patients want to be screened the same day. A preset one stop shop percentage gives patients the possibility to schedule an appointment another day. As mentioned in Section 3.3.2, we define an appointment as an option where patients choose a day and time to come back for examination. *An appointment is always scheduled on another day, so no appointments are planned on the same day as the scheduling date*. This definition of an appointment (and the assumption) may lead to a higher access time for some patients than in the real world system, where sporadically an appointment is planned on the same day if enough time is available.

To schedule patients that want or need an appointment, agendas are generated:

- At Almelo two agendas are generated; one for ASA score 1, and one for ASA score 2 and 3 patients.
  - For the ASA score 1 agenda, intervals of 30 minutes are used, starting with the first appointment at 8.30 AM and ending with the last appointment at 4.00 PM. Every half hour two timeslot are generated. For example, there are two timeslots from 8:30 AM till 9:00 AM, two time slots from 9:00 AM till 9:30 AM, etc.
  - For the ASA score 2 and 3 agenda, intervals of 15 minutes are used, starting with the first appointment at 8.30 AM and ending with the last appointment at 4.00 PM.
- At Hengelo two agendas are generated; one for ASA score 1 and 2, and one for ASA score 3 patients.
  - For the ASA score 1 and 2 agenda, intervals of 15 minutes are used, starting with the first appointment at 8.30 AM and ending with the last appointment at 4.00 PM.
  - For the ASA score 3 agenda, intervals of 15 minutes are used, starting with the first appointment at 8.30 AM and ending with the last appointment at 12PM. ASA score 3 patients can only schedule an appointment on Friday in the morning.

For selecting a timeslot, an appointment date and time have to be determined. The policy for selecting a date of an appointment depends on the operation date of a patient and the location. For example, *patients at Almelo are scheduled on the half length of the operation date* (e.g. a patient that is planned for operation in 4 weeks is scheduled on the first possible day after 2 weeks). *At Hengelo, an appointment is scheduled as soon as possible*, so preferably the next day. As found in the current situation (Section 2.3.3), these policies will lead to a high access time at Almelo, and a low access time at Hengelo. Hereby, we have to keep in mind that having short access times is desired by the ZGT, because when patients are already screened, ZGT has fewer backlogs and more flexibility to (re-)schedule patients for an operation. The policy for selecting an appointment time on a given date is determined by randomly selecting a possible timeslot from the available timeslots on a selected day. Hereby, *the available appointment timeslot is always accepted by the patient*. This may lead to lower access time in the simulation model, than in reality. Furthermore, in anticipation on the interventions, a factor with a maximum percentage of appointments per day is included in the model. In the current situation this factors is set to 100% percent.

Within the model we assume that *patients always show up for their appointment*. This may lead to a higher utilization rate and longer waiting times than in reality. However, in the current situation the percentage of patients not showing was only approximately 3%. Moreover, a no show rate is not applicable if a walk-in method is used. Therefore, the influence may be limited anyway. Additionally, we assume that *patients always are exactly on time for their appointments*. This assumption has two consequences. First, patients will not show up early for their appointment. Therefore, no extra (voluntary) waiting time for a nurse is included in the model and patients will not be screened before the appointment time. In the current situation we do not include this voluntary waiting time as well. Second, patients will not arrive late for their appointment. This leads to a higher utilization rate and less waiting time for the care providers in the simulation model. We correct this consequence with a correcting factor in Section 6.3. Again, this assumption only has influence if an appointment based planning method is used.

4.5.4 NEXT PATIENT

The last decision making policy we discuss is the decision which patient to examine next. This decision has to be made twice: (1) by a nurse and (2) by an anesthesiologist or anesthesia assistant. We first discuss the policy of the nurse followed by the anesthesiologist.

There are two situations to distinguish related to a patient and a nurse. The first situation is when a nurse is not screening a patient. *If a nurse is unoccupied a patient that just arrived is immediately examined*. This means that a patient without an appointment is screened despite of the probability that a patient with an appointment will arrive soon. This policy leads to a lower average waiting time for patients and less overtime of a nurse. The second situation is when a nurse is occupied and the patient needs to wait in the waiting room. In this case, *if a nurse finished screening the first patient that arrived in the waiting room is examined next (first come first serve)*. Hereby, no distinction is made between patients that walk-in or patients with an appointment. This may lead to a lower average waiting time for all patients, but to a higher average waiting time for patients with an appointment. Applying this first come first serve policy is a good representation for the policy of the model in the current situation. At Almelo, almost all patients have an appointment and arrive exactly on time. A patient arriving in the waiting room will always have an appointment time that is earlier than the next patient arriving. At Hengelo, almost all patients walk in. Most patients who schedule an appointment schedule an “appointment on walk-in”. This means that they are advised to come back and walk-in at another day and time when it is less busy. Therefore, because at Hengelo almost all patients walk in, first come first serve is usable in this situation as well.

ASA score 2 and 3 patients need to be screened by an anesthesiologist or anesthesia assistant as well. The rule of priority for these patients is the same as at the nurse.

- *If an anesthesia assistant or anesthesiologist is unoccupied a patient that just arrived is immediately examined.*
- *If an anesthesiologist or anesthesia assistant finished screening the first patient that arrived in the waiting room is examined next.*

The consequences of this first come first serve policy for anesthesiologists are the same as at the nurse.

4.6 CONCLUSION ON CONCEPTUAL MODEL ASSUMPTIONS

In this chapter, we discussed the processes that take place at the PAC. An explanation of the processing steps per patient type was followed by the dependencies within the process. After briefly describing the resources needed, the processing times of these resources are determined, followed by the decision making rules for scheduling appointments. Within this chapter several assumptions are made that may influence the output of the model.

The output parameter that is most influenced by these assumptions is the waiting time. There are several assumptions that may influence the waiting time in comparison to reality. Patients arrive with the correct ASA score, no urgency patients arrive, patients arrive exactly on time for their appointments, and a first come first serve policy for choosing the next patient, are all assumptions that may reduce the average waiting time for all patients in the model. On the other hand, an assumption as all patients showing up for their appointment may increase the waiting time.

Another output parameter that is influenced by the assumptions is the access time. Planning appointments on public holidays and a proposed appointment date that is always accepted are assumptions that shorten the access time in the model. On the other hand, a fixed period before an appointment is planned, the same acceptable waiting time for all patients, and appointments always being scheduled at least the next day are assumptions that increase the access time. To prevent the model from being too complex, we decide to keep these assumptions.

In Chapter 6, we discuss the effect of keeping the assumptions by verifying and validating the conceptual and simulation model. Hereby, we have to keep in mind that the goal of our model is to compare the effect of different interventions instead of giving an accurate representation of the real world system. In the next chapter, we first provide an extensive explanation of the organizational interventions we test and why these interventions are studied.

5 ORGANIZATIONAL INTERVENTIONS

Bottlenecks for high patient satisfaction are few one stop shop possibilities, a long access time, and a long waiting time. According to Scholtens [4], the most preferred service by patients (for a CT scan) is a one stop shop service (43.2% of respondents), followed by short access time (22.4%). Other patients prefer short waiting time (18.8%) and the autonomy in choice of moment (15.7%). We assume this is roughly the same for POS. We conclude that in the current situation the one stop shop percentage at Almelo is too low and the access time is too long. Moreover, the waiting times are exceeding the acceptable waiting time, especially at Hengelo.

The goal of our research is to come up with suggestions to increase patient satisfaction at the preoperative anesthesia clinic while not delaying the planning of surgical operations. More specifically, the objective is to increase one stop shop percentages (at Almelo) and shorten waiting times by changing the number of nurses, balancing the mixture between walk-in and appointment, and changing the timeslot intervals. This chapter focuses on six organizational interventions that will be tested with the simulation model to improve these aspects. We distinguish between two different levels for interventions. On the strategic level we study the effect of changing capacity (Section 5.1). On the tactical level, we study the effect of different planning rules, timing policies, and different appointment intervals (Section 5.2). Hereby, we research organizational interventions related to the mixture of walk-in and appointment as suggested in the literature review (Chapter 3). In Section 5.3, we elaborate on the output parameters.

5.1 STRATEGIC: CAPACITY DIMENSIONING

On a strategic level at the PAC, we come up with several interventions to consider. The first intervention we consider and rule out is studying the effect of employing an anesthesia assistant instead of an anesthesiologist to examine ASA score 2 patients at Almelo, which is already the case at Hengelo. We decide not to study this effect in the simulation model, because not enough information is known about the difference in screening time between an anesthesia assistant and an anesthesiologist. Therefore, we would have used the same consultation time as an anesthesiologist at Almelo, which would not lead to a difference in results in the model.

Another intervention we consider and rule out is only screening patients at one location. Although, this may lead to less variability and more efficient screening at the PAC, there are several drawbacks to this intervention. First of all, the capacity of the PAC should increase at one location, with high investment costs involved. Second, the employees at both locations have to adapt to the radical change, which takes time. Last but certainly not least, the patient satisfaction for the patients that have to travel to another location will decrease. This is not in line with the objectives of this research. With these drawbacks in mind, we decide not to study this intervention.

The last intervention we consider and rule out is analyzing the effect of adding an ECG machine at Almelo or removing the ECG machine at Hengelo. The inclusion of an ECG machine in Hengelo leads to more patients leaving the PAC with consent than without the machine. However, when a nurse is performing an ECG on a patient, another patient may be waiting in the waiting room to be screened. This leads to extra waiting time and lower patient satisfaction. Additionally, adding an ECG machine at Almelo would lead to a large investment and this intervention would lead to a radical change in the processes. Taking these aspects into account, we decide not to study this intervention.

An intervention that we do study is the effect of changing the number of nurses at both locations, also known as capacity dimensioning [5]. The reasons to study this intervention are discussed below.

5.1.1 INTERVENTION 1: CHANGE NUMBER OF NURSES TO TWO

An intervention that the management of the PACs is currently considering and even testing themselves is the effect of changing the number of care providers per location on the access and waiting times. Hereby, management mainly focuses on changing the number of nurses. Therefore, for this intervention we focus on the number of nurses as well.

An option we rule out is the possibility of an extra anesthesiologist at Almelo. In this case, there would be capacity for two nurses that on average need 16.5 minutes to screen a patient, and two anesthesiologists that on average need 11.2 minutes to screen a patient and do not have to screen ASA score 1 patients. An undesired consequence is that the utilization of the anesthesiologists would be very low. Another option we rule out is the possibility of two anesthesia assistants at Hengelo. In this case, there would be capacity for only one nurse to screen patients. This would not be sufficient to provide enough patients for the anesthesia assistants, and the waiting time for a nurse would increase dramatically.

We do consider changing the number of nurses. Currently, three nurses are working at Almelo. This leads to an average waiting time of only 3.1 minutes for these care providers. Moreover, a patient that arrives early for an appointment is screened before the appointment time in more than 50% of the occasions. This indicates that a nurse is frequently unoccupied/waiting when a patient arrives. Management at Almelo is wondering what the effect is of having two instead of three nurses at the PAC. Therefore, we study this change.

In the current situation at Hengelo, there are two nurses and one anesthesia assistant from Monday till Thursday. On Friday, one room is dedicated to an anesthesiologist and one room to an anesthesia assistant. This leads to only one room being available for a nurse, whereas extra ASA 3 patients arrive to be screened by a nurse before being screened by the anesthesiologist. This leads to longer waiting times. Therefore, management is considering the effect of dedicating an extra room to a nurse on Friday. We study the effect in the simulation model.

For this intervention we change the number of nurses at Almelo from 3 to 2, and the number of nurses on Friday at Hengelo from 1 to 2. The number of nurses assigned for the tactical level interventions will depend on the outcome of this strategic intervention.

5.2 TACTICAL: PLANNING RULES AND APPOINTMENT INTERVALS

In the literature review (Chapter 3) we found several interventions on a tactical level to improve the access and waiting times. Two notable organizational interventions we rule out are: the possibility to let every patient walk in and the possibility to schedule every patient. Walk-in for every patient is not realistic because some patient prefer being examined another day. An appointment based system is not realistic because it is not in line with the goals of ZGT. Moreover, Zonderland et al. [42] already found that scheduling an appointment for all patients did not have a significant effect on access and waiting time reduction. Other interventions we rule out are:

- Rescheduling appointments. Although Zonderland et al. show that this decreases the waiting time [42], rescheduling appointments may lead to less patient satisfaction, due to the increase in access time and patients may have to take another day off at work.

- Regrouping employee tasks. Zonderland et al. show that this decreases the waiting time as well. However, for this intervention we need more information on the specific tasks and time it would take
- Planning patients based on specialism. Research by Schoenmakers [43] shows that a planning method based on ASA scores instead of specialism leads to less variability and therefore to less waiting times.
- Tailor the appointment system to the individual care provider's style [49]. This intervention would lead to a lower waiting time. However, not enough information is known about the different care providers and an appointment system tailored for each care provider is not practical for a universal system at both locations. However, in Section 6.3.3, we perform a sensitivity analysis to determine the effect of different mean consultation times.

Organizational interventions that we do research focus on different planning rules and appointment intervals. As shown in the current situation (Chapter 2) and literature (Chapter 3), a walk-in system leads to a higher one stop shop percentage and thereby to shorter access times. Additionally, earlier timing of appointments leads to shorter access times as well. Moreover, appointment intervals that are equal to or slightly larger than the expected consultation time reduce the waiting time. This is in line with the objective to increase one stop shop percentages (at Almelo) and shorten waiting times. Therefore, the organizational interventions we study on a tactical level include several options to use the walk-in system, an option to change the timing of scheduling appointments, and an option to change the appointment intervals. Intervention 2 (Section 5.2.1) is based on scheduling appointments on the least busy moments. Intervention 3 (Section 5.2.2) studies the effect of a maximum percentage of walk-in and appointments per day. Intervention 4 is a combination of intervention 2 and 3 (Section 5.2.3). Intervention 5 focuses on different timing policy for scheduling appointments (Section 5.2.4). Intervention 6 focuses on changing the current timeslots to better match the expected consultation times (Section 5.2.5). More information on these interventions can be found below.

5.2.1 INTERVENTION 2: FIRST SCHEDULE APPOINTMENT DURING LEAST BUSY DAYS AND HOURS

The number of patients that arrive differs per day and hour. This intervention focuses on balancing the mixture between walk-in and appointments depending on the busyness per day and hour. On a busy day more patients are expected to arrive than on a less busy day. Therefore, scheduling an appointment on a less busy day would lead to a better balance in the expected number of patients screened per day and to a higher utilization.

We use a method derived from an iterative methodology by Kortbeek et al. [40] to design an appointment system that offers both walk-in and appointments. The model prescribes the number of appointments to plan per day and the moment on the day to schedule the appointments. The model determines the best appointment schedule to minimize access and waiting times with a first come first served priority rule for patient planning. Basically, the outcome of the methodology is to schedule more patients during the least busy days and hours than at the busiest moments. We do not use the methodology of Kortbeek et al. directly, because it is only applicable for a short time period (one week) whereas the situation at the PAC is more complex. However, the idea behind the model can still be used.

Patients per day

In Section 2.2.5 we discuss the expected number of arrivals per day and hour. We find that the busiest days at Almelo are Monday (22%) and Tuesday (24%) and at Hengelo Tuesday (23%) and Wednesday (22%). The least busy days are Thursday and Friday at Almelo, and Monday and Friday at Hengelo. Therefore, we schedule more appointments on these less busy days. The data for the arrival fraction per weekday are shown in Table 5.1.

Day	Monday	Tuesday	Wednesday	Thursday	Friday
Almelo	0.222	0.235	0.199	0.166	0.178
Hengelo	0.183	0.238	0.219	0.206	0.154

Table 5.1: Arrival fraction per weekday at Almelo and Hengelo

We use these data to determine the number of appointments that have to be scheduled on less busy days before scheduling appointments on busy days. First, we calculate the maximum expected number of arrivals for a weekday by multiplying the mean number of arrivals per week with the highest fraction found in Table 5.1. We expect the most patients to arrive on Tuesday at Almelo and Hengelo, respectively (0.235 *210.9 =) 49.6 and (0.238 * 188.3=) 44.8 patients.

Next, we determine the number of appointments that have to be schedule to have an equal expectation of the number of patients per day. For example, we expect (0.183 * 188.3 =) 34.5 patients to arrive on Monday at Hengelo. Therefore, we have to schedule (49.6 – 34.5 =) 15.1 patients on Monday at Hengelo, before scheduling patients on Tuesday. We determine the number of appointment to be scheduled per day on a weekly basis. This means that we compare the expected number of patients per weekday. When the expected number of patients is equal for every weekday in the same week, it becomes possible to schedule one appointment on every weekday again until all timeslots are filled on the least busy day.

Patients per hour

Section 2.2.5 also describes that the least busy moments per day for patients to arrive are early in the morning (till 9AM), early in the afternoon (between 12PM and 2PM), and late in the afternoon (4 PM). In our model no appointments are made earlier than 8:30AM or after 4PM. Therefore, we research the effect of first scheduling appointments between 8:30AM and 9AM and in the afternoon. Hereby, we keep in mind that at 12:00PM there are still patients waiting in the waiting room, and planning the first patient at exactly 12:00PM would lead to higher waiting times.

We use Little’s law [58] to calculate the expected number of patients in the system at 12:00PM, and to determine the first appropriate timeslot to screen patients without a long waiting time. Therefore, we first calculate the expected arrival rate (mean number of patients per week * maximum fraction per day * fraction between 11 and 12) and the throughput time for a nurse (average waiting time + screening time). This leads to a maximum expected arrival rate of 7.0 at Almelo and 6.6 at Hengelo, and an average throughput time for a nurse of 23 minutes at Almelo and 15 minutes at Hengelo. When multiplying these figures, we find that the expected number of patients at the PAC at 12:00 PM is 2.7 at Almelo and 1.7 at Hengelo. With two nurses at both locations, and an average screening time of 16 and 12 minutes, the first timeslot for patients to be screened without an increased waiting time is 12:15PM. Therefore, for this intervention we first schedule patients starting at 12:15PM till 2:00 PM. The least busy days and hours for intervention 2 are summarized in Table 5.2 on the next page.

Location	First appointments on (days)	First appointments between (hours)
Almelo	Thursday and Friday	8:30AM – 9:00AM and 12:15PM – 2:00PM
Hengelo	Friday and Monday	8:30AM – 9:00AM and 12:15PM – 2:00PM

Table 5.2: Least busy days and hours for intervention 2

For this intervention we first test the effect without first scheduling on the least busy hours. Next, we include the hour policy. We analyze the differences between the intervention and the current situation, and between the intervention with and without specific planning hours.

5.2.2 INTERVENTION 3: MAXIMUM PERCENTAGE OF WALK IN AND APPOINTMENTS PER DAY

The third intervention is based on balancing the mixture between walk-in and appointments. A study by Murray and Tantau [37] suggests that scheduling an appointment for a maximum of 30% of the timeslots per day lead to shorter access times. We research the effect of changing the planning policies according to this approach for the situation at the PAC. Hereby, we change the percentage of patients that is allowed to walk-in and randomly assigning patients to timeslots with a maximum percentage of filled timeslots per day. With the patient preferences in mind, we aim at a one stop shop approach for 40% till 65% of the patients. As shown in Table 5.3, we use a maximum percentage of appointments range between 30% and 80% per day with incremental steps of 10%. We compare the outcomes with the outcomes in the initial situation.

	Percentage of appointments	Percentage of walk-in
Experiment 1	30%	70%
Experiment 2	40%	60%
Experiment 3	50%	50%
Experiment 4	60%	40%
Experiment 5	70%	30%
Experiment 6	80%	20%

Table 5.3: Percentages of appointments per day for intervention 3

5.2.3 INTERVENTION 4: COMBINATION OF INTERVENTION 2 AND 3

Our forth intervention is a combination of intervention 2 and 3. We research the effect of scheduling appointments for a higher percentage of patients during the least busy days, whereas during the busier periods a low percentage is used. With the patient preferences in mind, we aim at a one stop shop approach for 40% till 65% of the patients. Therefore, for the least busy days we aim at scheduling 60% of the appointments, whereas on the busy days we aim at 35%. We use the percentages shown in Table 5.4. The calculations of these percentages are shown in Appendix F.

	Almelo	Hengelo
Monday	39.7%	51.4%
Tuesday	35.0%	35.0%
Wednesday	48.0%	40.7%
Thursday	60.0%	44.5%
Friday	55.7%	60.0%

Table 5.4: Percentages of appointments per day per location for intervention 4

5.2.4 INTERVENTION 5: CHANGE TIMING OF SCHEDULING APPOINTMENTS

An influential factor on the one stop shop possibility and the access time is the timing of scheduling an appointment. Scheduling appointments depending on the operation date, instead of using a fixed number of weeks for every patient, is performed to prioritize patients with an early operation date.

Moreover, in case of scheduling an appointment exactly a fixed number of weeks later will not lead to less variability. In the current situation, patients that have to schedule an appointment at the PAC at Almelo are scheduled at approximately half length of the operation date. This increases the access time. At Hengelo, patients are scheduled as soon as possible. This leads to low access times, but may lead to higher waiting times because fewer timeslots are available in the near future for (urgency) patients with an early operation date. Therefore, for this intervention we study the effect of changing the timing of the appointment. As shown in Table 5.5, we use a timing percentage between 5% and 95% of the operation date with incremental steps of 15%. We compare the outcomes with the outcomes in the initial situation.

	Timing of appointment
Experiment 1	5%
Experiment 2	20%
Experiment 3	35%
Experiment 4	50%
Experiment 5	65%
Experiment 6	80%
Experiment 7	95%

Table 5.5: Timing of an appointment for intervention 5

5.2.5 INTERVENTION 6: CHANGE APPOINTMENT INTERVALS

Our final intervention focuses on changing the appointment intervals. As shown in Table 5.6, in the current situation the consultation times and timeslots intervals do not always match the patient type.

	Screening time ASA 1 (timeslot interval)	Screening time ASA 2 (timeslot interval)	Screening time ASA 3 (timeslot interval)
Almelo			
Nurse	16 minutes (30 minutes)	16 minutes (15 minutes)	25 minutes (15 minutes)
Anesthesiologist		11 minutes (15 minutes)	17 minutes (15 minutes)
Hengelo			
Nurse	12 minutes (15 minutes)	13 minutes (15 minutes)	13 minutes (15 minutes)
Anesthesia Assistant		13 minutes (15 minutes)	
Anesthesiologist			13 minutes (15 minutes)

Table 5.6: Consultation time and timeslot interval per patient type, per care provider for intervention 6

The literature review shows that the waiting time for patients with an appointment may be reduced by choosing an appointment interval that is equal or slightly greater than mean consultation time instead of shorter (e.g. timeslot nurse for ASA score 3 patients at Almelo). Additionally, choosing an interval that is not too large (e.g. timeslot nurse for ASA score 1 patients at Almelo) leads to more throughput and to a higher utilization. However, when setting appointment intervals, an interval should be practical as well. We research this alternative by setting a practical appointment interval close to the mean consultation time per ASA score. We study two different settings:

1. At Almelo, the timeslot for a nurse will be 15 minutes for ASA score 1 and 2 patients and 2 sequential timeslots of 15 minutes (so 30 minutes) for ASA score 3 patients. The timeslot for an anesthesiologist will be 15 minutes for ASA score 2, and 2x15 minutes for ASA score 3 patients. At Hengelo, there will be 5 consults per hour. Therefore, timeslots for a nurse will be 12 minutes and 12 minutes for an anesthesia assistant/anesthesiologist.
2. At Almelo, all timeslot for a nurse will be 20 minutes for ASA score 1, 2, and 3 patients. The timeslot for an anesthesiologist will be 20 minutes for ASA score 2 and 3 patients as well. At Hengelo, timeslots for a nurse will be 12 minutes and 12 minutes for an anesthesia assistant for ASA score 1 and 2 patients. For ASA score 3 patients the timeslots are set at 15 minutes for a nurse and an anesthesiologist. These intervals can also be found in Table 5.7. Hereby, *the timeslot intervals for setting 2 are in italic*.

Patient type	ASA score 1	ASA score 2	ASA score 3
<u>Almelo</u>			
Nurse	15 minutes *20 minutes*	15 minutes *20 minutes*	2 x 15 minutes *20 minutes*
Anesthesiologist		15 minutes *20 minutes*	2 x 15 minutes *20 minutes*
<u>Hengelo</u>			
Nurse	12 minutes *12 minutes*	12 minutes *12 minutes*	12 minutes *12 minutes*
Anesthesia Assistant		12 minutes *12 minutes*	
Anesthesiologist			12 minutes *15 minutes*

Table 5.7: New timeslot intervals for intervention 6 (setting 2 in italic)

A consequence of more time per appointment intervals is that fewer timeslots per day are available. This may lead to a longer access time for patients. On the other hand, decreasing the timeslot interval may lead to longer waiting time. Therefore, we pay close attention to these parameters. We have to keep in mind that the appointment interval only influences the access and waiting time if an appointment-based planning method is used.

In the sections above we discussed several interventions for the situation at the PAC. The next section will focus on the parameters that are taken into account in the simulation model to determine the effect of these interventions.

5.3 OUTPUT PARAMETERS

To determine the effect of the interventions we need to compare the outcomes of several parameters. For every patient we register the following output:

- <u>*Walk-in:*</u> we register whether a patient made an appointment or walked in.
- <u>*Consent on time:*</u> we register whether a patient has consent on time. A patient has consent on time when the consent date is before the operation date. Otherwise it is categorized as consent not on time.
- <u>*The waiting time for a nurse:*</u> we register the waiting time for a nurse. The waiting time is determined by the difference between entering the waiting room and the start of the screening. Waiting time of a nurse starts when the patient enters the waiting room for the first time until the start of the screening by a nurse.

- *The waiting time for an anesthesia assistant or anesthesiologist:* we register the waiting time for an anesthesia assistant and anesthesiologist. The waiting time is determined by the difference between entering the waiting room and the start of the screening. The waiting time of the anesthesia assistant or anesthesiologist starts when the screening of the patient by the nurse is finished.
- *The access time:* we register the access time for a patient. The access time at Almelo is determined by the difference in days between arriving at the APA and arriving at the secretary of the PAC. At Hengelo, this is determined by the difference between arriving to schedule an appointment, and day of consultation. For walk-in patients, this would be on the same day.

With this information we calculate the mean, standard deviation, and maximum of the access and waiting times per day, week, and experiment. In the random sample, we do not distinguish between the waiting time for the anesthesia assistant and anesthesiologist at Hengelo. Therefore, the waiting times are the same. In the simulation model we do distinguish between the waiting times. We use the following formula to combine the waiting times of the anesthesia assistant and anesthesiologist at Hengelo:

$$\frac{(Average\ WT\ A.Assistant\ *\ ASA\ 2\ percentage)\ +\ (Average\ WT\ Anesthesiologist\ *\ ASA\ 3\ percentage)}{(ASA\ 2\ +\ ASA\ 3\ percentage)}$$

Furthermore, we calculate the percentage of patients that walked in (one stop shop percentage) and the percentage of patients with consent on time. We use this data to determine the effect of the interventions for ZGT.

In this chapter, we discussed several interventions that we considered to reduce the access and waiting times. We test six of these interventions with the simulation model. On a strategic level we introduced an intervention focusing on capacity dimensioning of the nurses at both locations. On a tactical level, we described several interventions related to block planning, an intervention related to the timing of appointments, and an intervention on scheduling appointments with different intervals. Furthermore, we discussed the different parameters we use to determine the effect of the interventions. In Chapter 6, we continue with the implementation of the conceptual model and the interventions in our simulation model. Furthermore, we verify and validate the resemblance between the conceptual model, simulation model, and real world system.

6 IMPLEMENTATION

Now the conceptual model and the interventions are known, a simulation model can be programmed. In this chapter we start with introducing our simulation model (Section 6.1). After verifying whether this simulation model is a correct representation of the conceptual model (Section 6.2), the next step is to validate whether the simulation model resembles the reality as well (Section 6.3). If the verification and validation lead to a sufficient simulation model, we can test the interventions as described in Chapter 5.

6.1 SIMULATION MODEL

We use the information as described in Chapter 4 and 5 to build a simulation model. Our model is developed with Tecnomatix Plant Simulation and a screenshot of the main window is shown in Figure 6.1. The processes at Almelo and Hengelo (Section 4.1), including the resources (Section 4.3) and decision making policies (Section 4.5), are divided per department and can be found in the upper left corner of the simulation screen under “Almelo” and “Hengelo”. The modules beneath “performance measurements” indicate the modules that register all output information as described in Section 5.3. The information about process dependencies (Section 4.2) and processing times (Section 4.4) are integrated in the modules under “settings & experimental factors”. The modules and tables needed for the interventions (Chapter 5) can be found under “interventions”. The modules under “event controls” are used to control the events for every new day, week, run, and experiment. Detailed information on the simulation model processes at Almelo and Hengelo can be found in Appendix G.

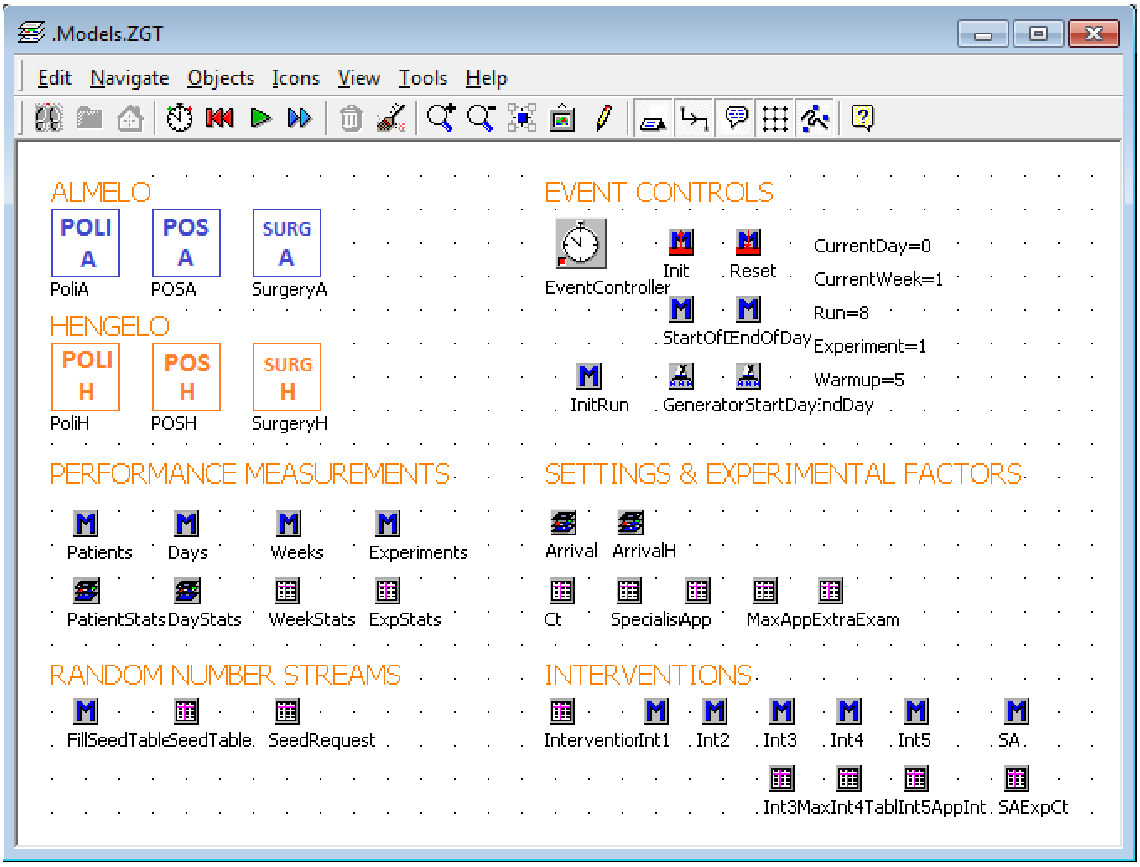


Figure 6.1: Screenshot of the main window of the simulation model

We need to verify whether our simulation model is conforming to the conceptual model as described in the previous chapters. This will be done in the next section.

6.2 MODEL VERIFICATION

According to Law [54], verification is needed to check whether the conceptual model has been correctly translated into a simulation model. There are several techniques to verify a simulation model.

The first technique we use is debugging modules separately. We test every module we create or improve to see the effect on the model and to see if errors occurred. The current simulation model does not contain errors anymore. The second technique we use is that we let more than one person review the model. We visit the PAC at Almelo and Hengelo to show the current model and ask for feedback on the simulation model. We used this feedback to improve our model. This same technique was used with the management of the PAC. Another helpful technique we frequently use is observing the animation to check if previously undetected errors occur.

Another technique is computing the sample mean and standard deviations for the simulation input probability distributions of the consultation times and compare these with the mean and standard deviation of the historical data. We analyze the output of ten years of simulation and find that for all consultation times the mean and standard deviation of consultation times were similar to the historical data.

The last technique is to use a variety of settings of input parameters, and check if the output is reasonable. This is a helpful technique. An error we find is that the maximum waiting time for an anesthesiologist is sometimes more than three hours, although we set the input parameter "max accepted waiting time" at 60 minutes. This error was easily fixed afterwards we found out that the waiting time in the waiting room of the anesthesiologist was not included.

A discrepancy we find, when comparing the input and output parameters, is that not all patients that enter the system also are registered to exit the system at the end of the experiment. This is caused by patients waiting at home till their appointment date or at the extra examination at the end of the experiments (end of the year). Patients still waiting at home do not have completed the whole POS process yet and their data on waiting time and consultation time is therefore not included in the statistics. However, when analyzing the results, we take into account the data on walk-in and access time of the patients that are waiting at home. All data of the patients waiting at the extra examination at the end of the experiment are included, because they completed the POS process and an estimation of the time till extra examination results can be made easily (fixed number of days per extra examination type).

We also find that the throughput at the beginning of a run is lower than from historical data, especially at Almelo. This is due to the fact that in the beginning no patients are scheduled in the agendas (the system is empty), whereas patients are being scheduled for appointment. This leads to a lower throughput, utilization, and waiting time. To handle this discrepancy, we use Welch's procedure (Appendix H) to determine a warm-up period. We find that a warm-up period of five weeks for the simulation model is appropriate.

The last discrepancy we find is that the output differs between runs. We determine the minimum number of replications needed, to reduce the variance of the results and to come to valid conclusions. We use a confidence interval of 95% with a relative error smaller than 0.05, and find that a run length of one year (52 weeks) with 23 replications is appropriate. The calculations can be found in Appendix I.

From the techniques we used in this section, we conclude that the simulation model is a good representation of the conceptual model. In the next section, we analyze whether the simulation model also resembles the real world system.

6.3 MODEL VALIDATION AND CREDIBILITY

After analyzing whether the simulation is a correct representation of the conceptual model, the next step is to validate whether it resembles reality as well. According to Law [54], there are six classes of techniques for increasing the validity and credibility of a simulation model.

1. Collect high-quality information and data on the system.
2. Interact with the manager on a regular basis.
3. Maintain a written assumptions document and perform a structured walk-through.
4. Validate components of the model by using quantitative techniques.
5. Validate the output from the overall simulation model.
6. Animation.

These techniques will be discussed in the following sections.

6.3.1 COLLECT HIGH-QUALITY INFORMATION AND DATA ON THE SYSTEM

We start with discussing the first technique as mention by Law, “collecting high quality information and data on the system”. We collected information and data on the system in several ways. To learn more about the process and understand the system we interviewed several employees who were involved in the system. To obtain high-quality information and data on the patients (arrival rates, access time etc.) we analyzed the ZGT database Chipsoft-EZIS. We used data from September 2010 till August 2011. These data give a good indication for a weekly basis. We used a random sample to obtain more insight in the current waiting times and consultation times. The waiting times and consultation time per care providers were measured for six days. 222 patients at Almelo and 222 patients at Hengelo participated. With an estimated population of 10000, 222 patients in the random sample, and a confidence interval of 95%, a marginal error of 6.5% was calculated. The calculations can be found in Appendix C. This is enough to give an indication of the waiting and consultation times. However, higher quality information may be obtained with a longer random sample period. To find relevant results of previous simulation studies related to our problem we researched literature.

6.3.2 INTERACT WITH MANAGERS, MAINTAIN WRITTEN ASSUMPTION DOCUMENT

As defined by Law as the second technique, we had several interactions with the managers. We discussed the progress of the project with the management of the PACs and we involved the employees of the PAC as well. We asked them to evaluate the model, to get feedback on how to develop a more realistic model and to get more credibility. We asked for feedback on the simulation model and how to improve it. We discussed the assumptions to be made without making the simulation model unrealistic or too detailed. These assumptions are written in Chapter 4 (third technique for validation).

6.3.3 VALIDATE COMPONENTS OF THE MODEL BY QUANTITATIVE TECHNIQUES (SENSITIVITY ANALYSES)

Law discusses several quantitative techniques to validate components. We use two of these techniques. The first technique is used to analyze the fit of a theoretical probability distribution to a set of observed data. We use this to determine the probability distribution functions of the consultation times. The second technique we use, called sensitivity analysis, is to investigate whether a particular factor appears to be important. We discuss these techniques below.

Probability distribution of the consultation times

We use a quantitative technique to determine the consultation times per care provider when we analyze the fit of a theoretical probability distribution to a set of observed data. We use ExpertFit to make a graphical plot of the observed data, followed by a Q-Q plot to test the discrepancies with the proposed distribution. Last, a goodness-of-fit test was performed. With this procedure we found an acceptable probability distribution function for all consultation times per care provider. More information on the consultations times can be found in Section 4.4.2.

Sensitivity analyses

Another quantitative technique we use is sensitivity analysis. We use this technique to investigate whether a particular factor appears to be important. For our model, sensitivity analysis is used to investigate the effect on the one stop shop percentage, percentage of patients with consent on time, waiting times, and access times. We perform sensitivity analysis on the arrival rates, mean consultation time, standard deviation of consultation time, and duration of extra examination by incrementally changing the value of one factor. The effects per analysis are discussed below. Appendix J shows more details and figures of the analyses.

Arrival rates: We investigate the arrival rates to analyze the influence of very busy and quiet periods. As suspected, we find that the average waiting time per care provider is influenced by the number of patients arriving at the PAC. Care providers with high walk-in percentages (nurse and anesthesia assistant at Hengelo) are influenced more than 'appointment based' care providers. The average waiting time for the care providers doubles when comparing very busy and very quiet periods Moreover, the waiting time is more influenced during the busy periods than during quiet periods. This is in line with Pollaczek-Khinchine formula which states that mostly equipment loading (utilization) drives the expected work in progress (WIP) and therefore waiting time [58]. In our simulation model we only take into account one standard deviation from the mean. Therefore, extremely busy or quiet days are not included. This may lead to a lower mean and standard deviation of the waiting time in the simulation model than in reality.

Mean consultation time: During the interviews we noticed that employees often noted that the consultation time is highly dependent on who is screening a patient. For example, the consultation time for the same patient would be 12 minutes for nurse A, 15 minutes for nurse B, and 18 minutes for nurse C. Employees suggest that causes for these differences are experience and the capability of some care providers to cut to the chase easily, whereas for others this is more difficult. We investigate the influence of the mean consultation times per care provider and whether these differences influence the waiting time for patients significantly. For example, when we analyze the data in Figure 6.2, we conclude that if a care provider at Hengelo needs 30% more consultation time per patients (factor 1.3), the waiting time can increase with more than 100%. If a care provider needs 30% less consultation time (factor 0.7), the waiting time can decrease with almost 50%. Again, this can be explained with Pollaczek-Khinchine formula [58]. More consultation time per patient leads to higher utilization and more WIP, whereas low consultation time leads to lower utilization and less WIP. According to this formula, a higher utilization has more influence on the WIP and therefore on the waiting time than a low utilization. This suggests that waiting times in the simulation model can be 50% less or 100% more in reality depending on the care provider on duty Moreover, a consequence of increased waiting times is that patients choose to come back another day. This leads to longer access times.

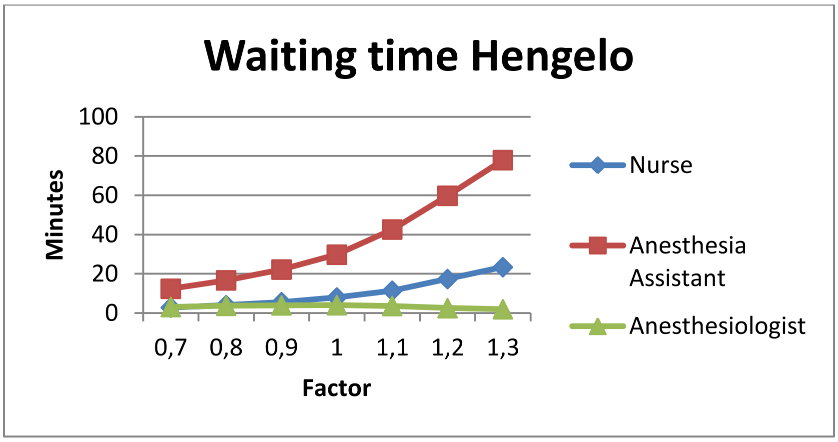


Figure 6.2: Influence of mean consultation time per care provider on the waiting time at Hengelo

Standard deviation of consultation time: We investigate the standard deviation of consultation times to analyze the influence of a high or low variance in consultation of patients. As the formula of Pollaczek and Khinchine [58] already indicates, a higher variance of consultation times leads to more WIP, and therefore to longer waiting times. Moreover, we find that the waiting times are more influenced for individual care providers (anesthesiologist and anesthesia assistant) than for nurses. The reason is that varying the standard deviation has more influence on the utilization of the individual care providers as well. We conclude that reducing the variability between patients leads to a lower standard deviation for the care providers and to less waiting time.

Duration of extra examination: Figure 6.3 shows the outcome of the last sensitivity analysis we performed. This analysis was related to the time till the results of extra examination are in. We research the effect of varying the duration for the extra examination type 'consult with cardiologist' from 5 till 35 days (currently 20 days). We find that the duration has more effect on the percentage of patients with consent on time at Hengelo than at Almelo. With almost three times more patients sent to the cardiologist and on average an earlier operation date than at Almelo, this is not surprising. We use a fixed number of days in the simulation model, whereas in reality there is more flexibility for a consult with a cardiologist. However, this analysis gives a good indication on the influence of the cardiologist on the percentage of consent on time.

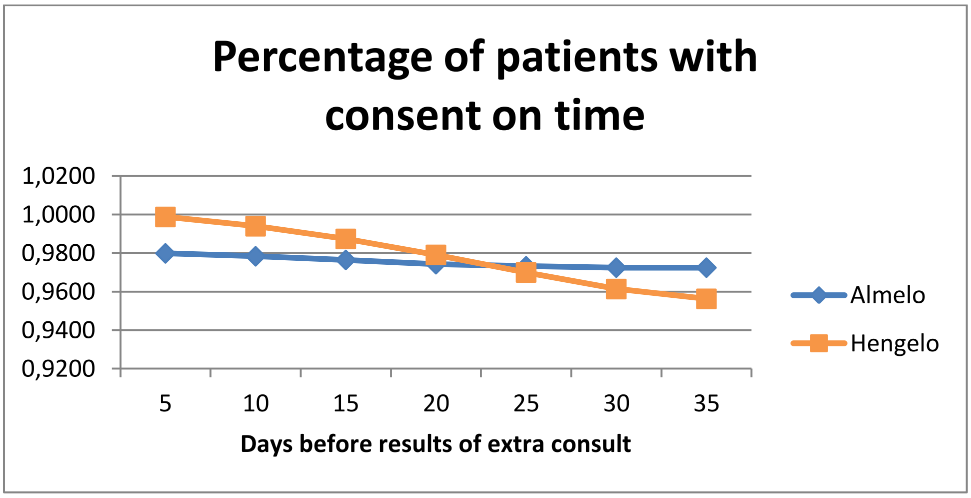


Figure 6.3: Influence of the duration of a consult with a cardiologist on the percentage of patients with consent on time

In this section we discussed the effects of several factors on the one stop shop percentage, percentage of patients with consent on time, waiting times, and access times. We conclude that the waiting time in our simulation model may be different than in reality. This is due to the assumptions not to include extremely busy or quiet days and not considering the difference between the mean consultation times per care provider. Quiet days and lower mean consultation times lead to lower waiting times, whereas busy days and higher mean consultation times have the opposite effect. We also found that the access time and consent on time is influenced by the duration of extra examination. In the simulation model this variable is fixed, whereas in reality it is more flexible. Some patients will be able to schedule a consult with a cardiologist earlier and for others the access time may be higher. However, these figures give a good indication on the influence of the variables without the interference of other aspects.

6.3.4 VALIDATE THE OUTPUT FROM THE OVERALL SIMULATION MODEL (CORRECTING FACTORS)

Another technique to validate the simulation model is to compare the output of the simulation model with historical data. Our model registers several outputs related to one stop shop percentage, waiting time, and access time. In this section we first compare these outputs with the expected outputs in reality. Next, we discuss several factors to correct the discrepancies and other factors that explain the differences.

Comparison of simulation model and reality

When comparing the output from the simulation model and the historical data, we have to keep in mind that during the measurement period the percentage of patients that had an ASA score 2 at Hengelo was lower than from historical data, respectively 70% and 80%. This leads to a higher number of patients that needed screening in the simulation and to a higher waiting time in the simulation model as well. To be able to compare whether the simulation output is equal to the historical data from the measurement period, we have to use the same settings for both situations. Therefore, we decrease the ASA score 2 percentage at Hengelo from 80% to 70% for this comparison. However, we keep a percentage of 80% of ASA score 2 when comparing the results of the intervention, because this is equal to the historical data (Section 2.2.4). The values of the current situation and the outcomes of the simulation model are shown in Table 6.1.

Situation (location)	Walk-in percentage	Average WT Nurse	Average WT Anesthetist	Average Access Time	St. Deviation Access Time
Current situation (Almelo)	0.21	3:06	15:30	13.7	21.0
Simulation model (Almelo)	0.23	0:38	7:42	12.9	11.0
Current situation (Hengelo)	0.78	19:42	18:24	1.9	9.4
Simulation model (Hengelo)	0.56	4:29	13:40	0.9	1.2

Table 6.1: Outcomes of the simulation model and the current situation

As expected, we find discrepancies between the simulation model and the expected data related to the one stop shop percentage, waiting times, and access times. In the simulation model, the one stop shop percentage is higher at Almelo and lower at Hengelo. The waiting times for all care providers at Almelo and Hengelo are lower than the waiting time in the measurement period. When we compare the outputs for the access time we conclude that at both locations the values in the simulation model are lower than in reality.

Within our conceptual model we made assumptions that influence the output of the simulation model, which led to these discrepancies. In the next sections we first discuss several factors that partly explain these differences, and which are implemented to correct the output of the simulation model to better match reality. We then compare the outputs of the simulation model with the correcting factors and the current situation. Finally, we elaborate on other factors that may cause the discrepancies after implementing the correcting factors. The correcting factors we introduce are based on the following assumptions: patients always arriving on time, no ECG by a nurse at the PAC at Hengelo, patients always arrive with the correct ASA score, and the maximum acceptable waiting time of 23 minutes.

Correcting factors

As mentioned above, there are several factors that may cause the discrepancies between the output of the simulation model and historical data. To get a better match between the model and reality, we introduce several correcting factors that we take into account for the analysis of the results. The correcting factors we use are based on the assumptions that patients always arriving on time, that no ECG by a nurse at the PAC at Hengelo, that patients always arrive with the correct ASA score, and that the maximum acceptable waiting time of 23 minutes. We elaborate on these factors below.

Patients always arrive exactly on time: For our model we assume that all patients arrive exactly on time for their appointments. This has two consequences. On the one hand, the (voluntary) waiting time for patients that arrive early is not taken into account. All patients that arrive early for their appointment have an average extra (voluntary) waiting time of 7.2 minutes (Section 2.3.5). However, we do not take these waiting times into account in historical data either, so no correcting factor is included.

On the other hand, in historical data we take into account that 13.8% of the patients arrive later for their appointments, with an average lateness of 7.0 minutes (st. dev. 6.6 minutes) (Section 2.3.5). This leads to a lower utilization for the nurse and a higher waiting time, because the next patient with an appointment has to wait for its predecessor. This means that if a patient arrives late, and the next patient is screened immediately after the patient leaves the room, on average this next patient has waited for 7.0 minutes extra. A patient can only arrive late if an appointment is scheduled, so we only take into account the percentage of patients that did not walk in (1-walkin percentage). Patients arrive on average 7.0 minutes late in 13.8% of the times an appointment is scheduled. Therefore, we add a factor that calculates the extra waiting time caused by the percentage of patients with an appointment that arrive late with an average of 7 minutes. This leads to the following formula: $((1 - walkin\ percentage)\ *\ 13.8\%\ * 7.0\ minutes)$, and an increase in average waiting time of a nurse by 44 seconds at Almelo and 34 seconds at Hengelo.

ECG at Hengelo: Another assumption which influences the outcomes of the simulation model is that performing an ECG by a nurse at Hengelo is not taken into account. This activity leads to another patient waiting until the ECG is finished. As discussed in Section 2.3.5, an ECG takes approximately 5 minutes and is taken by 31% of the patients at Hengelo Therefore, we add $(5\ minutes\ *\ ECG\ percentage\ at\ Hengelo)$ 1 minute and 33 seconds to the average waiting time for a nurse at Hengelo. Moreover, in general an ECG is performed before consultation by an anesthesia assistant or anesthesiologist. Therefore, the waiting time for these care providers decrease with 1 minute and 33 seconds.

Patients with wrong ASA score: The assumption that patients always arrive with a correct ASA score influences the outcome of the simulation model as well. In our simulation model we assume that every ASA score 1 patient with an appointment only needs screening by a nurse, and an ASA score 2/3 patient needs screening by an anesthesiologist as well. In reality some patients are only scheduled for an appointment with a nurse whereas they also need screening by another care provider, which is therefore not anticipated and leads to higher waiting times for an anesthesiologist or anesthesia assistant. In Section 2.3.5, we find that the probability of a patient being assigned the wrong ASA score is 5.4% at Almelo and 9.7% at Hengelo. If the care providers are occupied, the waiting time will increase with the expected consultation time of the patient. This consultation time is 11.2 minutes at Almelo and 12.7 minutes at Hengelo (Section 2.3.4). The correcting factor is only applicable for ASA score 1 patients with an appointment (1 – walk in percentage). Hereby, the percentage of patients with ASA score 1 is 33.7% at Almelo and 14.9% at Hengelo (Section 2.2.4). With this data we add a factor to the outcomes to better resemble the reality with the formula: $ASA1\,\% \, * \, probability\ of\ wrong\ ASA\ score * \left(1 - walkin\%\right) * mean\ consultation\ time\ ASA2$. This leads to an extra waiting time for an anesthesiologist at Almelo of 9 seconds (33.7% * 5.4% * 0.75 * 11.2 minutes) and 6 seconds (14.9% * 9.7% *0.59 * 12.7 minutes) at Hengelo.

Maximum acceptable waiting time: We find that the walk in percentage and waiting times at Hengelo in the simulation model are significantly lower than in reality, when using the mean acceptable waiting time of 23 minutes as suggested in Section 4.5.2. We test whether the mean maximum acceptable waiting time plus one standard deviation leads to a walk-in percentage that better resembles the reality. We find that this acceptable waiting time increase the walk-in percentage to 70%, and increases the waiting time as well.

We discussed several factors that influence the simulation model outcomes. We analyze what the effect is after including these correcting factors in the outcomes. The results are shown in Table 6.2.

Situation (location)	Walk-in percentage	Average WT Nurse	Average WT Anesthetist	Average Access Time	St. Deviation Access Time
Current situation (Almelo)	0.21	3:06	15:30	13.7	21.0
Corrected sim. model (Almelo)	0.24	1:25	8:24	12.8	11.0
Current situation (Hengelo)	0.78	19:42	18:24	1.9	9.4
Corrected sim. model (Hengelo)	0.70	7:51	17:35	0.7	1.1

Table 6.2: Outcomes of the simulation model and the current situation after the correcting factors

The table suggests that including the factors discussed above leads to a better resemblance of the real world than without the correcting factors. The walk in percentage is closer to the historical data, and the waiting times are closer to the waiting times from the measurement period. However, because of a higher percentage of walk in patients the access time slightly decreases. When we compare the absolute values of the access and waiting times from the corrected output with reality, we conclude that there are still discrepancies. There are several factors that can explain these discrepancies. For example, extra activities of care providers, a fixed number of care providers, extra activities of patients, busy periods, and appointment planning policy. Although these factors influence the output parameter, they are not directly quantifiable. Therefore, in the section below we discuss the expected effects of these parameters on the output parameters.

Other factors

After implementing the correcting factors, we still find discrepancies between the simulation model and the real world. We find several other factors that may be reasons for these discrepancies. However, for these factors a specific value of the influential factor is hard to determine.

Extra activities of care providers: The first factor that influences the average waiting time is that we only take the activity of screening a patient into account. In reality care providers perform other activities as well, and are therefore not available to screen patients all the time. For example, care providers may be busy with more administrative tasks (taking over patient information, or searching for medication data of a patient). These activities take time and increase the waiting time for patients.

Fixed number of care providers: Another factor that influences the average waiting time is that we always use a fixed number of care providers. In reality it happens that less care providers are available to screen patients. For example, a care provider may be on a coffee break, is having lunch, or may call in sick. When a care provider is not available, higher waiting times will occur. We do not simulate these aspects in the model, which leads to lower waiting times than in reality.

Extra activities of patients: At the PAC in Hengelo it occasionally happens that a (walk-in) patient checks in for screening, and then goes for a coffee or decides go to the laboratory first because of the expected waiting time. These activities are included when determining the waiting time, which may lead to a higher waiting time than when the patients had waited in the waiting room.

No extremely busy or quiet periods: Another factor that influences the waiting times and access times is that in the simulation model a uniform distribution with one standard deviation from the mean was used. Therefore, no extremely busy or quiet periods are included in the simulation model. As found in the sensitivity analysis (Section 6.3.3), the average waiting time for the care providers doubles when comparing very busy and very quiet periods Moreover, the waiting time is more influenced during the busy periods than during quiet periods. This may lead to a lower mean and standard deviation of the waiting times in the simulation model than in reality.

Appointment planning: The last influential factor we discuss is related to rules for appointment planning and the effect on the access time. There are two assumptions that mainly influence this parameter: the fixed timing for an appointment, and that the patient always accepts an offer. In reality there is more flexibility and patients may not be able or do not accept to come back as soon as possible (the next day), but prefer to choose a more convenient appointment date. Therefore, the mean and standard deviation of the access times at both locations in our simulation model are lower than in reality. However these parameters do not represent the reality, the effects of different interventions can still be compared.

In this section we discussed several factors that influence the outcomes of the simulation model. We started with the comparison of the simulation model and the real world system, and found that there were some discrepancies. Therefore, we introduced several correcting factors to correct the outcomes. We also elaborated on other factors that explain the discrepancy. Hereby, we have to keep in mind that we decreased the ASA score 2 percentage at Hengelo from 80% to 70% for this comparison to be able to compare the simulation model with the measurement period. However, we use a percentage of 80% of ASA score 2 when comparing the results of the intervention, because this is equal to the historical data (Section 2.2.4). We conclude that the absolute values of the access and waiting times in the simulation model still do not give an accurate representation of the expected times in reality. However, these factors give us a better interpretation for the analysis of the results. The goal of our research is to come up with suggestions to increase one stop shop percentages (at Almelo) and shorten waiting times. Our simulation model will be used to compare the effects of different interventions instead of giving an accurate representation of the real world system and is therefore still useable.

6.3.5 ANIMATION

The sixth technique for validation and credibility proposed by Law is developing a simulation model that looks like the real world system. As shown in Section 6.1, the visualization of our simulation model design does not represent the real world design. Although this is the case, the simulation model was developed using the expertise and feedback of involved stakeholders. These stakeholders understand how the animation of the simulation model is related to the real world design. Therefore, the simulation model is still credible.

In the previous sections we discussed six different techniques to validate our simulation model. We found that the developed model is sufficient to compare the effect of different interventions. However, the model cannot be used to provide an accurate expected waiting times of the real world system. In the next chapter we discuss the effect of the results of the interventions as proposed in Chapter 5 focusing on the relative change compared to the current situation.

7 INTERVENTION RESULTS

Now we know that the developed model is sufficient to compare the effect of different interventions, in this chapter, we discuss the results of the interventions (Chapter 5) tested with the model. The goal of our research is to provide suggestions for improving the one stop shop percentage, access time, and waiting time while not delaying surgery. Hereby, a higher one stop shop percentage and a lower access time at Almelo, and shorter waiting times at both locations, especially at Hengelo are desired. We use a paired sample t-test (in SPSS) to compare the results of the interventions and focus on the following parameters: one stop shop percentage, percentage consent on time, waiting time for a nurse, waiting time for an anesthesiologist/anesthesia assistant, and access time. The percentage consent on time is taken into account to analyze whether the interventions are delaying more surgeries. In our simulation model one run length is 52 weeks, with the first five weeks being the warm-up period (Appendix H). Every experiment has 23 replications (Appendix I), and a significant difference is determined by the lower and upper bound of the confidence interval. If the lower and upper bound does include the value of the initial situation, the difference is not significantly increasing or decreasing, otherwise it is. Therefore, in this chapter, when we mention a difference of a parameter, this is a significant difference.

This section will start with the analysis of changing the number of nurses (Section 7.1). Next, the interventions on first scheduling appointments on least busy days (Section 7.2) and a maximum percentage of appointments per day (Section 7.3) are discussed. Section 7.4 contains the results of a maximum percentage of appointment per day depending on the busyness per day. In Section 7.5, we discuss the effect of changing the timing of scheduling appointments. The final intervention, changing the appointment intervals, is analyzed in Section 7.6.

7.1 INTERVENTION 1: CHANGE NUMBER OF NURSES TO TWO

Management of the PACs is currently considering the effect of the number of nurses per location on access and waiting times. Management at Almelo is wondering what the effect is of having two or three nurses at the PAC, whereas management at Hengelo is considering the effect of dedicating an extra room to a nurse on Friday. We investigate the effect of changing the number of nurses at Almelo from 3 (initial situation) to 2 (intervention 1), and the number of nurses on Friday at Hengelo from 1 (initial situation) to 2 (intervention 1). The results are shown in Table 7.1.

Situation (location)	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Initial situation (Almelo)	0.24	0.9747	1:26	8:22	12.9
Intervention 1 (Almelo)	0.24	0.9752	+367% [6:33;6:51]	-18% [6:42;7:06]	0% (12.9)
Initial situation (Hengelo)	0.58	0.9793	9:06	25:51	0.9
Intervention 1 (Hengelo)	0.63	0.9796	-62% [3:24;3:33]	0% [24:57;26:38]	-10% [0,78;0.82]

Table 7.1: Comparison of results of intervention 1 with the current situation

As we can see in the table above, changing the number of nurses at the PAC at Almelo from three to two increases the waiting time for a nurse, whereas the waiting time for an anesthesiologist decreases. With less nurses to screen patients, this waiting time shift is a logical consequence. The waiting time increase for a nurse is higher than the decrease for an anesthesiologist. Furthermore, the access time, walk-in percentage and percentage of consent on time did not change. This shows that the effect of reducing the number of nurses at Almelo has a significant negative effect on the waiting times at Almelo. However, on the other hand, decreasing the number of nurses only increases the total waiting time with a couple of minutes, whereas staffing one nurse less decreases the personnel costs significantly.

At Hengelo, changing the number of nurses on Friday from one to two also has effect on several parameters. The waiting time for a nurse decreases, whereas the waiting time for an anesthesiologist increases. This leads to a shift for waiting for a nurse to an anesthesiologist, which is quite logical after increasing the number of nurses. The waiting time for an anesthesia assistant did decrease but not significantly. When combining the waiting times of the anesthesia assistant and the anesthesiologist, we conclude that this combination does not lead to a significant difference from the initial situation. The decrease in waiting time for a nurse increases the one stop shop percentage, which decreases the access time. This shows that the effect of adding an extra nurse on Friday at Hengelo has a significant positive effect.

We conclude that changing the capacity at Almelo increases the waiting time for a nurse and decreases the waiting time for an anesthesiologist. The increase of the waiting time for a nurse is larger than the decrease at the anesthesiologist. This intervention does not influence the total waiting time in a positive manner, but may not have a significant influence on the patient satisfaction as long as the waiting time per care provider does not exceed the maximum acceptable waiting time. Moreover, the personnel costs will decrease significantly when staffing one nurse less. Therefore, for the interventions on a tactical level at Almelo, we simulate with two nurses Hereby, we keep in mind that the effect of having three nurses would lead to less waiting time for a nurse and more waiting time for an anesthesiologist. Additionally, when the number of nurses does influence the effect of the tactical level interventions differently, we will discuss this.

At Hengelo, the waiting time for a nurse and the access time significantly decrease, whereas the waiting time for the (combination of the) other care providers does not change. Changing the number of nurses from one to two on Friday has a positive influence on patient satisfaction. Therefore, for our further research of the interventions, we continue with two nurses at Hengelo every day. This change in capacity is applicable in reality, because management is currently testing the effect of an extra nurse on Friday already.

7.2 INTERVENTION 2: FIRST SCHEDULE APPOINTMENT DURING LEAST BUSY DAYS AND HOURS

This intervention focuses on balancing the mixture between walk-in and appointments depending on the busyness per day and hour. The number of patients that arrive differs per day and hour. On a busy day more patients are expected to arrive than on a less busy day. Therefore, scheduling an appointment on a less busy day would lead to a better balance in number of expected patients per day and a higher utilization. We first test the effect without first scheduling on the least busy hours. Next, we include the hour policy. We analyze the differences between the intervention and the current situation, and between the intervention with and without specific planning hours. The results are shown in Table 7.2.

Situation	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1 (Almelo)	0.24	0.9752	6:41	6:54	12.9
Intervention 2 (Days)	0.23	0.9195	+37% [8:44;9:38]	+28% [8:35;9:08]	+11% [14.2;14.4]
Intervention 2 (Day and hour)	0.24	0.9240	+68% [10:59;11:29]	+23% [8:16;8:44]	+10% [14.1;14.3]
Intervention 1 (Hengelo)	0.63	0.9796	3:28	25:48	0.8
Intervention 2 (Days)	0.66	0.9746	+3% [3:30;3:40]	-7% [23:23;24:50]	+61% [1.2;1.3]
Intervention 2 (Day and hour)	0.66	0.9752	-5% [3:14;3:22]	-5% [23:40;25:17]	+57% [1.2;1.3]

Table 7.2: Comparison of results of intervention 2 (only taking the days into account) and the situation of intervention 1

We find that the intervention leads to a higher waiting time for both care providers at Almelo. The increase in waiting times is due to a significant increase in waiting time on the former less busy days. This may be due to the appointment planning method at Almelo. In the initial situation timeslots are filled randomly, therefore the less busy days had some empty timeslots left. With intervention 2, all timeslots on the less busy days are filled. With an average consultation time that exceeds the timeslot interval for the majority of the patients and fewer possibilities (less space) for walk-in patients, this leads to a higher waiting time on these days. Moreover, the one stop shop percentage on the busy days increases. This leads to increase in variability and therefore increase the waiting time. The access time at Almelo increases too, because patients are not planned on the first possible day but are planned later in the week. When we include the hour policy, we find that the waiting time of a nurse increases even more. The reason for this increase is that the schedule of planning patients is still based on the assumptions that three nurses are present. Therefore, three patients are planned on the less busy moments, whereas only two nurses are present. This leads to an increase in waiting time. When we test this intervention with 3 nurses we find that including the hour policy does decrease the waiting time for a nurse, however the waiting time is still higher than the initial situation.

At Hengelo, we find that the waiting time for a nurse increases and the waiting time for an anesthesiologist decreases. The increase for the nurse may be due to the higher one stop shop percentage. The decrease for the anesthesiologist may be caused by a better division of number of patients at the PAC per day. Hereby, the waiting time does not increase, because Hengelo aims at letting as many patients walk-in as possible. This leads to enough empty timeslots per day for walk-in patients. Again, the access time increases, because patients are not planned on the first possible day but are planned later in the week. When we include the hour policy, we find that both waiting times decrease in comparison to the situation at intervention 1. In this case patients are planned on less busy moment per day. Therefore, nurses are less busy as well. This leads to a decrease in waiting time. The waiting time for the anesthesia assistant is slightly higher, when including the hour policy. This is caused by the decrease in waiting time for a nurse, which leads patients to waiting longer at the anesthesia assistant.

We conclude that the effect of first scheduling appointments on the least busy days and hours depends on the planning methods and the timeslot interval. At Almelo, almost all patients leave the PAC with an appointment to come back another day. When first scheduling appointments on the least busy days, the timeslots on these days will be filled completely. With a consultation time that exceeds the timeslot interval, this leads to an increase in waiting time on these days. Moreover, the one stop shop percentage on the busy days increases. This leads to increase in variability and therefore increase the waiting time. At Hengelo, a walk-in system in used, this leads to fewer appointments being planned per week. Therefore, there are still empty timeslots during the less busy days. On the busy days, there is more room for patients to walk-in, whereas on less busy days there is still room as well. This leads to a higher one stop shop percentage, and lower waiting time. For both locations, the access time increase, because patients are not planned on the first possible day but are planned later in the week. We conclude that this intervention has a positive effect on the waiting times, if not too many appointments are scheduled per week and a correct timeslot interval is used. In both cases, the average access time will increase.

7.3 INTERVENTION 3: MAXIMUM PERCENTAGE OF WALK IN AND APPOINTMENTS PER DAY

The third intervention is based on changing the percentage of patients that is allowed to walk-in and randomly assigning patients to timeslots with a maximum percentage of filled timeslots per day. We use a maximum percentage of appointments range between 30% and 80% per day with incremental steps of 10%. The effects in comparison to the current situation at Almelo are shown in Table 7.3 and at Hengelo in Table 7.4.

Max. percent appointments	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1	0.24	0.9752	6:41	6:54	12.9
30	0.70	0.9428	+27% [8:24;8:42]	+19% [8:0;8:27]	-60% [5.1;5.2]
40	0.60	0.9485	+22% [7:58;8:20]	+19% [8:01;8:20]	-47% [6.8;6.9]
50	0.50	0.9556	+16% [7:33;7:54]	+14% [7:41;8:03]	-34% [8.4;8.5]
60	0.40	0.9620	+10% [7:09;7:28]	+7% [7:15;7:32]	-21% [10.1;10.2]
70	0.30	0.9691	+1% [6:36;6:57]	+2% [6:55;7:13]	-7% [11.9;12.00]
80	0.20	0.9756	-8% [5:59;6:16]	-7% [6:12;6:33]	+5% [13.5;13.6]

Table 7.3: Comparison of results of intervention 3 with the current situation (Almelo)

At Almelo we find that when the one stop shop percentage increases, the average waiting time for a nurse and an anesthesiologist increase as well. A reason for this increase is that with a higher walk in percentage more variability is created, which leads to higher waiting times. Additionally, the increase in one stop shop percentage, leads to a significant decrease of the average access time. Although the average access time decreases, the percentage of patient with consent on time decreases as well. A reason for this effect is that the current policy for the timing of appointments is fixed to half length of the operation date. With a maximum percentage of appointments per day, this leads to patients being scheduled close to the operation date, with a higher possibility of not having consent on time.

Max. percent appointments	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1	0.63	0.9796	3:28	25:48	0.8
30	0.68	0.9358	-2% [3:20;3:26]	-13% [22:00;22:42]	+362% [3.2;4.3]
40	0.59	0.9328	-4% [3:06;3:59]	-13% [20:28;23:06]	+422% [3.6;5.0]
50	0.50	0.9158	-7% [3:10;3:21]	-14% [21:40;22:26]	+591% [4.8;6.2]
60	0.40	0.8801	-10% [3:05;3:11]	-18% [20:52;21:36]	+890% [7.0;8.8]
70	0.30	0.8106	-15% [2:54;2:59]	-25% [18:59;19:40]	+1440% [11.4;13.3]
80	0.20	0.7380	-19% [2:48;2:51]	-34% [16:40;17:21]	+1968% [15.6;17.5]

Table 7.4: Comparison of results of intervention 3 with the situation with intervention 1 (Hengelo)

At Hengelo (Table 7.4) we find that if more appointments are scheduled per day, the waiting times for a nurse and for an anesthesia assistant decrease. This may be due to the fact that more patients have an appointment than in the current situation, which leads to a reduction in variability and a better distribution of patients over the days. However, reducing the number of patients that walk in has a negative effect on the access time. An important reason for the increase in access time is that in the current situation an appointment is planned for 15 minutes per patient. This leads to a total of 170 timeslots per week. With an average of 188 patients per week, all timeslots will be filled and backlogs and longer access times occur. This leads the percentage of patients with consent on time to decrease. Another reason for this effect is that the current policy for the timing of appointments is fixed. Patients are scheduled as soon as possible, which leads patients with an early operation date to be scheduled after patients with a later operation date.

We conclude that the planning policy to schedule a maximum number of appointments per day does affect the one stop shop percentage and waiting time at both locations. At Almelo, a higher percentage of one stop shop leads to extra waiting time for the nurse and anesthesiologist but to a shorter average access time. At Hengelo, a lower one stop shop percentage leads to shorter waiting times for a nurse and anesthesia assistant, and increases the average access time. However, the consent on time decreases. If we take our research goals in mind, we see that this intervention has potential but other timeslot intervals and more flexibility of the system is needed to deal with the percentage of consent on time.

Intervention 2 and 3 both lead to possible suggestions for improving the one stop shop percentage and waiting times. Therefore, the next intervention tests the influence of combining these interventions.

7.4 INTERVENTION 4: COMBINATION OF INTERVENTION 2 AND 3

The forth intervention is a combination of intervention 2 and 3. We research the effect of scheduling appointments for a higher percentage of patients during the least busy days, whereas during the busier periods a low percentage is used. The results are shown in Table 7.5.

Situation	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1 (Almelo)	0.24	0.9752	6:41	6:54	12.9
Intervention 4 (Almelo)	0.49	0.9550	+26% [8:10;8:35]	+14% [7:41;8:05]	-32% [8.6;8.7]
Intervention 3 (50%, Almelo)	0.50	0.9556	+16% [7:33;7:54]	+14% [7:41;8:03]	-34% [8.4;8.5]
Intervention 1 (Hengelo)	0.63	0.9796	3:28	25:48	0.8
Intervention 4 (Hengelo)	0.50	0.8835	-8% [3:10;3:16]	-20% [20:08;20:48]	+801% [7.2;7.3]
Intervention 3 (50%, Hengelo)	0.50	0.9158	-7% [3:10;3:21]	-14% [21:40;22:26]	+591% [4.8;6.2]

Table 7.5: Comparison of results of intervention 4 with the situation with intervention 1.

As expected, we find the same effects as with intervention 3. This intervention leads to a higher one stop shop percentage and longer average waiting time for a nurse and an anesthesiologist at Almelo. On the other hand, the access time decreases. At Hengelo, this intervention leads to a lower one stop shop percentage and lower average waiting time for a nurse and anesthesia assistant. On the other hand the average access time increases.

To determine whether intervention 4 is an improvement of intervention 2 and 3, we compare the output of intervention 4 with the closest walk-in percentage output of intervention 3. This leads to a comparison with the data of 0.50. We find that the average waiting time for a nurse at Almelo is longer for intervention 4 than for intervention 3. A cause for this increase may be that on less busy days more appointments are planned. This leads to a higher probability of an appointment being scheduled directly after another appointment. With a screening time which exceeds the appointment interval for the majority of the patients, this leads to extra waiting time on these days in comparison to intervention 3. Furthermore, on busy days more patients walk in with intervention 4, which leads to extra variability and therefore to higher waiting times.

At Hengelo, we find that the average waiting time is shorter for the anesthesia assistant with intervention 4. A cause for this decrease may be that on less busy days more appointments are scheduled. Because the appointment interval is larger than the average consultation time, this leads to lower waiting times on these days. Furthermore, on busy days with fewer appointments, more patients can walk in with less interference of patients with an appointment. The waiting time on these days still increases, but does not outweigh the decrease in waiting time on less busy days.

We also find that the access time increases at Hengelo, but stays the same at Almelo. This is due to the division of the percentages between days. In case of intervention 3, 50% of the timeslots per day are filled. With intervention 4, the percentage differs per day. At Hengelo, three sequential days (Tuesday, Wednesday, Thursday) now have at least 5% less timeslots available than with intervention

3. Therefore, patients have a lower possibility to be scheduled on these days and are scheduled later on. This leads to higher access times. At Almelo, the division of the available percentage of timeslots per day is better. On Monday and Tuesday less than 50% of the timeslots can be filled, on Wednesday approximately 50% can be filled, and on Thursday and Friday more than 50% can be filled. This leads to a more equal situation to intervention 3, and to a smaller increase in access time.

After this analysis we conclude that intervention 4 has a negative effect on the waiting times and access time at Almelo, and a positive effect at Hengelo. When we compare this intervention with intervention 3, we find that the waiting time increases in Almelo and decreases in Hengelo. A significant influence on these changes is the timeslot interval and one stop shop percentage per day. Additionally, we find that the access times increase at both locations. A cause for this increase is that the access time is influenced by the division of the percentages per day. If there are more (sequential) days with a percentage below the average percentage, the access time will increase. When the division of the percentage is better, the increase is not significant anymore.

7.5 INTERVENTION 5: CHANGE TIMING OF SCHEDULING APPOINTMENTS

The fifth intervention focuses on changing the timing of scheduling appointments. In the current situation, patients that have to schedule an appointment at the PAC at Almelo are scheduled at approximately half length of the operation date (0.50). This increases the access time. At Hengelo, patients are scheduled as soon as possible (0.05). This leads to low access times, but may lead to higher waiting times because fewer timeslots are available in the near future for (urgency) patients with an early operation date. We study scheduling appointments depending on the operation date instead of implementing a fixed number of weeks per patients, because in this case patients with an early operation date have a higher priority to be screened. Moreover, scheduling an appointment exactly a fixed number of weeks later will not lead to less variability. We use a timing percentage between 5% and 95% of the operation date with incremental steps of 15% to study the effect of changing the timing policy. We compare the outcomes with the outcomes of intervention 1. The results of Almelo are shown in Table 7.6 and of Hengelo in Table 7.7.

Situation at Almelo	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1 (Timing 0.50)	0.24	0.9752	6:41	6:54	12.9
0.05	0.25	0.9353	+3% [6:43;7:07]	+3% [6:57;7:19]	-88% (1.6)
0.20	0.24	0.9563	+1% [6:36;6:56]	+2% [6:53;7:14]	-59% (5.3)
0.35	0.24	0.9688	+1% [6:33;6:51]	+2% [6:51;7:13]	-30% (9.0)
0.50	0.24	0.9751	-1% [6:24;6:46]	-1% [6:39;7:03]	0% [12.8;12.9]
0.65	0.23	0.9741	-2% [6:23;6:45]	-1% [6:42;7:01]	+28% [16.4;16.5]
0.80	0.23	0.9682	-4% [6:15;6:39]	-2% [6:37;6:53]	+57% [20.1;20.3]
0.95	0.23	0.9053	+5% [6:39;7:18]	-9% [6:04;9:29]	+84% [23.6;23.7]

Table 7.6: Comparison of results of intervention 5 at Almelo with the situation with intervention 1.

At Almelo we find that the waiting times only differ for very early and very late timing policies, whereas the access time changes per incremental step. We also find that the percentage consent on time is the highest at 0.50. Although the percentage consent on time differs significantly between 0.35 and 0.80, the percentage does not change drastically as it does for early and late timing policies. Reasons for this decrease in consent on time are that, with an appointment based system at Almelo and early timing, patient that have a late operation date are planned before patients with an early operation date, which leads to less time for early patients. In this case the idea of prioritizing is not applicable anymore. On the other hand, with late timing, there is limited time to plan an appointment before the operation date, and if a patient needs extra examinations the results will be known after the operation date.

Situation at Hengelo	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1 (Timing 0.05)	0.63	0.9796	3:28	25:48	0.8
0.05	0.63	0.9794	0% [3:18;3:57)	-1% [22:56;26:45]	0% [0.8;0.9]
0.20	0.64	0.9768	-2% [3:21;3:29]	-5% [23:43;25:00]	+202% [2.4;2.5]
0.35	0.64	0.9736	-2% [3:20;3:28]	-7% [23:14;24:31]	+404% [4.0;4.1]
0.50	0.65	0.9698	-2% [3:20;3:28]	-8% [23:00;24:15]	+618% [5.6;5.9]
0.65	0.65	0.9630	-2% [3:20;3:29]	-9% [22:48;24:00]	+813% [7.2;7.4]
0.80	0.65	0.9511	-3% [3:19;3:26]	-11% [22:25;23:39]	+1012% [8.7;9.1]
0.95	0.65	0.8348	-3% [3:18;3:25]	-12% [22:14;23:17]	+1198% [10.2;10.6]

Table 7.7: Comparison of results of intervention 5 at Hengelo with the situation with intervention 1.

At Hengelo, we find that the waiting time for the anesthesia assistant and anesthesiologist decreases with every incremental step, whereas the waiting time for a nurse slightly decreases starting with a timing policy of 0.80. A reason for the decrease in waiting time may be that with a walk-in planning system and a later timing policy, not all patients will be scheduled as soon as possible (the next day). This will lead to a better division and less variability of the number of appointments per day. For example, if it is too busy on a specific day, not all patients are asked to come back the next day. A patient with an early operation date will be asked to come back next week, whereas a patient with a late operation date is asked to come back several weeks later. Logically, a later timing policy increases the access time as well. We also find that the percentage consent on time decreases. A reason is that patients have less time between the screening appointment and the operation date. If patients need extra examination the results have a higher probability of being known after the operation date.

With this intervention we found that a late timing policy has a negative influence on the percentage of patients with consent on time when the timing policy is later than 0.80. For earlier timing policies, the effect depends on the planning system. At Almelo, mostly appointments are scheduled for patients, which lead to a lower percentage consent on time for very early timing policies. For timing policies between 0.35 and 0.80 there is only a slight difference in consent on time and waiting times.

The access time depends on the timing policy as well. At Hengelo, the percentage consent on time increases and the access time decreases when the timing of scheduling appointments is earlier. However, the waiting time for an anesthesia assistant is higher as well, when an earlier timing policy is used. We conclude that changing the timing of the appointments has significant influence on the percentage of patients with consent on time, the access times, and the waiting times. An early timing policy leads to higher waiting time, but to lower access times as well.

7.6 INTERVENTION 6: CHANGE APPOINTMENT INTERVALS

For this intervention we change the timeslot at Almelo and Hengelo. We study two sets of different timeslots. The first set has a 15 minutes interval at Almelo for ASA score 1 and 2, and a 30 minutes interval for ASA score 3 patients. At Hengelo, the timeslot interval is 12 minutes for all patients. The second set has 20 minutes for all patients at Almelo. At Hengelo, there are 12 minutes for ASA score 1 and 2, and 15 minutes for ASA score 3 patients. The results of this intervention are shown in Table 7.8.

Situation	Walk-in percent	Consent on time	Average WT Nurse	Average WT Anesthetist	Average Access Time
Intervention 1 (Almelo)	0.24	0.9752	6:41	6:54	12.9
Intervention 6 (Almelo) set 1	0.24	0.9745	-4% [6:10;6:39]	-13% [5:49;6:10]	0% [12.9;13.0]
Intervention 6 (Almelo) set 2	0.24	0.9744	-11% [5:48;6:06]	-17% [5:35;5:56]	+1% [12.9;13.0]
Intervention 1 (Hengelo)	0.63	0.9796	3:28	25:48	0.8
Intervention 6 (Hengelo) set 1	0.63	0.9793	+5% [3:34;3:44]	+2% [25:42;27:30]	+3% (0.8)
Intervention 6 (Hengelo) set 2	0.63	0.9797	+1% [3:25;3:35]	+1% [25:20;26:55]	0% (0.8)

Table 7.8: Comparison of results of intervention 6 with the current situation

We find that when we change the appointment intervals to better fit the consultation times, this only has a significant effect for the waiting times at Almelo. Planning more time for an ASA score 3 patient in combination with planning less time for ASA score 1 patients (set 1) decreases the average waiting time. When the intervals are set slightly larger for ASA score 1 and 2 patients than the average consultation time, the waiting times decrease even more, without influencing the access times. This suggests that with a fixed number of two nurses, the waiting time can still decrease by just fitting the consultation times to the patient.

Changing the intervals at Hengelo has a negative effect on the waiting times for the nurse and anesthesiologist, which may be cause by using an appointment time which is slightly smaller than consultation times (set 1). However, the effect of the anesthesiologist does not have a significant effect on the total waiting time for the combination of the anesthesia assistant and the anesthesiologist at Hengelo. With less time between appointments, more appointment can be scheduled per hour. Therefore, more patients arrive for the nurse to screen. This leads to higher waiting time for this care provider. When we only change the timeslot interval for ASA score 1 and 2 patients (set 2), no significant change is found.

We conclude that changing the appointment interval to better fit the consultation times can improve the waiting times. Hereby, an interval equal to or slightly greater than the consultation time is advised.

7.7 CONCLUSION ON RESULTS

In this chapter we analyzed and compared the results of several interventions. We found that, on a strategic level, changing the number of nurses from one to two on Friday at Hengelo has a positive influence on the overall patient satisfaction. The waiting time and access time both decrease. Decreasing the number of nurses from three to two at Almelo increases the waiting time for a nurse, but decreases the waiting time for an anesthesiologist. The waiting time and point in the process shifts from the anesthesiologist to the nurse. The increase for a nurse is higher than the decrease for an anesthesiologist. This intervention does not influence the total waiting time in a positive manner, but may not have a significant influence on the patient satisfaction as long as the waiting time per care provider does not exceed the maximum acceptable waiting time. Moreover, the personnel costs will decrease significantly when staffing one nurse less. Therefore, for the interventions on a tactical level at Almelo, we simulate with two nurses Hereby, we keep in mind that the effect of having three nurses would lead to less waiting time for a nurse and more waiting time for an anesthesiologist. At Hengelo, we also continued with two nurses every day for the interventions on a tactical level.

When analyzing tactical level interventions, we keep in mind that to improve patient satisfaction, the one stop shop percentage and access times at Almelo should increase, whereas the desired effect on the waiting times at both locations depends on the planning method. We come to the following conclusions with respect to the tactical interventions:

- **Intervention 2:** The effect of first scheduling appointments on the least busy days and hours depends on the planning methods At Almelo, almost all patients leave the PAC with an appointment to come back another day. When first scheduling appointments on the least busy days, the timeslots on these days will be filled completely. With a consultation time that exceeds the timeslot interval, this leads to an increase in waiting time on these days. Moreover, the one stop shop percentage on the busy days increases. This leads to increase in variability and therefore increase the waiting time. Therefore, this intervention has a negative effect at Almelo.

  At Hengelo, a walk-in system in used. This leads to fewer appointments being planned per week. Therefore, there are still empty timeslots during the less busy days. On the busy days, there is more room for patients to walk-in, whereas on less busy days there are still empty timeslots as well. This leads to a higher one stop shop percentage, and lower waiting time.

  For both locations, the access time increase, because patients are not planned on the first possible day but are planned later in the week.

  We conclude that the effect of this intervention is positive on the waiting times, when not too many appointments are scheduled per week and a correct timeslot interval is used. However, if the planning method is appointment based, the waiting times will increase. In both cases, the average access time will increase.
- **Intervention 3:** The planning policy to schedule a maximum number of appointments per day affects the one stop shop percentage and waiting time at both locations. At Almelo, a higher percentage of one stop shop leads to extra waiting time for the nurse and anesthesiologist but to a shorter average access time as well.

At Hengelo, a lower one stop shop percentage leads to shorter waiting times for a nurse and anesthesia assistant, and increases the average access time. A reason for the increase in access time is that not enough timeslots are available per week. This leads to a decrease in percentage of consent on time.

When we take our research goals and patient preferences into account we conclude that intervention 3 has a positive influence on patient satisfaction. However other timeslot intervals and more flexibility of the system are needed to deal with the percentage of consent on time. The effect of the intervention differs per maximum percentage and picking a desired percentage is up to the management.

- **Intervention 4:** We analyzed the effect of combining intervention 2 and 3 and compare the results with intervention 3. We find that intervention 4 has a negative effect on the waiting times and access time at Almelo, and a positive effect at Hengelo.

  When we compare this intervention with intervention 3, we find that the waiting time increases in Almelo and decreases in Hengelo. A significant influence on these changes is the timeslot interval and the one stop shop percentage per day. When the timeslot interval is smaller than the average consultation time (as it is at Almelo), higher waiting times occur. If the timeslot interval is sufficient, the waiting times decreases. Additionally, we find that the access times increase at both locations. A cause for this increase is that the access time is influenced by the division of the percentages per day. If there are more (sequential) days with a percentage below the average percentage, the access time will increase. When the division of the percentage is better, the increase is not significant anymore.

  To conclude, if timeslots are used that fit the average consultation time, the average waiting time will decrease and the access time will increase. Deciding which of these interventions is more desirable in that case is up to the management.

- **Intervention 5:** This intervention focuses on the timing policy. We found that a late timing policy has a negative influence on the percentage of patients with consent on time when the timing policy is later than 0.80. For timing policies between 0.35 and 0.80 there is only a slight difference in consent on time and waiting times. For earlier timing policies, the effect depends on the planning system. At Almelo, patients mostly schedule an appointment, which lead to a lower percentage consent on time for very early timing policies.

  At Hengelo, the percentage consent on time decreases and the access time increases when the timing of scheduling appointments is later. However, the waiting time for an anesthesia assistant decreases as well. Logically, the access time depends on the timing policy.

  We conclude that changing the timing of the appointments has significant influence on the percentage of patients with consent on time, the access times, and the waiting times. Hereby, the effect depends on the planning policy. However, in general, an early timing policy leads to higher waiting times, but to lower access times as well. Picking a desired percentage for the timing policy is up to the management

- **Intervention 6:** The final intervention on a tactical level is changing the timeslot intervals to better fit the current consultation times. We find that changing the appointment intervals to better fit the consultation times, only has a significant effect on the waiting times.

  At Almelo, planning more time for an ASA score 3 patient in combination with planning less time for ASA score 1 patients (set 1) decreases the average waiting time. When the intervals are set slightly larger for ASA score 1 and 2 patients than the average consultation time, the

waiting times decrease even more. This suggests that with a fixed number of two nurses, the waiting time can still decrease by just fitting the consultation times to the patient.
Changing the intervals at Hengelo has a negative effect on the waiting times for the nurse and anesthesiologist, which may be cause by using an appointment time which is slightly smaller than consultation times (set 1). When we only change the timeslot interval for ASA score 1 and 2 patients (set 2), no significant change is found.
We conclude that changing the appointment interval to better fit the consultation times can improve the waiting times. However, an appointment interval that is slightly smaller than the consultation time is not improving the outcomes. An appointment interval that is equal to or slightly larger than the average consultation time is advised.

Now we know the effect of the interventions we make a scatter plot in Figure 7.1, with the total waiting time on the X-axis and the access time on the Y-axis, to compare the tactical level interventions with the strategic level intervention.

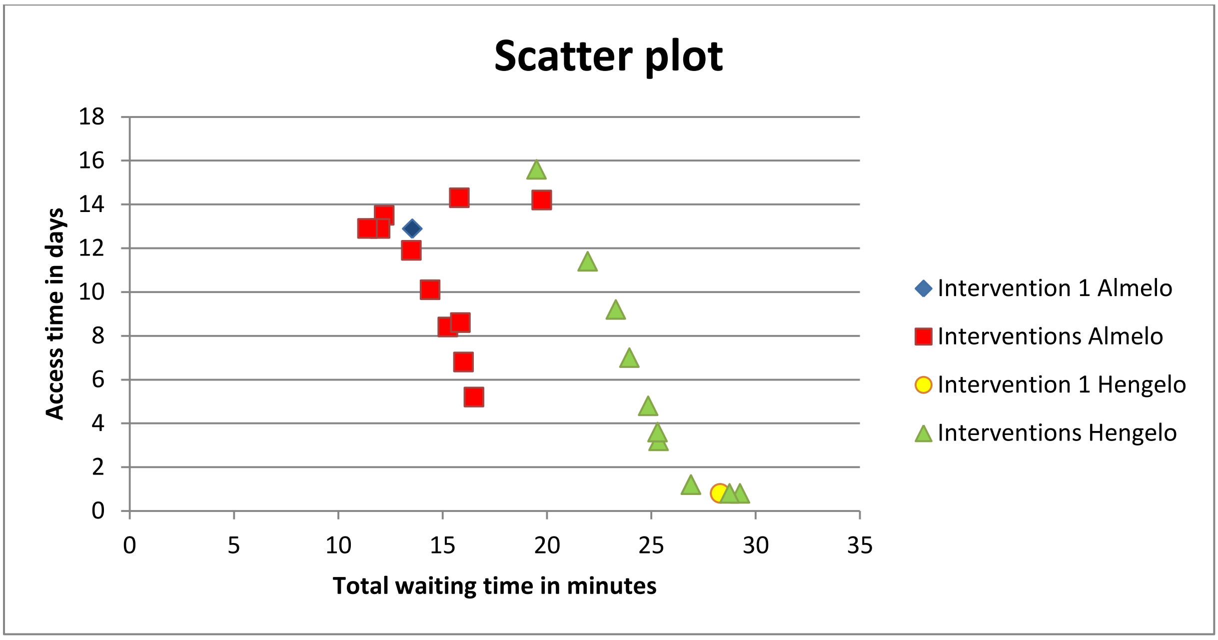


Figure 7.1: Scatter plot of interventions at Almelo and Hengelo

In Figure 7.1 we find the results of intervention 1, 2, 3, 4, 6. We see that in most cases (accept for intervention 2 at Almelo, and intervention 6 at Hengelo) there is a negative correlation between the waiting and access time. Furthermore, there are several tactical interventions that improve the waiting time without influencing the access time and vice versa (e.g. intervention 3 with a maximum percentage of appointment of 70% and intervention 6 at Almelo, and intervention 2 at Hengelo). Overall, the effect of the intervention differs and deciding which of these interventions is more desirable is up to the management.

After analyzing several interventions, the next chapter will focus on answering the research questions and providing recommendations for further research.

8 CONCLUSION AND FURTHER RESEARCH

In this chapter we answer our research questions as proposed in Section 1.4. We describe the process of our research and give suggestions to increase patient satisfaction at the PAC (Section 8.1). In Section 8.2, we give recommendations for further research.

8.1 RECOMMENDATIONS FROM RESEARCH

The goal of this research was to come up with suggestions to increase patient satisfaction at the preoperative anesthesia clinic while not delaying the planning of surgical operations. We researched six organizational interventions to increase the one stop shop percentage, reduce the access times (at Almelo) and shorten waiting times (especially at Hengelo) by changing the number of nurses, balancing the mixture between walk-in and appointment, changing timing policies, and changing the timeslot intervals.

The first question we had to answer was: w*hat is the current situation at ZGT within the preoperative screening process?* We discussed several aspects of the current situation in Chapter 2. We started with interviewing several involved employees in order to understand the preoperative screening process. Next, we analyzed data obtained through the registration software and a random sample to get more insight in the characteristics of the patients, patient inflow, and preoperative screening performances. With this data, we found several points of improvement to increase the patient satisfaction. These points of improvement are that in the current situation the access time at Almelo is too long, and the waiting times at both locations exceed the acceptable waiting time (based on different acceptable waiting times per planning methods).

In Chapter 3, we answered the second research question: *what relevant literature is available?* In this chapter we inquire whether similar problems are studied in the past and how they were handled. We found that a one stop shop approach is preferred the most by patients, followed by a short access time, and short waiting time. The acceptable waiting time depends on the planning method of a patient. If patients walk in a longer waiting time is accepted than when having an appointment. Furthermore, we found that the access and waiting times can be reduced if a right mixture between appointments and one stop shop, another timing policy, or other timeslots intervals are implemented. Several articles give suggestions how to do this.

The third research question, '*how can the current situation be modeled?*' is answered in Chapter 4. We started with describing the process steps that a patient needs to take before having consent and the different paths to take these steps. Next, we described that these process steps are dependent on several factors, what resources are needed, how the processing times per processing step are determined, and decision making policies.

In Chapter 5, we answered our forth research question: *what organizational interventions are available to improve the service level?* We discussed six organizational interventions to handle the points of improvement. Performance requirements as one stop shop percentage, access time and waiting time are taken as parameters to determine the relevance of the interventions. We distinguished between two different levels for interventions. On the strategic level we studied the effect of changing capacity to two nurses on every day (Section 5.1). On tactical level, we studied the effect of different planning rules and different appointment intervals (Section 5.2). Intervention 2 is based on scheduling appointments on the least busy moments. Intervention 3 studies the effect of a maximum percentage of walk-in and appointments per day. Intervention 4 is a combination of intervention 2 and 3. Intervention 5 focuses on different timing policy for scheduling appointments. Intervention 6 focuses on changing the current timeslots to better match the expected consultation times.

Our fifth research question '*how usable is the final simulation model to test the organizational interventions?'* is answered in Chapter 6. We started with introducing and describing our own simulation model, followed by the techniques we used to verify that the simulation model is a good resemblance of the conceptual model and can be used to compare the effect of different interventions. We also determined whether the simulation model was a sufficient representation of the real world. We introduced several correcting factors to better match the outputs of the simulation model with the real world data. The model is a sufficient representation of the real world to determine the effect of the interventions. However, it cannot be used to provide accurate expected waiting times of the real world system.

With this in mind, we used the simulation model to test and analyze the effect of six organizational interventions. We answered the sixth and final research question '*what are the results of the organizational interventions?'.* The results are shown in Chapter 7. We came to the following conclusions:

On a strategic level, changing the number of nurses from one to two on Friday at Hengelo has a positive influence on the overall patient satisfaction. The waiting time and access time both decrease. Changing the number of nurses from three to two for every weekday at Almelo increases the waiting time for a nurse, but decreases the waiting time for an anesthesiologist. The increase for a nurse is higher than the decrease for an anesthesiologist. This intervention does not influence the total waiting time in a positive manner, but may not have a significant influence on the patient satisfaction as long as the waiting time per care provider does not exceed the maximum acceptable waiting time. Moreover, the personnel costs will decrease significantly when staffing one nurse less. Therefore, for the interventions on a tactical level at Almelo, we simulate with two nurses Hereby, we keep in mind that the effect of having three nurses would lead to less waiting time for a nurse and more waiting time for an anesthesiologist. At Hengelo, we also continued with two nurses every day for the interventions on a tactical level.

The analyses of the results of the interventions on a tactical level can be found in Table 8.1 on the next page. Hereby, we focus on the one stop shop percentage, percentage consent on time, access time, and waiting time for a nurse (WT nurse) and for the combinations of the anesthesia assistant and anesthesiologist (WT anesthetist).

Intervention	Location	Significant increase	Significant decrease	No significant difference
2. First schedule at least busy periods	Almelo	WT nurse WT anesthetist Access time		One stop shop Consent on time
	Hengelo	Access time One stop shop	WT nurse WT anesthetist	Consent on time
3. Maximum percentage appointments per day	Almelo	Consent on time WT nurse WT anesthetist	Access time	
	Hengelo	WT anesthetist Access time	One stop shop Consent on time WT nurse	
4. Combination of intervention 2 and 3	Almelo	Consent on time WT nurse WT anesthetist One stop shop	Access time	
	Hengelo	WT anesthetist Access time	One stop shop Consent on time WT nurse	
5. Changing the timing policy	Almelo	Consent on time Access time (earlier timing)	Access time (later timing)	WT nurse WT anesthetist One stop shop
	Hengelo	Access time	Consent on time WT anesthetist	WT nurse One stop shop
6. Changing the appointment intervals	Almelo		WT nurse WT Anesthetist	One stop shop Consent on time Access time
	Hengelo	WT Anesthetist		One stop shop Consent on time WT nurse Access time WT Anesthesia Assistant

Table 8.1: Significant effects of interventions 2-6

When analyzing the table above, we keep in mind that to improve patient satisfaction, the one stop shop percentage at Almelo should increase, whereas the desired effect on the waiting times at both locations depends on the planning method. For example, if the intervention planning method at Almelo leads to an increase in walk-in percentage from 20% to 50%, the average waiting time may increase as well. We come to the following conclusions with respect to the tactical interventions:

- **Intervention 2:** The effect of first scheduling appointments on the least busy days and hours depends on the planning methods At Almelo, almost all patients leave the PAC with an appointment to come back another day. When first scheduling appointments on the least busy days, the timeslots on these days will be filled completely. With a consultation time that exceeds the timeslot interval, this leads to an increase in waiting time on these days.

Moreover, the one stop shop percentage on the busy days increases. This leads to increase in variability and therefore increase the waiting time. Therefore, this intervention has a negative effect at Almelo.

At Hengelo, a walk-in system in used. This leads to fewer appointments being planned per week. Therefore, there are still empty timeslots during the less busy days. On the busy days, there is more room for patients to walk-in, whereas on less busy days there are still empty timeslots as well. This leads to a higher one stop shop percentage, and lower waiting time.

For both locations, the access time increase, because patients are not planned on the first possible day but are planned later in the week.

We conclude that the effect of this intervention is positive on the waiting times, when not too many appointments are scheduled per week and a correct timeslot interval is used. However, if the planning method is appointment based, the waiting times will increase. In both cases, the average access time will increase.

- **Intervention 3:** The planning policy to schedule a maximum number of appointments per day affects the one stop shop percentage and waiting time at both locations. At Almelo, a higher percentage of one stop shop leads to extra waiting time for the nurse and anesthesiologist but to a shorter average access time as well.

  At Hengelo, a lower one stop shop percentage leads to shorter waiting times for a nurse and anesthesia assistant, and increases the average access time. A reason for the increase in access time is that not enough timeslots are available per week. This leads to a decrease in percentage of consent on time.

  When we take our research goals and patient preferences into account we conclude that intervention 3 has a positive influence on patient satisfaction. However other timeslot intervals and more flexibility of the system are needed to deal with the percentage of consent on time. The effect of the intervention differs per maximum percentage and picking a desired percentage is up to the management.
- **Intervention 4:** We analyzed the effect of combining intervention 2 and 3 and compare the results with intervention 3. We find that intervention 4 has a negative effect on the waiting times and access time at Almelo, and a positive effect at Hengelo.

  When we compare this intervention with intervention 3, we find that the waiting time increases in Almelo and decreases in Hengelo. A significant influence on these changes is the timeslot interval and the one stop shop percentage per day. When the timeslot interval is smaller than the average consultation time (as it is at Almelo), higher waiting times occur. If the timeslot interval is sufficient, the waiting times decreases. Additionally, we find that the access times increase at both locations. A cause for this increase is that the access time is influenced by the division of the percentages per day. If there are more (sequential) days with a percentage below the average percentage, the access time will increase. When the division of the percentage is better, the increase is not significant anymore.

  To conclude, if timeslots are used that fit the average consultation time, the average waiting time will decrease and the access time will increase. Deciding which of these interventions is more desirable in that case is up to the management.
- **Intervention 5:** This intervention focuses on the timing policy. We found that a late timing policy has a negative influence on the percentage of patients with consent on time when the timing policy is later than 0.80. For timing policies between 0.35 and 0.80 there is only a slight difference in consent on time and waiting times. For earlier timing policies, the effect

depends on the planning system. At Almelo, patients mostly schedule an appointment, which lead to a lower percentage consent on time for very early timing policies.
At Hengelo, the percentage consent on time decreases and the access time increases when the timing of scheduling appointments is later. However, the waiting time for an anesthesia assistant decreases as well. Logically, the access time depends on the timing policy.
We conclude that changing the timing of the appointments has significant influence on the percentage of patients with consent on time, the access times, and the waiting times. Hereby, the effect depends on the planning policy. However, in general, an early timing policy leads to higher waiting times, but to lower access times as well. Picking a desired percentage for the timing policy is up to the management

- **Intervention 6:** The final intervention on a tactical level is changing the timeslot intervals to better fit the current consultation times. We find that changing the appointment intervals to better fit the consultation times, only has a significant effect on the waiting times.
At Almelo, planning more time for an ASA score 3 patient in combination with planning less time for ASA score 1 patients (set 1) decreases the average waiting time. When the intervals are set slightly larger for ASA score 1 and 2 patients than the average consultation time, the waiting times decrease even more. This suggests that with a fixed number of two nurses, the waiting time can still decrease by just fitting the consultation times to the patient.
Changing the intervals at Hengelo has a negative effect on the waiting times for the nurse and anesthesiologist, which may be cause by using an appointment time which is slightly smaller than consultation times (set 1). When we only change the timeslot interval for ASA score 1 and 2 patients (set 2), no significant change is found.
We conclude that changing the appointment interval to better fit the consultation times can improve the waiting times. However, an appointment interval that is slightly smaller than the consultation time is not improving the outcomes. An appointment interval that is equal to or slightly larger than the average consultation time is advised.

When comparing the interventions, we find that in most cases (accept for intervention 2 at Almelo, and intervention 6 at Hengelo) there is a negative correlation between the waiting and access time. Furthermore, there are several tactical interventions that improve the waiting time without influencing the access time and vice versa (e.g. intervention 3 with a maximum percentage of appointment of 70% and intervention 6 at Almelo, and intervention 2 at Hengelo). Overall, the effect of the intervention differs and deciding which of these interventions is more desirable is up to the management.

A remark on our conclusions is that they are based on a waiting time without extra ‘voluntary’ waiting times. However, in reality patients generally arrive early because they do not want to be at risk of arriving late for their appointment. This voluntary waiting time is only applicable for patients with an appointment, and not for patients that walk in. Therefore, on the one hand, a higher one stop shop percentage leads to extra waiting time (because of more variability). On the other hand, more appointments lead to more patients arriving too early for their appointment which actually also creates extra ‘voluntary’ waiting time. The waiting time for a nurse would change and the conclusion can be different when we would have taken the voluntary waiting time into account.

To implement one of the interventions some minor changes may be necessary. At Hengelo management is already testing the effect of an extra nurse on Friday. Therefore no significant changes have to be made for this intervention. The tactical level interventions are based on changing the appointment planning system and policy. Blocking timeslots or dedicating specific hours for appointments or walk-in can help with these interventions. The application is already available in the appointment system. Changing the appointment intervals should not lead to major problems as well. When implementing these changes a factor which has to be taken into account is willingness of the stakeholders to change. During our research, employees at Almelo already tested the possibility of more walk-in patients. At Hengelo, the possibility to dedicate specific hours for appointments is also implemented already. The management is currently busy with reorganizing the PAC and is championing all possibilities to improve the current situation.

In this section we discussed the steps that had to be taken to come up with suggestions to improve the patient satisfaction at the PAC. The next section will provide several recommendations for further research which we encounter during our research period.

8.2 RECOMMENDATIONS FOR FURTHER RESEARCH

During the research period we interviewed several employees, analyzed data related to the PAC from the registration system, executed a random sample, and searched for relevant literature. These methods led to an extensive amount of information. For this master's thesis we had to determine a scope, make assumptions, and set boundaries to be able to deliver an advisory report within a limited time period. In this section we provide several suggestions for further research at the preoperative anesthesia clinic at ZGT Almelo and Hengelo.

Within our research we found that the processes and policies differ per location. For example, ASA score 2 patients are screened by an anesthesia assistant at Hengelo and by an anesthesiologist at Almelo. Moreover, a child (till sixteen years old) at Almelo only has to be screened by a nurse, whereas at Hengelo the patient is sent to the anesthesia assistant as well. This leads to approximately 80% of the patients being screened by an anesthesia assistant. We found that if this percentage decreases to about 70%, a significant difference in waiting time for the anesthesia assistant occurs. Other differences between the locations are that patients at Hengelo get an ECG at the PAC, and that the tasks of the care providers are not always the same at both locations. With the aims of the ZGT to have the same procedures at both locations, these discrepancies in policies can be investigated.

The focus of our research was on the mixture between one stop shop and appointments. In several articles we found that one stop shop is also possible by integrating an integral planning method with the policlinics. This means that policlinics and PACs cooperate and already make an appointment for patients that certainly have to be screened after consultation by a policlinic physician. The most common specialisms are orthopedics, surgery, and ENT.

In this report we only give suggestions on the effect of five interventions related to the appointment system. However, there are more possible interventions. Another approach would be to focus more on changing the capacity per day. For example, intervention 2 focused on the planning method depending on the busyness of a day. Further research can focus on the effect of having three nurses on the busy days, and 2 on least busy days. This is also a possibility for intervention 5. This interventions shows that there is no significant difference in waiting time at Almelo when changing the intervals because it seems that enough nurses are available to deal with the variability. However, the effect could be different if fewer nurses are assigned. Moreover, for intervention 3 we researched the effect of different maximum percentages of appointment. If more information is known about an acceptable range for the parameters, simulation optimization can be performed with intervention 3 to determine the optimal maximum percentage depending on the day.

Some other remarkable information we found and which may be interesting to research is:

- Throughout our research, we assume specific patient preferences on waiting time and access time which was based on study for a CT scan [4]. Research can be done on the patient preferences at the PAC.
- ASA score 2 patients are currently screened by an anesthesiologist or anesthesia assistant. A nurse practitioner is also allowed to screen ASA 1 and 2 patients. This can lead to one less step in the process and to a reduction in waiting time (no waiting time for the second care provider). Moreover, educating or hiring a nurse practitioner makes screening by an (more expensive) anesthesia assistant unnecessary.
- ASA score 1 patients are currently planned with an interval of 30 minutes, with two appointments every half hour. Changing the division to one every 15 minutes can reduce the waiting time.
- Patients with an ASA score 1 and older than 40 years old enter the ASA score 2 process. The reason behind the limit of 40 years is not completely clear. Researching the effect of increasing the age limit may be interesting.
- The number of patients that are classified as urgent is significantly higher at Hengelo. It may be that there are different policies between locations or specialism for assigning an urgency status to a patient.
- Although the division of extra examinations does not differ, the number of extra examinations ordered does differ significantly between Almelo and Hengelo. In total, 37 extra examinations were ordered at Almelo and 119 were ordered/performed at Hengelo during the random sample period. Employees indicate that at Hengelo there are procedures to determine if a patient needs extra examination, whereas at Almelo this is determined by the anesthesiologist. It may be interesting to research the effects of these differences.
- The consultation time may differ between care providers. It is shown that if a care provider in general needs more time than the average consultation time, this has a significant effect on the waiting times. Research can be performed to determine the consultation times per care provider and the effect of the differences.
- Related to the aspect above, another possibility for waiting time reduction may be assigning 'fast' care providers on busy days, and 'slow' care providers on less busy days.
- Also related to the aspect above, literature suggests that adjusting the appointment intervals to fit the consultation time per care provider may reduce the waiting times.
- Last, the process for a patient with one stop shop is to first be examined by a policlinic physician followed by preoperative screening at the PAC. If the opening hours at the policlinic are the same as at the PAC, this may lead to less one stop possibility at end of the day, and less utilization at the beginning of the day. Research can be performed on the effect of changing the opening hours.

In this chapter we discussed the process of our research and the results of our interventions. We gave several suggestions to improve patient satisfaction. Additionally, we gave recommendations for further research.

BIBLIOGRAPHY

[1] Wolff, A., Boermeester, M., Janssen, I., Pols, M., & Damen, J. (2010). De landelijke CBO-richtlijn 'Preoperatief traject': De essentie. *Nederlands Tijdschrift Geneeskunde* , 154:A2532.

[2] ZGT. (2010). *Jaardocument.*

[3] Wikipedia. (2012, January 4). *ASA physical status classification system*. Opgeroepen op March 27, 2012, van Wikipedia: http://en.wikipedia.org/wiki/Asa_classification

[4] Scholtens, M. (2009). Visiting the CT-scan; appointment system or walk in? : patient preferences and possible arrival pattern.

[5] Hans, E., Houdenhoven, M. v., & Hulshof, P. (2011). A framework for health care planning and control. In R. Hall, *Handbook of Health Care Systems Scheduling* (p. Chapter 12). Springer International Series in Operations Research & Management Science.

[6] American Society of Anesthesiologists. (2002). Practice Advisory for Preanesthesia Evaluatio: A Report by the American Society of Anesthesiologists Task Force on Preanesthesia Evaluation. *Anesthesiology* , 96:485–96.

[7] Holt, N., Silverman, D., Prasad, R., Dziura, J., & Ruskin, k. (2007). Preanesthesia clinics, information management, and operating room delays: results of a survey of practicing anesthesiologists. *Anesthesia and Analgesia* , Vol.104(3), p.615-8.

[8] Gupta, A., & Gupta, N. (2010). Setting up and functioning of a preanaesthetic clinic. *Indian Journal of Anaesthesia* , Vol.54(6), p.504-507.

[9] Lemmens, L., Klei, W. v., Klazinga, N., Rutten, C., Linge, R. v., Moons, K., et al. (2006). The effect of national guidelines on the implementation of outpatient preoperative evaluation clinics in Dutch hospitals. *European Journal of Anaesthesiology* , Vol.23(11), p.962-970.

[10] García-Miguel, F., Serrano-Aguilar, P., & López-Bastida, J. (2003). Preoperative assessment. *Lancet* , Vol.362(9397), p.1749-57.

[11] Harsoor, S. (2010). Changing concepts in anaesthesia for day care surgery. *Indian journal of anaesthesia* , Vol.54(6), p.485-8.

[12] Klopfenstein, C., Forsters, A., & Gessel, E. v. (2000). Anesthetic assessment in an outpatient consultation clinic reduces preoperative anxiety. *Canadian journal of anaesthesia-journal canadien d anesthesie* , Vol.47(6), p.511-515.

[13] Barkhordarian, S., & Dardik, A. (2004). Preoperative assessment and management to prevent complications during high-risk vascular surgery. *Critical care medicine* , Apr, Vol.32(4Suppl), p.S174-85.

[14] Blackwood, S. (1986). Back to Basics the Preop Exam. *The American Journal of Nursing* , Vol. 86, No. 1, pp. 39-44.

[15] Gupta, A. (2009). Preoperative screening and risk assessment in the ambulatory surgery patient. *Current opinion in anaesthesiology* , Vol.22(6), p.705-11.

[16] Lew, E., Pavlin, D., & Amundsen, L. (2004). Outpatient preanaesthesia evaluation clinics. *Singapore medical journal* , Vol.45(11), p.509-16.

[17] Singh, S., & Manji, M. (2001). A survey of pre-operative optimisation of high-risk surgical patients undergoing major elective surgery. *Anaesthesia* , Vol.56(10), p.988-990.

[18] Ferschl, M., Tung, A., Sweitzer, B., Huo, D., & Glick, D. (2005). Preoperative Clinic Visits Reduce Operating Room Cancellations and Delays. *Anesthesiology* , vol:103 iss:4 pg:855 -9.

[19] Hariharan, S., Chen, D., & Merritt-Charles, L. (2006). Evaluation of the utilization of the preanaesthetic clinics in a university teaching hospital. *BMC health services research* , Vol.6, p.59.

[20] Klei, W. v., Moons, K., Rutten, C., Schuurhuis, A., Knape, J., Kalkman, C., et al. (2002). The effect of outpatient preoperative evaluation of hospital inpatients on cancellation of surgery and length of hospital stay. *Anesthesia and Analgesia* , Vol.94(3), p.644-9.

[21] St. Jacques, P., & Higgins, M. (2004). Beyond cancellations: decreased day of surgery delays from a dedicated preoperative clinic may provide cost savings. *Journal of clinical anesthesia* , Vol.16(6), p.478-9.

[22] Langemeijer, J., Hemrika, M., & Lange, J. d. (1996). Doelmatig preoperatief onderzoek in de polikniek Anesthesiologie. *Nederlands Tijdschrijft Geneeskunde* , 1723-1726.

[23] Fischer, S. (1996). Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. *Anesthesiology* , Vol.85(1), p.196-206.

[24] Pollard, J. (2002). Economic aspects of an anesthesia preoperative evaluation clinic . *Current opinion in anaesthesiology* , Vol.15(2), p.257-61.

[25] Pollard, J., Garnerin, P., & Dalman, R. (1997). Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. *Anesthesia and Analgesia* , Vol.85(6), p.1307-1311.

[26] Pollard, J., Zboray, A., & Mazze, R. (1996). Economic benefits attributed to opening a preoperative evaluation clinic for outpatients. *Anesthesia and Analgesia* , Vol.83(2), p.407-410.

[27] Starsnic, M., Guarnieri, D., & Norris, M. (1997). Efficacy and financial benefit of an anesthesiologist-directed university preadmission evaluation center. *Journal of clinical anesthesia* , Vol.9(4), p.299-305.

[28] Parker, B., Tetzlaff, J., Litaker, D., & Maurer, W. (2000). Redefining the preoperative evaluation process and the role of the anesthesiologist. *Journal of clinical anesthesia* , Vol.12(5), p.350-356.

[29] Klei, W. v., Hennis, P., Moen, J., Kalkman, C., & Moons, K. (2004). The accuracy of trained nurses in pre-operative health assessment: results of the OPEN study. *Anaesthesia* , Vol.59(10), p.971-978.

[30] Vaghadia, H., & Fowler, C. (1999). Can nurses screen all outpatients? Performance of a nurse based model . *Canadian journal of anaesthesia-journal canadien d anesthesie* , Vol.46(12), p.1117-1121.

[31] Varughese, A., Byczkowski, T., Wittkugel, E., Kotagal, U., & Kurth, C. (2006). Impact of a nurse practitioner-assisted preoperative assessment program on quality. *Pediatric anesthesia* , Vol.16(7), p.723-733.

[32] Marty, J., & Plaud, B. (2009). Anesthetic process, organization, management and economic issues: the French perspective. *Current opinion in anaesthesiology* , Vol.22(2), p.249-54.

[33] Harnett, M., Correll, D., Hurwitz, S., Bader, A., & Hepner, D. (2010). Improving efficiency and patient satisfaction in a tertiary teaching hospital preoperative clinic. *Anesthesiology* , Vol.112(1), p.66-72.

[34] Halaszynski, T., Juda, R., & Silverman, D. (2004). Optimizing postoperative outcomes with efficient preoperative assessment and management. *Critical care medicine* , Vol.32(4), p.S76-S86.

[35] Pollard, J., & Olson, L. (1999). Early outpatient preoperative anesthesia assessment: Does it help to reduce operating room cancellations? *Anesthesia and Analgesia* , Vol.89(2), p.502-505.

[36] Dexter, F. (1999). Design of appointment systems for preanesthesia evaluation clinics to minimize patient waiting times: a review of computer simulation and patient survey studies. *Anesthesia and Analgesia* , Vol.89(4), p.925-31.

[37] Murray, M., & Tantau, C. (2000). Same-day appointments: exploding the access paradigm. *Family practice management* , Vol.7(8), p.45-50.

[38] Mallard, S., Leakeas, T., Duncan, W., Fleenor, M., & Sinsky, R. (2004). Same-day scheduling in a public health clinic: a pilot study. *Journal of public health management and practice* , Vol.10(2), p.148-55.

[39] Parente, D., Pinto, M., & Barber, J. (2005). A pre-post comparison of service operational efficiency and patient satisfaction under open access scheduling. *Health care management review* , Vol.30(3), p.220-8.

[40] Kortbeek, N., Zonderland, M., Boucherie, R., Litvak, N., & Hans, E. (sd). Designing Cyclic Appointment Schedules for Outpatient Clinics with Scheduled and Unscheduled Patient Arrivals.

[41] Edward, G., Razzaq, S., Roodj, A. d., Boer, F., Hollmann, M., Dzoljic, M., et al. (2008). Patient flow in the preoperative assessment clinic. *European Journal of Anaesthesiology* , Vol.25(4), p.280-286.

[42] Zonderland, M., Boer, F., Boucherie, R., Roode, A. d., & Kleef, J. v. (2009). Redesign of a University Hospital Preanesthesia Evaluation Clinic Using a Queuing Theory Approach. *Anesthesia and Analgesia* , Vol.109(5), p.1612-1621.

[43] Schoenmakers, J. (2008). Redesign of the Pre-operative process.

[44] Edward, G., Haes, J. d., Oort, F., Lemaire, L., Hollmann, M., & Preckel, B. (2008). Setting priorities for improving the preoperative assessment clinic: the patients' and the professionals' perspective. *British journal of anaesthesia* , Vol.100(3), p.322-326.

[45] Hepner, D., Bader, A., Hurwitz, S., Gustafson, M., & Tsen, L. (2004). Patient satisfaction with preoperative assessment in a preoperative assessment testing clinic. *Anesthesia and Analgesia* , Vol.98(4), p.1099-1105.

[46] Edward, G., Das, S., Elkhuizen, S., Bakker, P., Hontelez, J., Hollmann, M., et al. (2008). Simulation to analyse planning difficulties at the preoperative assessment clinic. *British Journal of Anaesthesia* , Vol. 100(2), p.195-202.

[47] Heaney, D., Howie, J., & Porter, A. (1991). Factors influencing waiting times and consultation times in general practice. *The British journal of general practice : the journal of the Royal College of General Practitioners* , Vol.41(349), p.315-9.

[48] Fetter, R., & Thompson, J. (1966). Patients' Waiting Time and Doctors' Idle Time in the Outpatient Setting. *Health services research* , vol:1 iss:1 pg:66 -90.

[49] Hill-Smith, I. (1989). Mathematical relationship between waiting times and appointment interval for doctor and patients. *The Journal of the Royal College of General Practitioners* , Vol.39(329), p.492-4.

[50] Tait, A., Voepel-Lewis, T., Munro, H., Gutstein, H., & Reynolds, P. (1997). Cancellation of pediatric outpatient surgery: Economic and emotional implications for patients and their families. *Journal of clinical anesthesia* , Vol.9(3), p.213-219.

[51] Ivarsson, B., Kimblad, P., Sjöberg, T., & Larsson, S. (2002). Patient reactions to cancelled or postponed heart operations. *Journal of nursing management* , Vol.10(2), p.75-81.

[52] Conway, J., Goldberg, J., & Chung, F. (1993). Preadmission anaesthesia consultation clinic. *Canadian Journal of Anaesthesia* , Vol.40(5), p.471-472.

[53] Correll, D., Bader, A., Hull, M., Hsu, C., Tsen, L., & Hepner, D. (2006). Value of preoperative clinic visits in identifying issues with potential impact on operating room efficiency. *Add to e-Shelf* , Vol.105(6), p.1254-1259.

[54] Law, A. (2007). *Simulation Modeling and Analysis (4th ed.).* United States: McGraw-Hill.

[55] Harper, P., & Gamlin, H. (2003). Reduced outpatient waiting times with improved appointment scheduling: a simulation modelling approach. *OR Spectrum* , Vol.25(2), p.207-222.

[56] Visser, R. (2011). Modeling an integrated emergency post.

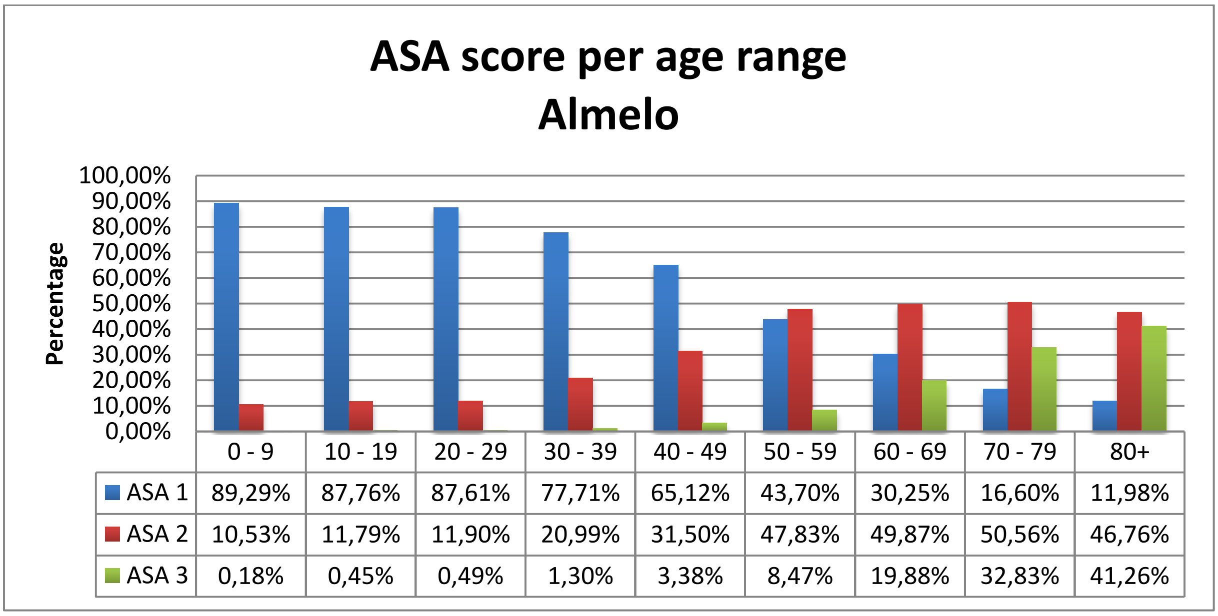
[57] Ozcan, Y. (2009). *Quantitative Methods in Health Care Management: Techniques and Applications.* John Wiley and Sons Ltd.

[58] Winston, W. (2004). *Operations Research: Applications and Algorithms* (4th ed.). Toronto, Canada: Brooks/Cole.

APPENDICES

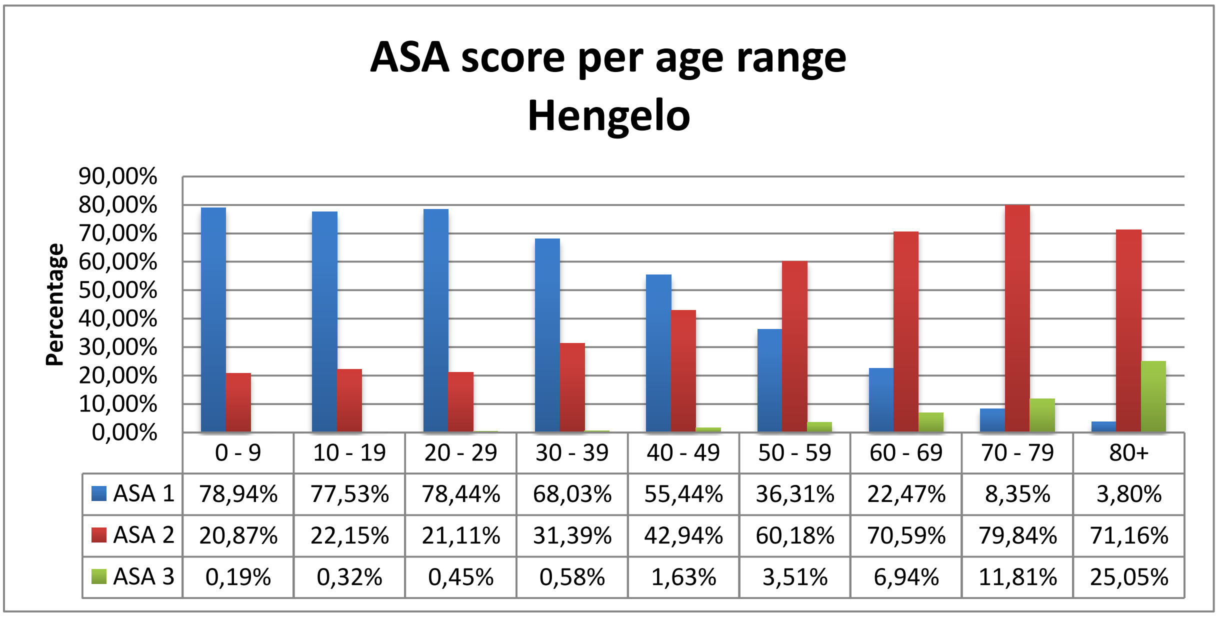
APPENDIX A: ASA SCORE PER AGE RANGE

We analyze the relation between ASA score and the age range to determine whether a higher age range correlates with a higher ASA score. The ASA score per age range are shown in Figure A.1 (Almelo) and Figure A.2 (Hengelo).



	0 - 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80+
ASA 1	89,29%	87,76%	87,61%	77,71%	65,12%	43,70%	30,25%	16,60%	11,98%
ASA 2	10,53%	11,79%	11,90%	20,99%	31,50%	47,83%	49,87%	50,56%	46,76%
ASA 3	0,18%	0,45%	0,49%	1,30%	3,38%	8,47%	19,88%	32,83%	41,26%

Figure A.1: ASA score per age range at Almelo



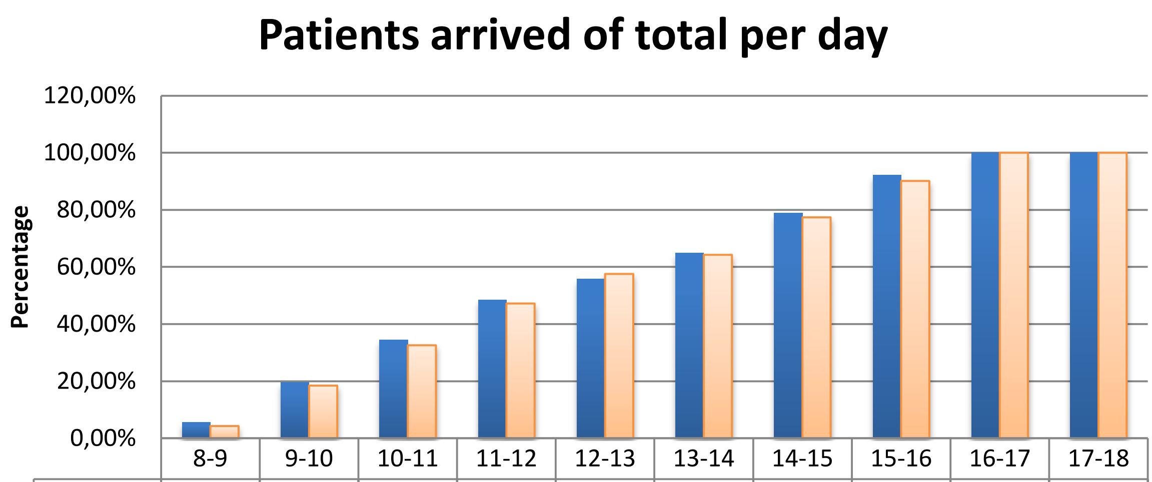
	0 - 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80+
ASA 1	78,94%	77,53%	78,44%	68,03%	55,44%	36,31%	22,47%	8,35%	3,80%
ASA 2	20,87%	22,15%	21,11%	31,39%	42,94%	60,18%	70,59%	79,84%	71,16%
ASA 3	0,19%	0,32%	0,45%	0,58%	1,63%	3,51%	6,94%	11,81%	25,05%

Figure A.2: ASA score per age range at Hengelo

These figures show that the percentage of high ASA score is correlated to the age range of the patients. The higher the age, the more patients are ASA score 2 and 3. With younger patients at Almelo and older patients at Hengelo, this explains the difference in ASA scores at Almelo and at Hengelo.

APPENDIX B: CUMULATIVE PERCENTAGE OF PATIENTS ARRIVAL PER HOUR

Figure B.1 shows the cumulative percent of patient arrivals per hour. For example, 34.4% of the patients at Almelo arrive before 11:00 AM.



	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Almelo	5,63%	19,51%	34,45%	48,51%	55,81%	64,94%	78,87%	92,15%	100,00%	100,00%
Hengelo	4,27%	18,44%	32,56%	47,20%	57,54%	64,24%	77,37%	90,11%	100,00%	100,00%

Figure B.1: Cumulative percentage of patient arrivals per hour

APPENDIX C: CALCULATION OF MARGIN OF ERROR

We use the formula shown below to determine the margin of error of our random sample.

$$n >= \frac{\mathrm{N} * \mathrm{z}^2 * \mathrm{p}(1-\mathrm{p})}{\mathrm{z}^2 * \mathrm{p}(1-\mathrm{p}) + (\mathrm{N}-1) * \mathrm{F}^2}$$

Hereby the variables are as follows:

- *n* is the number of participants of the random sample. This is set on 222 patients at both locations.
- *z* is the standard deviation with a certain confidence level. The confidence level is set on 95%, which leads to a z-value of 1.96.
- *N* is the total number of patients (population). This is set on 11000.
- *p* is the response distribution. This is set on 50%.
- *F* is the margin of error.

With all values of the variables known, expect the margin of error, we fill in the formula and conclude that the margin of error is 6.5%

APPENDIX D: FLOWCHART OF PROCESS STEPS AT ALMELO

Figure D.1 below shows a flowchart of the POS process at Almelo. The steps in the flowchart take place in different stages and departments. The different departments are indicated with different colors in the flowchart: The orange color indicate activities that take place in several policlinics before POS. The yellow color indicates activities that take place in the PAC, and activities that take place after the regular POS are shown in red.

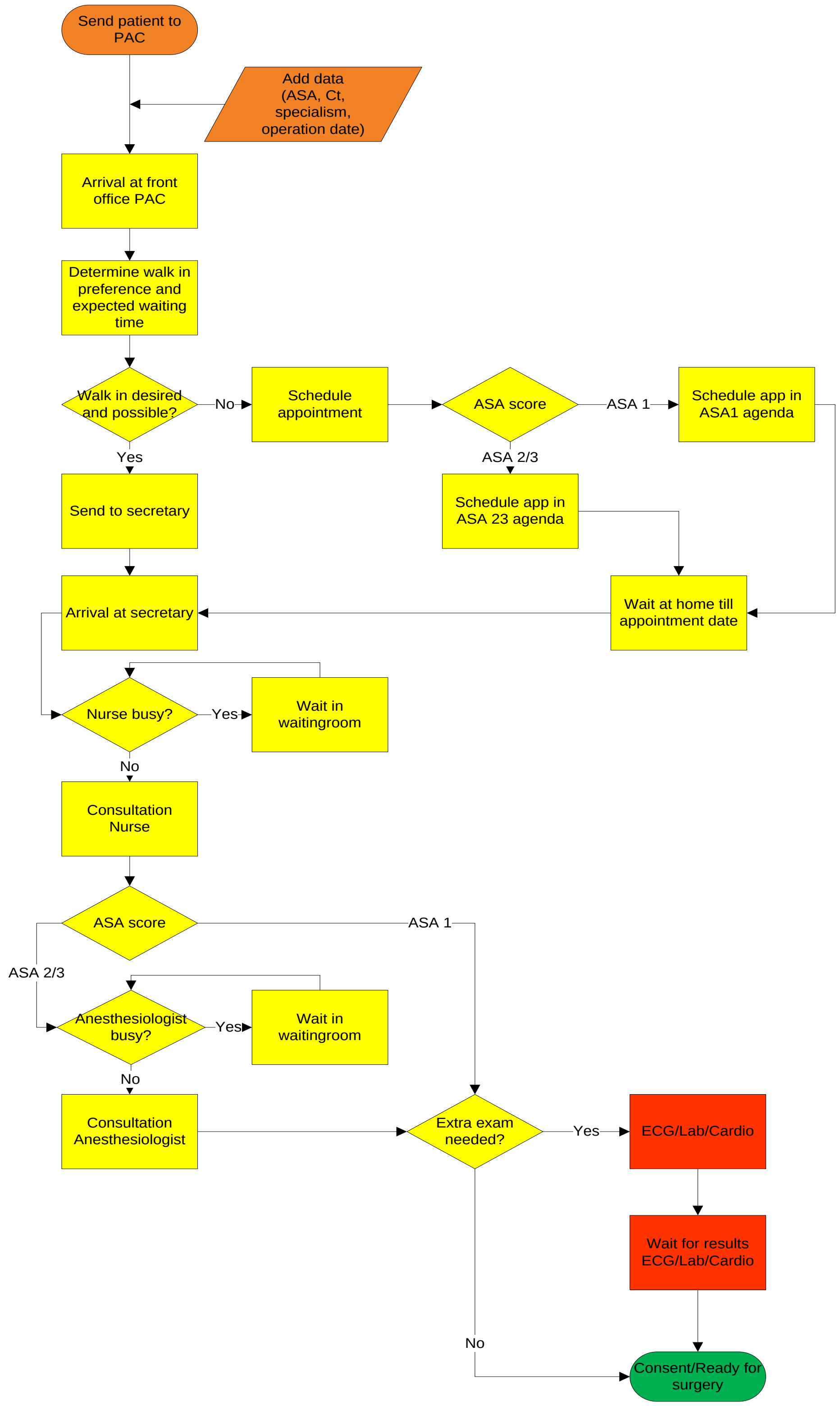


Figure D.1: Flowchart of the POS processes at Almelo

APPENDIX E: EXAMPLE OF CALCULATIONS FOR A DISTRIBUTION FUNCTION

We determine the screening time distributions per care provider from the data obtained from the random sample. We show an example of this process for the ASA score 2 patient at the anesthesiologist at Almelo below. We start with plotting a histogram of the data. The histogram of the ASA score 2 patients at the anesthesiologist (Figure E.1) shows a skewness to the left, which may imply a gamma or lognormal distribution.

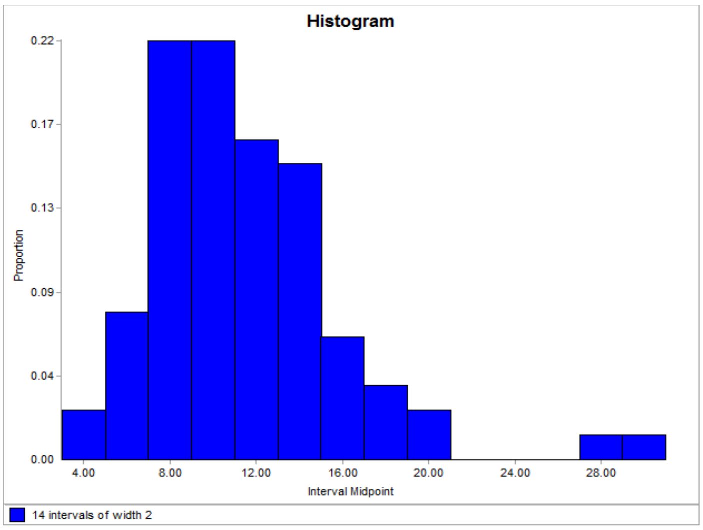


Figure E.1: histogram of the ASA score 2 patients at the anesthesiologist

To test our expectations we make a Q-Q-plot. In a Q-Q-plot a certain set of practical data is plotted against the corresponding theoretical data which can be expected using the assumed distribution. If all the points are on a straight diagonal line, this gives an indication that the assumed distribution is the right one. Figure E.2 shows the Q-Q-plot of a lognormal distribution. This seems to be the case for the plot below.

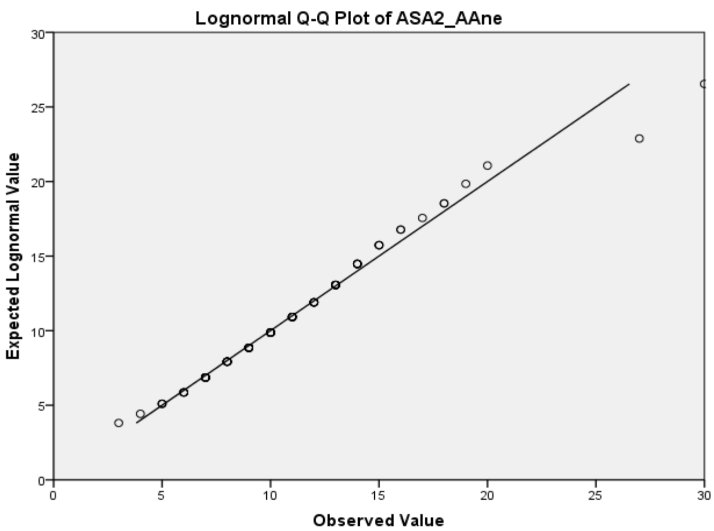


Figure E.2: Q-Q plot the arrivals of ASA score 2 patients at the anesthesiologist at Almelo and a lognormal distribution

With the program ExpertFit, we test multiple distributions with and find that the lognormal distribution fits better than the other distributions. Therefore, we choose a lognormal distribution for our model, with a scale of 10.89 and shape of 0.401.

We apply this method for all patient types per care provider. Table E.1 shows the probability distribution functions of the consultation time as used in the simulation model.

Patient type	ASA score 1	ASA score 2	ASA score 3
Almelo			
Nurse	Lognormal(15.51, 5.295)	Lognormal(15.51, 5.295)	Gamma(12.164, 1.979)
Anesthesiologist		Log normal(10.89, 4.570)	Gamma(10.245, 1.642)
Hengelo			
Nurse	Lognormal(11.62, 5.182)	Lognormal(11.62, 5.182)	Lognormal(11.62, 5.182)
Anesthesia Assistant		Lognormal(15.39, 7.650)	
Anesthesiologist			Lognormal (15.39, 7.650)

Table E.1: Probability distribution functions of the consultation time per patient type per location for the simulation model

APPENDIX F: CALCULATIONS OF PERCENTAGE FOR INTERVENTION 4

The percentages for intervention 4 are calculated in several steps. First, the difference between the maximum and minimum percentage of walk-in patients is determined. In our research the maximum percentage was 60% and the minimum percentage was 35%. Therefore, the difference is 25%. Next the difference between the highest and lowest fraction of arrivals per day is calculated. The figures can be found in Table F.1.

Day	Monday	Tuesday	Wednesday	Thursday	Friday
Almelo	0.222	0.235	0.199	0.166	0.178
Hengelo	0.183	0.238	0.219	0.206	0.154

Table F.1: Arrival fraction per weekday at Almelo and Hengelo

We determine that the difference at Almelo is 0.235 – 0.166 = 0.069 (Tuesday – Thursday) and 0.238 – 0.154 = 0.084 at Hengelo. The next step is to calculate the maximum percentages of appointments per day. Hereby, we set a percentage of 60% on the least busy day. The percentage on the other days should be less than this percentage.

Per fraction point of 0.001 deviation from the fraction of the least busy days a fixed percentage is deducted from 60%. The fixed percentage at Almelo is 25% / 69 = 0.36% per 0.001 and 25% / 84 = 0.30% per 0.001 at Hengelo. For example, the difference between Monday and Thursday (the least busy day) at Almelo is 0.222 – 0.166 = 0.056. Therefore, the percentage on Monday at Almelo is 60% - (56 * 0.36%) = 39.7%. The percentages for all patients are shown in Table F.

	Almelo	Hengelo
Monday	39.7%	51.4%
Tuesday	35.0%	35.0%
Wednesday	48.0%	40.7%
Thursday	60.0%	44.5%
Friday	55.7%	60.0%

Table F.2: Maximum percentage of appointments per day per location for intervention 4

APPENDIX G: SIMULATION MODEL PROCESS DETAILS

This section focuses on the process under "Almelo" and "Hengelo" in our simulation model. The process and departments at Almelo (Figure G.1) and Hengelo (Figure G.2) are shown in the figures below.

The process for a patient in the simulation model starts when leaving the policlinic (window on the left, "PoliA") and arriving at the "APA" at the PAC (window in the middle, "POSA"). Here, it is determined whether the patient walks in or schedules an appointment. If a patient thinks the expected waiting time is too long or does not want to walk in anyway, an appointment is schedule in the agenda (right side of middle window). In this case a patient goes to "HomeA". On the day of appointment the patient checks in at the secretary "SecrA", and is sent to the waiting room. If the nurse is unoccupied the patient enters "NurseA". After screening by a nurse, depending on the ASA score the patient needs screening by an anesthesiologist "AnestA". When the patient leaves the PAC, it goes to the next department (window on the right, "SurgeryA") for extra examination "ExtraExam" or immediately leaves the system with consent "ReadyForSurgery".

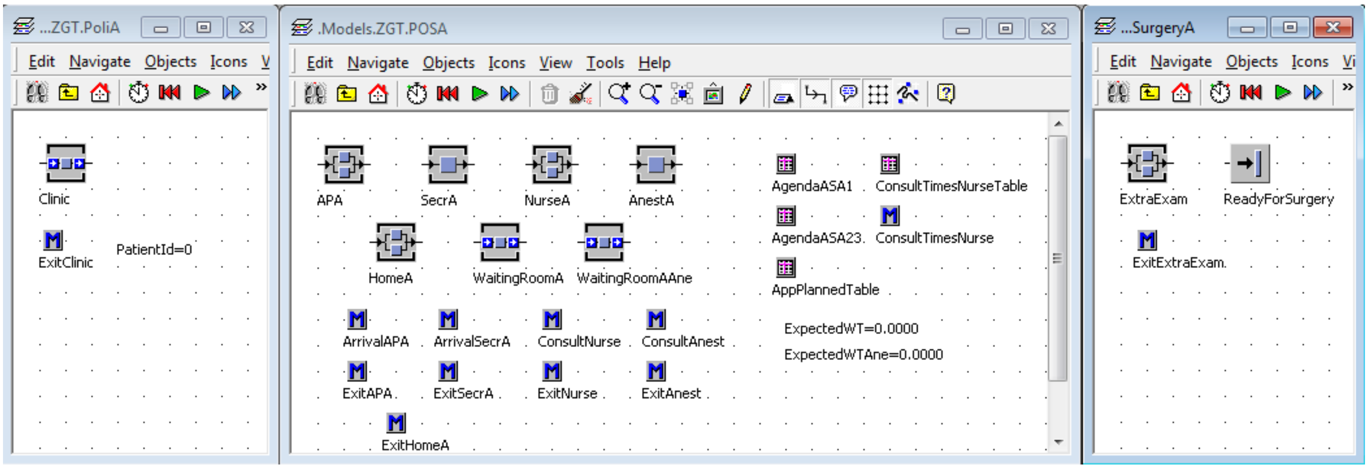


Figure G.1: Screenshot of the process of the simulation model at Almelo, with the policlinic (window on the left), the PAC (window in the middle), and extra examination and consent (window on the right)

The process at Hengelo in the simulation model is almost the same, except the secretary is not present, and ASA 2 patients go to "POPH" and ASA 3 patients to "AnestH".

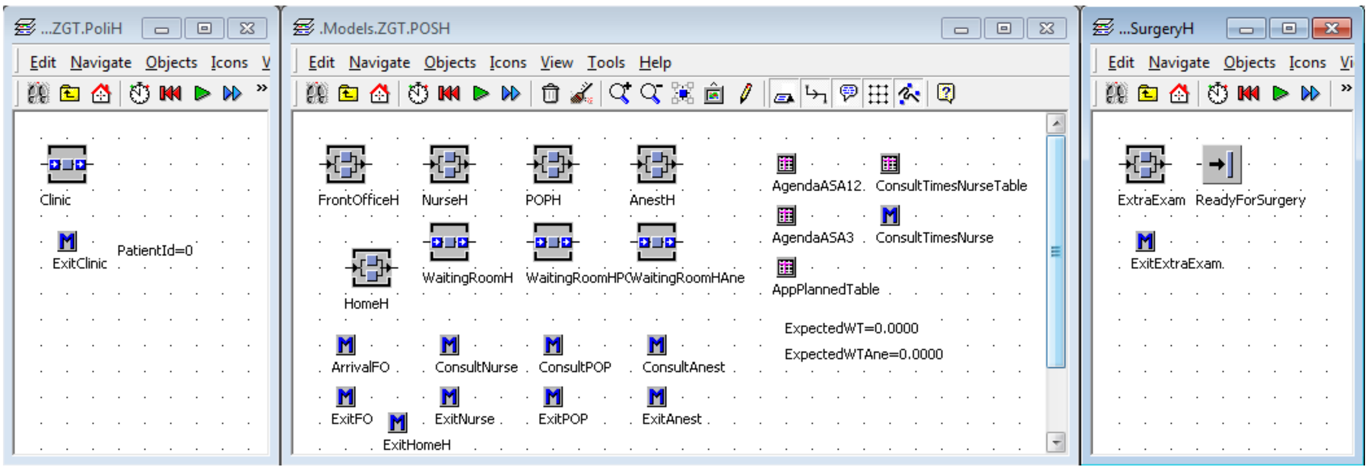


Figure G.2: Screenshot of the process of the simulation model at Hengelo, with the policlinic (window on the left), the PAC (window in the middle), and extra examination and consent (window on the right)

APPENDIX H: WELCH'S PROCEDURE

We find that the throughput at the beginning of a run is lower than from historical data, especially at Almelo. This is due to the fact that in the beginning no patients are scheduled in the agendas, whereas patients are being scheduled for appointment. This leads to a lower throughput, utilization, and waiting time, and a higher one stop shop percentage. To deal with an empty system at the start of each run, we have to take into account a warm-up period. We determine the warm-up period with the Welch's procedure as described by Law [54]. The results of Welch's procedure for the patients at Almelo are shown in Figure H.1

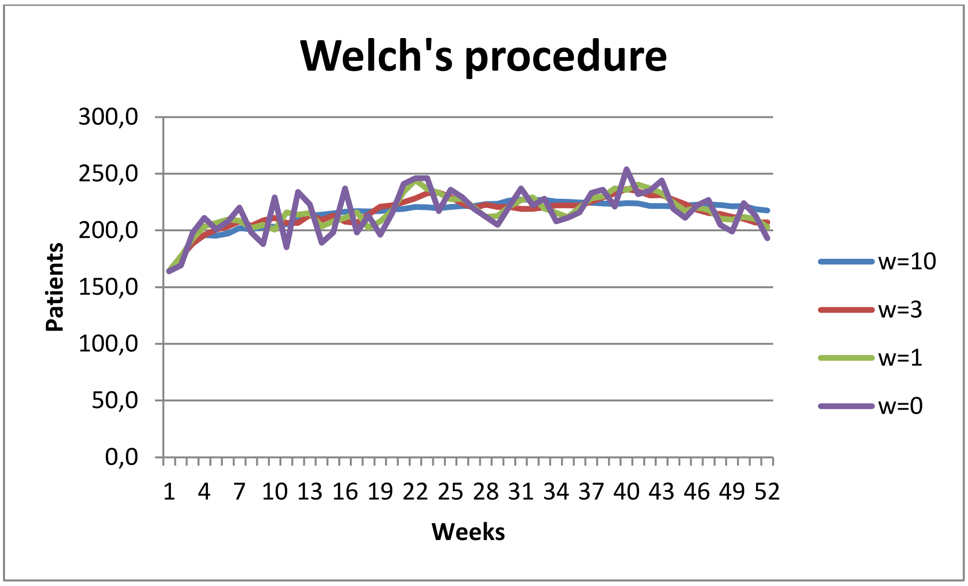


Figure H.1: Welch's procedure for the patients at Almelo

We find that the number of patients in the simulation model reaches the mean number of patients per week at Almelo between week 4 and 8. We compare the data on the one stop shop percentage in the simulation model with the expected percentage, to determine when this outcome of the simulation model equals the real world for the first time. This is the case in week 5. Therefore, we choose a warm-up period of five weeks.

APPENDIX I: RUN LENGTH AND NUMBER OF REPLICATIONS

We have to determine the run length and number of replications to reduce the variance of the output. The outcomes per year are quite similar (i.e. the number of patients, one stop shop percentage, average access times etc. for each year is the same). Therefore, we consider one year as an appropriate run length to equal one replication. One year consists of 52 weeks, with each 5 working days per. Hereby, we have to keep in mind that the warm-up period for each year is five weeks.

The next step is to determine the number of replications per experiment. The appropriate number of replications differs per output parameter. Therefore, we first analyze the number of replications per output parameter with the sequential procedure. We use a confidence interval of 95% (1-α, with α = 0.05), with a relative error (γ) smaller than 0.05. We start by determining the interval half-width, with the formula:

$$\delta(n, \alpha) = t_{n-1,1-\alpha/2} \sqrt{S_n^2 / n}$$

When we know the half-width, next we search for the largest value n for which holds:

$\frac{\delta(n,\alpha)}{X} \leq \gamma'$ with $\gamma' = \frac{\gamma}{1+\gamma}$ as corrected allowed relative error.

We do this by incrementally increasing n with 1 every step, with the starting position $n_0 = 2$.

Hereby, n is the number of replications, the number $t_{n-1,1-\alpha/2}$ is the critical point for the t distribution with $n-1$ degrees of freedom, and $1-\alpha$ for standard normal distribution. X is the sample mean, and S_n^2 the sample variance.

We find that the most replications are needed for the average waiting time of a nurse at Hengelo (11), and for a nurse (8) and anesthesiologist (10) at Almelo in the standard situation. All results are shown in Table I.1.

Output parameters	Number of replications Almelo	Number of replications Hengelo
Walk-in percentage	2	4
Consent on time	2	2
Average WT Nurse	8	11
Average WT Anesthetist	10	5
Average Access Time	2	5

Table I.1: Number of replications per output parameter per location

We now know that, for the experiments, we can focus on an appropriate number of replications for the average waiting time for a nurse at Hengelo and Almelo and for the waiting time of a nurse and an anesthesiologist at Almelo to reduce the variance of the outputs. The next step is to determine the minimum number of replications per experiment. We use the same procedure as described before. The minimum number of replications per experiment is shown in Table I.2.

Interventions	Minimum number of replications
Intervention 1	12
Intervention 2	22
Intervention 3	11
Intervention 4	23
Intervention 5	11
Intervention 6	10

Table I.2: Minimum number of replications per experiment

From this table we determine that we need 23 replications per experiment to reduce the variance of the results with a confidence interval of 95%.

APPENDIX J: CHARTS SENSITIVITY ANALYSES

In this section we provide details and figures of the sensitivity analyses which are not discussed in Section 6.3.

Arrival rates: We research the effect of changing the number of arrivals. We use a uniform distribution and vary the upper and lower bound to study the effect of quiet and busy periods on the waiting time. Figure J.1 and Figure J.2 shows the effect of changing the number of patients on the waiting time for Almelo and Hengelo. The average number of patients, per step, is shown on the X-axis in the figures below, the average waiting time on the Y-axis.

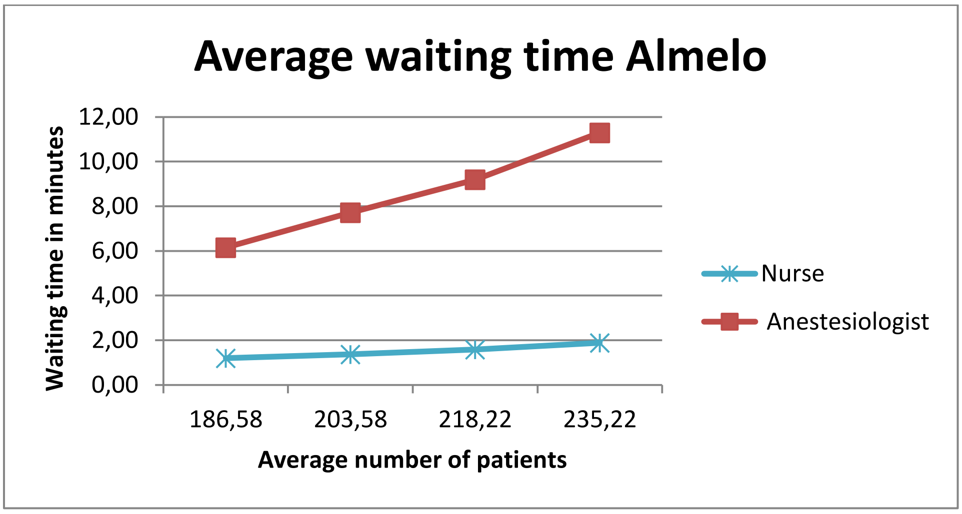


Figure J.1: average waiting time at Almelo when varying the arrival rates

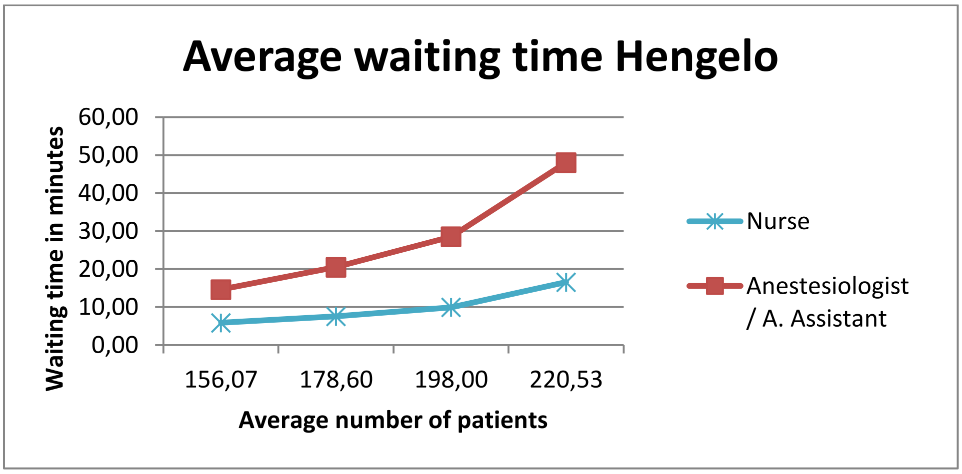


Figure J.2: average waiting time at Hengelo when varying the arrival rates

Mean consultation time: We vary the mean consultation time by multiplying the average consultation time with a factor ranging from 0.7 till 1.3. The effects on the waiting times at Almelo are shown in Figure J.3. Figure J.4 shows the effect on the access times per location.

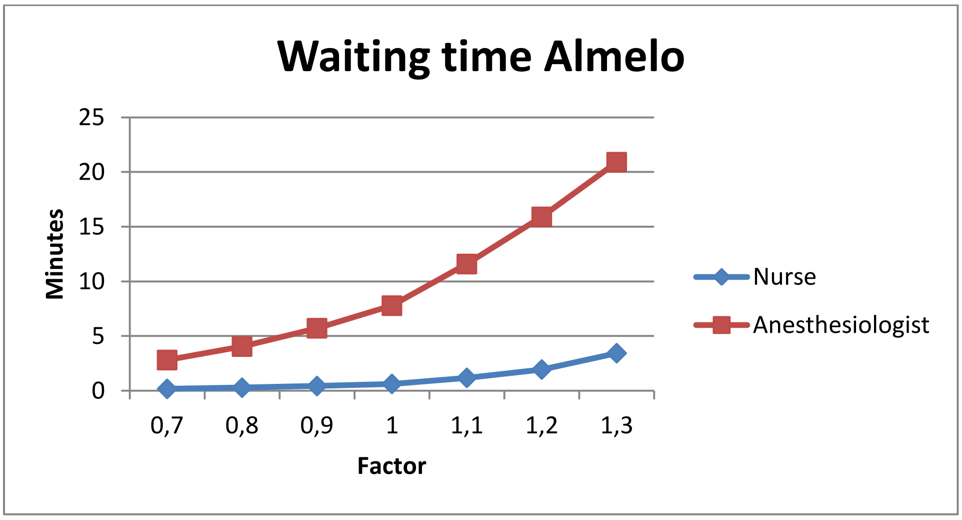


Figure J.3: average waiting time when varying the mean consultation time

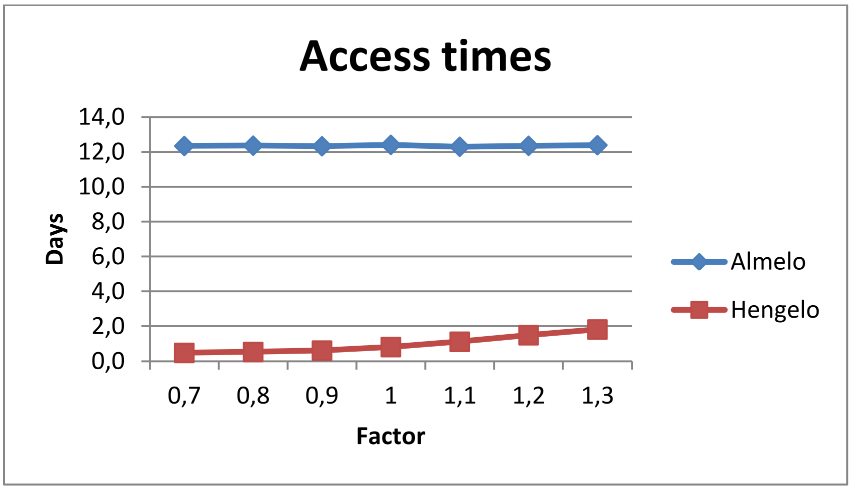


Figure J.4: average access time when varying the mean consultation time

Standard deviation consultation time: We vary the standard deviation of the consultation time by multiplying the average consultation time with a factor ranging from 0.7 till 1.3. The effect on the waiting times at Hengelo is shown in Figure J.5. Figure J.6 shows the effect on the waiting time at Hengelo.

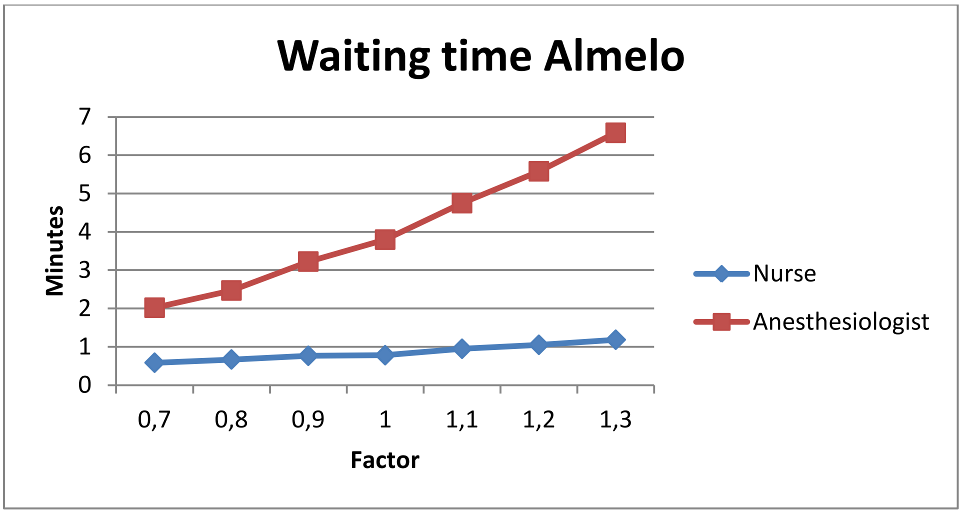


Figure J.5: average waiting time at Almelo when varying the standard deviation of consultation time

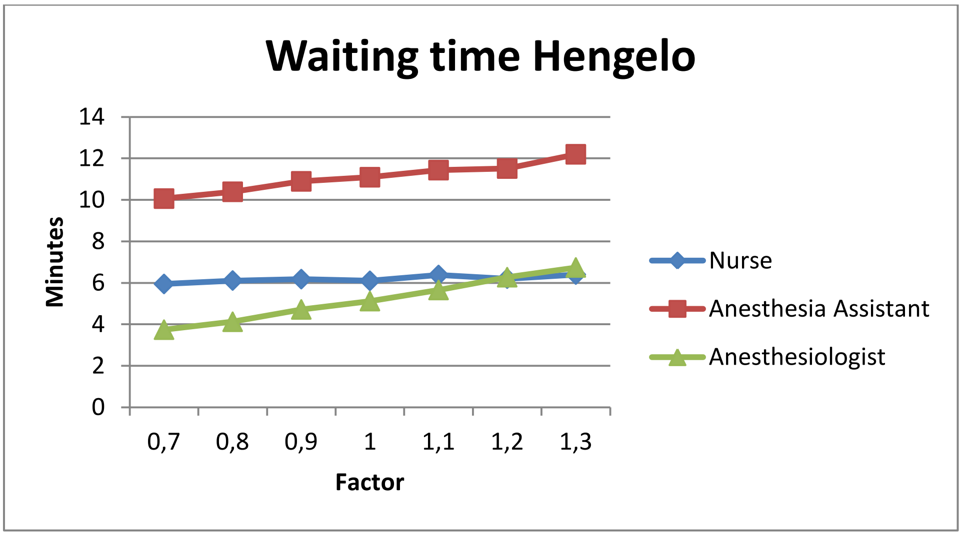


Figure J.5: average waiting time at Hengelo when varying the standard deviation of consultation time